Volume 25, Issue 3/2025 PRINT ISSN 2284-7995

E-ISSN 2285-3952

SCIENTIFIC PAPERS

SERIES "MANAGEMENT, ECONOMIC ENGINEERING IN AGRICULTURE AND RURAL DEVELOPMENT"

Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development"
PRINT ISSN 2284-7995, E-ISSN 2285-3952

Volume 25, Issue 3/2025
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To be cited: Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Volume 25, Issue 3/2025.

Publishers:
University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania. Address: 59 Marasti Blvd., District 1, 011464 Bucharest, Romania, Phone: + 40213182564, Fax: +40213182888**,** www.managusamv.ro
Ceres Publishing House, Address: 29 Oastei Street, District 1, Bucharest, 013701, Phone/Fax: +40213179023, E-mail: edituraceres@yahoo.com
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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MEAT CONSUMPTION IN NIGERIA: TREND ANALYSIS AND MACROECONOMIC VARIABLES DETERMINANTS

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Abstract

The study examined consumption trends in beef, chicken meat and Chevon and provided evidence of its correlation with some macroeconomic factors in Nigeria. Secondary data were obtained from official sources and covered the years from 1991 to 2022. The Engle Granger two–step technique of cointegration and autoregressive model were used to analyze the data. The findings indicated that the consumption rates of beef and chicken experienced annual declines of -2.27% and -0.99%, respectively, whereas Chevon consumption exhibited a slight annual growth of 0.74%. The empirical analysis revealed a significant negative correlation between the inflation rate and nominal exchange rate with the consumption of Chevon, chicken meat, and beef. Conversely, the per capita GDP, credit to the agricultural sector and the capacity utilization of the meat industry have a significant positive correlation with beef, chicken meat and Chevon consumption. To increase meat consumption in the country, it is strongly recommended that the country should developed its local inputs system/machineries and introduce input subsidies to ameliorate the negative effect of inflation and exchange rate volatility in meat production. Also, the provision of sufficient incentives to boost capacity utilization of the meat industry and expanded channels to inject credit to the agricultural sector would help to increase meat consumption in the country.

Key words: *meat, consumption, macroeconomic, per capita, Nigeria*

INTRODUCTION

The Nigeria's meat industry in recent times has been challenged by several factors and its production undermined by poor processing facilities and the unregulated market system among others [16, 3]. Despite the drawbacks, the production and consumption of meats in Nigeria present tremendous potentials for both domestic and foreign investors. However, efficient and sustainable production and consumption of meat are anchored on stable and favourable economic environment among other things [2,4]. According to recent surveys, the demand for meat in Sub Saharan Africa and especially Nigeria is on the rise [19]. The increase activities in the meat industry like other agro enterprises has provided food and constitute a formidable source of livelihood to millions of Nigerians [13]. The upsurge in youthful population, improved human and social capitals, increase in personal income as well as expanding cities and towns are some of the factors that contributed to increase in demand for meats [3]. Notwithstanding the boom in demand for meat and its derivatives in the country, the supply capacity is basically small-scale with marginal annual output growth rate [15, 4].

With the country's current population of more than 200 million [4], there are enormous challenges in realizing the recommended animal protein need of citizens. In addition, most of the country's livestock producers are poor in resources and are affected by climate change, high cost of feeds resulting from poor crop yields, conflicts and economics changes among others. Furthermore, the bulk of the nation's population (being young) is fast switching to diets rich in animal protein and its derivatives [1]. As a result, there a surge in the consumption of meat and its by-products in the country. It is imperative to enhance domestic production to prioritize the minimum animal protein consumption requirement of Nigerians [6].

The per capita meat consumption index in Nigeria is much lower than most African countries [17]. Information available has shown that, the per capita meat consumption in

Nigeria in 2021 was only about 8.30kg/ person annually, which is much lower than most African countries [10]. It is also significantly less than the average consumption of 19.0kg across the continent and the minimum standard (0.830g/kg of body weight per day) consumption recommended by the World Health Organization for adults [18]. To tackle the problem of animal protein deficiency in Nigeria, policies were enunciated and implemented within the framework of livestock transformation agenda of the federal government. The livestock transformation programme was developed to boost the production of animal-based protein sources with the aim of meeting the average minimum protein requirement of most Nigerians in 2027 [3]. However, the anticipated outcome of the program lies among other factors, on a sound macroeconomic environment [8]. It is shown that agricultural production and food consumption has a strong link with macroeconomic fundamental in developing countries [13].

Though there are few pieces of literature on the relationships between per capita meat consumption and macroeconomic variables, however their submissions need to be validated and updated especially considering the fact that unexpected economic downturns had bewildered the country in recent years. From the archive, related literature provided by Baskhronet al. [7], Akpan and Udoh [1], Akpan [3], Alsarawi et al. [11], Gale and Dong [12], Akpan et al. [4] have linked meat and its bye-products production and consumptions to changes in GDP, inflation, exports, imports, size of urban areas, per capita income, exchange rate, land density, credit availability, and price index thus producing a mixed inferences. Furthermore, Whitnall and Pitts [20] found that rising household income is a key driver of increased meat consumption in developing countries. Ewa et al., [9] put forward that poultry production is sensitive to macroeconomic shocks, particularly inflation and interest rate.

The scanty literature available suggests that there is no particular focus on per capita meat consumption in Nigeria. The meat subsector therefore needs a sound policy recommendation based on empirical evidence to isolate policy instrument necessary to close the current deficit gap in animal protein consumption among Nigerians. Over the years, the government has initiated and implemented several programs, created institutions and created delicious incentives for stakeholders in this sub-sector to increase meat production [5]. However, these attempts have resulted in marginal increase and unsustainable meat production and have continually widened the deficit in animal protein consumption among Nigerians [14]. The country needs a complementary policy direction that focuses on the macroeconomic environment related to meat production [7, 3]. Furthermore, Nigeria's macroeconomic environment, which is a key driver of real sectors, has changed significantly over the last two decades, including the recent global COVID-19 pandemic and recessions, necessitating an update in trend of meat consumption in the country and its relationship with some fundamental macroeconomic variables. There is also needed to access the country’s performance in meeting the SDG of zero hunger in the future.

In order to contribute to the above directions, the study was specifically designed to examine the trends in the per capita annual consumption of beef (cattle meat), chevon (goat meat) and chicken meat in Nigeria from 1981 to 2021 and establish the relationship between the per capita meat consumptions and some key macroeconomic fundamentals.

MATERIALS AND METHODS

The study was conducted in Nigeria. The country is rich in agricultural, mineral, marine, and forest resources. The study utilized secondary data obtained from the official sources such as: World Bank, Food and Agricultural Organization and the Central Bank of Nigeria. The data/information encompassed the time span from 1981 to 2022.

Model Specification

The trends in selected meat consumption

The explicit form of an exponential trend equation for the selected meats is represented in equation 1:

$$lnBMC_t = \delta_0 + \delta_1 t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots (1)$$

Note, variable "t" is the annual trend. The dependent variables are defined as:

(a) BMC_t= beef per capita consumption (kg/person) (meat from cow or bull)
(b) CMC_t= chicken meat per capita consumption (kg/person)
(c) GMC_t= chevron per capita consumption (kg/person) (meat from goat)

Therefore, the exponential growth rate is expressed in equation 2:

$$\text{Exponential growth rate} = \left(e^{\delta_1} - 1\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

To determine whether the specified per capita meat consumption growth rate suggests an accelerating or decelerating trend in an increase time period, an exponential equation in quadratic form was explicitly used as in equation 3:

$$Log_e BMC_t = \Psi_o + \Psi_1 t_1 + \Psi_2 t_1^2 + \varepsilon_t \ldots.(3)$$

If the estimated coefficient Ψ2 is found to be significant and possesses a positive sign, this indicates persistent growth in per capita meat consumption. Conversely, if Ψ2 is significant with a negative sign, it suggests a consistent deceleration in the growth of per capita meat consumption. However, if Ψ2 is not significant, it denotes stagnation in the growth of per capita meat consumption over time.

The factors influencing per capita meat consumption

The association between per capita meat consumption and some exogenous factors (i.e. macroeconomic fundamentals) was implicitly stated in a double -log form and is stated as:

$$BMC_t = f(FLT_t, INC_t, RET_t, CRD_t\ CAU_t) \ldots..(4)$$

where:

BMC_t = as defined previously in equation 1

FLT_t= Annual inflation rate (%) as a proxy for agricultural input price movement.

INC_t = Annual GDP per capita (Naira Person-1) as a proxy for household income.

RET_t= Annual nominal exchange rate (Naira per Dollar) (%) as a proxy for external influence (meat import) on meat consumption in Nigeria.

CRD_t = Annual domestic credit disbursed to the agricultural sector divided by GDP (%) to represent aggregate agricultural production.

CAU_t= Capacity utilization of the meat industry (%) as a proxy for substitutes.

An explicit form of equation 4 (representing the long run equation for cointegration meat equation) was specified and is expressed as shown in equation 5.

$$LnBMC_t = \partial_0 + +\partial_1 LnFLT_t + \partial_2 LnINC_t + \partial_3 LnRET_t + \partial_4 LnCRD_t + +\partial_5 LnCAU_t + U_t \ldots\ldots..(5)$$

Where U_t= error term defined as IID (0, δ^2_U)

To test for cointegration or a long run stable equilibrium link between the per capita meat consumption variable and some macroeconomic variables, the study used the Engle and Granger two-step technique. The conditions for using the method required that, all variables involved must be integrated in the same level. Following the confirmation of cointegration, the error correction model (ECM) was also estimated. The estimated ECM is shown explicitly in equation 6.

$$\Delta \text{LnBMC}_t = \theta_0 + \theta_1 \Delta LnBMC_{t-1} + \theta_2 \Delta LnFLT_t + \theta_3 \Delta LnINC_t + \theta_4 \Delta LnRET_t + \theta_5 \Delta LnCRD_t + \theta_6 \Delta LnCAU_t + \theta_7 ECM_{t-1} + U_t \ldots\ldots\ldots(6)$$

The coefficients (θ_7) capture the short run adjustment speed towards the long-run stability. The rest of the coefficients measure the short-run elasticity or impacts. The ECM stability and reliability was tested using the estimates of RESET test, serial correlation, normality and heteroscedasticity tests.

However, for the non-cointegrated equations of the per capita meat consumption, an autoregressive equation was specified to identify their plausible relationships with some key macroeconomic variables [11].

$$CMC_t = \partial_0 + +\partial_1 LnFLT_t + \partial_2 LnINC_t + \partial_3 LnRET_t + \partial_4 LnCRD_t + +\delta_5 LnCAU_t + \delta_6 LnCMC_{t-1} + U_t \ldots..(7)$$

Note, the dependent and explanatory variables specified in the model are defined in equation 4.

RESULTS AND DISCUSSIONS

The descriptive statistics of variables are shown in Table 1. The coefficient of variability is 39.40% in beef consumption; 14.56% in chicken meat and 21.15% in Chevon.
The results indicate that the country experienced only minor variations in annual per capita consumption of beef, chicken, and goat meat during the specified period. The findings suggest that the annual per capita meat consumption of beef, goat, and chicken remained largely stable throughout this timeframe. The indices of skewness are relatively low, further confirming that the annual per capita consumption of beef, goat, and chicken meat exhibited only marginal changes during the specified period.

Table 1. Descriptive tests

Variable	Mean	Minimum	Maximum	Std. dev.	CV	Skewness
Beef/capita (BMC_t)	2.5368	1.5165	5.2369	0.9994	0.3940	1.7110
Chicken meat/capita (CMC_t)	1.4921	1.0946	1.8275	0.2172	0.1456	-0.4930
Chevon/capita (GMC_t)	1.4263	0.8531	1.8915	0.3016	0.2115	0.1407
Inflation rate (FLT_t)	18.9490	5.3880	72.836	16.659	0.8792	1.8542
GDP/capita (INC_t)	1683.60	270.03	4471.10	1025.0	0.6088	0.3422
Exchange rate (RET_t)	108.170	0.6177	403.58	110.14	1.0182	0.9842
Domestic credit (CRD_t)	9.2506	4.9575	19.626	3.4678	0.3749	1.1862
Capacity utilization (CAU_t)	45.9710	12.700	75.750	14.450	0.3143	0.1553

Source: Computed by authors.

The mean for individual meat consumption is reported as 2.54kg/person for beef, 1.49kg/ person for chicken meat and 1.43kg/person for Chevon. These statistics revealed the country's gross deficiency in individual meat consumption when compared with other countries in Africa. For instance, poultry per capita consumption in Africa was reported as 5.77kg/person and beef as 3.68kg/person in 2020. Furthermore, the descriptive analyses performed on the macroeconomic variables indicated considerable fluctuations in the nominal exchange rate (RET), suggesting a degree of instability during the designated timeframe. The inflation rate similarly exhibited considerable variability, with an annual average of 87.92%. In contrast, the coefficient of variation was found to be minimal for both the capacity utilization variable within the meat industry and the credit disbursed to the agricultural sector. This suggests that the country's agricultural sector financing and meat industry capacity utilization rate only witnessed marginal changes during the study period. The skewness indices of the macroeconomic fundamentals all carried positive signs, which suggest that they exhibited a positive increment throughout the period of interest.

The patterns of meat consumption per capita in Nigeria

The findings displayed in Table 2 illustrate the parameters associated with the exponential and quadratic trend equations for the consumption of beef, chicken, and Chevon in Nigeria. The analysis indicated that the per capita consumption of both beef and chicken exhibits a negative correlation with time, implying that the consumption of these meat types diminishes as time progresses. The finding showed a negative exponential growth rate of -2.27% for beef and -0.99% for chicken from 1981 to 2022. However, Chevon consumption had a positive correlation with time, with an annual exponential growth rate of 0.74%. The finding aligned with the assertions of Baskhron*et al.,*[7] and Akpan [3]. The quadratic trend estimates for each meat equation showed that the consumption of these meats is significantly influenced by a longer period. For example, the negative coefficient of time-squared variable found in the chicken and Chevon equations imply that their consumptions decline as time increases. The

result also shows a significant increase in beef consumption over longer period.

The results of the analyzes suggest that the policies and programs adopted and implemented by the government to increase beef, chicken meat and Chevon in Nigeria have failed to achieve the desired objective in both the immediate and longer term. Although the result showed a slightly accelerated exponential growth rate in beef consumption, however this growth was not replicated in the square time-variable. In accordance with the result, several studies such as Baskhron et al. [7] and Akpan [3] have found similar relationship between some agricultural commodities and time variables in Nigeria.

Figure 1 shows a graphical illustration of the trend lines for beef, chicken meat and Chevon from 1981 to 2022 in Nigeria. The beef consumption followed a downward trend from 1981 to 1991. Thereafter, it assumed a progressive wave-like pattern until 2012. From 2013 to 2022, the beef consumption declines persistently. The trend in chicken meat showed a large fluctuation with distinct peaks and troughs.

Table 2. The exponential and quadratic trend equations for Beef, chicken and Chevon

	BEEF	**CHICKEN**	**CHEVON**
Variable	**Coefficient/t-test**	**Coefficient/t-test**	**Coefficient/t-test**
Constant	1.35(23.06)***	0.60(19.21)***	0.18(2.80)***
Time	−0.023(-9.54)***	−0.01(-7.71)***	0.007(2.81)***
R-square	0.69(88.63)***	0.60(59.45)***	0.17(0.74)
Exp. Gr (%)	**-2.268**	**-0.991**	**0.743**
F-cal.(1, 39)	88.634***	59.453***	0.7425
	Quadratic estimates		
Constant	1.50(17.31)***	0.51(11.32)***	−0.25(-6.15)***
Time	−0.04(4.63)***	0.003(0.56)	0.07(15.03)***
Time square	0.001(2.28)**	−0.0003(-2.67)**	−0.001(-13.79)***
R-squared	0.731***	0.667	0.861
F-cal.(2, 38)	51.689***	37.943***	118.116***

Source**:** computed by authors. The symbols ***, **, and * represent different levels of statistical significance.

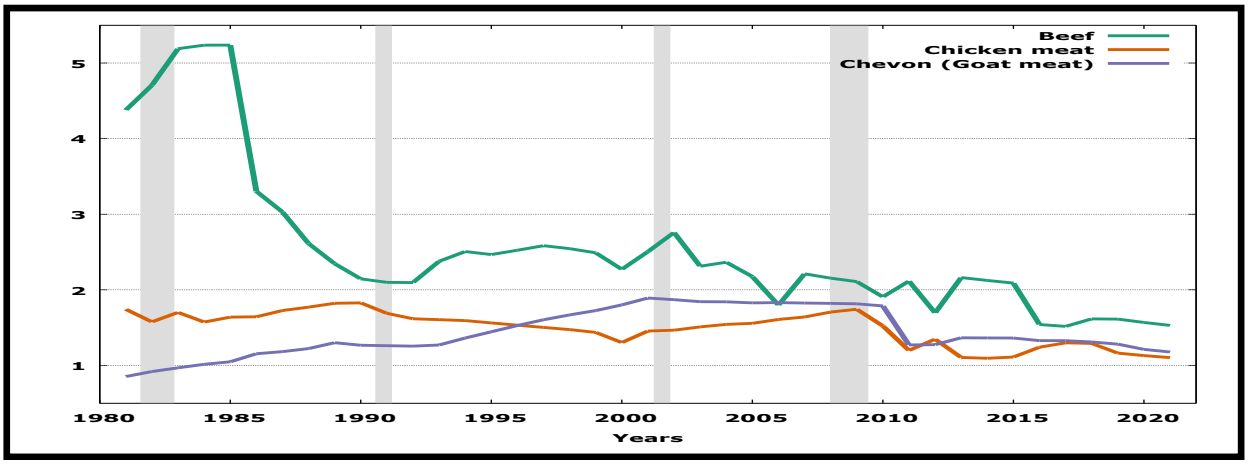


Fig. 1. Trends in per capita meat production in Nigeria (1981 to 2021*)*
Source: Own design based on the data from FAO.

The trend increased steadily from 1.74 kg per person in 1981 to 1.83 kg per person in 1990 and then worsened to 1.30 kg per person in 2000. From 2002 to 2021, the trend in chicken meat showed an average declining trend. The trend in Chevon consumption shows a gradual progressive growth from 1981 to 2001. From 2002 onwards, the trend steadily decreased, with a sharp decline in 2011 and minimal acceleration thereafter until 2021.

Stationarity test

The ADF unit root test was conducted at a 1% probability level. The results as shown in Table 3, confirms that the series were not stationary at their levels, but they were at their first difference.

Table 3. ADF estimates

Variables	ADF unit root (without constant)				
	Level	**Lag**	**1st Diff.**	**Lag**	**Decision**
Beef/capita (BMCt)	-1.7808	0	-6.5105***	0	1(1)
Chicken meat/capita (CMCt)	-1.3211	0	-6.9699***	0	1(1)
Chevon/capita (GMCt)	-0.5139	0	-4.9621***	0	1(1)
Inflation rate (FLTt)	-0.8074	0	-6.2809***	0	1(1)
GDP/capita (INCt)	-0.1086	0	-6.0466***	0	1(1)
Exchange rate (RETt)	1.9705	0	-4.3109***	0	1(1)
Domestic credit (CRDt)	0.2469	0	-5.7867***	0	1(1)
Capacity utilization (CUTt)	-0.4462	0	-6.5973***	0	1(1)
Critical values					
1%	-2.6241		-2.6256		

Source: Own results.
Note: Asterisks *** indicates 1% significance level. Variables in log.

This unit root results suggest that the appropriateness of the two-step Engle methodused to verify the presence of co-integration among variables. However, to use this method, it is required that all specified variables must be stationary at the same level.

Test of cointegration

The Engle Granger two-step method was employed to examine whether there is cointegration among the stated variables. The test results are presented in table 4. To confirm the presence of co-integration, it is required that the residuals from the long run equation must be stationary at level. The findings indicate that out of the three specified equations (beef, chicken meat and Chevon), only beef equation demonstrated evidence of co-integration. That is, the residuals of the beef long run model did not have unit root. Hence the null hypothesis was not accepted and this implies that the variable or residuals was stationary at level. This result suggests that there is a stable long-run correlation between the beef consumption and some macroeconomic variables.

Table 4. Co-integration test of variables

Equation residual	ADF test (without constant)	Order of integration	Remark
Beef/capita BMCt)	-3.7055***	1(0)	Co-integration
Chicken meat/capita (CMCt)	-1.9939	-	No co-integration
Chevon/capita (GMCt)	-1.8977	-	No co-integration
Critical value at 1%	-2.6241		

Source: Own results.
Note: Asterisks *** indicates 1% significance level. Variables in log.

The short and the long run determinants beef consumption

Following the confirmation of the co-integration in the beef equation, the short and the long run models were estimated and analyzed in the next sub-sections.

Long run determinants of the per capita beef consumption

The results in Table 5 shows the long-run estimates of beef consumption. The regression estimates divulged that the beef consumption has a positive association with per capita GDP, agricultural sector credit, and meat industry capacity utilization. This implies that a unit increase in the per capita GDP, agricultural sector credit, and meat industry capacity utilization would result in a corresponding increase in beef consumption in the long run.

By implication, an increase in per capita GDP means an increase in the citizens' disposable income, which in turn entails an increase in demand capacity of the population. Therefore, an increase in the demand potential or capacity of the population will correspondingly trigger an increase in effective demand for a beef which is considered a normal good. This finding is consistent with the reports of Akpan and Udo [1], and Whitnall and Pitts [20].

Likewise, an increase in total credit to agricultural sector increases the beef consumption. A unit increase in the total credit to the agricultural sector would lead to about 0.17467 unit increase in per capita beef consumption. By implication, increase in total credit to agricultural sector would lead to increase in beef production, since farm credit is known to enhance farm production. The finding is consistent with the submission by Whitnall and Pitts [20].

Table 5. Determinants of Beef/capita consumption in Nigeria

Variable	Coefficient	Std. Error	t-ratio	p-value
Constant	0.90932	0.47834	1.901*	0.0656
LogInflation rate	−0.03220	0.01075	−2.995***	0.0021
logGDP/capita	0.06157	0.02978	2.068**	0.0461
logExchange rate	−0.17394	0.01539	−11.29***	<0.0001
logCredit disbursed	0.17467	0.08519	2.050**	0.0479
logCapacity utilized	0.19581	0.08325	2.352**	0.0244
R^2	0.846			
F- cal. (5,35)	33.8479***			

Source: Own results.
Note**:** The asterisks ***, **, and * represent 1%, 5%, and 10% level of significance respectively. Variables in log.

In addition, higher capacity utilization rate of the meat industry will increase the absorption capacity of the industry and thus boost production at the farm level. An increase in production would likely expand demand capacity of consumers. In another dimension, the increase in the meat industry's capacity utilization rate would lead to increase in production of processed beef and its derivatives. This will equally create wider opportunities for consumers to purchase or consumed diversified beef products. The finding is similar to the empirical reports of Whitnall and Pitts [20], Akpan [3.

Conversely, the exchange rate (₦/$) and the inflation rate have a significant negative association with per capita beef consumption in the long run. The results meet *a priori* expectations. An increase in the Naira exchange rate means a depreciation of the domestic currency against the US dollar. Therefore, a high exchange rate of the domestic currency restricts imports and indirectly limits domestic production. The Nigerian meat industry is still developing and relies heavily on imported capital from developed countries and live animals from neighboring Niger, Chad, Benin Republic, Sudan, Mali and Cameroon. When production is hindered, total supply decreases, resulting in a higher price of beef per unit. As household disposable income deteriorates in the country, the increase in the exchange rate indirectly leads to a decline in per capita beef consumption. The results are consistent with the conclusions of Akpan [3]. Similarly, an increase in inflation rate would result to an increase in the real prices of the factor of production and the total cost of production for beef producers, thereby reducing production. For consumers, increase in inflation reduces the real value of household income and their demand capacities. Akpan [3] have reported similar results.

Short run estimates (beef equation)

The estimates of the short run model is presented in Table 6. The coefficient of ECM is negative and statistically significant, confirming the presence of co-integration between the beef consumption and specified macroeconomic variables. The ECM parameter indicates the speed of adjustment and convergence to long-run equilibrium from the short run disturbance. A convergence rate of about 72.17% to long-term equilibrium was found. The diagnostic tests showed that the short-run estimates are not biased, but they are efficient and sufficient. The diagnostic tests of the ECM suggest that the model estimates are stable, unbiased, and free of fundamental econometric problems.

Table 6. Short run determinants of Beef/capita consumption in Nigeria

Variables	Coefficient	Std. error	t-value	Probability
Constant	0.00379	0.01827	0.208	0.8370
ΔlogBeef(-1)	0.06876	0.12344	0.557	0.5821
ΔlogInflation rate	−0.06724	0.02782	−2.417**	0.0227
ΔlogInflation rate(-1)	0.01540	0.02725	0.565	0.5765
ΔlogGDP/capita	0.09021	0.03259	2.768**	0.0101
ΔlogGDP/capita(-1)	0.06752	0.03679	1.835*	0.0775
ΔlogExchange rate	−0.16705	0.07263	−2.300**	0.0294
ΔlogCredit disbursed.	0.04048	0.05918	0.684	0.4999
ΔlogCredit disbursed(-1)	0.09176	0.07769	1.181	0.2479
ΔlogCapacity utilized	0.13654	0.04782	2.856***	0.0082
ΔlogCapacity utilized(-1)	−0.00267	0.04984	−0.054	0.9577
ECM(-1)	−0.72174	0.15673	−4.605***	<0.0001
R^2	0.493895			
F(11, 27)	8.117340 (0.000)			

Source: Own results.

Note: The asterisks ***, **, and * signify probability levels at 1%, 5%, and 1%, respectively. The variables incorporated in the error correction model (ECM) are represented in logarithmic differences. The Akaike Information Criterion was employed to establish the suitable lag length.

The findings indicated a significant negative correlation between the rate of inflation and nominal exchange rates (N/$) with per capita beef consumption during the short run. A comparable outcome was observed in the long run. This means that as inflation and exchange rates rise, beef consumption falls. The increase in the inflation rate is typically accompanied by increases in prices and a decrease in real household income. As a result, a rise in inflation would diminish real household income, subsequently leading to a decrease in per capita beef consumption. Similarly, an escalation in the exchange rate will constrain domestic production, culminating in a supply shortfall and a decreased capacity for household demand. These findings were corroborated in the long-run model. Ewa et al. [9] reported analogous results.

Moreover, an increase in the exchange rate decreases the purchasing power of the domestic currency on the international stage, consequently limiting the import of live animals and their derivatives in the short term. Conversely, per capita income (GDP) exhibits a positive relationship with per capita beef consumption in the short term. This finding indicates that an increase in per capita income is likely to result in a corresponding rise in beef consumption.

The result aligned with *a priori* expectation since beef is considered a normal commodity whose consumption increase as household income increases. The results confirm Akpan [3] submissions.

Furthermore, the findings indicate a significant positive correlation between beef consumption and per capita income in the short run. It was observed that current per capita income (GDP) and its lagged value exhibited a positive association with beef consumption during this period. Additionally, a comparable relationship emerged between per capita beef consumption and the utilization of meat industry capacity. This association suggests that an increase in the meat industry's capacity utilization rate corresponds with a rise in per capita beef consumption in the short run. The underlying reasons for these relationships are consistent with those previously discussed in the context of long-run dynamics. These results are further supported by the work of Akpan and Udo [1] and Whitnall and Pitts [20].

Diagnostic assessment of the short-run model

The diagnostic tests concerning the ECM estimates are outlined in Table 7. The Breusch-Godfrey Serial Correlation (LM Test) result of 0.0006 indicates that serial correlation is not significant.

The result of the RESET test suggests that the ECM has structural rigidity.

The Breusch-Pagan test showed insignificant effect of heteroscedasticity while the normality

test confirms the normal distribution of the estimated residuals.

Table 7. Validity tests of ECM

Required Tests	Value	Probability
Ramsey RESET	3.487	0.073
Normality	0.223	0.895
Breusch-Pagan-Godfrey	5.445	0.908
Breusch-Godfry Serial Correlation LM test	0.0006	0.980

Note: composed by the authors.

Determinants of Chevon and Chicken Meat Consumption

After rejecting cointegration in chevon and chicken meat per capita consumption models, an autoregressive model was specified to examine the empirical relationships between these meat consumption indices and selected macroeconomic variables.

The results of the autoregressive model for chicken meat and chevon are presented in Table 8 and Table 9 respectively.

Table 8. Autoregressive estimates of chicken meat in Nigeria

Variables	Coefficient	Std. Error	t-ratio	p-value
Constant	-0.1151	0.1654	-0.6963	0.4914
LogInflation rate	-0.0236	0.0127	-1.8584*	0.0726
logGDP/capita	0.0118	0.0017	6.8395***	0.4991
logExchange rate	-0.0210	0.0115	-1.8231*	0.0835
logCredit disbursed	0.0396	0.0522	0.7579	0.4542
logCapacity utilized	0.0519	0.0271	1.9136*	0.0649
logChicken meat(-1)	0.7803	0.1758	4.4385***	0.0001
logChicken meat(-2)	0.0314	0.2130	0.1472	0.8839
R^2	0.812265			
F(7, 31)	31.97076			

Source: Own results.

Note: The asterisks ***, **, and * signify probability levels at 1%, 5%, and 1%, respectively. Variables used in the error correction model (ECM) are expressed in log differences. Akaike criterion was used to determine the appropriate lag length.

Table 9. Autoregressive estimates of Chevon estimates

Variables	Coefficient	Std. Error	t-ratio	p-value
Constant	0.1415	0.1612	0.8780	0.3872
LogInflation rate	-0.0703	0.0143	-4.9274***	0.0001
logGDP/capita	0.0265	0.0124	2.1414**	0.0430
logExchange rate	-0.0141	0.0048	-2.9441***	0.0063
logCredit disbursed	0.0250	0.0263	0.9495	0.3502
logCapacity utilized	0.0164	0.0341	0.4820	0.6334
logChicken meat(-1)	1.0081	0.1588	6.3480**	<0.0001
logChicken meat(-2)	0.2268	0.0810	2.8016***	0.0090
logChicken meat(-2)	0.1407	0.0584	2.4082**	0.0206
R^2	0.899951			
F(8, 29)	99.59958			

Source: Own results.

Note**:** The asterisks ***, **, and * signify probability levels at 1%, 5%, and 1%, respectively. Variables used in the error correction model (ECM) are expressed in log differences. Akaike criterion was used to determine the appropriate lag length.

The use of an autoregressive model was necessary to reduce the effect of autocorrelation on the models. The appropriatelag length was determined based on decision criteria. The Breusch-Godfry Serial Correlation coefficient (as shown in Table 10) indicates that, autocorrelation was not significant in the two models. This justifies the use of the autoregressive model.

Other diagnostic statistics revealed that the estimated model has structural stability, which is confirmed by the value of the RESET tests. The estimated models do not exhibit significant heteroscedasticity (Breush-Pagan test); while the model stability (CUSUMSQ tests) and the normality tests of the residuals met conventional requirements.

Table 10. Diagnostic Statistics of AR models

Test	Chicken meat	Chevon
Ramsey RESET Test	0.80 (0.46)	0.42(0.66)
Normality test	6.12(0.046)	1.68(0.21)
Heteroscedasticity (Breusch-Pagan-Godfrey)	11.04(0.136)	4.44(0.33)
Breusch-Godfry Serial Correlation LM Test	0.09(0.76)	0.79(0.38)
CUSUM test	-1.65(0.11)	-0.94(0.36)

Source: prepared by authors.

The findings indicate that the inflation rate, per capita GDP or income, and the capacity utilization rate within the meat industry significantly affect per capita chicken meat consumption in Nigeria. Notably, both the inflation rate and the exchange rate exhibit a negative correlation with per capita chicken meat consumption. For example, an increase of one unit in the inflation rate corresponds to a reduction of 0.0236 units in per capita chicken consumption in the country. Furthermore, a one-unit rise in the exchange rate (N/$) is expected to lead to a decrease in per capita chicken consumption by 0.0210 units. However, the result is consistent with the reports of Ewa et al. [9]. Likewise, a change in per capita GDP and capacity utilization of the meat industry were found to have a positive association with per capita chicken meat consumption. Consequently, an increase of one unit in both the per capita GDP and the capacity utilization rate of the meat industry would result in an increase of 0.0118 units and 0.0519 units in the per capita consumption of chicken meat within the country, respectively. The estimation of the Chevon model indicated that both the inflation rate and the exchange rate exhibit a negative correlation with per capita consumption of Chevon. Conversely, there exists a positive relationship between per capita GDP and prior levels of per capita consumption of Chevon. These findings align with the conclusions drawn by Akpan [3].

CONCLUSIONS

The research indicates that meat consumption per capita in Nigeria is significantly insufficient. The analyses found that the average per capita consumption of beef, goat meat, and chicken in Nigeria is below the average reported for Africa in 2021. The study estimated negative annual growth rates for beef and chicken meat per capita consumption and a marginal positive annual growth rate in Chevon consumption. The findings imply that the country consumed far less of animal protein compared to the recommended standard and most of the African countries. This has posed a serious challenge considering the fact the country is ranked among the top in poverty, malnutrition, and insecurity.

Secondly, the current meat consumption situation in Nigeria presents numerous opportunities for both domestic and foreign investments in the meat industry, taking advantage of the large population of over 200 million.

The results suggest that changes in per capita GDP, credit to the agricultural sector, inflation rate, nominal exchange rate and the meat industry's capacity utilization rates have significant impacts on meat consumption in Nigeria. These highlights the important role of macroeconomic environment in agricultural commodity consumption. Following the results obtained, it is recommended that the country effectively implement economic policies that will control inflation rate growth; improve per capita income; stabilize the exchange rate; enhance agricultural credit disbursement and increase capacity utilization in the meat industry as complementary strategies to improve meat consumption in the country.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

EXPLORING THE DRIVERS OF INCOME DIVERSIFICATION AMONG OIL PALM FRUIT (*Elaeisguineensis*) FARMERS IN SOUTHERN NIGERIA

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Abstract

The study delves into the extent and various factors influencing the drive for farm income diversification among small-scale oil palm fruit (Elaeis guineensis) farmers in Akwa Ibom State, Southern Nigeria. A structured questionnaire was utilized to gather data from 300 oil palm fruit farmers in the area. Descriptive tools, the Herfindahl index, and the Tobit model were employed to analyze the collected data. It was observed that the majority of oil palm fruit farmers were married women, educated but with limited social interactions, and had an average family size of 7 members. The research indicates that the average farm income diversification index was 0.73, suggesting that income diversification among oil palm fruit farmers in the region is a matter of concern.In addition, the results showed that oil palm fruit farmers' formal education, farming experience, socialization, household size, farmers' age, distance from the farm gate to the market and household expenditure were significant positive determinants of income diversification index; while land size and farmers' sex were negative determinants. For the improvement of farm income in small-scale oil palm fruit production in the southern region of the country, it is advised that stakeholders collaborate to allocate land for oil palm farmers. Furthermore, it is important to motivate youths to engage in oil palm fruit production in the region.

Key words**:** *income, diversification, oil palm fruit, sustainability, Nigeria*

INTRODUCTION

The oil palm tree (*Elaeis guineensis*) is one of the major economic tree crops in tropical regions of the World [41]. This monocotyledonous plant is a member of the palm family Arecaceae and Sub-family, Cocoideae [23], known for its versatility and economic value across all its parts. As of 2022, the country yielded 12.6 million metric tons of oil palm fruit from 4.91 million hectares of land [28]. One of the main outputs of the oil palm tree is the palm fruit. The fruit is customarily, processed to yield various marketable products, such as palm oil, palm kernel oil, and palm kernel cake [41]. Additionally, the tree is utilized for production of wine, which is often consumed locally, and is a valuable source for ethanol production among others [25, 48].

Palm oil is the most commonly used derivative of oil palm fruit, as it used for household consumption, pharmaceutical industry, toiletry and energy production among others [25]. In Africa, Nigeria is currently the leading consumer of palm oil, consuming about 1.8 million metric tons in 2023. With a population exceeding 200 million, Nigeria has historically played a crucial role in the global palm oil market. In the pre-independent era, the country accounted for nearly half of the world's palm oil exports. By the mid-1960s, Nigeria held a substantial 43% share of the global market, making a significant contribution to the nation's GDP [45]. In the recent years, Nigeria's position as a top palm oil producer has declined with the rise of Indonesia, Malaysia, and Thailand as industry leaders. This shift can be largely attributed to Nigeria's shift towards prioritizing crude oil extraction. As of 2023, Nigeria now ranks fifth in global palm oil production, producing approximately 1.50 million metric tons annually, and accounting for around 2% of the world's total output [28]. Despite being a major producer of oil palm derivatives in Africa, Nigeria's annual production falls short of domestic demand, leading the country to rely heavily on imports. This has significant financial implications for the Nigerian economy. Despite facing a supply

deficit in the sector, the importance of oil palm production is increasing due to its impact on job creation, industrialization, and rural income generation, among other factors [5, 47]. Palm oil is known for its rich content of carotenoids, vitamins, tocopherols, fatty acids, vitamin E, and emulsifiers, highlighting its nutritional value and versatility [30].

In the southern region of Nigeria, the production of oil palm fruit is primarily carried out by small-scale producers, comprising approximately 80.00% of the industry [4]. These small-scale farmers cultivate land area spanning from 1.04 to 1.33 million hectares, representing about 74.00% of the total production area in the region [37]. The remaining 26.00% of the production area is comprised of privately owned oil palm estates and other smallholder farmers who participate in government schemes like out-grower schemes, cooperative plantations, and other commercial ventures cultivating improved 'Tenera' varieties. According to MADE [37], the sub-sector provides employment opportunities for over one million smallholder plantation farmers, oil palm millers, processors, farm workers, and market agents, including wholesalers and retailers in the southern region of Nigeria.

The sustainability of oil palm fruit production in the southern region of Nigeria is a major concern due to increasing population density and poverty levels in the region. Farmers in this region face challenges such as rising input prices, income inequality, limited access to credit, price volatility, and an unfair marketing system [44, 10, 11]. Additionally, the remote location of oil palm farms, poor infrastructure, and lack of accurate market information hinder farmers from engaging in fair and competitive marketing activities [40]. These inefficiencies have a negative impact on farmers' incomes and livelihoods [32, 38].

Farm income diversification drive in small-scale farmers has become an effective way to reduce farm risk, provide cushion during economic downturn and pandemic, guaranteed farm financial security and create new opportunity for economic growth and innovation adoption. Income diversification among small-scale farmers also arose following the need by farmers to increase market share of their products and revenue opportunities as well as poverty mitigating strategy [12, 1, 35, 15]. Specifically in Nigeria, the inability of the government to provide adequate economic cushioning and security to farmers has persistently intensified the small-scale farmers' urge or yearning to diversify their farm likelihood income means [18, 34]. Documented evidence has shown that an average Nigerian farmer suffered low farm earnings, mounting risk in production and inefficient marketing environment [13, 6, 46, 49]. Additionally, factors such as population growth, deforestation, conflicts between herders and farmers, and unpredictable economic and political conditions, along with the impacts of climate change, have led to small-scale farmers in Nigeria diversifying their sources of income in various ways within the agricultural sector [27, 42].

While diversifying income streams can be beneficial for farmers in a stable economy by increasing their overall income [35, 1, 2], in Nigeria's current economic situation, it may connote persistent inefficiency in production and deteriorating well-being of farmers [15, 3]. It is worrisome that the persistency of livelihood/income diversification among resource poor small-scale farmers could further deteriorate the already flooded labour market in the country [3]. The situation could aggravate unemployment and further dwindles the efficiency of the agro-economy in the country.

The subject matter on income or livelihood diversification of oil palm fruit producers in the southern region of Nigeria is critical because the agro-enterprise is a significant employer of labour and a major contributor to the agricultural GDP of the region. This agro-enterprise is practiced mostly in rural areas, and is currently affected by increasing deforestation, seasonality in production, the nature of land ownership required for the establishment, high population density, urbanization and climate variability as well as pressure from alternative land uses [5, 12, 10, 4, 9]. The income diversification among oil palm fruit farmers in the region is exaggerated because evidence abound that farm resources

are seldom allocated efficiently in small-scale farm production [7, 12]. This is because the production system is still undeveloped and is characterized by using less efficient techniques than modern and improved methods. Despite these drawbacks in oil palm fruit production, several researchers have accredited the persistency in the production of oil palm fruit in the region to multidimensional factors connected to farmers' social and economic status as well as farm-specific features, among others [8, 39]. As part of the sustainability plan, an attempt to identify these key factors and their roles are critical in enunciating and implementing a workable policy framework that would fast track the overall development of oil palm fruit production and other tree crops in the region and Nigeria as a whole.

To chart a sustainable path for the sustainability of many agribusinesses in developing countries, several empirical studies have documented the relationship between the decision to diversify farm income and several categories of factors. In this regards, Edet and Etim [26] found family size, farming experience, social capital, non-farm income, farm income, asset base of farming household and farmers' access to farm credit as critical factors affecting likelihood diversification of rural farmers in Akwa Ibom State, Nigeria. According to Idris-Adeniyi et al. [33], income diversification among arable crop farmers in Osun State, Nigeria, is influenced by factors such as household age, access to credit, household size, and the frequency of extension visits. Crop. In a similar vein, Aynalem [19] provided documented evidence that revealed, educational status of household head, access to credit, access to electricity, distance to the nearest market, household head gender, yearly household income, entrepreneurial skill and household size were significant factors affecting income diversification of small holder farmers in Ethiopia. In a study conducted in Nigeria, Malami et al., [36] found that factors such as non-farm income, number of income sources, age of household head, and years of education were positively and significantly related to the income diversification index of smallholder farmers. Similarly, a study in India by Harishankar et al., [31] identified determinants of income diversification among dairy farm households including education level of farmers, household size, land tenure, size of herd, proximity to agricultural or allied industry, access to farm credit, and membership in social organizations. In a related study conducted in Ethiopia, Getahun et al., [29] identified several key factors that influence income diversification among rural households, including farmers' age, ownership of livestock, farm size, years of formal education, food scarcity, adoption of sustainable farming practices, as well as climate factors such as rainfall and temperature. Similarly, Atalelech and Alula [17] found that factors such as farmers' age, household size, livestock ownership, availability of farm inputs, access to credit, and participation in training programs play a significant role in driving income diversification among small-scale farmers in Ethiopia. Moreover, Andualem and Umer [16] showed that male controlled household, land size, socialization, and participation in government program have positive correlation with the rural household income diversification, while distance to market has a negative relationship. Akpan *et al.,* [3] showed that, farmers' family size, hired labour and formal education are positive determinants of income diversification among fluted Pumpkin farmers in Akwa Ibom State, Nigeria. On the other hand, the negative determinants were farmers' age, extension services, socialization, farm size, fertilizer, manure, and family labour. Alemu, [4] in Ethiopia, reported that farmers' education level, household size, type of irrigation, soil conservation practice, extension services, livestock owned, and the quality of infrastructure affect the intensity of their livelihood diversification. Chukwu, and Chukwu, [24] found income diversification index among households in Nigeria was driven by farmers' own assets, family size, female control household, formal education, family dependency ratio, access to credit and distance from the farm gate to the tarred road.

From the pool of literature, most income diversification studies in developing countries are tailored on household income behaviour generally. That is, the whole household farm

income sources are treated as a common source in estimating income diversification index. Thought this technique is revealing, but it however will hardly expose the sustainability prospect of individual agro-enterprise within the household. Again, some of these studies emphasized on arable crop farmers without due consideration to cash crop farmers like oil palm fruit farmers. Based on the peculiar characteristic of cash crop such as seasonality in production and its declining outputs in recent years [28], cash crop subunit needs a special consideration in the country. Therefore, the study was designed to provide a deeper insight especially on cash crop farmers' income diversification options. The need to generate current policy variables based on the current realities is necessary to achieve sustainability and open the sub-unit for more investment opportunities. Hence, the study was specifically aimed at estimating income diversification index of oil palm fruit farmer and identified factors that influence it.

MATERIALS AND METHODS

Area of study Description

Study Area The research was carried out in the agricultural zones of Abak and Uyo in Akwa Ibom State, situated in the southern part of Nigeria. Akwa Ibom State, found in the coastal area, comprises six agricultural zones. Other agricultural zones in the State include: Oron, Ikot Ekpene, Eket, and Etinan zones. The Abak agricultural zone consists of five (5) local government areas namely: EtimEkpo, Abak, OrukAnam, Ukanafun, and Ika local government areas, while Uyo zone consists of Uyo, Uruan, IbesikpoAsutan, Ibiono Ibom and Itu local government areas.

Sample Size Selection

The study used the Yamane, [50] method of sample size selection. From the large population of small-scale oil fruit farmers in the study areas, the representative sample was derived using the formula given in equation 1.

$$S_y = \frac{W^2\varphi(1-\varphi)}{L^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Note, S_y connotes sample size, W is 1.96 (that is 95% confidence interval); "φ" represents 80% (proportion in percentage of oil palm fruit farmers in the total population of cash crop farmers in the study areas); L represents the absolute error (at 5% probability level of type 1 error). The sample size was obtained using the formula presented in equation 2.

$$S_y = \frac{(1.96)^2 0.80(1 - 0.80)}{(0.05)^2} = 246 \dots (2)$$

From the calculation, the total of two hundred and forty-six oil palm fruit farmers were needed for the study. However, for the purpose of equality in distribution of respondents across the study areas, the sample size was scaled up to three hundred. Hence, the total sample size used in the study was three hundred oil palm fruit farmers selected across the study areas.

Sampling Technique and Method of Data Collection

The oil palm fruit farmers in the study area were selected using a combination of sampling methods.

Initially, a purposive sampling technique was employed to choose four local government areas in the IkotEkpene agricultural zone and three local government areas in the Uyo agricultural zone during the first stage. A total of seven (7) local government areas were used in the study.

The essence of using a purposive sampling technique in this stage was to target and capture heavy production areas within the State. During the second stage of the analysis, high production intensity areas were pinpointed in the local government areas, and a ppredetermined number of villages were randomly sampled as depicted in Table 1. Note.

The number of villages and respondents were randomly selected proportionally to the total numbers to obtain equity in sampling.

The next phase was a random sampling of the oil palm fruit farmers in each of the selected villages.

A total of three hundred (300) oil palm fruit farmers were randomly sampled and used for the study.

Table 1. Distribution of respondents

Sample Areas	No. of Villages	Farmers per village	Total sampled	% of total
Ukanafun	7	10	70	23.33
EtimEkpo	6	10	60	20.00
OrukAnam	7	10	70	23.33
Ika	4	10	40	13.33
Ibiono Ibom	5	4	20	6.67
IbesikpoAsutan	5	4	20	6.67
Itu	5	4	20	6.67
Total	**39**		**300**	**100.0**

Source: calculated by authors.

The primary data were extracted from the oil palm fruit farmers. Data were primarily gathered through a structured questionnaire, which was further supplemented by focus group discussions with multiple farmers' groups and key informants in villages. The questionnaire aimed to gather information on the socioeconomic profiles of the farmers, their marketing decisions, sources of income, as well as the various factors influencing their marketing strategies within the study area.

Method of Data Analysis

The data gathered from oil palm fruit farmers were analyzed in accordance with the study's objectives. Descriptive statistics such as means, standard deviation, and coefficient of variability were employed to investigate the socio-economic features of oil palm fruit farmers in the research area. Furthermore, diversification indices were generated using the Herfindahl index, while the Tobit model was utilized to ascertain the factors influencing farm income diversification among oil palm farmers in the region.

Theoretical framework

The theoretical framework of the study is based on the concept expected utility maximization concept of a rational farmer. The concept proposes that a farmer decision to maintain the current state of production is a choice among the alternatives. It is assumed that an oil palm fruit farmers has several options to earn income, and he would choose among the options based on the anticipated benefits or utility. Alternatively, the oil palm fruit farmer's option to participate in income diversification is conditioned by its expected satisfaction and the relationship can be expressed in utility function. Although the utility function is unobserved, the correlation between the expected utility corresponding to each of the alternative is assumed to be a function of the vector of observed explanatory variables and a stochastic error term [20]. In the case of utility maximization theory; an oil palm fruit farmer is assumed to have a full information about the various income sources available, with an infinite capacity to analyze the expected utility derivable from each of this option, and utilizing such information to maximize their expected utility from a set of decisions subject to budget constraint [21]. Hence, an econometric model such as Tobit can be employ to relate various variables from which marginal coefficients can be estimated [20].

The Herfindahl Index

Herfindahl Index (HI) is defined as the square of the proportion of farm income (oil palm fruit farming income) in the total income (both farm and non-farm income) of the oil palm fruit farmer. This index was computed with reference to one farming season preferably the last farming season at the point of interview to allow for fair comparison of income sources. The index is described as follows:

$$HI = \left(\frac{\sum_{i=1}^{n} oil\ palm\ fruit\ farm\ income}{\sum_{i=1}^{n} Total\ income}\right)^2 = \left(\frac{FI}{TI}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In the given formula, HI represents the Herfindahl Index, 'n' denotes the total number of income sources accessible to the oil palm fruit farmer during the previous production season, and FI signifies the total farm income acquired by the oil palm fruit farmer solely from production and processing of oil palm fruit in the last production season; TI is the total income including total farm income and total non-farm income accrued to an oil palm fruit farmer in the last production season. The Herfindahl index is also known as concentration/intensification index. The value ranges from zero to one. It measures the degree of concentration or intensification of a particular income source in the total income of a farmer at a particular period. The Herfindahl concentration index of zero and unity imply complete diversification and specialization

respectively. The Herfindahl index was transformed to measure income diversification index of oil palm fruit farmers as shown in equation 4.

$$DIN = 1 - (HI) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The Diversification Index (DIN) is a reverse of Herfindahl index (HI) and it takes the value of zero to one. A diversification index approaching zero implies increasing income intensification/specialization, while a diversification index of zero connotes complete specialization or intensification of farm income. On the contrary, a diversification index approaching one (1) indicates increasing diversification. While a diversification index of one, indicates complete income diversification.

Determinants of income diversification among oil palm fruit farmers

A Tobit model regression was specified to identify determinants of income diversification among oil palm fruit farmers. The standard Tobit model for this study is defined as follows:

$$Y_i^* = X_i\beta_i + U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$Y_i = Y_i^*, if\ Y_i > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$Y_i = 0, if\ Y_i \leq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where Y* is the latent dependent variable, Y_i is the observed dependent variable, X_i is the vector of the independent variables, β is the vector of coefficients, and the $\underline{U_i}$ is a stochastic error term and is assumed to be independent, normally distributed with zero mean and constant variance ($U_i \sim$ iid, N (0, σ^2).

The explicit form of the Tobit model is presented in equation 8.

$$\begin{aligned} DIN = Z_i = {} & \beta_0 + \beta_1\emptyset_1 + \beta_2\emptyset_2 + \beta_3\emptyset_3 + +\beta_4\emptyset_4 \\ & + \beta_5\emptyset_5 + \beta_6\emptyset_6 + \beta_7\emptyset_7 + \beta_8\emptyset_8 \\ & + \beta_9\emptyset_9 + \beta_{10}\emptyset_{10} + \beta_{11}\emptyset_{11} \\ & + \beta_{12}\emptyset_{12} + \beta_{13}\emptyset_{13} \\ & + U_i \ldots\ldots\ldots\ldots (8) \end{aligned}$$

where DIN is the measure of farm income diversification index noted in equation 4. The marginal effect of the Tobit model captures an instant impact that a shock in independent variable has on the latent or dependent variable. It captures the percentage change in a dependent variable attributed to the same percentage change in an explanatory variable. It is computed as the first partial derivative with respect to each of the explanatory variable specified. Variables used in equation (8) are defined in Table 2.

Table 2. Description of explanatory variables

S/n	Variable	Symbol	Unit	Expected sign
1	Marital status	$\emptyset_1$	dummy (1 for married and 0 otherwise)	Positive or negative
2	Years of formal education	$\emptyset_2$	Years	+ or –
3	Farming experience	$\emptyset_3$	Years	+ or –
4	Socialization of farmers	$\emptyset_4$	Years	+ or –
5	Household size	$\emptyset_5$	Number	+ or –
6	Household Dependent ratio	$\emptyset_6$	Ratio	+ or –
7	Household expenditure	$\emptyset_7$	Naira	+ or –
8	Age of a farmer	$\emptyset_8$	Years	+ or –
9	Distance to market	$\emptyset_{10}$	Dummy (far = 1 and 0 otherwise)	+ or –
10	Hectare of land own by a farmer	$\emptyset_{11}$	Hectares	+ or –
11	Access to extension services	$\emptyset_{12}$	Number of times	+ or –
12	Access to farm credit	$\emptyset_{13}$	Naira	+ or –
13	Farmer's sex	$\emptyset_{14}$	Dummy (1 for female and 0 otherwise)	+ or –

Source: Prepared by the authors. Note, dependent ratio = number of children less than 15 years plus number of adult greater than 65 years divided by the household size.

RESULTS AND DISCUSSIONS

The social and economic features of oil palm fruit farmers

The data in Table 3 showcases an overview of the socioeconomic characteristics of oil palm fruit farmers in the research area. It was found that the most of farmers in this sub-sector are women, who often engage in the business to supplement their family's income. The average age of oil palm fruit farmers was found to be

49.10 years, indicating a relatively young and active age bracket. It is essential to note the importance of encouraging more youth participation in oil palm fruit production based on these findings.

The data indicates that the most of oil palm fruit farmers are married, suggesting a strong appeal of oil palm fruit production to households with married couples. This is likely due to the advantage of having access to affordable family labor, which is beneficial in the semi-labor-intensive nature of oil palm fruit production in the research area. Furthermore, the study revealed that the average farming experience of oil palm fruit farmers in the region is 17.50 years. This implies that oil palm fruit production is a well-established agribusiness in the region. Furthermore, the distribution of membership in social organizations among showed a low participation profile with an average of 2.65 years. Over 50% of farmers in the study area are not affiliated with any social organization, indicating a lower level of social capital among oil palm fruit farmers in this region. About 83.00% of farmers confirmed to the fact that the distance to the market is far, while an average of 0.66 hectares of farmland was obtained for the group.

Table 3. The socio-economic characteristic s of oil palm fruit farmer

Variable	Mean	Min	Max	Std. Dev.	C.V.
Marital status	0.67	0.0	1.00	0.47	0.71
Education	9.20	0.0	16.0	3.52	0.43
Farming experience	17.50	2.0	50.0	7.19	0.44
Socialization	2.65	0.0	34.0	4.38	1.60
Household size	7.00	2.0	13.0	2.11	0.30
Dependent ratio	0.55	0.0	1.25	0.26	0.47
Farmer's age	49.10	29.0	70.0	8.28	0.17
Distance to the market	0.83	0.0	1.00	0.38	0.46
Hectare of land	0.66	0.23	2.03	0.22	0.33
Access to extension services	0.49	0.0	6.00	1.10	2.26
Access to credit	19333	0.0	120000	26216	1.36
Household expenditure	173740	50000	273000	48209	0.28
Farmer's sex	0.59	0.0	1.000	0.50	0.10

Source: Computed by authors and information derived from field survey 2023.

The household size distribution showed an average family size of seven (7) members. The importance of family labor in oil palm fruit production in the study area is further emphasized. Due to the inelastic demand for hired labor in rural communities and the trend of rural-urban migration among young people, family labor has become the primary source of labor for small-scale farmers in the region. Additionally, the findings indicate that over 90.00% of oil palm farmers have received some form of formal training. On average, farmers in the region have about 9.20 years of formal education, which falls within the realm of secondary education. This suggests that the most of oil palm fruit farmers are literate and skilled in reading and writing. The attainment of formal education is believed to enhance decision-making abilities and resource management in agribusiness.

Diversification index of oil palm farmers

The diversification indices for oil palm fruit farmers are presented in Table 4. The results indicate that 1.00% of oil palm farmers have reached a nearly ideal level of income intensification in the production of oil palm fruit. This means that only 1.00% of oil palm fruit farmers are heavily dependent on income solely from oil palm fruit production.

The result further showed that only 14.66% of oil palm farmers have diversification index less than or equal to 0.500. The range of diversification index spanning from 0 to 0.50 is considered as the region of decreasing diversification of income or region of increasing specialization of income generation. The findings suggest that fewer than 15.00% of oil palm fruit farmers actively seek to boost their income through oil palm fruit production. Alternatively, it is indicated that less than 15.00% of oil palm farmers are willing to focus solely on oil palm fruit production in the area. Conversely, approximately 85.34% of oil palm fruit farmers have a diversification index exceeding 0.50. A diversification index ranging from greater than 0.50 to 1.00 is seen as a region where income diversification is on the rise.

This suggests that a large number of oil palm fruit farmers in the region are exploring alternative sources of income on their farms. In other words, the most of oil palm fruit farmers in the area do not rely heavily on revenue generated solely from oil palm fruit

production. For example, approximately 13.00% of oil palm fruit farmers have a diversification index ranging from 0.900 to 1.00. This indicates that oil palm fruit income contributes minimally to their overall earnings. A higher income diversification index signifies that farmers are less reliant on the income generated from oil palm fruit production. These findings reveal that many oil palm fruit farmers in southern Nigeria are either diversifying their income sources or shifting their focus away from oil palm fruit revenue. The mean and maximum diversification indices were recorded at 0.730 and 0.996, respectively. This suggests that the sustainability of oil palm fruit production in the southern region of Nigeria may not be entirely assured in the future. The result connotes that oil palm fruit farmers are not generating sufficient income from the agribusiness compared to alternative livelihood activities in the region.

Table 4. Diversification index of oil palm fruit farmers

S/n	Category	Frequency	Percentages
1	0.000 – 0.100	3	1.00
2	0.101 – 0.200	21	7.00
3	0.201 – 0.300	3	1.00
4	0.301 – 0.400	10	3.33
5	0.401 – 0.500	7	2.33
6	0.501 – 0.600	20	6.67
7	0.601 – 0.700	45	15.00
8	0.701 – 0.800	140	46.67
9	0.801 – 0.900	12	4.00
10	0.901 – 1.000	39	13.00
	Total	**300**	**100.00**
	Mean	0.73047	
	Standard deviation	0.19789	
	Median	0.75000	
	Minimum	0.019417	
	Maximum	0.99556	
	Coefficient of variability	0.27091	
	Skewness	-1.8973	

Source: Calculated by the authors using data obtained from a field survey in 2023.

Apart from the seasonality in production, the population density is mounting in the region thereby putting much pressure on land availability. Furthermore, the labor-intensive nature of oil palm fruit production and the limited availability of labor in rural communities have both played a role in the high level of diversification observed among oil palm fruit farmers in the area. This discovery aligns with previous research Harishankar et al., [31].

Determination of income diversification among oil palm fruit farmers

An important challenge in cross-sectional data analysis is the issue of multicollinearity. To determine the presence of this econometric issue, the variance inflating factor (VIF) was calculated and the results are displayed in Table 5. The result revealed that there is no serious or significant collinearity among explanatory variables specified. The VIF estimates for explanatory variables exceeded unity, but they fall below the threshold value of 10. The findings imply insignificant presence of multicollinearity among independent variables. This connotes that the Tobit model estimates are consistent, unbiased with minimum variance. Also, the choice of maximum likelihood estimation method over other estimation methods is appropriate.

The results showing the estimates of the Tobit model are presented in Table 5.

The diagnostic tests revealed the value of pseudo R-squared at 0.5045. This indicates that approximately 50.50% of the variation in income diversification indices among oil palm fruit farmers is linked to the independent variables. Therefore, the most of significant variables affecting income diversification among oil palm fruit farmers are incorporated in the specified Tobit model. Additionally, the calculated Chi square value of 39.48 and the sigma estimate suggest that the Tobit model estimates have a good fit.

The findings of the study suggest that an increase in formal education among oil palm fruit farmers has a significant impact on their income diversification. Specifically, for each unit increase in formal education, the income diversification index increases by 0.009 at a statistically significant level of 1%. This indicates that farmers with lower levels of education are more likely to rely solely on farm income, while those with higher levels of education are more inclined to diversify their income sources. Furthermore, obtaining additional formal training can also enhance the

chances of farmers connecting with other potentially profitable employment opportunities. Moreover, increase in years of formal education comes with more responsibilities and the demand to expand the income sources became obvious in the long run. This result is in line with the findings of [19, 36, 31, 29, 3, 14, 24].

Table 5. Determinants of income diversification

Variable	Coefficient (dy/dx)	Std. Error	Z	p-value	VIF
Constant	0.75437	0.1079	6.9930***	<0.0001	-
Marital status of a farmer	0.02671	0.0237	1.1258	0.2602	1.088
Education	0.00992	0.0034	2.9045***	0.0093	1.252
Farming experience	0.00308	0.0018	1.7569*	0.0789	1.382
Socialization	0.00763	0.0026	2.9365***	0.0080	1.123
Household size	0.02399	0.0060	3.9772***	0.0000	1.401
Dependent ratio	0.02269	0.0470	0.4832	0.6290	1.262
Age of a farmer	0.00259	0.0016	1.6580*	0.0973	1.448
Distance to the market	0.10886	0.0307	3.5517***	0.0004	1.171
Hectare of land	-0.09623	0.0528	-1.8240*	0.0681	1.123
Extension visits	0.00159	0.0101	0.1590	0.8736	1.063
Access to credit	-7.50E-07	0.0000	-1.5483	0.1216	1.399
Household expenditure	2.98E-02	0.0156	1.9143*	0.0556	1.316
Sex of a farmer	-0.03986	0.0215	-1.8554*	0.0635	1.004
Sigma	0.18568	0.0076	24.4952		
Chi-square(13)	39.47719 (0.0000)		Pseudo R^2		0.5045
Log-likelihood	79.37248		Normality test Chi-square (2)		169.23(0.000)

Source: Computed using Gretl econometric software.
Asterisks *, ** and *** represent significant levels at 10%, 5% and 1% respectively.

The result also revealed that the farming experience has a positive significant relationship with income diversification index of oil palm fruit farmers. An increase of one year in the farming experience of an oil palm fruit farmer is associated with a 0.003 unit increase in the farmer's income diversification index, at a 10% probability level. This finding suggests that as the number of years of farming experience grows, the income diversification index of oil palm fruit farmers also increases. This result could be explained by the fact that, experienced oil palm farmers have good knowledge and information on income profile of the enterprise and challenges such as the seasonality and price volatility among others. As such, experienced oil palm farmers will adjust by diversifying income sources to avert the inherent risk in the enterprise. Edet and Etim[26] reported similar result.

Being a member of a social organization exposes one to variety of ideas, opportunities, information and accumulated social capital. The above assertion was confirmed as the empirical evidence showed a significant positive correlation between the participation of palm oil fruit farmers in social organizations and their income diversification levels. Specifically, each year of membership in a social organization led to a 0.0076 unit increase in the income diversification index of oil palm fruit farmers. This indicates that continuous engagement with group members and exposure to diverse information sources contribute to the enhancement of income diversification. This finding suggests that oil palm fruit farmers that belong to social group are more susceptible to change and adopting innovation probably due to evidences/ testimonies on such innovation that abound among group members. The finding is supported by Edet and Etim [26], Harishankar et al. [31], Andualem and Umer [16] and Akpan et al. [3].

Furthermore, the findings revealed that, household size of oil palm fruit farmers has a direct relationship with the income diversification index. The result indicates that a unit increase in household size will increase income diversification index by 0.0239 at 1% probability level. This result suggests that larger farm households' size will probably increase household demand, which will consequently increase the household income need. The increase in farmers' household income demand will prompt them to look for other income sources to augment the farm income. The finding agrees with the works ofEdet and Etim [26], Idris-Adeniyi et al. [33], Aynalem [19], Harishankar et al. [31], Atalelech and Alula [17], Akpan *et al.* [3], Alemu [14] and Chukwu and Chukwu [24].

The slope coefficient for the age of oil palm fruit farmers is positive (0.00259), and it is statistically significant at the 10% probability level. This indicates that as the age of oil palm fruit farmers increases, so does their income diversification index. The correlation between age and income diversification may be attributed to the experience and household income demands of older farmers. Older oil palm fruit farmers likely require more resources compared to younger farmers, as the production of oil palm fruit in the region is labor-intensive and requires the payment of wages.In order to meet the recurrent expenditures including household expenses and the cost of labour, an aged oil palm fruit farmer will need more income to finance his/her expenditure. Surely these and more reasons will intensify income source diversification. The finding corroborates Edet and Etim [26], Idris-Adeniyi et al. [33], Malami et al. [36], Getahun et al. [29], Atalelech and Alula [17] and Akpan *et al.* [3].

The marginal effect of the distance to the local market is positive (0.10886) and is found to be statistically significant at a conventional level of 1%. This connotes that, the longer or farer the distance from the oil palm fruit farm to the local marketplace, the more oil palm fruit farmers diversify their farm income sources. This suggests that farer distance would induce additional cost to the production process through transportation cost. Since the production is small-scale, increase in transaction cost could reduce the net income and gross margin of farmers. Hence, the option of income diversification will increase with an increase in the distance from farm gate to marketplace. In the same fate, Aynalem [19] and Harishankar et al., [31] have submitted similar results earlier.

The findings also demonstrated a positive correlation between household expenditure and income diversification among oil palm fruit farmers. This means that as household expenditure rises, the diversification index of the farmers also increases. The result is in line with the expectation, since an upsurge in household expenditure will obviously expand the resource needs of the household. To finance the mounting household expenditure will require diversifying from the primary source of income.

On the contrary, the estimated coefficient of land size has a significant adverse correlation with the income diversification indices of oil palm fruit farmers in the southern region of Nigeria. The finding entails that as land size increases, the income diversification index diminishes, or specialization is intensified. Currently, the population density of the region is mounting with increasing alternative land uses. The increase in urban areas and the development processes in the region have resulted in the destruction of a large quantity of wild oil palm trees. Hence, any farmer who is able to harnesses land will likely intensified production. This result corroborates Harishankar et al. [31], Getahun et al. [29], Andualem and Umer [16], Akpan et al. [3] and Chukwu, and Chukwu [24].

Additionally, the number of female oil palm fruit farmers is significantly correlated with a decrease in income diversification index. Specifically, a 10% increase in the number of female oil palm fruit farmers is associated with an average decrease of approximately 0.399 unit in their income diversification indices.

The high level of unemployment among youths might help to explain this result. Also, women folk are more patient than the male and would likely endure a prolong production process of

oil palm fruit compared to the male counterparts. The finding corroborates the empirical finding of Aynalem [19], Andualem and Umer [16], Chukwu, and Chukwu [24].

CONCLUSIONS

Income diversification among farmers in developing countries has continued to draw the attention of the policy makers in the region. The situation is compounded by increasing youth unemployment, poverty and food insecurity. Farm income diversification occurs because farmers feel that there are better and efficient alternatives elsewhere. In the southern region of Nigeria, the production of oil palm fruit and its associated value chain play a significant role in providing livelihoods for a large number of individuals. Over one million Nigerians are engaged in various aspects of the oil palm fruit production value chain in this region.

Palm oil, one of the derivatives of the oil palm fruit production is a major constituent in the daily dietary intake of Nigerians, hence its sustenance in production is of upmost importance to the country. Investigating income diversification among oil palm fruit farmers in the southern region of the country is vital, especially considering the historical significance of the subsector to the Nigerian economy in the 1960s. This research focuses on analyzing the income diversification index and the factors that influence it among oil palm fruit farmers in Akwa Ibom State, a prominent producing area in Nigeria.

The Herfinhdal index and Tobit model were employed to analyze information collected from oil palm fruit farmers. The outcome showed that income diversification indices had a mean of 0.731, a minimum value of 0.019, and a maximum value of 0.996. Factors positively influencing income diversification among oil palm fruit farmers include level of formal education, farming experience, socialization, household size, age of the farmers, proximity to the market, and household expenditure. On the contrary, land size and farmers' sex were negative determinants. To reduce income diversification among oil palm fruit farmers in the State, all stakeholders should work together to provide land for oil palm farmers. Again, youths should be encouraged to participate in oil palm fruit production in the region

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

USING FINITE ELEMENT ANALYSIS FOR DEVELOPMENT OF BOGIE SUSPENSION SYSTEM FOR AGRICULTURAL SEMI-TRAILER AND EVALUATION OF THE RELATED COSTS

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Abstract

Unite Finite Element Analysis- FEA model has been developed containing material properties, loads, fixtures, constraints and connections among all parts, faces and edges of the suspension system components. FEA analysis showed that U-bolt is a critical component of this suspension system. Simulation study analyzed both U-bolt diameter and doubling the Quantity of U-bolts from four to eight U-bolts. Von-Mises stresses, displacements and Shear stresses have been monitored and analyzed. U-bolt diameter has gradually increased with 2mm steps from 20mm to 22mm to 24mm for a first configuration with four U-bolts and second design configuration with eight U-bolts. Taking into consideration available materials, manufacturing methods and cost in Egyptian market showed that using the first design configuration with four U-bolts of 24mm diameter decreased the maximum von-Mises stress, displacement and shear stress on the U-bolts from 775 to 547 MPa, 4 to 2.4 mm and 335 to 222 MPa respectively instead of using the same configuration with 20mm diameter U-bolts. A more durable option is using the second design configuration with 24mm diameter U-bolts which decreased the maximum von-Mises stress, displacement and shear stress on the U-bolts from 775 to 321 MPa, 4 to 2.19 mm and 335 to 108 MPa respectively. The results showed the importance of CAD software for improving the design process of the suspension system with minimum cost and time. Also, the effects of using thicker U-bolts and doubling their quantity were noticeably observed. The allowable shear stress of the U-bolt material is 254 MPa, after running FEA analysis the maximum shear stress on U-bolts has been reduced to 222 MPa and 108 MPa for both design configurations and the shear stress ratio were 0.874 and 0.425 respectively which make both design configuration safe for operation. The total cost of imported bogie suspension system worthed 3,447 US dollars. while the total cost of the local manufactured bogie suspension system for the 1st consideration and 2nd consideration were 3,257.4 and 3,358.6 US dollars respectively. The local component percentage of the local manufactured bogie suspension system for the 1st consideration and 2nd consideration were 51.602% and 53.06% respectively.

Key words**:** *local development, trailers, SolidWorks software, stress analysis, suspension, Bogie and costs*

INTRODUCTION

Transportation is one of the most important operations of agricultural production system. Transportation is a game changer especially for mega agricultural projects, where transportation concept is simple: Less Time & Higher Speed. Agricultural Trailers manufacturers face a challenge to prove their design and products for such a "simple" concept.

Egypt imported 17.76 thousand unit of various Agricultural Machinery worth 193.99 million US dollars in 2022 0. Agricultural trailers and semi-trailers production in Egypt reached 824 units worth 53.826 million Egyptian pounds in 2020, Agricultural trailers and semi-trailers Exports reached 22 units worth 828 thousand Egyptian pounds, and Agricultural trailers and semi-trailers Imports reached 68 units worth 2.552 million Egyptian pounds 0. Total Area of field crops reached 12.3 million feds., total production of field crops was 110.6 million tons and Total Agricultural tractors was 133.5 thousand in 20210.

Transportation is one of the most important and energy consuming operations in Agricultural production before, within and after planting the crops. Transportation is the activity of moving something from one place to another 0. It can be said that agriculture is an industry of conveyance, because various types of vehicles

are required for transportation tasks ranging from carrying fertilizer and chemicals to getting the actual crops to market. It is not always evident that a high proportion of the work on farms consists of transporting. Off road conditions include uneven field surfaces and bumpy roads on which the trailer must operate. These irregularities lead to unexpected loads on the trailer components [1]. That is why task of moving this varied type and amount of material requires different and specialized vehicles. in western Europe, transportation tasks make up 30% to 40% of a tractor's operating time. In developing countries, a similar trend is emerging 0.

An agricultural trailer can be used with various tractor types, for multiple purposes, from light duty range (0.5-5tons), medium duty range (6-16tons), up to heavy duty range (18-30tons). In more details, Agricultural Trailers can be classified according to:

Hitching tractor: trailer working with two-wheels tractors and trailers for four-wheels tractors 0.

Axle(s) arrangement: one axle with two wheels, two axles each with two wheels, one axle with four wheels (dual tires), and a tandem axle with four wheels (dual tires) 0.

Mass transfer between trailer & tractor: trailer can be as simple as balanced trailer whose total load is supported by at least two axles with four or more wheels, or it can be a semi-trailer where a part of its load is transferred to the towing tractor and the rest of the load is carried on its axle 0.

Trailer usage: agricultural trailers are used for many purposes, here are the common uses of an agricultural trailer: flatbed trailer, tipping trailer, liquid transfer trailer (tanker), fuel dispensing trailer, low-bed trailer, grain cart, manure or slurry spreader, special purpose trailer.

The Main components of an agricultural trailer are chassis, drawbar, tow eye, platform, side boards and the suspension system. The suspension system consists of leaf spring, axle and wheel hub 0.

These components manufactured of different Materials and the design, material and terminology of these components are dependent on the functions and loading capacity of the trailer.

Chassis is a frame on which the body of a trailer is mounted [12]. It is the structural unit, and one of the main parts of a semi-trailer. Also, it is the most decisive element that gives stability and strength under different load conditions of the trailer. Many things are considered while designing a chassis such as weight, material selection, strength of the material, and other material properties. It is the main mounting part for all the components including the body, so it is also called the carrying unit [21].

Drawbar design of a balanced trailer differs from a semi-trailer, in balanced trailers drawbar has a separate steel frame which is connected to the chassis through a turntable frame which is free to rotate 360 degrees, whether in semi-trailers drawbar could be welded or bolted part of the chassis or it can be hinged to chassis and supplied with a shock absorber i.e. helical spring, leaf spring, solid rubber, or hydraulic spring.

Tow-eye is an important part of any trailer, which connects a trailer to a tractor. Tow-eye transfer draft forces from the tractor to the trailer, also it should handle the mass transferred from the trailer to the tractor especially in semi-trailer tow-eye, that is why tow-eye material selection and design should be done with both maximum draft force and the vertical loading calculated and tested for this component.

Suspension system is a system of springs, shock absorbers, and other devices supporting the upper part of a trailer, in simple words a suspension system is a set of springs and shock absorbers that connect the wheels to the vehicles body, A vehicle suspension system provides a smooth ride over rough roads while ensuring that the wheels remain in contact with the ground and vehicle roll is minimized 0.

The main function of the suspension is to connect the wheel to the vehicle with a degree of freedom. The degree of freedom is an essentially vertically directed possibility of movement of the wheel. The wheel, or more precisely the tire, should always make the maximum possible contact with the road surface 0.

A suspension connects a trailer's wheels to its chassis while supporting the trailer's weight. It allows for the relative motion between the wheel and trailer chassis; theoretically, a suspension system should reduce a wheel's degree of freedom (DOF) from 6 to 2 on the rear axle and 3 on the front axle even though the suspension system must support propulsion, steering, brakes, and their associated forces. The relative motions of a wheel are its vertical movement, rotational movement about the lateral axes, and rotational movement about the vertical axes due to steering angle 0.

The suspension system and frame must also position the wheels and tires properly to provide normal tire life and proper steering control. If the suspension system does not position each wheel and tire properly, wheel alignment angles are incorrect and usually cause excessive tire tread wear. Improper wheel and tire position can also cause the steering to pull to one side. When the suspension system positions the wheels and tires properly, the steering should remain in the straight-ahead position if the car is driven straight ahead on a reasonably straight, smooth road surface 0.

The suspension system contains three major parts: a structure that supports the vehicle's weight and determines suspension geometry, a spring that converts kinematic energy to potential energy or vice versa, and a shock absorber that is a mechanical device designed to dissipate kinetic energy 0.

A suspension system should satisfy certain requirements for use in vehicles. The main desired features like: Independency, camber control, structural efficiency, isolation, low weight, long life, low cost 0.

U-bolt is a structure element that bolts the leaf spring to the bogie-pin flange of the suspension system (Figure 1). The U-bolt does not constrain the displacement of the leaf spring against soil reactions while moving, but it supports the leaf spring and maintains it in position which a relatively small force is applied to the U-bolt compared to the leaf spring 0.

U-bolts can have various types of forces which can lead to failure. Horizontal forces cause bending in the bolting area. Axial forces generated in the U-bolts cross-section. Shear failure generated in the threads where the U-bolt is fixed by a nut for vertical load. U-bolt can handle much larger load-carrying capacity for vertical load than horizontal load. According to laboratory tests calibrated with FEM analysis the thread region is the most vulnerable location and that most of the failures start from that region 0. In addition, Fracture stress should be taken into consideration for the design of U-bolts. 90% of mechanical failures is caused mainly by fatigue. Fatigue arises from multiaxial forces on the U-bolt 0.

Finite Element Analysis, commonly referred to as FEA, is a numerical method used for analysis of structural and thermal problems encountered by mechanical engineers during Design is process. Design analysis can be conducted on a real object or on models that represent certain aspects of the real object. If models are used instead of a real object, the analysis can be conducted earlier in the design process before physical prototypes are built. The models can be physical models (scale-down models, mock-ups, photoelastic models, etc.) or mathematical models where a certain behavior of the design in progress is captured and described by a mathematical apparatus. Simple mathematical models can be solved analytically. More complex models require the use of numerical methods. FEA is one of those numerical methods used to solve complex mathematical models. The FEA is a powerful but demanding tool of engineering analysis. The expertise expected from FEA users depends on the complexity of analysis but always requires familiarity with Mechanics of Materials, Kinematics and Dynamics, Vibration, Heat Transfer, Engineering Design, and other topics 0.

SOLIDWORKS Simulation is a commercial implementation of FEA capable of solving problems commonly found in design engineering, such as the analysis of displacements, stresses, natural frequencies, vibration, buckling, heat flow, etc. It belongs to the family of engineering analysis software products originally developed by the Structural Research & Analysis Corporation (SRAC).

SRAC was established in 1982 and since its inception has contributed to innovations that have had a significant impact on the evolution of FEA.

The focus of the FE analysis is to accurately simulate the interactions between components using contact, friction, and elasto-plastic material definition **Error! Reference source not found.**. The starting point for any SOLIDWORKS Simulation project is a SOLIDWORKS model, which can be a part or an assembly. First, material properties, loads, and restraints are defined. Next, as is always the case with using any FEA-based analysis tool, the model geometry is split into relatively small and simply shaped entities called finite elements. The elements are called "finite" to emphasize the fact that they are not infinitesimally small, but relatively small in comparison to the overall model size. Creating finite elements is commonly called meshing. When working with finite elements, the SOLIDWORKS Simulation solver approximates the sought solution (for example stress) by assembling the solutions for individual elements 0. A FEA model is composed of several different components that together describe the physical problem to be analyzed and the results to be obtained. At a minimum the analysis model consists of the following information: discretized geometry, element properties, material data, loads and boundary conditions, analysis type, and output requests. Agricultural Machinery Industry in Egypt was and still depend on small farm workshops spreading over rural areas, however there were some efforts to develop the local manufacturing of agricultural machinery which produce "Society of Agricultural Machinery Manufacturers and Trading" in 1991 at that time it included 43 manufacturer companies in addition to 71 supplier's facilities under supervision of Agricultural Engineering Research Institute in Cairo 0. But it is unknow for now whether how active this society is or if it is still working.

Most of agricultural farms in Egypt used to have balanced trailer with load capacity ranges up to 25 tons, agricultural trailer used as flatbed or two ways or three ways tipper. In the last two decades having more agricultural projects mainly in the western desert region of Egypt, the need for an agricultural semi-trailer is increasing because of the soil conditions which full of rocks, holes, and bumps. Also, transportation is becoming more energy consuming because agricultural trailers will be operated for longer distances especially in mega agricultural projects. In addition, the design of semi-trailer transfers a portion of its mass to the tractor which will maintain the trailer more stable behind the tractor and the operator has more manoeuvrability control of the trailer especially while the trailer is loaded and passing over hard soil conditions.

Agricultural semi-trailers firstly used in Egypt were imported by agricultural companies, which inspire local manufacturers to copy that design, and the first trails to manufacture agricultural semi-trailer was in 2012 when the need for semi-trailer increasing and some local manufacturers proposed local manufacturing of semi-trailer, the first products of semi-trailers have loading capacity 16tons, supplied with two tandem axles rear suspension, the stub axles are welded to a rocker arm which is hinged to chassis and free to rotate up and down on both sides according to soil conditions.

The first local developed suspension system for agricultural semi-trailer has a recurrent problem the stub axles cannot maintain the loading capacity, the axles deformed until it breaks under loading, and suspension hinge pin wear rapidly and the wheels get an unacceptable camber angle. Many modifications have been made to this design; however, it becomes clear that the components of this design are not suitable for the loading capacity. Also, the suspension system did not have a basic component, i.e. the shock absorber, a spring should be added to the suspension system to help it have more impact resistance. That is why restructuring of the suspension system design will be done in this study.

The main objectives of the study are:

(i)Development of local manufactured suspension system for increasing suspension components efficiency and enhancing Semi-trailers' performance.

(ii)Reducing the cost of production requirements.

MATERIALS AND METHODS

The first prototype of the semi-trailer has been manufactured in Egypt by **Delta Agricultural Machinery** Company in 2021. The semi-trailer has been tested in field in different agricultural sites as shown in Photo 1.



Photo 1. Local developed semi-trailer field test
Source: Delta Agricultural Machinery at Tanta-Egypt.

Hardware and software used in creating the 3D assembly model and FEA analysis are shown in Table 1.

Table 1. computer hardware and software specifications

Hardware	
Computer	HP Z420 workstation
Processor	Intel(R) Xeon(R) CPU E5-1650 0 @ 3.20GHz
RAM	16.0 GB
Display	HP Compaq LA2205 Wide LCD Monitor
Graphics	NVIDIA Quadro M2000
Software	
Operating System	Windows 10 Pro 64-bit
CAD software	SOLIDWORKS® Premium 2020 SP 0.1

Source: Authors' determination.

Computer Aided Design (CAD) software SOLIDWORKS® is used to create a suspension system 3D model, every part of the suspension system has been created and assembled, both imported components and local developed ones are assembled in virtual reality before the actual manufacturing to reach the best possible terminology and dimensions and to provide more stability in future modifications or manufacturing.

A 3D model of the Agricultural Semi-trailer has been built in the virtual environment of SOLIDWORKS® software as shown in Photo 2. The suspension system and all of its components are shown in Photo 3.



Photo 2. Agricultural semi-trailer 3D-model
Source: Authors' drawing.

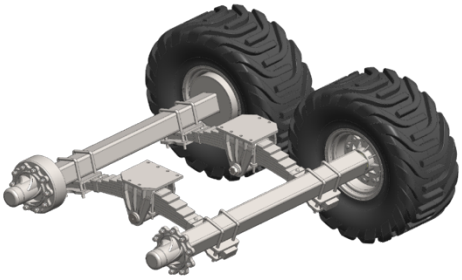


Photo 3. Suspension system 3D-model
Source: Authors' drawing.

Engineering Design of suspension components

There are some factors that should be considered in the suspension system design.

Load capacity calculation

First, the loads should be calculated to be considered for the suspension component loading capacity. This design will be designed to transport 16tone of agricultural material, this should be the payload of a semi-trailer, while there is another load that should be added to the payload which is the unladen mass of the semi-trailer, the unladen mass of a trailer is about 3.5tons. Then we add a loading factor of safety 25% of the total gross load as follows:

$$grossload = (16 + 3.5) \times 1.25 = 24.375 \cong 25tons$$

Semi-Trailer Component Selection

Not all the suspension system will be locally manufactured, some components will be imported like tires, rims, and axles. However these components should be selected with the gross load distributed equally on each component, that means for: gross load will be divided on the quantity number of each component to calculate the minimum

requirement of loading capacity for each component. The suspension has 4 tires so every tire should have loading capacity= 25/4= 6.25tons per tire. The same way axles loading capacity= 25/2= 12.5tons per axle.

The rest of the suspension system component will be locally manufactured so stress calculation will be done after a 3D model is built to have the right terminology of each part. After reviewing many suspension designs, a promising bogie suspension using two heavy duty leaf springs hinged to the chassis has been chosen to be locally developed.

Semi-trailer manufacturing materials

Material selection is a critical step in the design, for a suspension system there are many types of materials that will be used according to the function and the predicted stress of each component of the suspension system.

Figure 1 below shows the 3D CAD model and an exploded view of one side of the suspension system.

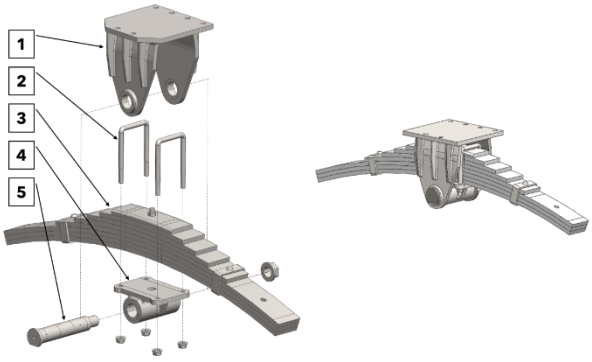


Fig. 1. CAD model and exploded view of bogie suspension system (1) Chassis bracket, (2) U-bolt, (3) Leaf Spring, (4) Bogie-pin flange, (5) Bogie pin
Source: Authors' drawing.

Component 1 is the chassis bracket which connects the suspension system to the main chassis of the semi-trailer. Component 4 is the bogie pin flange. This flange is the hinge of the bogie suspension; it connects most of the suspension components together. Both component 1 & 4 should have ductile feature with enough strength to deal with the exerted stresses. S235JR (1.0038) is the material selected for these components according to EN 10025:2004 0, this material has minimum yield strength Fy= 235MPa and tensile strength Fu= 360MPa this material is available in Egyptian local market mostly called steel 37.

Component 2 is the U-bolt which tightens the leaf spring to the bogie pin flange. This component is critical in its design and the material used should have higher tensile strength to endure shear stresses exerted on this component. Material selected for this U-bolt is A325 grade 8.8 according to ISO 898-1:2013 0 and ASTM A325-10 0, this material used to manufacture high tensile bolts and its minimum yield strength Fy= 635MPa and tensile strength Fu= 825MPa.

Component 3 is the articulate member of the bogie suspension and at the same time it is a leaf spring that can resist damping and impact loads coming from the soil. Spring Steel 38Si7 (1.5023) is the one of the suitable materials that have the properties and characteristics needed for the function of this component of the suspension system. According to EN 10089:2002 0, this material is used to manufacture leaf spring and its minimum yield strength Fy= 1,150MPa and tensile strength Fu= 1,300-1,600MPa.

Component 5 is the bogie pin. This is the articulation hinge point of the bogie suspension so the material used in this component should have good machining ability and enough strength to resist the exerted loads and stresses. C45 (1.0503) is a good choice for this application. This material can be found in the local market whether in hot or cold rolled bars. According to EN 10083-2:2006 0, its minimum yield strength Fy= 430MPa and tensile strength Fu= 650-800MPa.

Stress calculation of critical parts

In this section some design calculation will be run for the most critical components of the suspension assembly, in the calculation the maximum gross load is considered as and exerted on each part to have a safe design with higher factor of safety.

U-bolt (Figure 1, component 2)

This component should be designed for the allowable shear stress to be exerted on it. The allowable shear stress in pins and bolts is 0.4 Fy0 with a factor of safety 2.5. So, this allowable shear stress should be calculated for the U-bolt material and compared to the calculated shear stress on U-bolt. The average shear stress on U-bolt is calculated from this equation:

$$\tau_{ave} = \frac{V}{A_v} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

where:

τ_{ave}: average shear stress on U-bolt (MPa)

V: shear force (N)

A_v: shear area (mm2)

Since we already know the minimum allowable shear stress for the selected material then τ_{ave} is considered to equal:

$$\tau_{ave} = 0.4 \times 635 = 254MP_a$$

The shear force is already known as the maximum gross load divided by 4 because the calculation is for each side of the suspension and each side has 2 U-bolts, so:

$$V = \frac{25}{4} = 6.25\ tons = 6{,}250kg$$

The shear area is the cross-section area of the bolt and is equal to:

$$A_v = \pi \frac{d^2}{4} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Then the only parameter that should be calculated is the U-bolt diameter and this calculated size is the minimum size for the U-bolt diameter:

$$\therefore d = \sqrt{\frac{4 \times 6{,}250 \times 9.81}{\pi \times 254}} \cong 17.5mm$$

The standard available round material according to the calculated U-bolt diameter is 18mm, however for more stiffness and durability for this component a 20mm U-bolt diameter is selected. Then the shear stress ratio for this component will be calculated to be sure about its safe design. The shear stress ratio should be less than one for accepted design, it will compare the calculated shear stress f_v for the selected U-bolt size to the allowable shear stress τ_{ave}:

$$\frac{f_v}{F_v} = \frac{\frac{V}{A_v}}{0.4F_y} = \frac{\frac{4 \times 6{,}250 \times 9.81}{3.14 \times 20^2}}{0.4 \times 635}$$

$$\therefore \frac{f_v}{F_v} = 0.768 < 1$$

Bogie pin flange (Figure 1, component 4)

The critical stress exerted on this flange is the bearing stress behind the U-bolts, the allowable bearing stress behind pin or bolts is 0.9 Fy with 1.11 factor of safety 0.

$$\sigma_{br} = 0.9F_y = 211.5MP_a$$

And the bearing stress equal to:

$$\sigma_{br} = \frac{P}{A_{br}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

where:

σ_{br}: bearing stress behind the U-bolt (MPa)

P: bearing force (N)

A_{br}: bearing area (mm^2)

The bearing force equals the total gross loading of the semi-trailer divided by 8 because the calculation is for each side of the suspension and each side has 2 U-bolts in addition each U-bolt has two bearing area, so:

$$P = \frac{25}{8} = 3.125\ tons = 3{,}125kg$$

The bearing area is the cross-section area of the bogie pin flange at the U-bolt hole center and is equal to:

$$A_{br} = t \times d_b \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

where:

t: flange thickness (mm)

d_b: bolt diameter (mm) = 20mm

Since the thickness of the flange is parameter to be determined:

$$\therefore t = \frac{3{,}125 \times 9.81}{20 \times 211.5} \cong 7.5mm$$

The standard sheet metal thickness available in the local market is 8mm, however 20mm thickness is used for this flange to handle more stresses and have high factor of safety. The bearing stress ration is calculated, and it should be less than one, it will compare the allowable bearing stress to the calculated bearing stress for the selected sheet metal thickness:

$$\frac{f_{br}}{F_{br}} = \frac{\frac{P}{t \times d_b}}{0.9F_y} = \frac{\frac{3{,}125 \times 9.81}{20 \times 20}}{0.9 \times 235}$$

$$\therefore \frac{f_{br}}{F_{br}} = 0.362 < 1$$

FEA simulation Analysis using SOLIDWORKS® software

SOLIDWORKS SIMULATION® software used to evaluate the design in more complicated situations, stress analysis will be run on the suspension assembly not on every part of the suspension system, this will help to understand the behavior of each part of the suspension assembly taken into consideration the combined forces, torques or displacements which may arise in the stress analysis. Figure 2 below shows the suspension assembly after applying the same material properties described in Figure 1. Loads are applied on the chassis bracket which is 12,500 kgf equally distributed on the chassis bracket flange and directed in the downward direction of the Y-plane that represents how the semi-trailer load would be transferred to the suspension assembly in the field. Gravity is taken into consideration with 9.81 N/m$_2$ in the downward direction of the Y-plane. fixed fixtures are applied on both ends of the leaf spring which represents how the leaf spring is fixed on the axles.

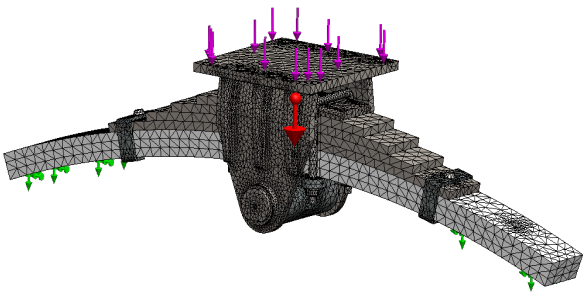


Fig. 2. Suspension assembly after meshing process on SOLIDOWRKS SIMULATION® software
Source: Authors' determination.

In Addition, other connections are used to represent how all of the suspension components interact with each other, No-Penetration contact sets are used to describe the interaction between inner faces on the suspension components especially for tangent faces on the leaf spring, between leaf spring and U-bolts, among bogie pin, bogie pin flange and chassis bracket, while Bonded global contact are applied to the rest of suspension components.

After analysis some parameters like stress, strain, displacement, reaction forces and shear forces will be monitored and discussed to evaluate the design of the suspension system.

RESULTS AND DISCUSSIONS

The analysis type was static analysis, with solid mesh type used along with curvature-based high quality mesher with maximum element size 30mm and minimum element size 6mm.

The total number of nodes was 168,977 nodes, and total elements number was 96,415 elements, number of degrees of freedom was 505,581, time of meshing was nine seconds, total solution time was one hours, nine minutes and 46 seconds.

The Analysis results after solving the calculations for the suspension system assembly showed that maximum von Mises stress value is 872 MPa on the inner rear U-bolts threading area which has diameter of 18mm, while maximum displacement was 4.19mm on the tangent area between the U-bolt and the leaf spring, maximum reaction force was 2,650 kgf acting on the fixture surface of the leaf springs where arrow pointing in Figure 6.3, and the maximum shear stress was 380 MPa in XY-plane acting on the outer front U-bolt threading area as shown in Figure 3.

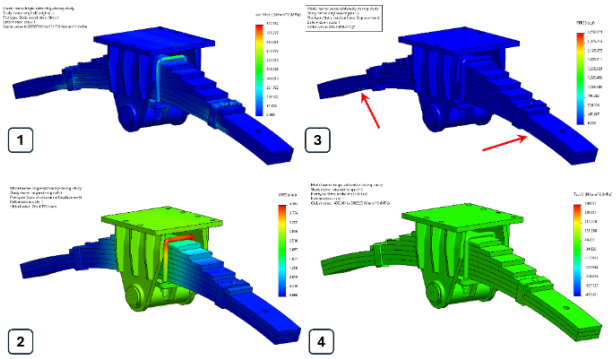


Fig. 3. Chassis bracket and Leaf Spring components: (1) von Mises stress, (2) displacement, (3) reaction force and (4) shear stress plots of suspension assembly.
Source: Authors' determination.

After reviewing the results of the whole suspension assembly, the same results will be

viewed and analyzed for every component individually to make sure we are in the safe design limitations.

Chassis bracket, Figure 1, component number 1 had maximum stress of 65 MPa acting at the weld bead between chassis connecting flange and bogie pin bracket flange.

Chassis bracket has also maximum displacement was 2.75 mm in the middle of front edge of the connecting flange, there were not any reaction forces on this component and maximum shear stress was 31 MPa on the YZ-plane acting near the bogie pin hole as shown in Figure 3 and Figure 4.

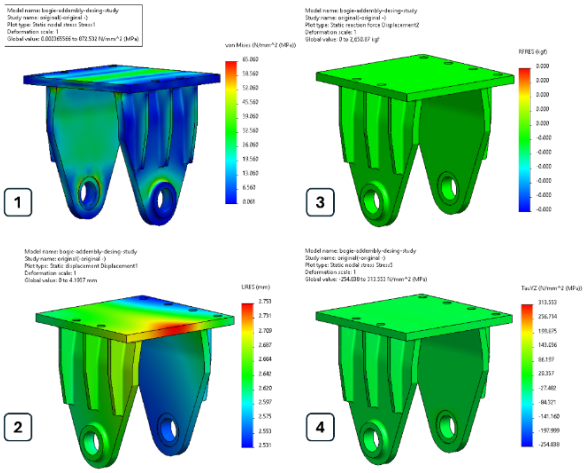


Fig. 4. Chassis bracket and its components: (1) von-Mises stress, (2) displacement, (3) reaction force and (4) shear stress plots of chassis bracket.

Source: Authors' determination.

U-bolt, Figure 1, component number 2, had maximum stress of 771 MPa acting near the bending radius area of the front U-bolt, maximum displacement was 4.19mm on the tangent area between the U-bolt and the leaf spring, no reaction forces on the U-bolts, and maximum shear stress on the YZ-plane was 313 MPa acting near the bending radius area of the U-bolt as shown in Figure 5.

Leaf spring, Figure 1, component number 3, had maximum stress 419 MPa acting in the contact area between U-bolt and the upper leaf of the spring, maximum displacement was 2.06 mm acting in both expecting position and direction in the middle of the leaf spring in the downward direction of the Y-Axis, maximum reaction forces was 2,650 kgf acting in the fixture area between leaf spring and axle and the maximum shear stress was 192 MPa in XY-plane acting in the tangent edge between spring collar and the leaves of the spring as shown in Figure 6.

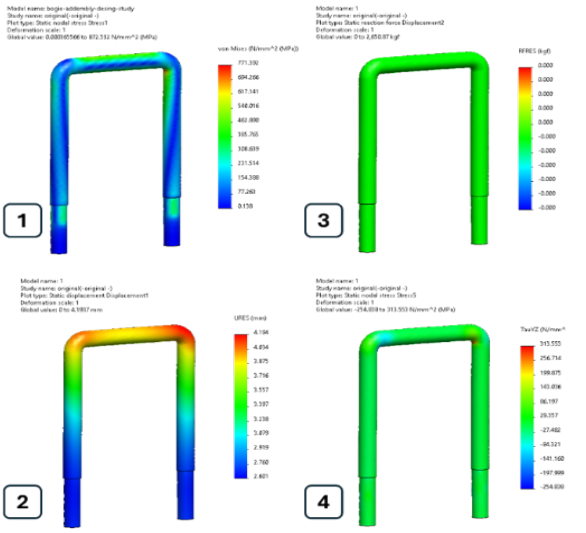


Fig. 5. U-bolt and its components: (1) von-Mises stress, (2) displacement, (3) reaction force and (4) shear stress plots of the U-bolt.

Source: Authors' determination.

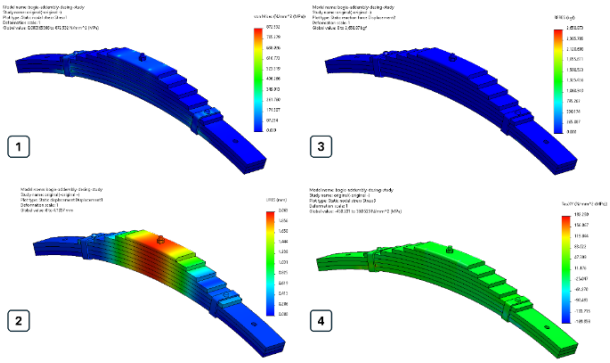


Fig. 6. Leaf spring and its components: (1) von-Mises stress, (2) displacement, (3) reaction force and (4) shear stress plots of suspension leaf spring

Source: Authors' determination.

Bogie pin flange, Figure 1, component number 4, had maximum stress of 325 MPa acting in the weld bead between bogie pin hinge and bogie pin flange, maximum displacement of 2.63mm on the outer section of the bogie pin hinge, there were not any reaction forces on this component and the maximum shear stress was 144 MPa in XY-plane acting in the weld bead between bogie pin hinge and bogie pin flange as shown in Figure 7.

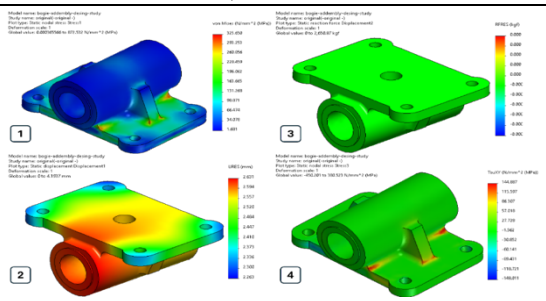


Fig. 7. Bogie pin flange and its components: (1) von-Mises stress, (2) displacement, (3) reaction force and (4) shear stress of bogie pin flange
Source: Authors' determination.

Bogie pin, Figure 1, component number 5 had a maximum stress of 39 MPa in an expected common area where bogie pin connect the chassis bracket with bogie pin flange, the maximum displacement was 2.65mm near the pin head, there were not ant reaction forces on this component and the maximum shear stress was 8.8 MPa in XZ-plane in the area where bogie pin connect the chassis bracket with bogie pin flange as shown in Figure 8.

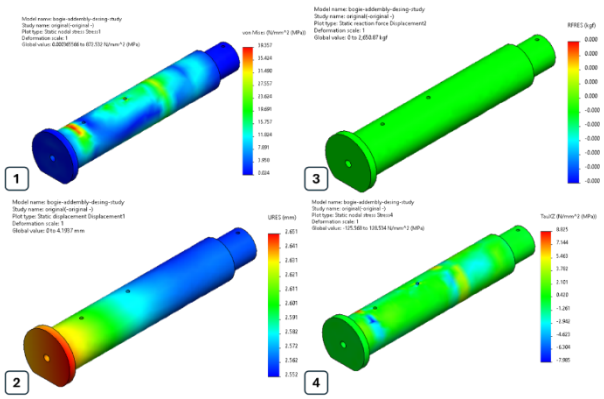


Fig. 8. *Bogie pin*: (1) von-Mises stress, (2) displacement, (3) reaction force and (4) shear stress of bogie pin
Source: Authors' determination.

The above results showed that some design modifications need to be done for critical component specially the U-bolts, there are two main factors that affect the performance of this critical component: 1st the clearance between U-bolt and leaf spring or the bogie pin flange, 2nd the possible movements of the U-bolts on the tangent face of the upper leaf spring which would arise during operation of the trailer and passing through rough terrain.

A new simulation design study has been done using SOLIDWORKS SIMULATION® software focused on the U-bolt diameter size to be the main factor under study and another design configuration has been added to the study which will have the same conditions of material, fixtures, loads and constraints however the design has been modified to have four U-bolts of every bogie hinge instead of two. Which means the suspension system will have eight U-bolts instead of four U-bolts in the whole suspension assembly to enhance the performance, safety and life of this critical component of the suspension system.

Also, another component has been added to the design, which is U-bolt lock plate. This part will reduce the amount of displacement and restrict any possible movements of the U-bolts, which is one of the important concerns from the previous simulation study Figure 9 showing the 2nd design configuration.

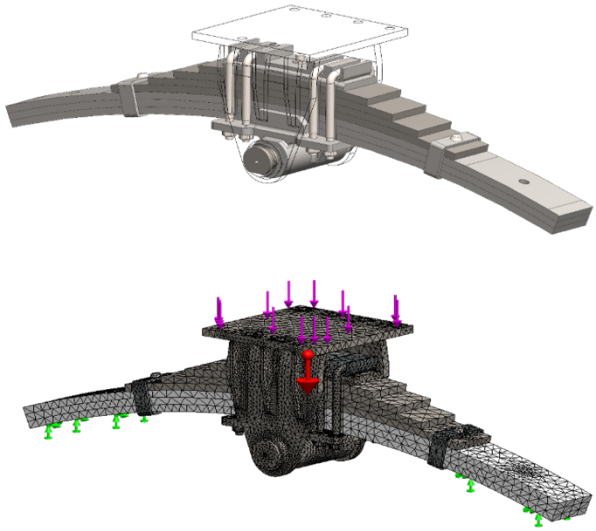


Fig. 9. 2nd design configuration with four U-bolts, (up) CAD model, (down) FEA model
Source: Authors' determination.

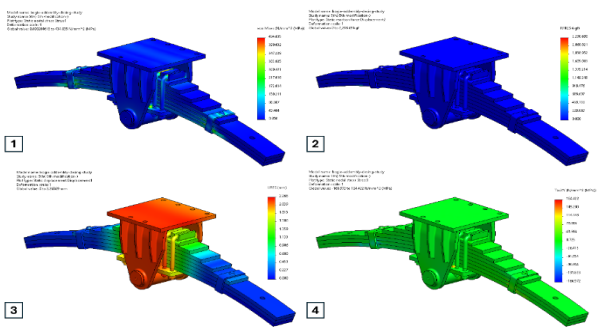


Fig. 10. The 2nd design configuration: (1) von Mises stress, (2) displacement, (3) reaction force and (4) shear stress of the 2nd design configuration
Source: Authors' determination.

Figure 10 showing the simulation analysis results plots of the 2nd design configuration.
Maximum stresses, displacements and shear stresses of the U-bolt are the measurement of this study. The U-bolt diameter has been modified by increasing it from 20mm, 22mm to 24mm. for every U-bolt diameter all calculations have been repeated.

Stress, displacement and shear stress have been monitored and plotted for both design considerations. Table 2 shows the maximum stresses, displacements and shear stresses on the U-bolts obtained for both design configurations and U-bolt diameter sizes.
Figures 11, 12, 13, show Maximum von-Mises stress, displacement and shear stress on U-bolt for both configurations respectively.

Table 2. maximum stresses, displacements and shear stress for different design configurations

Design Configuration	Two U-bolts			Four U-bolts		
U-bolt diameter (mm) / Study Parameter	20	22	24	20	22	24
Maximum Stress (MP_a)	775	596	547	412	320	321
Maximum Displacement (mm)	4	2.68	2.4	2.27	2	2.19
Maximum Shear Stress (MP_a)	335	230	222	181	114	108

Source: Authors' determination.

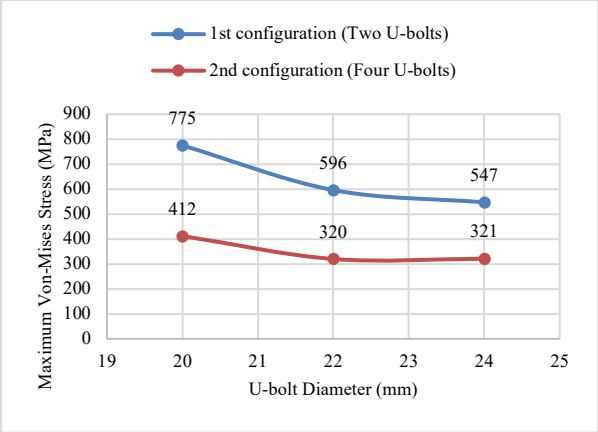


Fig. 11. Maximum Von-Mises stress on U-bolt for both design configurations
Source: Authors' determination.

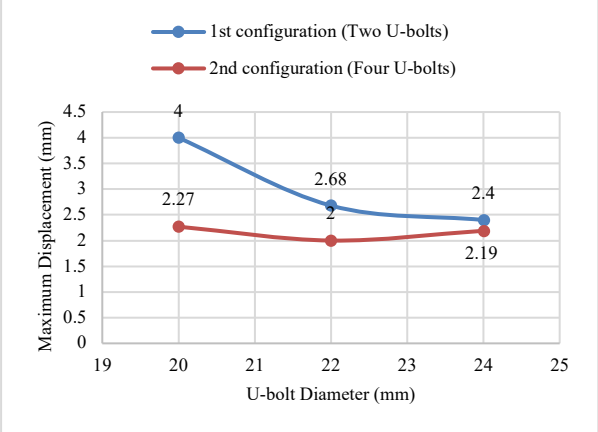


Fig. 12. Maximum Displacements on U-bolt for both design configurations
Source: Authors' determination.

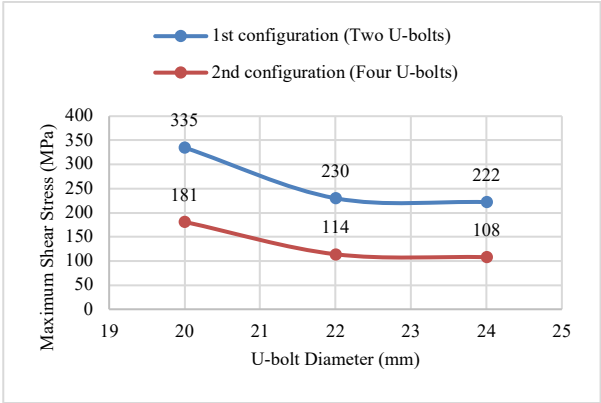


Fig. 13. Maximum Shear Stress on U-bolt for both design configurations
Source: Authors' determination.

Economic cost analysis

According to the manufacturer data, In 2025 the total cost of imported bogie suspension system worthed 3,447 US dollars. While the total cost of the local manufactured bogie suspension system for the 1st consideration and 2nd consideration were 3,257.4 and 3,358.6 US dollars respectively. Hence, the local component percentage of the local manufactured bogie suspension system for the 1st consideration and 2nd consideration were 51.602% and 53.06% respectively. Table 3 below show the total cost of local manufactured bogie suspension parts along with the local component percentage of each component with Quantities.

Table 3. local manufactured bogie suspension components cost, quantity and local component percentage

No.	Component	1st consideration			2nd consideration		
		Quantity	Price (US $)	Local component (%)	Quantity	Price (US $)	Local component (%)
1	Chassis Bracket	2	96.85	100	2	96.85	100
2	Bogie U-bolts	4	19.6	100	8	19.6	100
3	Leaf Spring	2	397	100	2	397	100
4	Bogie-Pin Flange	2	84.9	100	2	90.5	100
5	Bogie Pin	2	27.25	95	2	27.25	95
6	Axles	2	784.3	0	2	784.3	0
7	Axle-Spring U-bolts	8	23.5	100	8	23.5	100
8	Axle-Spring flanges	8	10.25	100	8	10.25	100
9	Miscellaneous components	---	51.9	90	---	51.9	90
10	Manufacturing, assembly and paint	---	76.5	100	---	76.5	100
11	Bogie U-bolt lock	---	---	---	2	5.8	100
12	Total price (US $)	3,257.4			3,358.6		

Source: Authors' determination.

CONCLUSIONS

The increasing agricultural production in Egypt requires more efficient and durable transportation trailers. Semi-trailers specially are required for the most rough and harsh conditions of agricultural roads and field operation. Bogie suspension system provides higher loading capacity with independent axle arrangement for each axle in addition it has a shock absorbing member which can maintain the semi-trailer performance and longer operating life.

CAD and FEA software are important tool which save time and effort consumed in complicated mathematical analysis.

Also, with a simple comparison between the maximum total cost of local manufactured bogie suspension system after the reviewed modification and enhancement was 3,358.6 US dollars, while the imported bogie suspension system worthed 3,447 US dollars with 2.56% saving of the imported bogie cost and 53.06% local component percentage. In addition to the higher loading capacity of the local developed suspension after applying the U-bolt modification and enhancement along with the after-sales support and the availability of any parts of the suspension components which are not available for the imported suspension. Then it can be clear that the local developed suspension system is a cost-effective solution for the local manufacturing of agricultural semi-trailers in Egypt.

ACKNOWLEDGEMENTS

A tribute to **Delta Agricultural Machinery** at Tanta-Egypt, which supported the researchers during the research with equipment and technical support.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CONSUMER PREFERENCE FOR FISH PRODUCT TYPES IN IWAJOWA LOCAL GOVERNMENT, IGANNA, OYO STATE, NIGERIA

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Abstract

This study examined the consumers' preference for fish products types in Iwajowa local Government, Iganna Oyo state, Nigeria. This study used data from a primary source and descriptive statistics such as frequency, mean and percentages were used to the analysed the data collected. It also utilized a Multinomial Logit regression (MNL) Model to determine the consumers' preference. The results showed that about 68% of the respondents were female and approximately 32% were male. The mean age and household size is 35.55±11.01 and 4 ±2 respectively. Result revealed that 57% of the respondents had formal education. About 29%, 31% and 38% of the sampled consumers preferred fresh, smoked and frozen fish respectively. There is no clear-cut distinction in preference for a particular fish product among the consumers and the respondents were not so concerned about the nutritional quality of the fish consumed. The mean income of the respondents was ₦28,883.72 (USD17.17) per month with a standard deviation of 34,219.02 (USD 20.31). The study revealed that ₦ 1,629.96 (USD 0.97) as the per day expended on fish on average while ₦1,467.73 (USD 0.87) was on close substitutes. The mean income and amount expended on close substitutes was relatively low among the respondents. Gender, household size, fish price per day, price of fish close substitute, health status and fish quality had significantly effect on the consumers' behaviour for consumers' preference for fish products consumption. It is recommended that there is need for quick intervention by the government to create awareness to consume fish of a good nutritional quality and a concerted effort to improve the standard of living of the respondents. Fish farming should be encouraged to boost production of fresh fish. This will go a long way to improve fresh fish protein consumption. Fish industries are also advised to incorporate all the identified factors affecting fish preference into their policy.

Key words**:** *preservation, processing nutritional quality, consumer behaviour, multinomial logit, Nigeria*

INTRODUCTION

Fish has been classified as an important source of food in supporting the growth and well-being of humans being. It provides an appreciable portion of the protein needed for healthy growth in humans. It supplies fats, and fat-soluble vitamins in the diets of people, and most especially in developing countries. It gives a valuable medicinal, feeding and

technical products. Fish is seen as relatively cheap source of animal protein. It has little or no religious rejection, unlike other sources of animal protein such as pork. Fish play a substantial role in livestock and fishery industries.

Furthermore, the lack connective tissue in fish make it easily digestible [8]. Besides other factors that are commonly identified with fish consumption, the health benefit is gaining prominence. The change in human dietary sources of protein to fish consumption, a white meat from the consumption of red meat is also of a great advantage. Recently, meta-analyses have revealed the relationship between a life-threatening colorectal cancer disease, [9]; [37], type II diabetes [3] stroke, coronary heart disease and heart failure [5], obesity [36] and all-cause mortality [24] and consumption of beef, lamb, pork, and other mammalian meat. Therefore, based on these discoveries, [29]; [21] reported that, organizations including the American Cancer Society recommend consumption of poultry, fish, or plant-based proteins [29]; [21] and limiting red meat consumption.

However, despite all the benefits from fish consumption mentioned, it spoils quickly. According to [15], fish gives certain signal which make it unsuitable for human consumption as a result of microbiological, chemical, enzymatic and physical action [19]. Therefore, when fish is removed from its original natural environment, it is highly prone to deterioration if not preserved or processed [27].

Spoilage in fish occurs straight away the fish succumb to death. In a minute, lot of physiological and microbial deteriorations begin and as a result degrading the quality of the fish which reduce post-harvest rate. Spoilage of fish is speedier than that of beef and pork due to the high load of bacteria in gills, skin and viscera part.

However, the good news is that there are some activities that could prevent spoilage in fish. In Nigeria, fish spoilage can be prevented through fish processing and preservation. The outcome of preventing fish spoilage is to make it more acceptable for consumers, this could either be through fish smoking, frozen and drying. These are the commonest in Nigeria.

Nigeria is a fish producing country, but during the last decade production declined, and imports are required to cover the consumers' needs [2, 7].

Fish is presented in various forms as a consumer's diet in Nigeria, this includes fresh fish, frozen fish, dry fish, fried fish and smoked fish. Other forms that are available but not popular in Nigeria are fish crackers, fish fingers and fish chinchin.

The forms of fish products that are presented to consumers in the market vary with the location of the source of fish relative to market distance, time, culture, size of fish, available processing and storage facilities, and consumer desired taste and preference. From these, the consumers as rational beings have freedom of choice that will give the highest level of satisfaction. The consumer choice among these forms of fish also could be influenced by numerous factors. [39] and [43] opined that consumer decision or choice could be determined due to patterns of food consumption, diversity of attitudinal dimensions, health status as well as socio and economics factors.

A review of available literature on the fish consumption behavior using the multinomial log model revealed scanty empirical studies in the study area. Available studies are [13] and [22]. Therefore, this research work adds value to the existing body of knowledge by providing scientific-based information on fish consumers' behaviour in the Ibadan metropolis. The following are the objectives; depicting the socio-economic of the fish consumers, fish products available and determining factors influencing fish consumers' behaviour in the choice of fish types they consume.

Theoretical / Conceptual Framework – Consumption Preference Theory

Consumers are rational in their choices to satisfy their needs at the least cost. The theory of consumer behaviour is paramount in the growth and development of any given market frontier. Studying consumer rationality is key because it indicates that producers and marketers can recognize what determines consumers' purchasing choices. By

understanding how customers make a choice on a product they can tailor their products to meet market demand as well as determine the items that are required to satisfy their goals. From the theory of consumer behaviour, each desires to derive the best satisfaction from a set of alternative bundles of options obtainable from the market [12]. The satisfaction or utility of a given bundle of goods varies with place, price, product, time or form. For instance, fish products could be consumed in fresh, fried, dried, smoked, or frozen forms, [8]. The choice made by a given consumer is determined by many intrinsic, social, psychological and economic factors [33].

[23] asserted that a consumer behaviour study seeks to disclose why, what, when and how the consumer purchases a product. Likewise, it establishes how people decide on what they purchase. [34] referred to this as the decision process. Decisions on the type of fish products and what quantity to consume are affected by socio-economic and geographic characteristics factors of consumers and fish attributes [32], [42], [18].

Consumer preference on the other hand describes how a consumer places likeness among a group of related goods. It gives an excellent association between actual purchase and consumption [17] and [28]. Consumers' choice has been viewed as a microeconomic theory that relates expenditure and preferences for consumption of goods and services together which culminate in consumer demand curves. The links between personal preferences consumption and the demand curve are one of the most closely studied relations in consumer economics. Choice theory is a way of analysing how consumers may achieve equilibrium preferences and expenditures by maximizing utilities as subject to consumer budget constraints. As reported by [26], preference has been viewed to be a major factor influencing general food consumption behaviour. According to [30], tradition and habit often affect fish consumption which could also be enhanced by nutritional awareness.

MATERIALS AND METHODS

Study Area

Iwajowa is a Local Government Area in Oyo State, Nigeria. Its headquarter is in the town of Iwere Ile. Iwajowa Local Government is bounded in the North by Itesiwaju Local Government, in the south by Ibarapa North Local Government, in the East by Kajola Local Government and in the West by Republic of Benin. It has an area of 2,529 km^2 and a population of 102,980 inhabitants at the 2006 census. Iwere-ile became the headquarters of Iwajowa Local Government Area on 4 December 1996 upon the creation of the new local government under the Gen Sanni Abacha's regime. Other town and settlements include Iganna, Ilaji-Ile, Idiko-Ile, Ayetoro Ile, Itasa, Idiko Ago, Elekookan, Ijio, Ayegun Wasimi and over 350 villages and farm settlements. The inhabitants of the area are predominantly Yoruba cohabiting peacefully with other tribes such as Fulani, Hausa, Tiv, Egede and others who engage in cattle rearing, large scale farming and hunting. Iwajowa local government was chosen for this study because it has a relatively number of freshwaters such as rivers which encourages fish farming. Frozen fish are available in the towns and there are markets where smoked fish is being sold.

The sampling technique involves a random sampling procedure. This technique was employed to select 172 respondents randomly from the towns and settlements. These towns (Iganna, Ilaji-Ile, Idiko-Ile, Ayetoro Ile, Itasa, Idiko Ago, Elekookan, Ijio, Ayegun Wasimi) were used because they have appreciable number of respondents who could be used for the purpose of this research work. Data collected were thoroughly cleaned and subjected to the required analysis to achieve the purpose of the objectives of this study.

Analysis of Data

The results derived from this survey were analysed using simple descriptive statistics and multinomial logit (MNL) regression. Descriptive statistics include frequency table, mean and standard deviation, these were used to describe the socio-economic characteristics of the respondents. While multinomial logit regression model was used to determine the factors influencing consumers' behaviour on their fish types option in the study area.

Literature Review on Multinomial Logistic Regression Model (MLM)

The application of the Multinomial Logistic Regression Model (MLM) has been used extensively to determine a consumer's choice. This includes [20]; [38]. The model springs from the theory of rational choice of consumers of a product within a probabilistic framework. The model applies the use of the utility maximization hypothesis which says that a decision maker's choice is the result of their preferences [25]. According to [14], the model based on four core concepts: (i) the customer has an unobservable (at least to the modeller) preference or utility for each of the choice alternatives, (ii) the utility of each choice alternative is made up of two additive terms namely, a deterministic component (the intrinsic value or attractiveness of the choice alternative), and a random component which varies randomly across choice alternatives, customers, and purchase occasions, (iii) the distribution of the random component can be specified, and (iv) on each choice occasion, the customer chooses the alternative that provides him the highest utility. Consequently, the decision-maker is assumed to select the alternative with the highest preference or utility.

Multinomial Logit Model (MLM) Specification:

Let πj denote the multinomial probability of an observation falling in the j[th] categories of fish forms option, to find the relationship between this probability and the p -explanatory variables, X_1, X_2,....., X_p, the multinomial logistic regression model is given thus:

$$\log\left[\frac{\pi_j(x_i)}{\pi_k(x_i)}\right] = a_{0i} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + ... + \beta_{pj}x_{pi},$$

..... (1)

where:

j=1, 2, … (k-1), i = 1, 2, … p.

k = number of response or dependent categories (fish types option).

Note: one of the categories must be considered the base level and all the logits are constructed relative to it.

P = number of explanatory variables included in the model.

Since all the π add to unity, this reduces to

$$\log \pi_j(x_i)) = \frac{\exp(a_{0i} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + ... + \beta_{pj}x_{pi})}{1 + \sum_{j=1}^{k-1}\exp(a_{0i} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + ... + \beta_{pj}x_{pi})}$$

.....(2)

For j = 1, 2, …..(k-1), the model parameters are estimated by the method of multinomial logit

$U_i = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + \beta_{12}X_{12} + \beta_{13}X_{13} + ei$

.....(3)

where:

U_i, =Fish types (Fresh fish, Smoked fish and Frozen fish).

The independent variables are as follows

X_1 is gender (male = 0, female = 1)

X_2 is Age of respondents (in years)

X_3 is Marital Status (single = 0, married = 1)

X_4 is Level of education (Non-formal = 0, formal =1)

X_5 is Household size (numbers)

X_6 is Monthly income (naira)

X_7 is Price of fish (naira)

X_8 is Price of close substitute (naira)

X_9 is Fish taste (Yes = 1, No = 0)

X_{10} is Health factor (Yes = 1, No = 0)

X_{11} is Fish odour/aroma (Yes = 1, No = 0)

X_{12} is Fish appearance (Yes = 1, No = 0)

X_{13} is Nutritional quality (Yes = 1, No = 0)

e_i is Disturbance error

RESULTS AND DISCUSIONS

Table 1 showed the result of the analysis of socioeconomic characteristics of fish consumers in the study area. The results reveal that about 68% of the respondents were female and approximately 32% were male. It could be inferred that there is no gender discrimination against fish consumption in the locality. This is also in agreement with the findings of [41].

The probable justification for the higher percentage of females in the study area is that women are usually in charge of food preparation for most households. It was also observed that a larger proportion of males were bachelors. Generally, the positive behaviour of fish consumers is observed towards a well-

preserved fish product form because it could be kept for a long time when bought and easily accessible if other alternatives or substitutes are not affordable and reachable at the time of need.

Table 1 reveals that a typical fish consumer in the study area was young with an average of about 36 years and a standard deviation of about 11 years. The distribution shows that more than 74% of the respondents were within the age bracket of 40 years. This implies that many of the fish consumers in the study area are at a productive stage and they would require high-quality protein in their daily food consumption. According to [41], age was found to be significantly associated with determination to eat healthy food. [31] also discovered an association between age and knowledge of fish preference.

Furthermore, 57% of fish consumers have formal education. As gathered from this study, a large number of respondents have secondary school educational qualifications. Generally, the influence of education on human behaviour towards the consumption of healthy food could not be overemphasized. A typical educated person would prefer to choose a healthy and balanced diet that will not result in ill health such as cholesterol and other similar health challenges. [40] also emphasized that there is a positive association between consumption of fishery products and education. It is well known that red meat consumption is being discouraged for health reasons, while consumption of white meat, of which fish is one source, is being encouraged among educated societies [35]. This is evidence of the influence of education on human behaviour toward food consumption. [4] opined that education brings improvement in the standard of living and this also invariably affects their choice of fish products

A greater percentage of the fish consumers in the area of study were married. Being married imposes responsibilities on the household breadwinner and one of such responsibilities is the provision of a healthy and balanced diet for family members. Fish is common in household dietary food consumption due to many factors; it is relatively cheap, a source of vitamins, minerals, and protein with essential amino-acid, easy to digest and less cholesterol [11]. For these reasons, most married households choose different forms of fish products for their satisfaction.

In the study area, 35%, 52% and 13% of the respondents have household sizes of 1-3, 4-6 and 7-9, respectively, while the average household of a typical family was about 4 persons with a standard deviation of 2.1. This result is in consonance with the findings of [41]. Also, as pointed out by [40], consumption of fish was discovered to be positively correlated with household size. However, [42] reported a contrary result. This study shows that residents in the study area keep moderate family sizes which could be attributed to the education among the sample population.

The mean income of ₦28,883.72 (USD17.17) with a standard deviation of 34,219.02 (USD 20.31) per month were obtained among the fish consumers in the study. As reveal in this study, the income received in a month by most of the respondents was relatively low. This could have a negative impact on their choice and consumption of their preferred fish products.

This agreed with the submission of [6] and [16] who opined that income levels might affect fish consumption. The average amount spent per day on fish consumption in the study area was ₦ 1,629.96 (USD 0.97) with a standard deviation of ₦741.79 (USD 0.44). Given the current rate of food inflation, this amount was low. The combined effects of low monthly income, household size and high food inflation would result in inadequate consumption of daily dietary protein that is obtainable from fish.

Furthermore, Table 1 reveals that the respondents spent ₦1,467.73 (USD 0.87) per day on close substitutes for fish with a standard deviation of ₦448.06 (USD 0.27). This value was also relatively low. It could be deduced that the price of fish and other sources of protein might be a major constraint and negatively influence fish consumption among the respondents.

Table 1. Description of socio-economic characteristics of the respondents (n =172)

Variable	Frequency	(%)	Mean ±S.D
Gender			
Male	55	31.98	
Female	117	68.02	
Age			
21-30	70	40.70	35.55±11.01
31-40	58	33.72	
41-50	30	17.44	
>50	14	8.14	
Educational Status			
Non Formal	74	43.02	
Formal	98	56.98	
Marital Status			
Single	52	30.23	
Married	120	69.77	
Household size			
1-3	61	35.47	4 ±2.1
4-6	89	51.74	
7-9	22	12.79	
Monthly Income (₦)			
<10,000	66	38.37	₦28,883.72± 34,219.76
10,000 – 50,000	94	54.65	
50,001 – 100,000	10	5.81	
>100,000	2	1.16	
Price of fish per day			
<500	12	6.98	₦1,629.96± 741.79
500-1,000	84	48.84	
1,001-1,500	36	20.93	
1,501-2,000	12	6.98	
>2,000	28	16.28	
Price of close substitute per day			
<500	2	1.16	₦1,467.73± 488.06
500-1,000	66	38.37	
1,001-1,500	14	8.14	
1,501-2,000	14	8.14	
>2,000	76	44.79	

Source: Field survey, 2023.
$1 is equivalent to ₦ 1,684.64 as of October 2024 [Central Bank of Nigeria] [10].

Fish Products Type and Quality of Parameters Considered by the Consumers

Generally, food preference and consumption inducement vary with individual cultural background, prevailing economic power, social class and strata, health status, age, occupation and employment status, education, gender, etc. Specifically, preference and choice of a given fish product by the individual consumer could also be influenced by its price, price of close substitutes, taste and fish species, health factor, appearance, taboo, odour, nutritional quality and household size. In the study area, the common forms of fish products identified by the respondents are fresh fish, smoked fish and frozen fish. While the attributes considered include taste, health factors, appearance, odour and nutritional quality.

The fish products available were almost evenly distributed among the consumers in the study area. No less than 32%, 29% and 39% of the sampled consumers preferred fresh, smoked and frozen fish. This implies there is no clear-cut high preference for a particular fish product among the consumers. The findings from this study may be attributed to low income.

Table 2. Type of fish products and quality of parameters considered by the consumers (n= 172)

Variable	Frequency	Percentage (%)
Type of fish		
Fresh fish	50	26.07
Smoked fish	54	31.39
Frozen fish	66	38.37
Taste		
No	24	13.95
Yes	148	86.05
Total	172	100
Health factors		
No	54	31.40
Yes	118	68.60
Appearance		
No	60	34.88
Yes	112	65.12
Odour		
No	36	20.93
Yes	136	79.07
Nutritional quality		
Yes	66	38.37
No	106	61.63

Source: Field Survey, 2023.

On the other hand, the taste of the fish product is of utmost concern to the people in the locality of this study. This is noticeable in the response of about 87% of the fish consumers who reported that fish taste positively influences their preference for their choice. Also, 68% considered health factors as their inducement for their fish consumption. The appearance of fish was of a great importance to about 65% of the consumers' behaviour

towards their choices. Since fish come with different odours, about 79% of fish consumers according to this study considered odour of the fish consumed. The result agreed with the findings of [18], who opined that food preferences are affected by several sensory (taste, smell, and texture) and non-sensory factors (behaviour, beliefs, personal characteristics, and risk perception). However, it was observed that the respondents were not so concerned about the nutritional quality of the fish consumed as indicated by 61%. In other words, many of the respondents are of the opinion that all the fish products are of the same nutritional quality. This may be a result of their low monthly income and rising food prices.

Multinomial Logit Regression Analysis Result

Table 3 reveals the outcome of multinomial logit regression analysis performed to determine the factors that influence the independent choices made on fish forms by the fish consumers in the study. Fresh fish was used as a base category for the analysis, therefore, the discussion will be with reference to fresh fish.

The results indicate that the factors which influenced the consumers' preference for smoked fish are age, gender, and marital status, and household size, price of fish per day and price of close substitutes. Statistically, age and household size were significant at 10%, price of close substitute was significant at 5% while gender, marital status and price of fish were statistically significant at 1%. In terms of direction, the coefficient of gender and marital status were negative, meaning that being a married woman would reduce the consumption of smoked fish and increase the consumption of fresh fish.

Table 3. Parameter estimates of multinomial logit regression for fresh fish product type

Fish product forms	**Smoked fish**			**Frozen fish**		
Variables	**Coefficients**	**z**	**P>|z|**	**Coefficients**	**z**	**P>|z|**
Age	0.0415365*	1.82	0.069	-0.0234962	-1.16	0.247
Gender	-1.056471***	-2.51	0.012	1.210067***	2.98	0.003
Marital status	-1.321026***	-3.21	0.001	0.1634163	0.44	0.662
Educational status	0.6706687	1.45	0.146	0 .2236792	0.50	0.617
Household size	0.207212*	1.73	0.084	-0.1986693*	-1.69	0.091
Monthly income	8.47e-06	1.31	0.189	3.38e-06	0.63	0.528
Price of fish	0.0006495***	3.25	0.001	-0.0003288*	-1.89	0.059
Price of close subt.	0.0004224**	2.28	0.023	-0.0004928***	-2.65	0.008
Fish taste	-16.05645	-0.02	0.985	17.14352	0.02	0.984
Health status	15.67552	0.01	0.989	1.032233*	1.67	0.095
Fish Odour	-1.375388	-0.00	0.999	0.4780953	0.00	1.00
Fish appearance	14.80692	0.02	0.983	-13.66837	-0.02	0.985
Fish quality	19.01946	0.02	0.986	-3.519471***	-4.43	0.000
Constant	-18.01946	-0.02	0.986	0 .2656968	0.23	0.819
Log likelihood	-254.42124					
Likelihood ratio	233.71					

Significant level: 1%, 5% and 10% ***, ** and *, respectively.
Source: Own results.

The preference for fresh fish could be because married women like to satisfy their husbands with freshly prepared meals. This agreed with the findings of [1], in Gorgan City, Iran and [22] in Ibadan, Nigeria, who discovered a clear preference for fresh fish in their studies. The factors that determine the consumers' preference regarding the consumption of frozen fish include gender, household size, fish price, fish close substitute price, heath status and fish quality.

Statistically, gender, price of close substitute and fish quality were significant at 1%, while household size, fish price and health status were significant at 10%.

The coefficient of household size, fish price, price of close substitute and fish quality were negatively related to frozen fish. Increasing the

price of frozen fish would lead to more consumption of fresh fish, increase in fish quality would reduce consumption of frozen fish, which would lead to fresh fish consumption in the study area.

The Marginal Effect of Fish Consumers' Behaviour on their Preference of Fish Product Type

The results of the marginal effects of determinants of fish consumers' preference on their choice of fish product forms are shown in Table 4.

Summarily, the results show that being a female would reduce the tendency to consumption of smoked fish by 12% and increase fresh fish by the same proportion. Being married would reduce consumption of smoked fish by 7% and frozen fish by roughly 13% with the tendency of increasing the consumption of fresh fish in the study area.

Table 4. Results of the marginal effect of determinants of fish consumers' preference on their choice of fish product type

Fish product forms	**Smoked fish**			**Frozen fish**		
Variables	$\partial y \partial x$	**z**	**P>|z|**	$\frac{\partial y}{\partial x}$	**Z**	**P>|z|**
Age	0.0033807*	1.66	0.102	0.0007762	0.25	0.778
Gender	-.1247539***	-3.29	0.001	0.0958679*	1.76	0.078
Marital status	-0.0705605*	-1.90	0.570	-0.1348971***	-2.56	0.010
Educational status	0.0164123	0.36	0.717	0.1263695**	2.13	0.033
Household size	0 .022021*	1.83	0.067	-0.115039	-0.91	0.364
Monthly income	1.72e-07	0.32	0.749	1.70e-06*	1.84	0.066
Price of fish	0.0000504***	2.81	0.005	0 .0000194	0.88	0.381
Price of close subt.	0.0000505***	2.80	0.005	-0.00004*	-1.69	0.092
Fish taste	-1.817079	-0.02	0.985	1.221568	0.02	0.982
Health status	0.6491966	0.01	0.990	2.161603	-0.02	0.987
Fish Odour	-0.0929575	-0.00	0.999	-0.0823169	-0.00	0.999
Fish appearance	1.540146	0.02	0.984	-0.7223536	-0.02	0.990
Fish quality	1.540146	0.02	0.983	-0.7223536	-0.02	0.990

Significant level: 1%, 5% and 10% ***, ** and * respectively
Source: Own results.

CONCLUSIONS

This paper had critically examined fish consumers' preference analysis in Iwajowa Local Government, Oyo State. There is no clear distinction in preference for a particular fish product among the consumers. The amount spent on fish consumption as well as amount spent on close substitutes for fish were found to be relatively low which could have adverse effect on fish product forms consumption. This issues of low income is adjudged for the respondents unconcerned attitude to the nutritional quality of the fish products consumed.

Generally, gender, household size, fish price per day, price of fish close substitute, health status and fish quality had significantly effect on the consumers' behaviour for consumers' preference for fish product types consumption. The study recommends a quick intervention and awareness to open the eyes of the respondents the nutritional quality of different fish products in the area so to improve fish preference. Moreover, a concerted effort is needed to improve the standard of living of the respondents as the income obtainable is found to be relatively low. This has greatly affected the household in their preference for fish products. Moreover, all the identified factors

affecting fish preference should be incorporated into the policy.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

HOW TO ILLUSTRATE THE CONCEPT OF SUSTAINABLE AGRICULTURE IN THE ROMANIAN ECONOMY

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Abstract

In the context of the scarcity of conventional resources and an irrational use of resources which, combined with the arbitrariness of agricultural policies in Romania, have generated waste and impoverishment, it becomes necessary to develop mechanisms through which the economy aligns itself with the laws of nature that govern it, to sustainably use natural resources, to devise strategies through which the use of free goods confers balance and limits in the production process, generated in particular by the natural, sustainable degree of absorption of products in the environment. This natural approach to economic processes is closely associated with the concept of eco-economy. The paper essentially aims to apply the principles of sustainability and sustainable development at the group level and to transpose them into the community, thereby reinforcing the perception of the indissoluble link between the natural environment and the rational use of natural resources. At the same time, the paper aims to raise awareness among young people about the importance of preserving and protecting the natural environment. Environmental education exerts a significant influence on the outcomes achieved, with cascading effects on the overall performance of the economy. Through a questionnaire addressed to a representative sample of rural areas, we sought to identify the relationship between agricultural policy instruments applicable to rural areas and their concrete results, measured in terms of the well-being of the farming population.

Key words**:** *sustainability, agriculture policy, economy*

INTRODUCTION

Agriculture in Romania is a priority sector of the economy currently undergoing extensive restructuring, driven by the evolution of the agricultural market and the changing requirements of both domestic and international consumers. At the same time, given the existence of competitive segments, both within the regional agricultural market and as a result of the implementation of the Common Agricultural Policy (CAP), Romania's agriculture must strengthen its competitiveness in terms of quality–price ratios, while upholding high quality standards, particularly environmental standards.

The Common Agricultural Policy represents the primary instrument through which European Union member states support sustainable agriculture and rural development. In Romania, the evolution of agriculture has followed the transition from a planned economy to a market economy, with the CAP exerting a significant impact on regional convergence and sectoral competitiveness [11]. Recent studies indicate moderate convergence in agricultural efficiency across regions, although substantial gaps persist between developed and peripheral areas [6]. Moreover, the implementation of LEADER programs and Rural Development Programs (RDP) has had positive effects on infrastructure development and the diversification of rural economic activities [14].

The vulnerability of Romanian agriculture to climate change is underscored by the increasing frequency of droughts and declining crop yields [19]. Remote sensing analyses reveal severe drought impacts on agricultural production in Dobrogea and southern Romania [21]. The risk of drought is becoming increasingly high, especially in agrarian areas that depend on irrigation, generating an urgent need for modernized infrastructure and

investments in water resource management [3]. Agriculture plays a fundamental role in regional development, yet persistent disparities between urban and rural regions continue to hinder economic convergence [10]. The CAP policies have only partially contributed to reducing these disparities, as regions with weak infrastructure and limited capital remain disadvantaged [4]. In addition, analysis of RDP implementation confirms that European funds had a greater impact in regions with high administrative capacity, thereby further accentuating territorial imbalances [15].

The integration of renewable energy into agriculture has become a crucial factor in advancing sustainability. Agrivoltaics — the use of agricultural land for solar energy production — has been widely discussed at the European level as a solution to enhancing resource efficiency and diversifying farmers' incomes. In Romania, recent research has revealed significant changes in agricultural land use between 1990 and 2022, with a decline in arable land in favor of construction and renewable energy projects [2].

The agricultural labor force remains a significant challenge for Romania. Studies indicate an accelerated aging of the rural population and external migration, which adversely affects production capacity [12]. At the same time, the structural transformations of European agriculture demand the adaptation of workforce skills and the integration of young people into modern agricultural practices [1]. Furthermore, the expansion of organic farming is regarded as an opportunity for sustainable development and employment creation in rural areas [17].

In this context, the goal of this research is to apply the principles of sustainability and sustainable development at the group level and to transpose them into the community, emphasizing on the awareness of the indissoluble link between the natural environment and the rational use of natural resources [8].

MATERIALS AND METHODS

The development of the economic approach through the lens of sustainability policies contributes to the positive behavioral and attitudinal formation of young people, reinforcing their connection to nature as a counterbalance to urban development. At the same time, it also supports schools' efforts to develop activities that bridge the gap between the populated environment, dynamic from both an economic and social perspective, and a natural environment that ensures the perpetuation of species and life in general. Such perceptions should be translated into practice, through which young people can allocate time to study nature and its benefits, in order to foster activities aimed at conserving non-renewable resources.

To this end, it is necessary to educate young people on responsible consumption and efficient resource management to protect biodiversity, preserve the natural heritage, foster ecological awareness, and strengthen their commitment to environmental protection and conservation actions [20]. There is a need to educate young people in developing creative activities for waste recycling, environmental protection, and conservation to cultivate a responsible attitude toward the natural environment, alongside pro-ecological skills and practices related to its safety and preservation, raise public awareness of the problems caused by irrational resource exploitation and its adverse environmental effects, the most significant of which are high pollution levels and climate change [18].

Thus, we aim to promote a modern form of education that fosters ecological awareness and human responsibility, enabling active participation and cultivating an environmentally conscious stance, thereby encouraging the rational use of natural resources in line with sustainable development and environmental protection [16] [23].

In relation to quantitative variables, geographical, geodesic, and morphological factors indicate that agriculture holds significant potential [7] [13]. However, it does not generate sufficient added value due to the absence of a medium- to long-term strategic

vision that could foster efficient and sustainable development, consistent with the Sustainable Development Goals embedded in the European Union's agricultural policy.

In order to identify the need for agricultural development in order to increase the competitiveness of the Romanian economy, we surveyed 100 respondents, based on their answers to seven questions, who originate from the Bucharest–Ilfov region and southern Muntenia, areas recognized for their agricultural potential and for their contribution to supplying agricultural products to the major cities in these regions, including Romania's capital. The survey was distributed via email to a statistical population identified from the database of the National Institute of Statistics, consisting exclusively of entities engaged in agricultural production within the two macro-regions.

A survey is a collection of questions addressed to a small group of individuals, used to assess the opinions of a broader population. The margin of error is a mathematical calculation that determines the accuracy of the survey results, specifically how well the responses from a small group align with the opinions of the larger group, potentially at the population level. Survey reports often present margins of error together with another statistical concept, namely the "confidence interval." This is a statistical term used to describe the range in a distribution within which the most of data points are expected to fall. To obtain the mean responses and confidence intervals for survey questions, follow these steps:

→ calculate the mean of the responses (commonly for scale-based questions, such as Likert items), by adding up all the numerical responses (from 1 to 5, for example) for a given question and dividing the sum by the total number of participants.

→ calculate the standard error, which measures the average variability of the sample distribution:

standard error = standard deviation / SQRT (number of participants)

→ establish the confidence level by applying a Z value (usually chosen to be approximately 1.96 for a 95% confidence interval) to determine the confidence interval.

→ calculate the confidence interval:

*confidence interval = mean ± (Z value * standard error).*

The questionnaire consisted of seven questions composed of multiple Likert-scale items – a scale that allows for expressing the degree of agreement or disagreement with statements formulated in clear, simple, and concrete terms, which facilitates the collection of quantitative data from subjective perceptions.

Q1. How do you think agriculture influences the local economy?
- A. Increase the number of jobs
- B. Increase local income
- C. Stimulate other economic sectors
- D. It does not have a significant impact

Q2. In your opinion, what are the main challenges for local agriculture in the context of climate change?
- A. Decrease in crop yield
- B. Higher costs for adaptation
- C. Lack of resources necessary for adaptation
- D. Others (please specify)

Q3. To what extent do you think that the diversification of agricultural production can contribute to local economic stability?
- A. Very much
- B. Moderate
- C. A little
- D. Not at all

Q4. What impact do you think technology and innovation have on local agriculture?
- A. Improve efficiency
- B. Reduce costs
- C. Increase sustainability
- D. It does not have a significant impact

Q5. How do you think labour migration in the agricultural sector affects the local economy?
- A. It has a major negative impact
- B. Has a minor negative impact
- C. It does not have a significant impact
- D. It has a positive impact

Q6. How do you assess the influence of government policies on local agriculture?
- A. Very positive
- B. Moderately positive

- C. Neutral
- D. Negative

Q7. Do you believe that sustainable agricultural practices contribute to long-term economic growth in your community?

- A. Yes, significantly
- B. Yes, but only to a small extent
- C. I'm not sure
- D. No, it does not contribute

The validated questionnaires were processed to obtain the data required for statistical analysis. The statistical processing of the data was carried out using specialized software, namely the "Statistical Package for the Social Sciences" (SPSS 12 (Statistical Package for The Social Sciences)). This program enables the processing of virtually unlimited datasets, allowing for the calculation of frequency, arithmetic mean (x), standard deviation (s), correlation coefficients, regression parameters, and the generation of diverse graphical representations, depending on the calculated statistical parameters (indicators).

The research findings indicate a clear interest among the population employed in Romanian agriculture for development, training, and specialization, with the aim of achieving higher valorization of resources, in order to access specialized markets through the economic goods produced.

RESULTS AND DISCUSSIONS

Agrarian and rural areas make significant contributions to the national economy, both in terms of resident population and the economic activities conducted within them. From the perspective of the population residing in rural areas, in 2024, it represented 48.08% of Romania's total population, according to INSSE [24]. By contrast, the registered population living in rural areas accounted for 44.18%, indicating labor migration to urban areas in search of economic opportunities. Thus, in terms of employment level, 19.83% of the total employed population is engaged in agriculture, forestry, and fishing, according to INSSE, in an area that represents over 50% of the country's total area. Romania, with an agricultural area of 14.741 million hectares, has among the largest agricultural resources in Central and Eastern Europe. However, it loses arable land to the benefit of buildings and housing areas, without a corresponding development of Romania's economy in terms of rational and sustainable resource use, particularly agricultural resources.

According to Eurostat, the utilized agricultural area in Romania has decreased significantly between 2011 and 2023, due to market transformations and the economic dynamics of services, construction, and industry. Consequently, the decline in agricultural land contributes significantly to the allocation of land for the restoration of the productive capital structure of the Romanian economy, primarily serving industrial or non-agricultural activities. At the same time, Romania's dependence on imports to meet basic needs, especially those of agri-food goods, for which Romania has a comparative advantage in production, is deepening due to disparities in the availability of production factors.

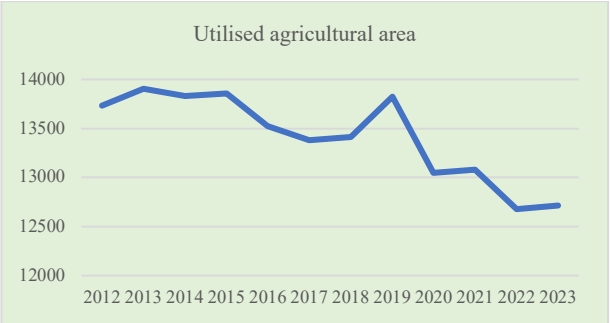


Fig. 1. Evolution of utilized agricultural area in Romania (2012–2023)

Source: Authors' calculations based on national statistics. Utilised agrarian area by categories [25].

In the context of global warming, dependence on irrigation for sustaining agricultural activities is particularly high, which means that many of the lower-fertility lands, located outside urban areas, are used for electricity production through photovoltaic farms [5].

Considering that Romania owns 12.678 million hectares of agricultural land, comprising 8.211 million hectares of arable land, 4.073 million hectares of meadows and pastures, 6.929 million hectares of forest, and 3.410 million hectares of other land categories,

the agricultural area that can be covered with photovoltaic panels, in conditions of economic efficiency, represents only 0.03% of Romania's arable land. This area cannot significantly affect the country's agricultural or overall economy, since the green energy obtained contributes to reducing production costs, provided that the national energy system is able to balance the amount of energy produced from renewable sources with that produced from conventional sources, thereby enabling users to benefit from affordable energy throughout the consumption period [22].
As can be seen from INSSE data, the decrease in agricultural area has led to an increase in Romania's imports. Specifically, regarding agriculture, imports have tripled, primarily consisting of food products and live animals.

Table 1. Evolution of agricultural imports in Romania by product categories (2012–2024)

	Import product categories (thousand euros)			
Year	**Total import**	Food and live animals	Raw materials, inedible, exclusively combustible	Oils, fats, and waxes of vegetable and animal origin
2012	**54,703**	3,666	1,738	226
2013	**55,317**	3,860	1,720	188
2014	**58,522**	4,066	1,671	149
2015	**62,971**	4,798	1,778	162
2016	**67,364**	5,477	1,940	160
2017	**75,604**	5,957	2,240	160
2018	**82,840**	6,070	2,460	152
2019	**86,297**	6,771	2,384	162
2020	**80,570**	7,185	2,178	191
2021	**98,379**	8,089	3,006	246
2022	**126,034**	10,066	3,810	436
2023	**122,046**	10,872	2,879	266
2024	**126,083**	11,449	2,932	304

Source: Authors' calculations based on national trade statistics [24].



Fig. 2. Evolution of total agricultural imports in Romania (2012–2024)
Source: Authors' calculations based on national trade statistics [24].

In this situation, it is necessary to design a development strategy for Romanian agriculture focused on strengthening its productive capacity, commensurate with the generation of economic goods for both domestic and foreign consumption. At the same time, there are opportunities to increase the added value of gross agricultural production within specific industries, such as processing, which would foster job creation and improve overall societal well-being.
The results of the statistical tests for 100 respondents are shown in Table 2. The results regarding the descriptive statistics of the survey responses: mean, confiednce intervals, median, variance and distribution indicators are persented in Table 3.
Agriculture's contribution to Romania's gross value added is 4.3% in the second quarter of 2024, compared with 19.88% for industry, 9.35% for construction, and 22.46% for trade.

Table 2. Descriptive statistics of survey responses: Mean, confidence intervals, median, variance, distribution indicators (Q1–Q4)

	Q1	Q2	Q3	Q4
Mean	21.733	18.400	18.400	20.267
95% Confidence Interval for Mean, Lower Bound	19.360	16.624	16.259	17.967
95% Confidence Interval for Mean, Upper Bound	24.107	20.176	20.541	22.567
5% Trimmed Mean	21.370	18.222	17.667	19.741
Median	20.000	20.000	20.000	20.000
Variance	1.064	0.596	0.866	0.999
Minimum	1.00	1.00	1.00	1.00
Maximum	4.00	3.00	4.00	4.00
Range	3.00	2.00	3.00	3.00
Interquartile Range	2.00	1.00	2.00	2.00
Skewness	0.400	0.286	0.742	0.446
Kurtosis	-0.993	-1.257	-0.552	-1.038
Sum	163.00	138.00	138.00	152.00
Standard deviation	103.157	0.77180	0.93056	0.99964
Valid N (listwise)	75.000	75.000	75.000	75.000

Source: Authors' calculations based on survey data.

Also, Fig. 3 illustrates the average responses and confidence intervals for survey questions (Q1–Q7).

Table 3. Descriptive statistics of survey responses: Mean, confidence intervals, median, variance, distribution indicators (Q5–Q7)

	Q5	Q6	Q7
Mean	18.133	28.267	23.733
95% Confidence Interval for Mean, Lower Bound	15.521	25.747	21.092
95% Confidence Interval for Mean, Upper Bound	20.746	30.786	26.375
5% Trimmed Mean	17.370	28.630	23.593
Median	10.000	30.000	20.000
Variance	1.289	1.199	1.318
Minimum	1.00	1.00	1.00
Maximum	4.00	4.00	4.00
Range	3.00	3.00	3.00
Interquartile Range	2.00	2.00	2.00
Skewness	1.005	-0.343	0.155
Kurtosis	-0.576	-1.246	-1.407
Sum	136.00	212.00	178.00
Standard deviation	113.535	109.512	114.813
Valid N (listwise)	75.000	75.000	75.000

Source: Authors' calculations based on survey data.

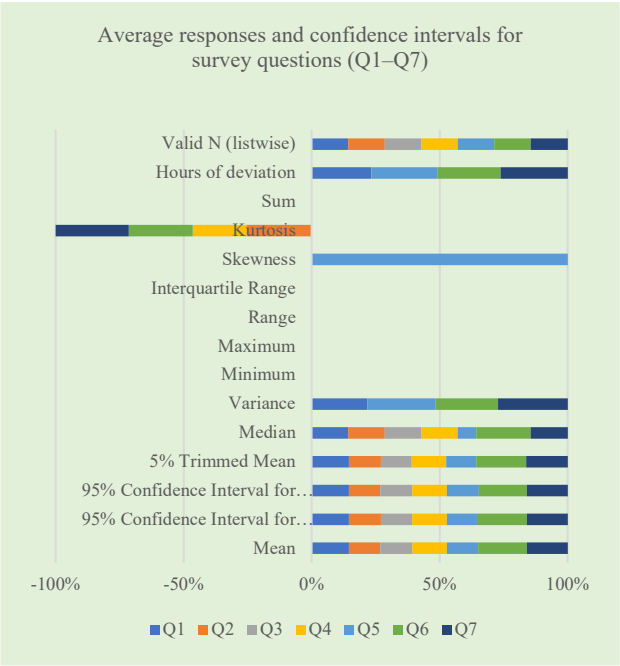


Fig. 3. Average responses and confidence intervals for survey questions (Q1–Q7)
Source: Own calculation.

From Table 3, we may see that the mean values range from 18.133 to 28.267, suggesting that the average responses lean towards the lower end of the scale, which, assuming a 1–4 scale, indicates a moderate level of agreement with the statements in the questions. In particular, Q6 ("How do you assess the influence of

government policies on local agriculture?") has the highest average (28.267), suggesting a stronger agreement with this statement compared to the others. The 95% confidence intervals are relatively narrow, indicating consistency in the responses.

The narrower the interval, the greater the confidence that the population mean is close to the sample mean. The medians are 20.000 for most questions, except Q5, where it is 10.000. The median represents the midpoint of the datase and is less sensitive to extreme values, suggesting that for Q5, most responses fall into the categories of 'disagree' or 'strongly agree' with the statement. Variance and standard deviation indicate the degree of dispersion of responses around the mean. A larger standard deviation indicates a greater dispersion of responses. Q5 has the highest dispersion, suggesting more varied views on the impact of labour migration on the local economy. Skewness measures the degree of skewness in the distribution of responses. A positive value indicates a longer tail to the right of the mean, while a negative value indicates a tail to the left. Most questions exhibit positive skewness, indicating that more answers are concentrated towards the lower end of the scale. Q6 has a negative skewness, suggesting a concentration of responses towards the top of the scale. Kurtosis measures the degree of peakedness or flatness of the distribution tails of the distribution are, compared to a normal distribution [9]. All Kurtosis values are negative, indicating relatively flat distributions, suggesting a lack of extreme outliers. The Range shows the difference between the highest and lowest response, and the IQR shows the range in which the middle 50% of the data falls. The values suggest that most answers are distributed in a reasonably concentrated range, except for question Q2, which has a narrower range.

According to the research data, the population employed in Romanian agriculture is interested in development, training, and specialization to improve resource utilization and access niche markets through the economic goods produced.

In Romania, the fiscal instability transferred to the business environment, as a result of a lack of budgetary foresight and a rigidity of the fiscal policy instruments, including the lack of transparency regarding the process of redistribution of budgetary revenues, corroborated with high credit costs in the economy, reduces the profitability and efficiency of private entrepreneurial activities. This fact reinforces the conviction that Romania has not yet consolidated itself as a fully functional market economy, as the actions and pressures of interest groups create significant dysfunctions in both the mechanisms of resource allocation and the redistribution of benefits.

At the same time, to address the lack of competitiveness in Romania's agriculture and the limited capacity to capitalize on its own resources, a solution would be to intensify production and expand sales markets by actively promoting the country's agricultural economic potential. There are numerous opportunities to attract human capital for productive purposes, especially in agriculture, tourism, artisanal industries, and light industries. However, we believe that the Romanian workforce lacks adequate institutional support through economic policy decisions, particularly in terms of taxation and financial predictability. Perhaps the lingering constraints of the communist period have not yet been fully overcome, or maybe the high level of corruption in the administration leads to a lack of motivation and involvement, but Romania cannot achieve sustainable economic and social development if it continues to import the majority of consumer products, if it exports a significant volume of raw materials and if it performs a limited number of economic operations within a product, leaving resources unexploited and wasting factors of production.

We believe it is opportune to actively engage society by stimulating private interest in rethinking and reconfiguring Romania’s agricultural market system, thereby creating the premises for the conservation and efficient exploitation of the domestic economic potential. Romania must also implement a coherent mix of fiscal, budgetary, and

monetary policies designed to outline an attractive and stimulating business environment, in which the actions of interest groups are aimed solely at increasing added value and intensifying internal and external competitiveness.

We believe that the sustainable development of agriculture contributes not only to job creation for the capitalization of local resources and industries adjacent to the production of agricultural goods (including tourism, dual education, and the wellness industry) and to the development of creative sectors generated by the farming/rural potential and transposed into the production of energy from renewable sources. In this way, long-term prospects for the sustainable development of agriculture are thus ensured.

To assume fundamental convergence criteria, Romania's agricultural development strategy must take into account the following:

- preservation of productive capacity. In this regard, investments managed by public-private partnerships will be allocated for the restoration or construction of irrigation networks, the provision of technical capital to enhance agricultural productivity;
- retention and attraction of the agricultural workforce. The agricultural population in Romania is either aging or lacks access to financial resources to initiate economic activities. The primary deficiencies of the farming population are the reduced opportunities for schooling, low qualifications, and the mismatch of professional skills and competencies to the current specificity of the agricultural products market. In this regard, local authorities should actively support the educational process in rural areas and provide motivation and facilities to attract the farm workforce;
- the development of agricultural product processing networks, particularly through small-scale or artisanal family associations, which should be complementary to medium or large farms;
- clarification of the legal framework for enabling the agricultural population to accumulate production factors and establish medium and large farms;
- the establishment of a functional agricultural land market to form a realistic price for land as a production factor, which would favor accumulation and production;
- ensuring that competitive mechanisms in the agricultural products market operate in ways that facilitate domestic producers' access to market;
- supporting agricultural producers through a system of subsidies aligned with the actual costs of production, meant to encourage production and sales;
- the possibility of accessing loans with preferential interest rates for agricultural producers;
- encouraging large-scale intensive agriculture through mechanization to increase productivity and achieve economies of scale;
- discouraging subsistence practices that foster self-consumption, economic demotivation, and deterioration of the workforce's physical and mental health;
- elevating agriculture to a profitable and efficient sector, to the detriment of the current attitude of marginalization, discrimination, and degradation.

The agricultural policy in Romania's past economy had a pervasive character, with the distribution and consumption process ensured by a large market in which centralized orientation was predominant. The recent period has been marked by institutional, particularly legislative, instability, which has caused the restriction of production capacity for several reasons:

1. the fragmentation of agricultural land, with negative consequences both on production capacity and product quality;
2. the lack of agricultural financing has caused a technological gap and hindered research development in the field of agriculture, with consequences on the productive potential in the medium and long term.
3. the widening of the gaps between rural and urban areas due to the insufficiency of the income of the labor force employed in rural areas caused by the lack of a flow of income

that would ensure the coverage of living needs and the premises of sustainable economic development;

4. limited opportunities for small producers to access markets for agricultural products. The agricultural market in Romania is an oligopolistic market that imposes significant barriers on small producers, both in terms of price and the quality conditions imposed on farm products. This fact is also accentuated by the limited access of small producers to forms of financing that would enable them to increase and develop efficient agricultural holdings.

5. Romania's accession to the European Union has not sufficiently stimulated small producers' interest in attracting material and financial resources to any small extent. In this case, there is a need for programs to inform the rural population about the importance of attracting European funds for the development of agriculture on a basis compatible with that of the European Union, but also to change people's mentality regarding the attitude towards work in agriculture: substituting labor with capital to a greater extent, the use of marketing techniques to streamline the process of distribution of agricultural products, emphasizing the training of the agricultural workforce and attracting as many young people as possible in the agricultural processes;

6. Romania's EU integration subjects its agriculture to the Common Agricultural Policy (CAP), which attracts both advantages and disadvantages. Thus, Romania must improve its production capacity on a competitive, compatible, and convergent basis in consensus with the standard agricultural policy, relying on the exploitation of comparative advantages in relation to other countries in the European Union: a large market for agricultural products, high productive potential, and access to European financing to the extent that they are attracted.

Domestically, Romanian agriculture exhibits low growth rates due to low productivity and insufficient development of human capital, primarily caused by the lack of an adequate rural school infrastructure adapted to the requirements of a competitive agricultural market and aligned with the standard agrarian policy.

The economic development of rural communities largely depends on the same factors as urban development: access to well-paid jobs, critical services (education, health, technology, transport, telecommunications), and a sustainable natural environment. The rural area offers several additional advantages, including abundant and relatively inexpensive labor, significantly lower building costs, a lower cost of living, less congestion, and a quieter lifestyle. Thus, three key aspects are essential for diversifying the rural economy: capital investment for business development in rural areas, the rural population's orientation towards other fields of activity, and the development of basic infrastructure necessary for carrying out other economic activities.

Therefore, in a first phase, the creation and maintenance of adequate infrastructure are essential conditions for the economic and social development of rural areas. Modern infrastructure determines the capacity of rural areas to compete effectively for domestic investment promotion. It also contributes to increasing the attractiveness of rural areas in terms of living and employment opportunities. Transport, telecommunications, electricity, and water infrastructure are essential for business development and attracting investment in rural areas.

Capital, the third factor of agricultural production, plays a vital role because the development capacity and efficiency of agriculture depend on its volume and structure. The increasing role of capital as a substitute for labor is a result of technologically modernized agriculture.

For Romania, it is necessary to ensure, in accordance with the principles of the reformed CAP and the evolution of the European rural area, adequate farmer incomes, preservation of rural specificities, employment opportunities in rural areas, prevention of depopulation, preservation of local traditions, and consolidation of CAP objectives in food security.

As a result of the development of cutting-edge technologies, the intensification of scientific research, and the unprecedented influence of

the mass media on the decision-making behavior of the consumer, the relationship between resources and needs, between availability and demand, is experiencing substantial distortions, which undermines the production of economic goods to meet essential needs. This assault has direct repercussions on the way of combining financial resources, both own and attracted, respectively, requiring convergent implications from the productive sector to size the supply at the level of demand.

The problem is, on the one hand, the efficient management of own and borrowed resources, in the context of the continuous depletion of conventional energy reserves and the adjustment of demand in relation to its purchasing power and, on the other hand, in the management of trade balance imbalances, respectively of the balance of payments at the level of countries, as a result of the discrepancy between exports and imports.

The advantage of globalization lies in the mobility of production factors, enabling them to meet the demand for economic goods. In economies where the endowment of factors of production is insufficient, imports are made. This limits agricultural development, as demand for agricultural goods cannot be sustained by domestic consumption, which depends on the local labor force as a prerequisite for ensuring societal well-being.

CONCLUSIONS

Essentially, the factors driving economic growth can be summarized as those fostering entrepreneurship. Entrepreneurship seeks to increase the income of both entrepreneurs and society, thereby contributing to economic growth and development. It is exciting to see how today's society fosters the entrepreneurial spirit and initiative, which are crucial for achieving core economic objectives, such as employment and wealth creation, in the agricultural sector. Through entrepreneurship, individuals empower their creative energies to generate sources of income for themselves and the community to which they belong. This motivates them to improve service quality, create economic goods that meet demand, and use resources efficiently. The need to provide reliable economic goods through the quality-price ratio leads to supporting the image of the products made and marketed by capitalizing on agricultural resources.

Implementing the principles of sustainable agriculture in Romania will lead to eco-efficient utilization of agricultural and environmental resources, paving the way to minimize the adverse effects of environmental and species degradation, with significant implications for human health. At the same time, we will identify opportunities to increase producers' incomes and consumer benefits in the medium and long term, as well as the positive effects of participatory agricultural practices.

According to the study, there is a marked interest in developing agriculture as a driver of local economic support, by attracting and utilizing local economic resources to create welfare for resource holders and to harness the potential for local development. In this respect, the study highlights the need for investment, particularly in crop regeneration, in capitalizing on work flows, and in ensuring the necessary irrigation, under conditions where the need for agricultural diversification is increasingly understood, as a result of a growingly fragmented demand in the agricultural market. Another element emphasized by the study is the necessity of labor force specialization, in alignment with innovative technologies employed in agriculture, to ensure the sustainable use of resources.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECOLOGICAL AND ECONOMIC OUTCOMES OF LONG-TERM IRRIGATION WITH MINERALIZED WATER

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Abstract

Irrigation is essential for food security, but freshwater scarcity necessitates using mineralized water, which can degrade soil quality. This study analyzed the long-term effects of irrigating dark-chestnut soil in southern Ukraine with mineralized water from the Ingulets system and the economic impact. A stationary field experiment (1971–2020) assessed soil quality (cations, salts, sodicity) and water properties. Statistical analysis (Mann-Kendall, Sen's slope, ANOVA, regression, correlation) in Python 3 showed that Ingulets water (Class II, high mineralization) remained unsuitable for irrigation. Over time, irrigation increased sodification, toxic salts, and sodium while reducing calcium, harming soil structure and fertility. Fertilizers mitigated salinization in deeper layers and improved cation content. Economically, irrigation increased wheat yield by 0.82–1.66 t/ha, with pure additional profit of $206–$403/ha after deducting amelioration and fertilization costs. Despite soil risks, irrigation with mineralized water is economically viable in semi-arid regions, especially when combined with fertilizers and land reclamation practices.

Key words: *land degradation and reclamation, the Ingulets, mineralized water, economic efficiency*

INTRODUCTION

Current agriculture faces several serious challenges, which threaten sustainable crop production and food security, namely, global warming and consequent changes in climate patterns, and adverse effects of hostilities in Ukraine and Middle East [1]. Climate change resulted in dramatic shifts in air temperature on the annual scale and within the growing season, as well as disturbing usual regularities of rainfall distribution, air humidity, led to increased frequency of adverse meteorological events such as steep unpredictable shifts in temperatures, hailstorms, prolonged severe drought events, etc. All these changes arouse new difficulties for sustainable agricultural development, as well as aggravated the issues of natural resources use and environmental stability. Arid and semi-arid regions of the Earth are the most vulnerable to current climate change and related food insecurity issues [22].

Among the challenges, an important role belongs to freshwater resources availability for agricultural purposes. As far as it is known, agriculture is one of the biggest consumers of freshwater resources. Considering global climate aridization, the demand for irrigation to satisfy sufficient crop production and satisfy the needs of animal husbandry in arid and semi-arid zones will increase, simultaneously increasing the demand for freshwater in agriculture. General freshwater scarcity is one of the greatest issues for current agricultural science and practice [8]. On one hand, it will be almost impossible to deal with climate aggravation and related aridity issues to provide food security without proper irrigation. For this reason, researchers are looking for to solutions to help the farmers to maintain yields. For example, in Romania, there investigated crops, the average yields per hectare obtained under irrigated system were higher than those obtained under non-irrigated system [19].

In Egypt, it was studied the effect of water and fertilization levels on barley using different irrigation systems [3].

As for Ukraine, it was established that now nearly half of the country's territory requires irrigation to provide sustainable crop yields, and in the context of Kakhovka dam and reservoir destruction, the situation with national agricultural sector of economy in the South of the country, looks even more dramatic and threatening [13]. On the other hand, the water resources deficit calls for the development of resource-saving irrigation methods, as well as looking for alternative sources of water. In some cases, such sources include treated wastewater, collector and effluent waters, seawater, and other sources, which can provide sufficient volumes of water resources for irrigation but considering low water quality may pose risks of negative environmental impacts, especially on soils [7, 15]. These impacts include hazards of soil salinization, alkalization, sodicity increase, fertility loss, and general deterioration of soil health. Soil degradation prevention is an important task of modern ecology and agriculture, as far as normal life on the planet depends greatly on soil conditions [10]. To prevent soil quality deterioration, it is crucial to perform careful studies on possible negative consequences of irrigation with water of unfavorable quality on soil ecological and meliorative state. Apart from ecological threats, irrigation with low-quality water possesses economic disadvantages, as additional expenditures related to soil amelioration arise.

The main goal of this study was to establish the effects of continuous irrigation with mineralized water on the conditions of the dark-chestnut soil of the South of Ukraine and point out connected risks to environmental sustainability and evaluate whether there are any real economic benefits from applying irrigation with low-quality water through the calculation of real pure profits after irrigation application and consideration of land reclamation expenditures.

MATERIALS AND METHODS

The study was carried out at the irrigated and non-irrigated lands of the experimental fields of the Institute of Climate-Smart Agriculture of NAAS (former – the Institute of Irrigated Agriculture of NAAS), located in the Bilozersky district of Kherson region, Ukraine. The irrigated lands are of the Ingulets irrigation array. These lands are irrigated with the mineralized water from the Ingulets irrigation system, which nowadays is the main system, which supplies fields with water in Kherson and Mykolaiv regions of Ukraine. The water is polluted with the effluent disposals and wastes from the metallurgy industry; therefore, it is highly mineralized and saline [14].

To determine the peculiarities of elementary soil processes (ESP) in the dark-chestnut soil under the conditions of long-term irrigation with the Ingulets water, the study was carried out in a stationary experiment, which was established in 1971. Data from previous studies were used to determine changes in soil properties. The experiment is carried out with the following crop rotation: alfalfa (3 years old), winter wheat, grain corn, silage corn, winter wheat. The fertilizer rate is calculated for each crop in the crop rotation for the irrigated conditions (210 kg of NPK per hectare of crop rotation area). The sowing plot area was 240m^2. Crops cultivation technologies were generally accepted for the agroclimatic zone of the South of Ukraine. Mineral fertilizers (ammonium nitrate, superphosphate) were applied prior to the main tillage. The yields of wheat (as a reference crop for economic calculations) were estimated after complete harvesting of the experimental plots with self-propelled combine harvester. The yield of wheat grain was recalculated to standard moisture content in kernels (14%).

The water quality for irrigation by agronomic criteria was conducted with accordance to DSTU 2730:2015 [2013]. The analysis of the ionic and total dissolved solids (TDS, total and toxic salts) composition of the aqueous soil extract was performed by Hedroyts [8]; exchangeable sodium, calcium and magnesium contents were determined in an extract of 1% ammonium acetic acid using flame photometry [23]. Soil sodification was established with accordance to DSTU 3866-99 [20].

Statistical processing of the experimental data was performed in Python 3 within the IDE VS Code. Statistical procedures of Mann-Kendall and Sen's slope trend test at alpha=0.05, OLS linear regression analysis [2], correlation matrix analysis [17], heatmap analysis [5] were performed. The standard deviation (SD) and coefficient of variation (CV) were calculated and interpreted with accordance with common international guidelines [18]. Economic outcomes were estimated for winter wheat reference crop through the calculation of grain yield price, additional yield price received at the expense of irrigation and fertilizers, and the difference between the variants. The price of amelioration measures to restore soil conditions in terms of salt content in the 0-30 cm layer was calculated assuming the application of phosphogypsum for this purpose. Water costs for irrigation and costs for fertilizers application were also accounted for. All the prices were paid as of February 4th, 2025.

RESULTS AND DISCUSSIONS

Table 1 provides a detailed analysis of the quality of Ingulets irrigation water from 2001 to 2020, with key findings summarized as follows. The average TDS content was 1.531 g/L, with relatively low variability (CV = 4.35%). The values remained consistent over the years, indicating stable salinity levels, which are marginally suitable for irrigation. The mean pH was slightly alkaline at 8.1, with minimal fluctuation (CV = 2.61%). This aligns with typical irrigation water requirements, posing no significant risk to soil fertility and structure. Toxic concentrations were expressed in chloride equivalents and averaged to 14.3 meq/L with a CV of 16.70%, suggesting moderate variability. These levels generally fall within acceptable ranges for irrigation purposes but may pose some harm to susceptible plants. The average sodium percentage was 52.72%, with low variability (CV = 7.41%). While consistent, high sodium levels could potentially contribute to soil sodification and related hazards if not managed properly. The magnesium and calcium ion content averaged to 1.95 meq/L (CV = 18.34%) and 0.34 meq/L (CV = 20.02%), respectively. These levels reflect a balanced ionic composition that supports soil structure. The mean concentrations of carbonates, bicarbonates, and chlorides were 0.11 meq/L, 2.4 meq/L, and 10.45 meq/L, respectively, with bicarbonates and chlorides showing moderate variability. The low carbonate content indicates minimal alkalinity risk. As for hazard assessments, the Ingulets irrigation water was classified as "Class II" (moderate risk) throughout the study period, as it possesses occasional risks of alkalization and toxicity that require appropriate ameliorative monitoring and management.As for the tendencies in the Ingulets irrigation water quality, it was established that there is no significant trend to change for most quality indicators. Bicarbonates content was the only indicator with reliable trend to increase, talking about potential increase in alkalization hazards and toxicity of the studied water for soil and agricultural plants (Table 2).

As for soil sodium content analysis, following regularities were established across the studied options. In the variant 'No Irrigation, Without Fertilizers' sodium levels ranged from 0.27 to 0.39 meq/100 g, averaging to 0.32 meq/100 g. The sodification level remained consistently classified as "slight" over the years, indicating minimal impact on soil salinity in this variant. As for the variant 'Irrigation, Without Fertilizers', sodium content varied between 0.45 and 0.65 meq/100 g, with an average of approximately 0.56 meq/100 g. The sodification level was predominantly "moderate," reflecting increased sodium accumulation due to irrigation without the mitigating effects of fertilizers. The same was true for the variant 'Irrigation Plus Fertilizers', where sodium levels ranged from 0.40 to 0.65 meq/100 g, with an average around 0.54 meq/100 g. Thus, the application of fertilizers did not significantly alter sodification traits (Table 3).

Table 1. Quality of the Ingulets irrigation water during 2001-2020 assessed by agronomic criteria, evaluated with accordance to DSTU 2730:2015

Year	TDS content, g/L	pH	Toxic ions in eCl^-, meq/L	Sodium percentage, %	$\frac{Mg^{2+}}{Ca^{2+}}$	$\frac{Ca^{2+}}{Na^+}$	Anions content, meq/L			Water quality for irrigation according to DSTU 2730:2015			
							CO_3^{2-}	HCO_3^-	Cl^-	Salinization hazard	Sodification hazard	Alkalization hazard	Toxic effects hazard
2001	1.492	8.2	11.8	50.9	1.8	0.3	0.1	2.2	9.7	II	II	II	II
2002	1.539	7.8	12.4	57.4	1.9	0.3	0	2.1	9.8	II	II	II	II
2003	1.547	8.1	13.3	58.3	2.0	0.4	0.1	1.6	10.9	II	II	III	III
2004	1.473	8.0	16.4	51.0	1.6	0.3	0.1	2.0	9.2	II	II	II	II
2005	1.528	8.5	13.4	49.8	1.9	0.3	0	1.8	10.9	II	II	II	II
2006	1.425	8.6	14.6	54.8	1.8	0.3	0.2	2.6	9.4	II	II	II	III
2007	1.462	8.3	18.2	51.6	1.8	0.4	0.1	2.3	6.9	II	II	II	II
2008	1.580	8.2	20.1	63.7	1.8	0.2	1.2	2.9	10.3	II	II	II	II
2009	1.526	8.0	13.1	50.0	2.1	0.3	0	2.8	11.1	II	II	III	III
2010	1.436	8.1	14.1	50.1	2.1	0.3	0	2.3	11.6	II	II	II	II
2011	1.522	8.3	18.9	54.4	3.1	0.3	0.1	1.2	12.5	II	II	II	II
2012	1.599	7.9	14.1	49.0	2.6	0.3	0	1.1	12.0	II	II	II	II
2013	1.528	8.1	11.4	51.8	1.6	0.5	0	3.2	9.2	II	II	II	II
2014	1.565	8.3	13.8	58.2	1.8	0.4	0.1	3.2	10.2	II	II	II	II
2015	1.633	8.0	13.7	49.7	2.2	0.3	0	2.1	11.6	II	II	II	II
2016	1.596	8.2	15.5	51.2	1.9	0.3	0.2	3.0	10.3	II	II	II	II
2017	1.432	7.8	11.5	49.6	1.8	0.4	0	2.9	9.5	II	II	II	II
2018	1.661	7.9	13.4	49.6	1.7	0.4	0	3.6	11.0	II	II	II	II
2019	1.581	8.1	14.0	51.0	1.9	0.3	0	2.6	11.7	II	II	II	II
2020	1.489	8.0	12.9	52.2	1.6	0.4	0	3.0	11.1	II	II	II	II
mean	1.531	8.1	14.3	52.72	1.95	0.34	0.11	2.4	10.45				
SD	0.07	0.21	2.39	3.91	0.36	0.07	0.27	0.68	1.28				
CV, %	4.35	2.61	16.70	7.41	18.34	20.02	241.25	27.90	12.27				

Source: [14].

Table 2. Mann-Kendall and Sen's slope test (alpha = 0.05) for the Ingulets irrigation water quality indicators for 2001-2020

Statistics	TDS, g/L	pH	eCl^-, meq/L	Sodium percentage, %	$\frac{Mg^{2+}}{Ca^{2+}}$	$\frac{Ca^{2+}}{Na^+}$	CO_3^{2-}	HCO_3^-	Cl^-
Mann-Kendall test									
MK-stat	43	-38	-6	-38	-9	37	-41	70	53
SD	30.805	30.386	30.789	30.789	30.139	26.627	27.489	30.724	30.741
Z-stat	1.363	-1.218	-0.162	-1.202	-0.265	1.352	-1.455	2.246	1.692
P	0.173	0.223	0.871	0.229	0.791	0.176	0.146	0.025	0.091
trend	no	no	no	no	no	no	no	yes	No
Sen's slope test									
slope	0.005	-0.011	-0.016	-0.083	0	0	0	0.061	0.073
lower	-0.002	-0.033	-0.160	-0.456	-0.020	0	-0.008	0.008	-0.017
upper	0.010	0.006	0.122	0.068	0.017	0.006	0	0.100	0.186

Source: Own results.

Table 3. Long-term changes in sodium content in the soil depending on irrigation and fertilizers application with accordance to DSTU 3866-99

Year	Variant					
	No irrigation, without fertilizers		Irrigation, without fertilizers		Irrigation plus fertilizers	
	Na^+ meq/ 100 g	Sodification level	Na^+ meq/ 100 g	Sodification level	Na^+ meq/ 100 g	Sodification level
2001	0.30	Slight	0.65	moderate	0.65	moderate
2002	0.27	Slight	0.53	moderate	0.49	moderate
2003	0.32	Slight	0.58	moderate	0.57	moderate
2004	0.29	Slight	0.53	moderate	0.48	moderate
2005	0.28	Slight	0.55	moderate	0.51	moderate
2006	0.30	Slight	0.50	moderate	0.45	moderate
2007	0.30	Slight	0.45	moderate	0.40	moderate
2008	0.30	Slight	0.50	slight	0.65	slight
2009	0.28	Slight	0.65	moderate	0.46	slight
2010	0.30	Slight	0.56	moderate	0.47	moderate
2011	0.35	Slight	0.58	moderate	0.48	moderate
2012	0.31	Slight	0.57	moderate	0.52	moderate
2013	0.36	Slight	0.52	moderate	0.59	moderate
2014	0.32	Slight	0.59	moderate	0.46	moderate
2015	0.35	Slight	0.58	moderate	0.48	moderate
2016	0.36	Slight	0.61	moderate	0.56	moderate
2017	0.34	Slight	0.56	moderate	0.64	moderate
2018	0.39	Slight	0.49	moderate	0.57	moderate
2019	0.35	Slight	0.57	moderate	0.63	moderate
2020	0.38	Slight	0.61	moderate	0.54	moderate

Source: Own results.

Trend analysis showed no significant sodification in irrigated soils, while rainfed soils exhibited increasing sodification. In semi-arid conditions, lack of irrigation prevents sodium leaching, leading to accumulation. Thus, irrigation helps reduce sodification by flushing excess sodium from the arable layer (Table 4).

Table 4. Mann-Kendall and Sen's slope test (alpha = 0.05) for the sodium content in the studied soil within the period 2001-2020

Statistics	No irrigation, without fertilizers	Irrigation, without fertilizers	Irrigation plus fertilizers
Mann-Kendall test			
MK-stat	116	21	28
SD	30.441	30.665	30.714
Z-stat	3.778	0.652	0.879
P	0.0001	0.514	0.379
trend	yes	no	no
Sen's slope test			
slope	0.005	0.002	0.004
lower	0.003	-0.004	-0.004
upper	0.006	0.005	0.010

Source: Own results.

As for salts content in the soil, it was established that there are some differences across the variants of the study in their distribution over the layers and accumulation patterns (Table 5). In the variant 'No Irrigation, Without Fertilizers' the total salt content in the 0–30 cm layer decreased slightly over time, from 2.949 t/ha (2001) to 2.231 t/ha (2020); in the 0–100 cm layer, the total salt content remained relatively stable, around 12.3 t/ha by 2020. Toxic salt content decreased marginally in both layers, with a more pronounced decline in the 0–30 cm layer (from 1.470 t/ha in 2001 to 1.282 t/ha in 2020). In the variant 'Irrigation, Without Fertilizers' the total salt content in the 0–30 cm layer decreased over time, from 3.920 t/ha (2001) to 2.961 t/ha (2020). In the 0–100 cm layer, total salt content reduced slightly from 16.848 t/ha (2001) to 13.228 t/ha (2020). Toxic salt content in the 0–30 cm layer also declined, from 2.850 t/ha (2001) to 2.467 t/ha (2020). However, the toxic salt content in the deeper 0–100 cm layer showed fluctuations, ending at 10.656 t/ha in 2020. As for the variant 'Irrigation Plus Fertilizers', the total salt content in the 0–30 cm layer slightly increased, from 4.004 t/ha (2001) to 3.504 t/ha

(2020). In the 0–100 cm layer, total salt content decreased slightly, from 15.268 t/ha (2001) to 14.548 t/ha (2020). Toxic salt content in the 0–30 cm layer fluctuated, remaining almost similar by 2020 (2.540 t/ha). In the deeper 0–100 cm layer, toxic salt content showed a notable decrease, from 10.510 t/ha (2001) to 8.494 t/ha (2020). As for the temporal changes, differences were also observed among the studied variants. Thus, in the variant 'No Irrigation, Without Fertilizers' salt content showed a gradual decline over two decades, particularly in the arable layer (0–30 cm), indicating natural leaching or stabilization over time. In the variant 'Irrigation, Without Fertilizers' both total and toxic salt contents decreased over time, especially in the arable layer (0–30 cm), suggesting the partial leaching effect of irrigation water. However, toxic salt content remained higher in deeper layers (0–100 cm), indicating possible accumulation in subsurface soil layers due to the mentioned above leaching. This may improve the growth of agricultural plants with shallow and moderately deep root systems but will have adverse effects on the plants with deep root systems. In the variant 'Irrigation Plus Fertilizers' the arable layer (0–30 cm) showed relatively stable toxic salt content, while the deeper layer (0–100 cm) experienced a decline in toxic salts content over time. Total salt content exhibited weak reductions, indicating some mitigation of salinity risks through fertilizer use.

To sum up, non-irrigated soil maintained the lowest salt content overall, confirming minimal salinization risks in the absence of irrigation with mineralized water. Irrigation without fertilizers application resulted in higher salt accumulation through the whole soil profile compared to non-irrigated soil, though reductions were observed over time due to partial leaching. Irrigation with fertilizers usage showed slight increases in arable layer salt content but notable reductions in toxic salts in the deeper layer, suggesting fertilizers may help mitigate long-term salinization.

Table 5. Effect of long-term irrigation and fertilizers on salt content in the studied soil

Year	Soil layer, cm	Salt content, t/ha	
		total	toxic
No irrigation, without fertilizers			
2001	0-30	2.949	1.470
	0-100	12.740	7.140
2006	0-30	2.574	1.148
	0-100	11.900	6.300
2010	0-30	2.306	1.319
	0-100	12.320	7.140
2015	0-30	2.416	1.386
	0-100	12.180	7.000
2020	0-30	2.231	1.282
	0-100	12.320	6.860
Irrigation, without fertilizers			
2001	0-30	3.920	2.850
	0-100	16.848	12.700
2006	0-30	3.192	2.184
	0-100	15.600	10.650
2010	0-30	3.044	2.169
	0-100	13.228	9.634
2015	0-30	3.066	2.100
	0-100	14.400	9.750
2020	0-30	2.961	2.467
	0-100	13.228	10.656
Irrigation plus fertilizers			
2001	0-30	4.004	2.540
	0-100	15.268	10.510
2006	0-30	3.182	1.958
	0-100	14.544	9.072
2010	0-30	3.253	2.457
	0-100	13.972	9.646
2015	0-30	3.345	2.448
	0-100	14.256	9.648
2020	0-30	3.504	2.540
	0-100	14.548	8.494

Source: Own results.

Both regression models for total and toxic salt content in the soil provided great fit quality and high accuracy. The model for total salts content is more accurate and fits the data somewhat better than the model for toxic salts, as evidenced by higher R^2, adjusted R^2, and better AIC/BIC scores. Both models are statistically significant, with negligible p-values indicating strong relationships between predictors and outcomes, testifying that the inputs are decisive for the output formation, and almost no external effects are present. While both models are robust, the model for total salts content shows a stronger association with the inputs compared to the model for toxic salts content. Lower AIC and BIC values for the model of total salts suggest that this model is more efficient in balancing complexity and accuracy (Table 6).

Table 6. Regression statistics for the total and toxic salts content in the studied soil

Statistical indicator	Total salts	Toxic salts
R^2	0.982	0.922
Adjusted R^2	0.980	0.913
F-statistics	472.6	102.1
Prob (F-statistics)	8.70×10^{-23}	1.66×10^{-14}
Log-likelihood	-33.351	-43.839
AIC	74.70	95.68
BIC	80.31	101.30

Source: Own results.

Detailed regression statistics and model parameters are provided in Table 7. According to the t and P values, the greatest impact on salts content is associated with irrigation treatment. Soil depth plays a secondary role, while the time span is the least important influential factor. It must be stressed that the negative values of the 'Year' coefficient testifies about slight tendency to salt content decrease over the years, while the highest value of the coefficient for 'Irrigation' input suggests that irrigation is the main driving force to salinization hazards.

The effect of long-term irrigation and fertilizers on the cations' ratio and content in the studied soil is presented in Table 8.The correlation matrix for the main cations in the studied soil is provided on Fig. 1.

Table 7. Regression models and their statistical evaluation for the total and toxic salts content in the studied soil

	coefficient	SD	t	P > |t|	0.025	0.975
Total salts model						
Intercept	104.6178	43.598	2.400	0.024	15.001	194.234
Year	-0.0532	0.022	-2.453	0.021	-0.098	-0.009
Soil depth, cm	0.1537	0.004	37.301	0	0.145	0.162
Irrigation	0.7970	0.177	4.512	0	0.434	1.160
Toxic salts model						
Intercept	61.2697	61.844	0.991	0.331	-65.852	188.392
Year	-0.0314	0.031	-1.021	0.317	-0.095	0.032
Soil depth, cm	0.0999	0.006	17.087	0	0.088	0.112
Irrigation	0.9134	0.251	3.645	0.001	0.398	1.428

Source: Own results.

Table 8. Effect of long-term irrigation and fertilizers on the cations' ratio and content in the studied soil

Variant	Year of the study, period	Soil layer, cm	Cations content, meq/100 g			Total exchangeable cations content, meq/100 g	Share, %		
			Ca^{2+}	Mg^{2+}	Na^{+}		Ca^{2+}	Mg^{2+}	Na^{+}
No irrigation, without fertilizers	2001 (31 years)	0-30	13.8	4.8	0.30	18.90	73.02	25.40	1.59
	2006 (36 years)	0-30	13.2	4.8	0.30	18.30	72.13	26.23	1.64
	2010 (40 years)	0-30	12.4	4.6	0.30	17.30	71.68	26.59	1.73
	2015 (45 years)	0-30	12.2	4.6	0.35	17.15	71.14	26.82	2.04
	2020 (50 years)	0-30	12.5	4.7	0.38	17.58	71.10	26.73	2.16
Irrigation, without fertilizers	2001 (31 years)	0-30	11.8	5.6	0.65	18.05	65.37	31.02	3.60
	2006 (36 years)	0-30	12.0	5.2	0.50	17.70	67.80	29.38	2.82
	2010 (40 years)	0-30	12.0	5.4	0.56	17.96	66.82	30.07	3.12
	2015 (45 years)	0-30	11.9	5.5	0.58	17.98	66.18	30.59	3.23
	2020 (50 years)	0-30	12.3	6.0	0.61	18.91	65.04	31.73	3.23
Irrigation plus fertilizers	2001 (31 years)	0-30	12.2	5.2	0.65	18.05	67.59	28.81	3.60
	2006 (36 years)	0-30	12.4	4.8	0.45	17.65	70.25	27.20	2.55
	2010 (40 years)	0-30	12.2	5.4	0.47	18.07	67.52	29.88	2.60
	2015 (45 years)	0-30	12.1	5.3	0.48	17.88	67.67	29.64	2.68
	2020 (50 years)	0-30	12.4	5.9	0.54	18.80	65.85	31.28	2.87

Source: Own results.

There is a strong correlation between magnesium and sodium content (R=0.81), suggesting a cumulative effect of these ions, likely from irrigation. Both ions are antagonistic to calcium [21], with moderate negative correlation for magnesium (R=-0.44) and stronger for sodium (R=-0.69), supporting the idea that sodium displaces calcium and affects soil structure. Magnesium also exacerbates sodium's harmful effects.

Heatmaps of cation content show that non-irrigated soils have the highest calcium (71-

73%), while irrigated soils have lower calcium (65-70%), with higher levels in 2006 for irrigated and 2001 for non-irrigated soils. Magnesium content is lowest in rainfed soil (25-27%) and highest in irrigated soils (27-32%), with peak values in 2020.

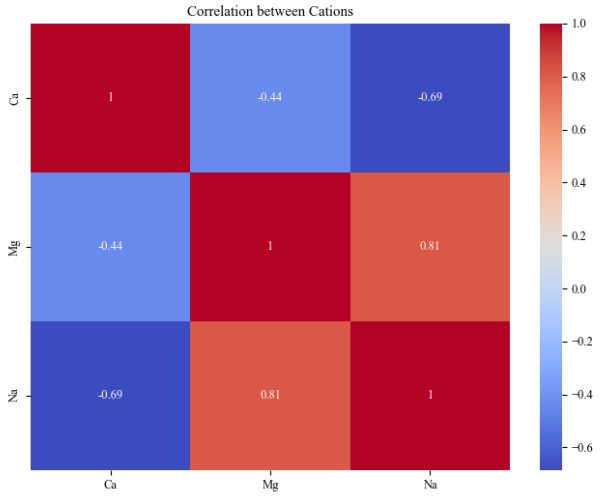


Fig. 1. Correlation matrix for cations content in the studied soil
Source: Own results.

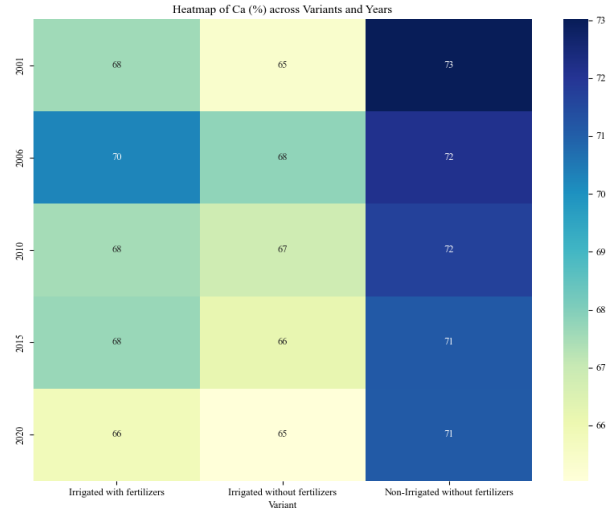


Fig. 2. Heatmap of Ca^{2+} cations across the variants and years of the study
Source: Own results.

Sodium content is lowest in non-irrigated soils (1.6-2.2%) and highest in irrigated soils (2.5-3.6%), particularly in 2001, indicating that irrigation contributes significantly to soil alkalization and sodification, with fertilizers offering some detoxification effect. These findings align with the view that irrigation is a major cause of soil salinity and sodicity, while organic fertilizers also improve soil health [16]. The fact that not only chemical amelioration agents such as gypsum are efficient in soil sodification management, but fertilizers, especially organic ones, play a crucial role in soil health improvement is also supported by some scientists [11].

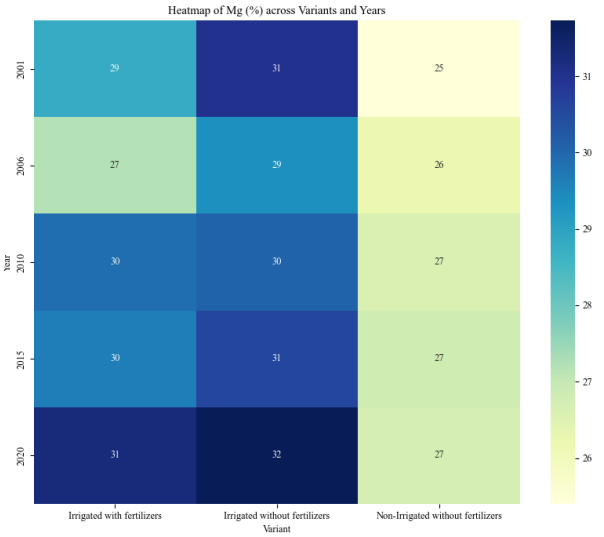


Fig. 3. Heatmap of Mg^{2+} cations across the variants and years of the study
Source: Own results.

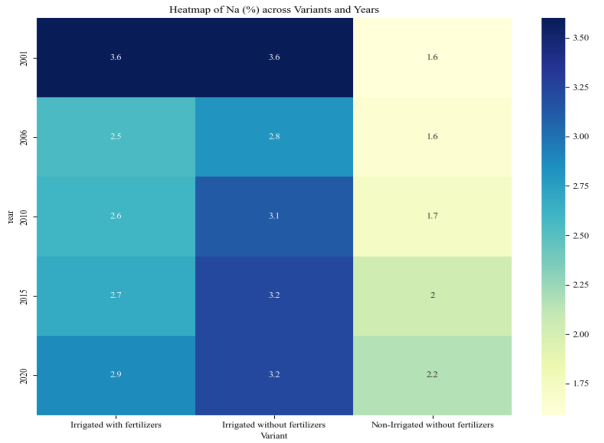


Fig. 4. Heatmap of Na^{+} cations across the variants and years of the study
Source: Own results.

Over the years, the yield of winter wheat declines in the absence of irrigation, leading to lower income per hectare (Table 9). Conversely, irrigation – both with and without fertilizers – substantially improves yield, increases revenue, and enhances economic efficiency. The application of phosphogypsum was required (0.618–1.25 t/ha) to manage salt accumulation due to mineralized water irrigation. After deducting amelioration, irrigation, and fertilization costs, the pure additional profit ranged from $66 to $269 per

hectare. Fertilizers were the most powerful factor of yield increase and economic efficiency rise. Irrigation alone increased profits, but irrigation with fertilizers yielded 2 to 3 times higher net economic returns.

Table 9. Economic evaluation of the irrigation with mineralized water and fertilizers application for the reference crop – winter wheat

Year	Winter wheat yield, t/ha	Yield price, USD/ha	Additional profit, USD/ha	Salts to be removed, t/ha	Phosphogypsum needed, t/ha	Amelioration, irrigation, and fertilization price, USD/ha	Pure additional profit, USD/ha
No irrigation, without fertilizers							
2001	2.66	644	-	-	-	-	-
2006	2.30	557	-	-	-	-	-
2010	2.59	627	-	-	-	-	-
2015	2.35	570	-	-	-	-	-
2020	2.18	529	-	-	-	-	-
Irrigation, without fertilizers							
2001	3.51	850	206	0.971	1.25	140	66
2006	3.56	864	307	0.618	0.80	132	175
2010	3.89	942	315	0.738	0.95	134	180
2015	3.61	876	307	0.650	0.84	132	174
2020	3.84	932	403	0.730	0.94	134	269
Irrigation plus fertilizers							
2001	5.40	1310	666	1.055	1.36	142	524
2006	4.48	1087	530	0.608	0.79	131	399
2010	4.71	1141	513	0.947	1.22	139	374
2015	5.41	1312	742	0.929	1.20	139	603
2020	5.32	1290	761	1.273	1.64	147	614

Source: Own results.

In general, our study provides additional proof and valuable insights about adverse effects of irrigation with mineralized water on soil health. Its main advantage is a long-term nature, as well as comprehensive statistical evaluation of the results. It agrees with the works on long-term effects of saline water irrigation on microbial activity and carbon storage in soils [25]; the study of the adverse effects of mineralized water on soil salinity and yield reduction of cotton plants in China [4]. Another study highlights the susceptibility of finer-textured, clay-rich soils of Egypt to structural degradation under the impact of irrigation with water containing high TDS and sodium [6]. To sum up, soil quality and health deterioration, connected with mineralized water irrigation and consequent soil salinization, alkalization and sodification, results in great environmental hazards and reduces productivity of agricultural ecosystems, threatening global food security [12]. As for the economic outcomes, foreign studies also support the need for irrigation in semi-arid regions regardless of water quality, because irrigation in such cases is the only factor which can dramatically improve crops productivity and provide for food security and sustainable agriculture [24].

CONCLUSIONS

Irrigation with mineralized water risks soil degradation and requires careful monitoring. It leads to gradual salt accumulation (0–30 cm, 0–100 cm) and shifts cation balance toward magnesium and sodium. These statistically significant changes must be considered in irrigation planning. Fertilizers help mitigate soil degradation but do not prevent long-term harm. Continuous irrigation with poor-quality water necessitates land reclamation and chemical amelioration. Economically, it increases yield (0.82–1.66 t/ha) and profitability, with phosphogypsum costs outweighed by higher net profit. Despite soil risks, it remains a viable strategy for sustainable agriculture in water-scarce regions.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC DETERMINANTS OF GROWTH IN AGRICULTURE – THE IMPACT OF INVESTMENTS, CREDITING AND ENTREPRENEURIAL INCOME

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Abstract

The focus of this study is to evaluate the effects of fixed capital investments, credit availability, and net entrepreneurial income on the gross value added of Bulgaria's agricultural sector during the years 2004 to 2022. The primary goal of this research is to investigate the development of gross value added in Bulgaria's agriculture, focusing on the effects of fixed asset investments, the influence of agricultural sector financing and the relevance of net entrepreneurial income. This investigation involved the creation and testing of three distinct hypotheses. Multiple regression analysis is utilized to explore how the sector's gross value added, investment activities, credit resources, and entrepreneurial income are interrelated in terms of both direction and strength. Data from Eurostat, FAOSTAT, and the Bulgarian National Bank (BNB) are used for the study. The results allow us to conclude that these three indicators strongly correlate with gross value added and explain a significant part of its dynamics. It has been established that investments in fixed capital in agriculture and net entrepreneurial income have a strong positive impact on gross value-added growth. A positive effect has also been demonstrated regarding credit but with statistical significance at a higher confidence interval. As a result, the study suggests broadening the range of financial tools available for agricultural lending, encouraging capital investment in agriculture, implementing tax relief measures, and easing administrative procedures for small and medium-sized enterprises to foster entrepreneurship. Collectively, these actions would support the sustainable growth of the agricultural sector while improving its productivity and global competitiveness.

Key words**:** *gross value added, agriculture sustainability, credit, fixed asset investments, net entrepreneurial income*

INTRODUCTION

Agriculture is a traditional sector in Bulgaria that is strategically important because it ensures food security for the population and provides employment and income for a large part of the rural population. At the same time, agriculture is among the most complex, dynamic, and fast-evolving sectors, demanding ongoing modernisation and digital transformation. Furthermore, it plays a central role in the circular economy, facing multiple challenges in the pursuit of sustainability and enhanced competitiveness.

All these factors necessitate government support and intervention to increase investments and provide more accessible credit options to ease the financial burden on agricultural producers. The interplay between investments in fixed capital and the enhancement of external financing options for farmers fosters an enabling environment for greater productivity and long-term sustainability in agriculture.

Research has shown that growth in Gross Fixed Capital Formation (GFCF) lead to notable enhancements in agricultural productivity over time, demonstrating a positive correlation between these indicators [1, 3, 10, 23]. Examining the relationship between fixed capital investments and agricultural gross value added is crucial for understanding agricultural productivity and development [19]. The interaction between these factors highlights the importance of capital investments in boosting productivity and growth. For example, Kusz found that the effective use of technical equipment and assets per hectare could significantly improve agricultural output, suggesting that well-planned capital formation strategies are essential for maximising the impact of investments on agricultural productivity [13].

Similarly, Dossa et al. emphasised that capital formation provides critical infrastructure for agricultural development, ultimately contributing to increased productivity [6].

Understanding the relationship between credit availability and agricultural gross value added is essential for analysing how financial resources influence agricultural productivity and economic development.

Agricultural credit provides farmers the necessary financial resources to invest in their activities, affecting their productivity and profitability. Existing research [5, 15, 16] confirms the positive relationship between agricultural credit and productivity. Nevertheless, several factors can deter farmers from seeking credit, with financial risk being a primary concern [11].

Existing research [21, 22, 24] generally indicates a positive relationship between access to bank financing, public agricultural spending, and increased productivity in the sector.

The relationship between agricultural gross value added and net entrepreneurial income is also crucial for understanding agricultural enterprises' economic resilience and revenue-generating capacity.

Studies confirm that increased agricultural gross value-added correlates positively with net entrepreneurial income [4, 14, 20].

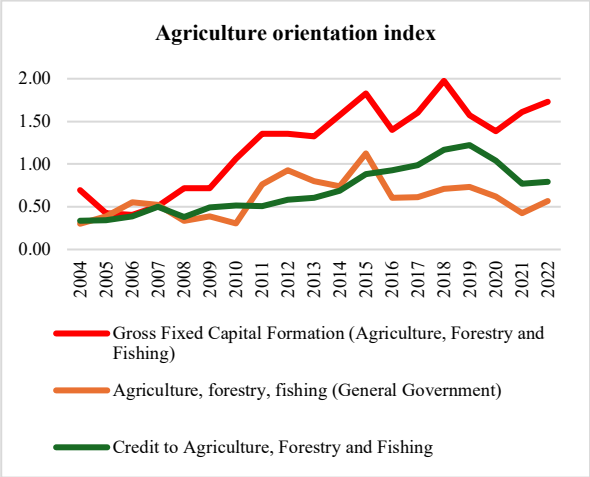


Fig.1. Agriculture orientation index in Bulgaria 2004-2022
Source: Faostat [9].

The effectiveness of this relationship is further reinforced by investments in technology, market access, and relevant agricultural policies [12, 18].

The significance of the agricultural sector in Bulgaria can be analysed using the Agricultural Orientation Index (AOI). This index can be evaluated separately regarding government expenditures, fixed capital investments, and agricultural credit. Its values for Bulgaria are presented in Figure 1.

According to FAO [8], the AOI for public expenditures in agriculture, forestry, and fisheries is an indicator that measures the extent to which public spending in this sector corresponds to its economic contribution to the overall economy. It is calculated as the ratio between government expenditures for the sector relative to total public expenditures and the gross value added (GVA) relative to the total GVA. Its values can be above or below one:

-When AOI > 1, government expenditures on agriculture are higher compared to its economic share, suggesting that the sector is regarded as a priority in terms of public investment.

-When AOI = 1, expenditures on the agricultural sector fully correspond to its significance in the economy.

-When AOI < 1, the government invests less than what the sector contributes to the economy, signalling an underestimation of the sector.

The values shown in Figure1 indicate that the government invests less in the sector than it contributes to the overall economy in Bulgaria. The index has consistently remained below 1, with 2015 being the only year the threshold of 1 is exceeded.

Consequently, agriculture in Bulgaria does not receive sufficient public investments relative to its economic contribution. This leads to low productivity, a lack of innovation, and slow growth.

The AOI for credit in agriculture, forestry, and fisheries measures the proportion of total credit in the country allocated to the agricultural sector. It is calculated as the ratio between credit extended to the sector relative to total credit and the GVA of the sector relative to total GVA. Its values can also be above or below one:

-When AOI > 1, agriculture receives more credit resources than its economic share, indicating that financial institutions prioritise the sector.
-When AOI = 1, credit for the agricultural sector is proportional to its share in the economy.
-When AOI < 1, the agricultural sector receives less credit relative to its economic importance, which may indicate lower attractiveness for banks or higher risks.
The values in Figure1 show that the index has remained consistently below 1, with the only exception being 2018-2020, when the threshold is slightly exceeded. Since 2016, credit to the sector has consistently exceeded government expenditures, indicating that the private sector compensates for the lack of public support.
This suggests insufficient access to credit, with evident difficulties in securing external funding for agricultural activities. This signals the need for more active support and attention to the agricultural sector in Bulgaria.
The AOI for investments in fixed assets in agriculture, forestry, and fisheries reflects the degree to whichi nvestments in this sector correspond to its economic contribution to the overall economy. It is calculated as the ratio between investments in fixed capital for the sector relative to total investments and the GVA of the sector relative to total GVA. Its values can also be above or below one:
-When AOI > 1, investments in agriculture are higher compared to its share in the economy, indicating that the sector is a priority for investment.
-When AOI = 1, investments in agriculture fully correspond to its share in the economy.
-When AOI < 1, investments in agriculture are lower relative to its share in the economy, meaning the sector remains underfunded.
As seen in Figure 1, since 2010, the index values for investment in fixed assets in Bulgaria have consistently remained above 1, reaching their highest point in 2018. This trend reflects a sustained increase in investments in agricultural fixed assets, indicating ongoing growth and modernisation within the sector. However, public expenditures on agriculture have remained limited and have not kept pace with the broader trends in economic investment. While investments in fixed assets serve as a key engine of growth, their long-term impact may be fragile in the absence of adequate government support.
At the same time, credit to the sector shows a positive trend, indicating increased confidence from financial institutions in agribusiness.
Despite the observed trends, the agricultural sector in Bulgaria remains underfunded.
The primary objective of this study is to evaluate the formation of gross value added (GVA) in the country's agricultural sector by examining the influence of key economic factors. Specifically, the study aims to:
(i) analyse the impact of investments in fixed assets on the formation of GVA in Bulgaria's agricultural sector;
(ii) assess the effect of agricultural lending on the generation of GVA;
(iii) examine the role of net entrepreneurial income in contributing to value added in agriculture.
To achieve these objectives, the following research hypotheses are formulated and subject to empirical testing:
H01: Investments in fixed assets have no significant impact on the gross value added of the agricultural sector.
H02: Loans granted to the agricultural sector do not significantly influence its gross value added.
H03: Net entrepreneurial income does not significantly affect the gross value added generated by the sector.

MATERIALS AND METHODS

The article employs descriptive and analytical methods to process and analyse the data and individual dependencies. The descriptive methods include the historical method, chronological analysis, comparative and content analysis, and graphical methods.
The analytical methods involve inductive and deductive approaches, quantitative analysis of dependencies, and critical analysis. Correlation and multiple regression analysis are applied to establish cause-and-effect relationships and dependencies and test hypotheses.

The study is based on data from Bulgaria covering 19 years from 2004 to 2022. The objective is to determine which factors influence the agricultural sector's gross value added (GVA).

The analysis employs four key economic indicators.

-Gross Value Added (GVA) serves as dependent variable,

The independent variables include:

- Gross Fixed Capital Formation (GFCF), excluding deductible VAT,

-Credit to Agriculture, and

-Net Entrepreneurial Income (NEInc)

Data on Gross Value Added at current prices are sourced from Eurostat and are expressed in million euros, covering the sectors of agriculture, forestry, and fishing. This indicator measures the value created by agricultural enterprises over a year and is a key element reflecting the sector's productivity. An increase in GVA indicates that the sector contributes more to the country's economy. A decrease in GVA suggests lower productivity and a declining economic role of the sector.

For Gross Fixed Capital Formation (GFCF), data from Eurostat in million euros are used. This is a key economic indicator that measures investments in fixed assets in agriculture. This metric is derived by removing the value of assets that have been sold or taken out of service from the value of assets that have been newly acquired. Investments in fixed assets include buildings, infrastructure, machinery, equipment, perennial crops, and information and communication technologies.

GFCF reflects the degree of renewal and expansion of production capacity in the agricultural sector. An increase in GFCF shows that farmers invest more in modernisation and business expansion, improving productivity, efficiency, and overall sectoral growth.

For Credit to Agriculture, Forestry, and Fishing (CAFF), data from FAOSTAT in million euros are used. This critical indicator measuring the sector's access to financing is essential for its efficiency and development. Higher credit availability indicates easier access to external funding for business expansion.

An increase in credit values suggests greater investments, more mechanisation, and modern technologies, which enhance productivity. Low credit availability signals insufficient support, including governmental assistance, highlighting the need for state policy changes and additional subsidies [2]. Thus, CAFF significantly impacts sectoral development, mechanisation, and competitiveness.

For Net Entrepreneurial Income (NEInc), data from the National Statistical Institute (NSI) in million euros are used. This is an important economic indicator of profitability and financial stability in agricultural enterprises. It assesses the net income of farmers after deducting operational costs, including employee wages, interest on loans, land rents, etc. It measures the compensation for unpaid labour, returns on owned land, and capital usage income.

It is calculated as the sum of net operating surplus/mixed income plus interest received by enterprises, minus interest and rent paid. Higher NEInc values indicate effective management, high profitability, and financial stability.

Research Model Specification

Based on the presented criteria, the research model is functionally specified as follows:

$$GVA=f(GFCF,CAFF,NEInc) \quad (1)$$

where:

-GVA – Gross Value Added (million euros)

-GFCF – Gross Fixed Capital Formation, excluding deductible VAT (million euros)

-CAFF – Credit to Agriculture, Forestry, and Fishing (million euros)

-NEInc – Net Entrepreneurial Income (million euros)

To evaluate the above model, the following regression equation is formulated:

$$GVA = a_0 + a_1GFGC + a_2CAFF + a_3NEInc \quad (2)$$

where:

- GVA – dependent variable
- GFCF, CAFF, NEInc – independent variables
- a_0 – Intercept of the model

- a_1, a_2, a_3 – regression equation parameters

The expected signs associated with the parameters of the regression model are outlined as follows:
$a_1 > 0$, $a_2 > 0$, $a_3 > 0$

RESULTS AND DISCUSSIONS

Analysis of the Dynamics of Selected Macroeconomic Indicators

We may observe the dynamics of GVA and investments in fixed assets (in million euros) in Figure 2.

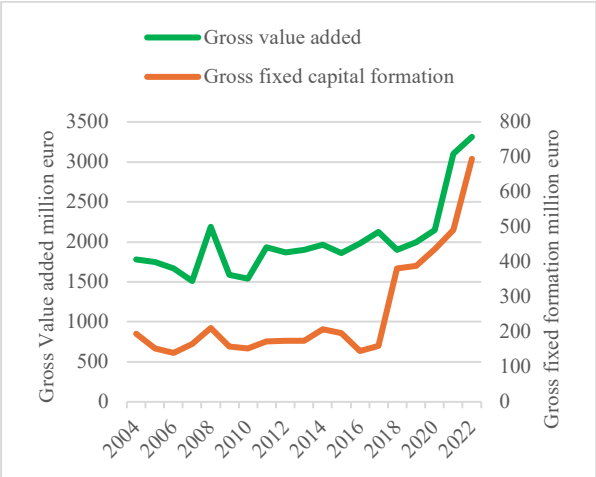


Fig.2. Gross Value Added and Gross Fixed Capital Formation in Bulgaria 2004-2022 (million euro)
Source: Eurostat [7].

The value added from agriculture in Bulgaria exhibits an upward trend. Starting at approximately 1,700 million euros, there is a slight decline in 2017, followed by a stabilisation period with a moderate upward dynamic until 2018. After that, the indicator rises sharply, reaching around 3,300 million euros in 2022, almost doubling its initial value.
The dynamics of investments in fixed assets are also notable.
Despite minor fluctuations, their value triples over the entire period, starting at 195 million euros and reaching 695 million euros in 2022. A significant increase is observed after 2018.
An interesting observation is that the trends of both indicators closely align and run almost parallel, suggesting a potential relationship between them. This implies that investments in fixed assets may positively affect productivity, serving as a key driver of growth. With the help of the regression analysis, we will further explore this relationship
Figure 3 shows the trends in agricultural credit, which could also influence the sector's productivity.

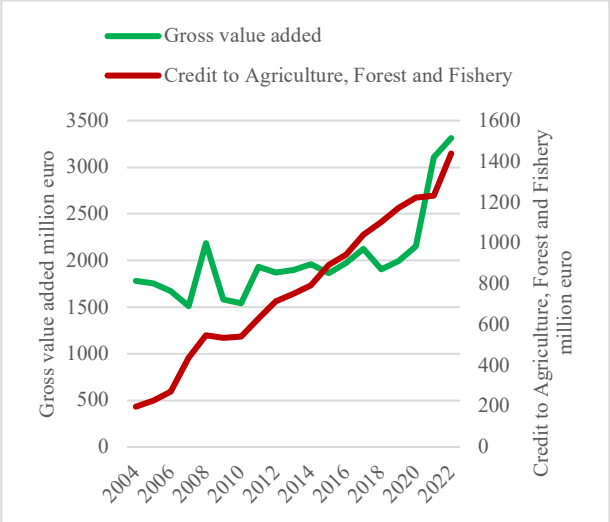


Fig.3. Gross Value Added and Credit to Agriculture, Forest and Fishery, million euro in Bulgaria 2004-2022
Source: Eurostat [7].

The rapid upward trend in credit values is particularly noteworthy. Throughout the entire period, there has been only one year—2009—in which a slight decrease in credit value has been observed.
In all other years, the trend remains consistently positive. Starting at 197 million euros, the credit volume reaches 1,439 million euros by the end of the period, marking a sevenfold increase. This growth is linked, among other factors, to Bulgaria's stimulative credit policies during the period analysed.
Distinct periods can be identified by examining credit and gross value-added relationships. For example, after 2018, the sharp increase in gross value added coincides with a rise in credit volume. This suggests that improved access to financing may have contributed to enhanced productivity and efficiency in the sector.
On the other hand, periods such as 2009–2012 show that while credit continues to rise, gross value added remains stable. This could indicate that some investments may have been inefficiently allocated or that external factors—such as climate conditions, economic crises, etc.—may have hindered the sector's growth. This highlights the need for further

research into the relationship between these indicators.

The dynamics of net entrepreneurial income is revealed in Figure 4, which supports additiona l analysis.

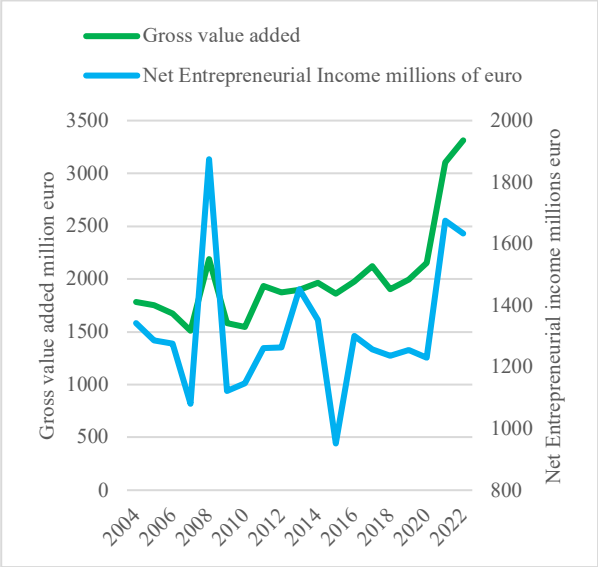


Fig.4. Gross Value Added and Net Entrepreneurial Income in Bulgaria 2004-2022 (million euro)
Source: Eurostat, NSI [7, 17].

Unlike GVA, net entrepreneurial income is significantly more volatile. It reaches its peak in 2008, followed by a sharp decline in 2009. This drop can be partially linked to the financial crisis, negatively impacting profitability.

Another decline is observed in 2015, marking the lowest value of net entrepreneurial income within the analysed period. After this, a partial recovery follows, and from 2020 onward, an upward trend emerges, with a second peak in 2021. During these years, both indicators (GVA and net entrepreneurial income) increase, which could signal sector stabilisation and improved profitability. Although these two indicators follow relatively similar trends over the analysed period, net entrepreneurial income exhibits stronger fluctuations. This suggests that it is more sensitive to market and economic factors. The impact of individual indicators on GVA dynamics will be further analysed using multiple regression analysis.

Multiple Regression Analysis of Gross Value Added in Bulgaria

As result we obtain following regression equation:

GVA = 143.74+ 1.2987*GFGC +0.3759*CAFF +0.9454*NEInc

The empirical results of the study are presented in Table 1.

Table 1. The empirical result of the regressions

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	143.7385	297.3905	0.4833	0.6358	-490.1343	777.6113
GFCF	1.2987	0.5034	2.5796	0.0209	0.2256	2.3717
CAFF	0.3759	0.1938	1.9395	0.0715	-0.0372	0.7890
NEInc	0.9454	0.2292	4.1253	0.0009	0.4569	1.4339
Multiple R	0.9311	R Square	0.8670	Adjusted R Square		0.8404

Source: Own calculation based on data from Eurostat and NSI [7, 17].

The multiple correlation coefficient is 0.9311, indicating a strong positive correlation between the dependent variable – GVA - and the independent variables: investments, credits, and net entrepreneurial income. With a coefficient of determination (R^2) of 0.8670, it can be concluded that these independent variables account for 86.70% of the fluctuations observed in the dependent variable. The Adjusted R^2, which accounts for the number of variables and dataset size, is 0.8404, suggesting that the model contains few irrelevant variables and accurately describes the relationship between them.

The high F-statistic (32.60) and the very low Significance F value (8.17127E-07) indicate that the model is statistically significant, confirming that at least one independent variable impacts the dependent variable.

The intercept, representing the agricultural sector's GVA when all independent variables are zero, is 143.74. However, it is not statistically significant (p-value > 0.05), meaning that the baseline level of the dependent variable without the influence of other factors is not meaningful.

The regression coefficient for the independent variable GFGC is positive, aligning with the theoretical assumption regarding the sign of the regression coefficients. The results show that a one-unit increase in investments leads to a 1.2987-unit increase in Gross Value Added. This result is statistically significant at the 5% level, as the p-value is 0.0209, meaning that the effect is not random. Consequently, the null hypothesis **(H01):**

"Investments in fixed capital have no significant impact on Gross Value Added"

is rejected, and the alternative hypothesis is accepted.

The confidence interval boundaries are entirely positive, ranging from 0.2256 to 2.3717, meaning that with 95% confidence, the strong positive effect of investments on GVA is confirmed.

Thus, we can conclude that investments in fixed assets in the agricultural sector significantly contribute to the sector's Gross Value Added. They play a key role in ensuring sustainable growth in agriculture. The development of modern infrastructure and technology improves the quality and quantity of agricultural production, leading to lower costs, higher efficiency, and increased contribution to GVA.

The regression coefficient for CAFF is positive (0.3759), supporting the initial theoretical assumption about the coefficient signs. This means that a one-unit increase in agricultural credit leads to a 0.3759-unit increase in GVA.The result is marginally significant at the 10% level, as the p-value is 0.0715. Therefore, the null hypothesis **(H02):**"Agricultural sector credit has no significant impact on Gross Value Added" is rejected, but with weaker evidence, as the p-value is greater than 0.05 but less than 0.1.

The confidence interval ranges from -0.0372 (negative) to 0.7890 (positive), indicating that the actual effect of credits could vary from slightly negative to strongly positive.

In summary, credit financing has a weaker but potentially significant effect on GVA. It enables farmers to invest in modernisation and technology, enhancing productivity. Additionally, improving liquidity reduces financial stress related to cash flow timing mismatches, helping farmers expand their operations.

However, the weaker statistical significance at 10% (instead of the conventional 5%) suggests possible reasons, such as:

-inefficient use of loans – for example, covering operational costs instead of investments

-influence of government subsidies, which reduce the relative effect of credit financing

-challenges in loan repayment, which may limit long-term positive effects.

This calls for further investigation, which will be part of the author's future research.

The regression coefficient for NEInc is positive (0.9454), consistent with the theoretical assumption regarding the coefficient sign. This means that a one-unit increase in NEInc leads to a 0.9454-unit increase in GVA.

The result is highly statistically significant, as the p-value is 0.0009. Therefore, the null hypothesis **(H03):**"Net Entrepreneurial Income has no significant impact on Gross Value Added" is rejected, and the alternative hypothesis is accepted.

The confidence interval boundaries are entirely positive, ranging from 0.4569 to 1.4339, meaning that with 95% confidence, the impact of NEIncis definitively positive, ruling out the possibility of a zero or negative effect.

Higher NEIncfor farmers translates into greater available income for investments in modernisation and innovation, which in turn enhances productivity and efficiency, leading to an increase in GVA.

The model can be further expanded and refined by incorporating additional independent

variables, which will be the subject of future research by the author

CONCLUSIONS

Drawing upon the analysis of the dynamics of the specified indicators and the regression analysis concerning the influence of investments, loans, and net entrepreneurial income on the gross value added in Bulgaria's agriculture between 2004 and 2022, the following conclusions can be outlined:

-The gross value added to agriculture in Bulgaria has shown an upward trend over the past two decades, almost doubling its value over the entire period

-In terms of credit, there is a sharp upward trend, resulting in a sevenfold increase in the indicator

-Net entrepreneurial income is more volatile compared to other indicators, experiencing sharp declines and rises, but in the last three years, its dynamics have gradually stabilised

-The positive and statistically significant regression coefficient for investments in fixed assets in agriculture indicates that increased investment contributes to greater value added in the sector

-The positive and statistically significant coefficient for credits—though at a higher confidence threshold—suggests that loans exert a weaker but potentially meaningful impact on gross value added

-The positive and statistically significant coefficient for net entrepreneurial income implies that as entrepreneurial income rises, so does the productivity of the agricultural sector.

As a result of the above conclusions, several specific recommendations can be made:

-Encouraging investments in fixed assets in agriculture. It is important to stimulate investments in modern technologies, infrastructure, and mechanisation to enhance productivity and efficiency in the agricultural sector.

-Providing better credit conditions, including longer repayment periods and lower interest rates for investment loans in the agricultural sector. High interest rates can limit farmers' investment activities. Therefore, approaches to reducing interest rates on loans for agricultural enterprises should be considered, such as state support or subsidies.

-Introducing lower interest rates for loans used for investments in sustainable and innovative agricultural practices, such as "green" loans that promote sustainable farming and reduce the environmental footprint of agricultural production.

-Implementing tax relief and reducing administrative burdens for small and medium-sized enterprises to stimulate entrepreneurship.

All these measures will contribute to the sustainable development of the agricultural sector and enhance its efficiency and competitiveness.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CONFLICT MANAGEMENT TECHNIQUES AND EMPLOYEE'S JOB PERFORMANCE IN FEDERAL COLLEGES OF AGRICULTURE IN SOUTH-WEST NIGERIA

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Abstract

The study aims at exploring the effect of conflict management techniques on employees' job performance in Federal Colleges of Agriculture in South-West Nigeria. A descriptive research design was used to solicit information from employees, and the instrument used was a questionnaire. A multistage sampling technique was used: the first stage was random sampling of 2 colleges out of 5 colleges in South-West Nigeria, and a random sampling technique was used to sample 162 employees from 1,621 employees in the 2 colleges. Data were analysed using frequency counts, percentages, the mean, and the Pearson Product Moment Correlation Coefficient (PPMC). Structural factors ($\bar{x}$=3.0) *were adjudged to be the predominant determinant of conflict in the two colleges. Collaborative was the most effective technique* ($\bar{x}$=4.0) *that brought the harmony necessary to increase employees' performance in the two colleges. Job performance was statistically significant to conflict management techniques. Organization directors and managers should sensitize their employees to techniques to resolve conflicts and create an enabling work environment that will enhance job performance.*

Key words*: *conflict, management, employees, performance

INTRODUCTION

Conflict is considered a natural event that is unavoidable as long as human connections are involved in every element of human civilization and activity. It is a procedure that starts when one party feels that something significant to their party has been negatively impacted by another party or soon will be.
[2] view conflict as the existence of disagreement in terms of the ideals, aspirations, or aims of various people or groups that obstruct one another's efforts to accomplish organizational goals. From the standpoint of the conflict dimension, however, conflict is a phenomenon with two sides: dysfunctional and functioning. Conflict or disagreement between individuals, teams, and groups that produces favorable outcomes and the accomplishment of organizational objectives and goals is referred to as constructive conflict or functional conflict. [9]. It spurs workers to come up with innovative solutions to the current problems and boosts production. When conflict creates an atmosphere that is conducive to self-evaluation and change, releases stress, encourages creativity and invention, and facilitates decision-making, it is considered constructive. Conversely, conflict or disagreement between parties within an organization that is detrimental to the achievement of organizational goals is referred to as dysfunctional conflict or destructive conflict. This is a situation in which disputes or confrontations among members of an organization hurt the organization or make it more difficult to achieve its objectives [13]. It usually hurts individuals, teams, groups, and management, as well as leads to decreased productivity and hinders organizational performance. Dysfunctional conflict may totally halt group functioning and potentially threaten the survival of the organization. Management must, hence, seek to eliminate dysfunctional conflict. It could be deduced from the dimension of conflict that conflict is an agitation for change by the employee; such

agitation could be handled functionally or dysfunctional based on the handling of the conflict by the employee or administrator. In an organization or community, conflict is unavoidable; in fact, the degree to which competing interests and needs are skilfully managed to prevent violence from endangering the organization's or society's survival is what distinguishes good governance/administrator from bad. Thus, it is important to focus on how people handle conflict rather than conflict itself. Therefore, conflict should not be understood exclusively in the negative context of dysfunctional or disjunctive processes and a breakdown in communication. It is a process by which interdependent individuals express their differences in order to fulfil their demands and realize their objectives [4]. Therefore, conflict occurs when one or more parties' differences require at least one of them to alter in order for their relationship to continue and grow. Without some sort of adjustment, the difference cannot coexist; it is the process of adjustment that typically leads to conflict. If handled incorrectly or mishandled, conflicts that have the potential to be constructive and functional might instead become destructive and dysfunctional. The organization that would be called successful, therefore, needs to ensure conflict is effectively managed and remains functional so that divergent views can be analyzed and innovations can spring up.

Organizational managers are often seen as the only ones who can resolve disagreements, and they often adopt a strict approach to doing so. When organizations handle conflicts in this way, they miss the fact that conflict is a normal part of organizational life and that it has advantages as well as disadvantages [13]. Intrapersonal and interpersonal conflicts are taking up so much time and energy in many Nigerian companies that it appears as though conflict is their main concern [6].

This trend can be attributed, in large part, to managers' incapacity in Nigerian work organizations to approach conflict management with the same systematic approach that they use in information, human resource, and financial management systems. The managers rather see conflict as a local occurrence that is addressed piecemeal. Employee performance in businesses has been negatively impacted by workplace conflicts due to an inability to view and manage conflicts in a systematic way. Workplace conflict that is not addressed can have a number of detrimental effects, including significant human and financial expenses. Conflict can lead to a variety of negative outcomes, including stress, low morale, missed deadlines, low trust, and lack of confidence, communication issues, absenteeism, and legal actions. Conflict is inevitable in any dynamic organization, to which agricultural colleges belong. However, few studies have been carried out on this concept in federal colleges of agriculture in south-west Nigeria.

For this reason, this study sought to:

(i)examine the causes of work-place conflict in agricultural colleges

(ii)identify the conflict management technique; utilized in the institutions;

(iii)ascertain employee job performance levels during conflict in the institutions.

Hypothesis: There is no significant relationship between conflict management techniques and employee performance.

MATERIALS AND METHODS

The research study was carried out at the Federal College of Agriculture in South Western State, Nigeria, at longitude 30° and 7°E and latitude 4° and 9°N. These colleges of agriculture located in the south-western states are: the Federal College of Agriculture, Akure, the Federal College of Agriculture, Ibadan, the Federal College of Fisheries and Marine Technology, Lagos, the Federal College of Animal Health and Production Technology, Ibadan, and the Federal College of Forestry, Ibadan.

A multistage sampling technique was used; the first stage was random sampling of 2 (10%) colleges out of 5 colleges. The second stage was a random sampling of 81 employees per college. Therefore, a total of 162 employees from 1,621 employees in the 2 colleges were sampled. Data were obtained on employees' causes of conflicts, conflict management techniques utilized, and employee performance using a structured questionnaire. Causes of

conflict were measured by using 20 statements classified into three indexes: physiological factors, communication factors, and structural factors. Indicators were measured using a five-point Likert scale of "Strongly Agree = 5," "Agree = 4," "Undecided = 3," "Disagree = 2," and "Strongly Disagree = 1" for positive statements and/or negative statements measurement in reversed order.

Conflict management technique was measured by using 25 variables classified into five indexes: competition, accommodation, compromising, collaboration, and avoiding. It was measured by using a five-point Likert scale of "strongly agree = 5," "agree = 4," "undecided = 3," "disagree = 2," and "strongly disagree = 1" for positive statements and reverse order for a negative scale.

The minimum score obtainable was 25, while the maximum score was 125. Employee job performance was measured using 15 statements classified into three components: task performance, contextual performance, and adaptive performance.

The variables were measured using a five-point Likert-type scale of Strongly Agree (S.A.) = 5, Agree (A.) = 4, Undecided (U) = 3, Disagree (D.) = 2, and Strongly Disagree (S.D.) = 1 for positive statements and reverse order for negative statements.

The sum of points assigned to each point on the scale divided by the scale point number gives a mean cut-off score for each item or index on each variable. A mean less than 3.0 reflected less than of the variables that were measured on a 5-point scale, while in reverse order, there was a high manifestation of the variables (causes of conflict, conflict management technique, and level of job performance) that were measured. The data were analyzed using frequency counts, percentages, means, and Pearson Product Moment Correlation (PPMC).

RESULTS AND DISCUSSIONS

Table 1 shows that structural factors that cause workplace conflicts are: employee inability to work in harmony with those that are awarded an unfair reward ($\bar{x}$=3.07); lack of resources to perform work ($\bar{x}$=2.85).

Table 1. Causes of workplace conflict in the Agricultural Colleges

Statements	$\bar{x}$	**Std. d**
Structural factor	**3.01**	**0.91**
Don't feel comfortable to work in harmony with those who receive unfair reward.	3.06	1.31
No enough resource to perform my job	2.84	1.36
Uncertain about what task is expected from one to do.	2.82	1.27
Feeling unsatisfied with the reward system that the organization follows.	2.81	1.37
Entering into argument with my manager as a result of reward system.	2.74	1.38
Facing a clash over one's role in the organization.	2.56	1.22
Psychological factor	**2.98**	**0.85**
Negative feeling affects my effective performance	3.79	1.22
Don't have the energy to work and communicate when my feeling is down	3.61	1.32
'Angry when my supervisor criticized my work	3.20	1.39
Enter into disagreement with my colleagues	3.01	1.29
Not comfortable working in wide divers work environment.	2.98	1.33
Failures to avoid difficult conversations thata problem just goes away	2.93	1.29
Not having ability to reason logically, collaborate, and network with others	2.24	1.30
Communication factor	**2.69**	**1.06**
Supervisor/manager fail to use sincere, clear, concise, and kind words during communication.	2.92	1.31
Falling short to give time and attention while communicating with colleagues and supervisor.	2.74	1.27
Instead of providing quality information, I focus on quantity of information.	2.73	1.41
Failure to provide information most of the time	2.71	1.40
Misperceive by co-workers.	2.63	1.36
Inability to logically reason, to collaborate and network with others.	2.58	1.40
Judging co-workers the first time of meeting them	2.50	1.22

Source: Field survey, 2022.

This result is in line with [3], who found that lack of resources has the highest frequency as the cause of conflict in Nigerian institutions. On the other hand, the psychological factors that cause workplace conflicts were employees having negative feelings ($\bar{x}$=3.79) and when employee feelings are down ($\bar{x}$=3.79). This result is in line with the research of [1], who stated that some behavioral factors, such as negative attitudes, affect how workers approach their jobs, and attitudes can have a ripple effect on those around them. In a professional workplace setting, a negative attitude can affect everyone and cause conflict among employees [7]. Furthermore, Table 1 shows that communication factors that cause workplace conflicts are: superiors not using clear, concise, and kind words during communication ($\bar{x}$=2.92), falling short to give time and attention to colleagues, and superior not communicating ($\bar{x}$=2.74).

Vocabulary differences, unclear language, a lack of information sharing, and noise in the communication channel are obstacles to communication and possible preconditions for conflict [5].

In the Nigerian service industry, communication issues are the second-most common cause of conflict. Employees view perception and communication issues as moderately serious sources of conflict, although staff members' assessments of these issues' seriousness varied from officers.

Conflict Management Techniques in Agricultural Colleges

Figure 1 shows that the collaborating technique ($\bar{x}$ =4.00) ranked first among the conflict management techniques, followed by the accommodating technique ($\bar{x}$=3.96) and the avoiding technique ($\bar{x}$ =3.94). Also, compromising technique ($\bar{x}$ =3.80) ranked fourth, while competing technique ($\bar{x}$=3.42) was the least utilized technique in the institutions. It could be deduced from the result of the five-management technique weighted mean that each management technique mean was greater than the cut-off point mean of 3.0. Hence, the institutions effectively made use of the five conflict management techniques. However, the institutions made more use of collaborative techniques to resolve conflict. Similarly, [1] found that staff collaboration and work performance are positively correlated. That is, combining employees' ideas to achieve a specific goal reduces disagreements because it promotes involvement. The collaboration strategy side-lines differences and promotes idea sharing to arrive at a workable solution for all parties. By being more concerned for employers' own needs as well as the needs of their employees. Organizations that apply this strategy deal with problems head-on and come up with innovative and constructive solutions by keeping both their own and the workers' needs in mind [11]. The advantage of using the cooperative approach to conflict resolution is that both parties benefit in the end.

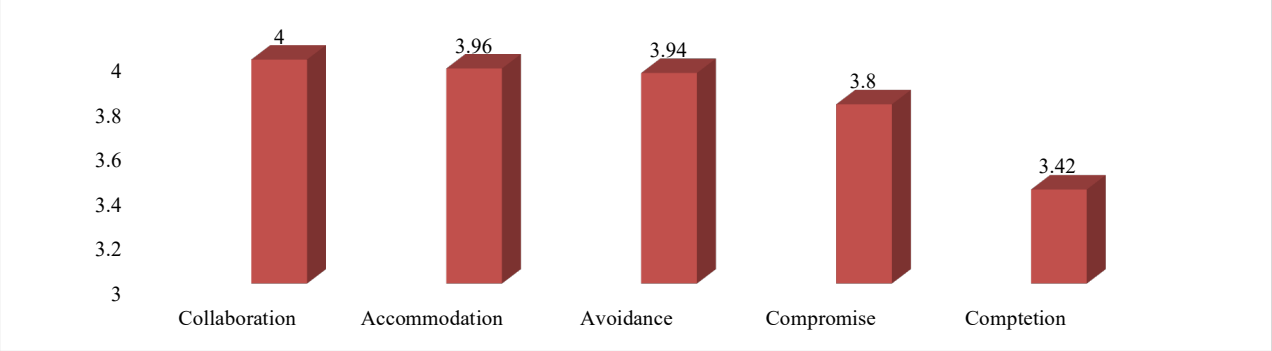


Fig. 1. Conflict Management Techniques in Agricultural Colleges
Source: Field survey, 2022.

Employee job performance in agricultural colleges

Table 2 shows under task performance that the determination of priorities ($\bar{x}$=4.37) was rated higher, followed by organizing the workload to complete it by the deadline ($\bar{x}$=4.26). This implies that employees were efficient in their job performance. The result is in line with [12],

who found that the key to high levels of performance lies in having employees who can set priorities, carry out their work efficiently, plan work accordingly, manage their time, and always re-skill. Contextual performance ($\bar{x}$=4.14) was the second most rated part of job performance in the institutes. Also, Table 2 indicates that under contextual job performance for employees, the most effective aspect of a contextual job was employees' ability to discover original solutions to a new issue ($\bar{x}$=4.31) and employees keeping their skills set current ($\bar{x}$=4.12) This implies that employees possess a sense of self-efficacy because they take on challenging tasks and do their best to perform extra responsibilities. This brings a positive outlook towards the supervisor and organization because of increasing the likelihood of organizational citizenship behaviours. Furthermore, Table 2 shows that under adaptive job performance, staying current in their understanding of their jobs ($\bar{x}$=4.00) ranks higher than any other adaptive job performance in the institution. This implies that employees keep updating their skills and knowledge, which enables them to be creative when solving organizational problems. An employee's talents are developed by a constant acquisition of professional or managerial skills and experience, which can lead to awards and promotion [8].

Table 2. Employees' Job Performance in Agricultural College

Items	$\bar{x}$	Std. D.
Task performance	4.23	
Able to set priorities	4.37	.721
Able to plan my work so that I finished it on time	4.25	.718
Kept in mind the work result I needed to achieve	4.21	.719
Able to carry out my work efficiently	4.12	.892
Managed my time well	4.10	.860
Contextual performance	4.14	
Came up with creative solutions to new problems	4.31	.901
Love keeping my work skills up-to date	4.11	.967
Actively participated in meetings and/or consultations	4.10	.800
On my initiative, I started new tasks when my old tasks were completed	4.09	.871
Continually sought new challenges in my work	4.05	1.016
Adaptive performance	4.12	
Keep job knowledge up-to-date	4.28	.922
Show resilience (coping with stress, difficult situations and adversities)	4.27	.947
keep job skills up-to-date	4.12	.906
deal with uncertain and unpredictable work situations	4.09	.947
adjust Adjusted work goals when necessary	4.01	.877

Source: Field survey, 2022.

Influence of Conflict Management Techniques on Employee Job Performance

Table 3 shows that accommodating technique (β = 0.58), compromise technique (β = 0.47), and avoiding technique (β = 0.70) had a positive and significant influence on employees' job performance. On the other hand, competing (β = -0.34) had a negative and significant influence on employees' job performance. Based on the outcome, it can be concluded that using these strategies more frequently will improve employees' job performance. These strategies, according to [2] and [10] are utilized to sustain a cordial working relationship between management and staff, which promotes great employee performance, particularly when the method works.

Table 3. Relationship between Conflict Management Technique variables and Employee Job Performance

Model	B	Std. Error	t-Value
(constant)	34.12	5.44	6.28
Competing	-0.34*	0.14	-2.48
Accommodating	0.58*	0.20	2.89
Collaborating	0.01	0.20	0.06
Compromising	0.47*	0.19	2.45
Avoiding	0.70*	0.23	3.00
R	**0.49**		
R^2	**0.24**		

Source: Field survey, 2022.

CONCLUSIONS

Conflict is unavoidable in the daily routine of organizations, and it is a latent factor that most managers marginalize when considering factors that will boost employee performance. The predominant determinant of work-place conflict in agricultural colleges is structural factors.

The institutions managed intra-conflict and interpersonal conflict constructively using all five conflict management techniques, and this contributed immensely to harmony and promoted employee job performance. It is therefore recommended that managers and employees undergo training on workplace conflict management. This will enable them to acquire conflict management knowledge and skills that will boost organizational performance. Since conflict is inevitable in any organization, every organization should plan, develop, and have strategies for managing conflict**.**

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ROLE OF THE CIRCULAR ECONOMY IN MANAGING THE PROFITABILITY OF WINE INDUSTRY ENTERPRISES IN BULGARIA

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Abstract

Winemaking has long been one of Bulgaria's leading agricultural sectors, generating billions of dollars annually in a highly competitive global market. The industry operates under conditions of intense competition, which significantly limits profitability. Effective integration into the value chain and cost optimization are key factors in enhancing financial performance. This research seeks to examine how the application of circular economy practices impacts the profitability of wine production. An essential part of the methodology involves classifying wine industry businesses according to the degree to which they have adopted circular economy strategies. This classification follows the Technology Readiness Levels (TRL) approach, which evaluates enterprises according to their technological preparedness for circular economy adoption. Based on the statistical analysis of key indicators such as investments, operating income, and net sales revenue, it is evident that level 4 enterprises exhibit the highest levels of investment activity and operating expenses. These enterprises also report the highest net sales revenue. It is clear that enterprises that have integrated technologies to close the production cycle through recycling and resource reuse demonstrate high efficiency in managing cash flows derived from investment activity.

Key words**:** *circular economy, winemaking, profitability, enterprise, circular economy adoption*

INTRODUCTION

A major obstacle to the broad implementation of the circular economy at both national and international levels is the uncertainty surrounding its effect on investment profitability. This raises a central question: Does the circular economy have the potential to improve financial returns on investments?

The linear business model, which has been traditionally employed in economic systems worldwide, has demonstrated its profitability and remains the preferred approach in many countries. It has played a crucial role in the globalization of economic activities, enabling entrepreneurs to achieve their financial goals regardless of their geographic location. Furthermore, the linear model facilitates business operations without imposing additional considerations regarding the environmental footprint of the enterprise.

Winemaking has long been one of Bulgaria's leading agricultural sectors, generating billions of dollars annually in a highly competitive global market. The industry operates under conditions of intense competition, which significantly limits profitability [26]. Effective integration into the value chain and cost optimization are key factors in enhancing financial performance. As with other European industries, Bulgarian winemaking is subject to European Union (EU) policies especially Green Deal [29] and regulations. In recent years, there has been a pronounced political commitment to promoting the circular economy in agriculture and the food industry.

This research seeks to examine how the application of circular economy practices impacts the profitability of wine production. An essential part of the methodology involves classifying wine industry businesses according to the degree to which they have adopted circular economy strategies.

Conceptualizing Profitability in the Context of the Circular Economy. Profitability is a fundamental economic concept that serves as a guiding principle, an approach, and a strategic objective in business management. It is a multifaceted category influenced by numerous factors, making it difficult to quantify using a

single metric. While a comprehensive examination of the concept is beyond the scope of this study, it is essential to outline the key characteristics relevant to assessing the impact of the circular economy on profitability:

-*Efficiency*– Profitability serves as an indicator of business process excellence [4].

-*Return on Investment* – It reflects the rate at which invested resources generate income for the enterprise [4].

-*Value Recovery* – Profitability measures the ability of resources allocated to production to regain their economic value [3].

-*Equity and Distribution* – It assesses the fair distribution of income generated by business activities, determining the portion appropriated by the entrepreneur [5].

-*Decision-Making Tool* – Profitability provides an objective framework for evaluating investment alternatives and making data-driven business decisions [7].

These characteristics highlight the role of profitability in managing business models. The successful integration of circular economy principles into various economic sectors should, at a minimum, maintain existing profitability levels or, ideally, enhance financial performance [2].

Empirical Evidence on the Circular Economy and Profitability. A growing body of scientific literature supports the claim that circular economy strategies can significantly influence business model profitability [13]. Key findings from empirical studies include:

-*Reduction in Raw Material and Supply Costs* – The application of circular economy principles in the automotive industry has demonstrated cost savings in raw material procurement, leading to lower production expenses and improved profitability [10].

-*Enhanced Production Efficiency* – The optimization of resources through sustainable product design and manufacturing processes leads to reduced energy consumption, decreased operational costs, and higher profitability [10].

-*Waste Reduction and Cost Savings* – Implementing circular economy strategies minimizes waste disposal expenses, thereby decreasing operational costs and increasing financial returns [12].

-*Improved Market Competitiveness and Customer Satisfaction* – Businesses that adopt circular economy principles have reported increased competitiveness by offering more sustainable and environmentally responsible products and services, resulting in expanded market share and improved profitability [22].

-*Extended Product Lifecycle and Long-Term Revenue Generation* – Business models that prioritize durability, repairability, and reusability secure more stable market positions and generate sustained revenue streams [23].

Sector-Specific Considerations in Winemaking. The winemaking industry presents unique challenges in profitability management due to its reliance on living organisms [6]. The sector is characterized by strong seasonality, influenced by the biological cycles of plants and fermentation processes. This pronounced seasonality affects financial performance, necessitating the introduction of subsidies and financial incentives to mitigate income fluctuations. Unlike other industries, winemaking offers opportunities for synergies, wherein a single investment can generate multiple valuable outputs. For example, biomass—a byproduct of wine production—can be commercialized, contributing to diversified revenue streams and enhancing overall profitability.

Numerous studies indicate that biomass utilization remains an underexploited economic opportunity in agriculture, particularly in the wine industry [24, 27, 19, 20, 31, 29, 25, 16, 15]. Scholars suggest that the circular economy should be integrated with the ***bioeconomy***to maximize its benefits [18]. The bioeconomy is a multidisciplinary field focused on the sustainable use of biological resources to produce materials, energy, and services [30]. It encompasses diverse domains such as biology, agriculture, ecology, engineering, and economics [28]. The fundamental objective of the bioeconomy is to establish an economic system that harmonizes with nature, ensuring the sustainable utilization of biological resources without causing environmental degradation [21]. This includes developing innovative technologies for processing biomass, utilizing plants, micro-

organisms and animals for food, energy, medicine, and material production [21].

According to recent research, the bioeconomy holds significant potential for addressing critical global challenges, including climate change, biodiversity loss, and resource scarcity. Furthermore, it contributes to economic growth and fosters job creation in high-tech sectors related to biology and innovation [8].

The convergence of circular and bioeconomy approaches within agriculture offers considerable potential for fostering sustainable and competitive growth. In the context of winemaking, however, applying circular economy principles requires careful consideration of the sector's unique biological cycles and seasonal limitations. Leveraging biomass as a resource and integrating bioeconomic strategies could enhance financial returns while promoting environmental sustainability. Future research should focus on the practical application of these approaches, exploring policy frameworks and business models that support the transition toward a more resilient and profitable circular economy in winemaking.

Table 1 outlines the advantages and drawbacks associated with applying circular economy principles to the management of business model profitability. The information presented highlights the complexity of the circular economy's impact on financial outcomes, emphasizing the need for strategic planning to ensure that its benefits outweigh potential downsides.

Table 1. Impact of circular economy principles on business profitability

Principles of the circular economy	Positive impact on profitability	Negative impact on profitability
Reducing the costs of acquiring raw materials and supplies	Reducing costs, all other things being equal, creates "the opportunity to realize a higher margin" [1]	
Improved efficiency of production processes	Higher efficiency is a reason for saving materials and raw materials, which creates an "opportunity for a higher profit margin" [11]	
Waste reduction	Reducing waste by re-incorporating it into the production cycle "creates conditions for minimizing costs within the framework of the applied technology." [14]	"Additional investments are needed to move to a new technological level, which in the short term reduces profitability due to the higher investment costs" [9], required to implement the new technology. The process of implementing the new resource-saving technology requires time, which can negatively affect profitability.
Increased life cycle duration of the products offered		"A longer product life cycle can create conditions for a decrease in sales turnover, and hence sales revenue" [17]. All other things being equal, this may lead to lower profitability based on sales revenue. The consumer may quickly get bored with the product and prefer a competing one, thus reducing sales and, consequently, revenue and profitability based on sales revenue.

Source: own interpretation.

MATERIALS AND METHODS

Defining the Scope and Limitations of the Research. Developing an objective and reliable methodology to analyze and assess the impact of circular economy principles on the profitability of enterprises in the wine industry requires clearly defining the research scope and its inherent limitations. These limitations pertain both to the availability and reliability of information related to the research object and subject, as well as to external, uncontrollable factors that may influence profitability levels in the studied enterprises.

The critical limitations identified in this study include:

-*Reliability of selected metrics* – The indicators used to assess the degree of circular economy

adoption in the studied enterprises must be robust and accurately reflect the extent of implementation.

-*Scientific validity of analytical measures* – The selected metrics must be based on established scientific methodologies and terminologies to ensure analytical rigor.

-*Measurability and interpretability* – The chosen metrics must be easily quantifiable and interpretable within the framework of scientific research.

-*Relevance of the indicators* – The chosen indicators should offer valuable understanding of how circular economy practices relate to the profitability of enterprises.

Classification of Research Objects. An important element of the study's methodology involves grouping wine industry enterprises according to the extent to which they have adopted circular economy practices. This classification follows the **Technology Readiness Levels (TRL)** approach, which evaluates enterprises according to their technological preparedness for circular economy adoption. For this purpose, a four-level classification scale is employed:

Level 1 – Enterprises that have implemented or are in the process of implementing technologies enabling them to close production cycles and recycle up to **30%** of their waste.

Level 2 – Enterprises that have integrated technologies allowing them to recycle resources, products, or waste from previous production cycles at a rate exceeding **50%**.

Level 3 – Enterprises that have adopted technologies facilitating not only recycling but also the reuse of recycled materials in subsequent production cycles at a rate exceeding **75%**.

Level 4 – Enterprises that have achieved **100% recycling and reuse**, fully closing their production cycle.

This classification enables a structured comparison of enterprises based on their circular economy adoption level, providing a foundation for further statistical analysis.

Analytical Approach and Statistical Methods. Once enterprises are classified, they will be analyzed using *multiple comparison methods* to identify statistically significant differences in profitability levels across the groups. The statistical techniques employed in this study include:

-***T-test*** – To compare profitability indicators between groups and assess significant differences in financial performance.

-***Regression analysis*** – To examine the relationship between circular economy adoption and enterprise profitability, identifying key influencing factors.

-The primary indicators used to measure profitability in the studied enterprises include [6]:

-***Cost-based profitability*** (expressed as a percentage)

-***Return on investment (ROI)*** (expressed as a percentage)

-***Profitability of sales revenue*** (expressed as a percentage)

Data Sources and Reliability. The financial data required for calculating these indicators will be obtained from the accounting records of the surveyed wine-making enterprises. All enterprises registered in the Commercial Register of the Republic of Bulgaria are legally required to publish their annual financial and accounting reports, which serve as publicly available and reliable data sources for this research.

By utilizing these financial disclosures, the study ensures data accuracy, transparency, and the validity of its findings, enabling a comprehensive assessment of how circular economy principles impact the profitability of wine industry enterprises.

Approach to Validating the Main Research Hypothesis. The primary hypothesis examined in this study asserts that the adoption of circular economy principles influences the profitability of enterprises in the wine industry. To validate this hypothesis, a hierarchical framework of research hypotheses is developed, each tested for statistical significance throughout the study. The validation process follows a structured approach comprising the following key stages of testing using the t-Test tool:

The t-test is employed to assess the relationship between circular economy implementation and various profitability indicators. The hypotheses tested include:

Hypothesis 1: Relationship Between Circular Economy Adoption and Cost-Based Profitability

-*Null Hypothesis (H_0):* There is a statistically significant relationship between the adoption of circular economy technologies and cost-based profitability.

-*Alternative Hypothesis (H_1):* There is no statistically significant relationship between the adoption of circular economy technologies and cost-based profitability.

Hypothesis 2: Relationship Between Circular Economy Adoption and Return on Investment (ROI)

Null Hypothesis (H_0): The use of circular economy technologies is significantly associated with variations in return on investment.

Alternative Hypothesis (H_1): The use of circular economy technologies does not have a statistically significant effect on return on investment.

Hypothesis 3: Relationship Between Circular Economy Adoption and Sales Revenue Profitability

Null Hypothesis (H_0): The implementation of circular economy technologies has a statistically significant impact on the profitability of sales revenue.

Alternative Hypothesis (H_1): The implementation of circular economy technologies does not significantly influence sales revenue profitability.

Study Organization. At this stage of the survey we point the research location and sample selection process. The Republic of Bulgaria is divided into *four wine-growing regions*—North, East, South, and South-West—and *six planning regions (NUTS 2)*—North-West, North-Central, North-East, South-East, South-Central, and South-West. For the purposes of this study, the wine-growing regions have been chosen as the basis for determining the research location. This selection ensures consistency with the specific environmental and economic conditions influencing wine production. Thus, the study encompasses all four wine-growing regions in Bulgaria.

The sample for this study was drawn from the National Chamber of Vine and Wine Register, based in Sofia. This register contains voluntarily registered wine enterprises, with a total population of 9,340 wine-producing enterprises as of December 31, 2024. The sample was formed using random selection with non-replacement, ensuring an unbiased representation of enterprises engaged in wine production.

A final sample of **94 enterprises** was selected for participation in the study. The sample size was determined based on the financial constraints of the research while ensuring a sufficient number of enterprises in each category to meet the statistical reliability criteria necessary for analysis.

Questionnaire Structure. The data collection instrument used in this study was a **structured questionnaire** comprising three sections:

General Enterprise Characteristics

This section collects information on the fundamental characteristics of the surveyed wine enterprises, including their **legal form, size, and life cycle stage**.

-Circular Economy Practices

-This section gathers information on **business practices** that align with circular economy principles.

-The responses from this section allow for an objective classification of enterprises based on the extent to which they have integrated circular economy strategies into their operations.

-Intentions and Future Adoption

The final section focuses on the **enterprises' intentions and capacity** to further implement circular economy principles in their management and production processes.

RESULTS AND DISCUSSIONS

This study primarily investigates whether adopting circular economy principles affects the profitability of wine-producing enterprises. To evaluate this hypothesis, a cost-based profitability analysis was carried out among enterprise groups categorized by the extent of their circular economy adoption (as defined in the methodology section). The primary statistical tool used for hypothesis verification is the **t-test**, which evaluates whether significant differences exist in **cost-based profitability** among the enterprise groups.

The results of the **t-test analysis** are summarized in **Table 2**. By conducting multiple comparisons across enterprise groups, the study identifies the systematic influence of circular economy principles on **profitability levels**. The findings provide empirical evidence to determine whether circular economy adoption contributes to increased profitability in the wine industry.

Table 2. Results of the application of the t-test method for comparing group averages, in this case cost-effectiveness in the studied enterprises

	Level 1	***Level 2***			***Level 1***	***Level 3***
Mean	6.570828	6.064045		Mean	10.51559	12.56074
Variance	240.0994	194.5923		Variance	613.8018	568.2404
Observations	31	31		Observations	31	31
Pearson Correlation	-0.00205			Pearson Correlation	0.394788	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	0.135198			t Stat	-0.42563	
P(T<=t) one-tail	0.446679			P(T<=t) one-tail	0.336708	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	0.893358			P(T<=t) two-tail	0.673416	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	
	Level 1	*Level 4*			*Level 2*	*Level 3*
Mean	10.51559	28.01429		Mean	6.064045	12.56074
Variance	613.8018	664.3362		Variance	194.5923	568.2404
Observations	31	31		Observations	31	31
Pearson Correlation	0.375962			Pearson Correlation	-0.18263	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	-3.44897			t Stat	-1.2164	
P(T<=t) one-tail	0.000845			P(T<=t) one-tail	0.116659	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	0.001691			P(T<=t) two-tail	0.233318	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	
	Level 2	*Level 4*			*Level 3*	*Level 4*
Mean	6.064045	28.01429		Mean	12.56074	28.01429
Variance	194.5923	664.3362		Variance	568.2404	664.3362
Observations	31	31		Observations	31	31
Pearson Correlation	0.149611			Pearson Correlation	0.175719	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	-4.45862			t Stat	-2.69851	
P(T<=t) one-tail	5.34E-05			P(T<=t) one-tail	0.005663	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	0.000107			P(T<=t) two-tail	0.011325	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	

Source: results of statistical data analysis with the SPSS product.

The summarized results of the analysis conducted using the t-test method are presented in Table 3. This table also indicates whether each hypothesis has been confirmed or rejected.

By applying the multiple comparison method for group means, with a statistical significance level of $\alpha = 0.05$, a statistically significant difference was identified in the mean values of the indicator "Cost Profitability" across the four groups of enterprises.

To determine statistical significance, the value of the P (two-tailed) indicator must be lower than the selected significance level α (0.05). If this condition is met, the null hypothesis can be accepted, confirming that there is a statistically significant difference between the various enterprise groups in terms of cost profitability. This conclusion provides empirical support for the hypothesis that the degree of circular economy adoption influences profitability levels in the wine industry.

Table 3. Results of statistical hypothesis testing regarding whether there is a difference between the individual groups of enterprises according to the indicator - "Cost profitability"

Comparison between→	**Level 1**	**Level 2**	**Level 1**	**Level 3**	**Level 1**	**Level 4**	**Level 2**	**Level 3**	**Level 2**	**Level 4**	**Level 3**	**Level 4**
Null hypothesis – there is a statistically significant difference	is rejected		is rejected		accepted		is rejected		accepted		is rejected	
Alternative hypothesis – there is no statistically significant difference	accepted		accepted		is rejected		accepted		is rejected		accepted	

Source: results of statistical data analysis with the SPSS product.

The results presented in Table 3 indicate a statistically significant difference in cost profitability between enterprises at Level 1 and those at Level 4 (as highlighted in the grayed-out cell of Table 2). Additionally, a significant difference is observed in the comparison between enterprises at Level 2 and those at Level 4.

The analysis suggests that enterprises implementing technologies enabling 100% closure of the production cycle—through recycling and efficient resource utilization—achieve substantially higher cost profitability than enterprises at Level 1 and Level 2.

Table 4. Results of the application of the t-test method for comparing group averages, in this case profitability of sales revenues in the studied enterprises

	Level 1	***Level 2***			***Level 1***	***Level 3***
Mean	19.59663	4.194949		Mean	19.5966328	12.02208
Variance	806.6298	119.7633		Variance	806.62979	207.1829
Observations	31	31		Observations	31	31
Pearson Correlation	0.073448			Pearson Correlation	0.33262757	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	30			df	30	
t Stat	2.889523			t Stat	1.54838321	
P(T<=t) one-tail	0.003551			P(T<=t) one-tail	0.06600796	
t Critical one-tail	1.697261			t Critical one-tail	1.69726089	
P(T<=t) two-tail	0.007102			P(T<=t) two-tail	0.13201592	
t Critical two-tail	2.042272			t Critical two-tail	2.04227246	
	Level 1	*Level 4*			*Level 2*	*Level 3*
Mean	19.59663	43.88442		Mean	4.19494897	12.02208
Variance	806.6298	199.8661		Variance	119.763332	207.1829
Observations	31	31		Observations	31	31
Pearson Correlation	-0.03389			Pearson Correlation	0.06363178	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	30			df	30	
t Stat	-4,206			t Stat	-2.48762762	
P(T<=t) one-tail	0.000108			P(T<=t) one-tail	0.00932182	
t Critical one-tail	1.697261			t Critical one-tail	1.69726089	
P(T<=t) two-tail	0.000216			P(T<=t) two-tail	0.01864364	
t Critical two-tail	2.042272			t Critical two-tail	2.04227246	
	Level 2	*Level 4*			*Level 3*	*Level 4*
Mean	4.194949	43.88442		Mean	12.022081	43.88442
Variance	119.7633	199.8661		Variance	207.182935	199.8661
Observations	31	31		Observations	31	31
Pearson Correlation	0.119056			Pearson Correlation	-0.37701083	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	30			df	30	
t Stat	-13.1409			t Stat	-7.49335034	
P(T<=t) one-tail	2.79E-14			P(T<=t) one-tail	1.1821E-08	
t Critical one-tail	1.697261			t Critical one-tail	1.69726089	
P(T<=t) two-tail	5.58E-14			P(T<=t) two-tail	2.3642E-08	
t Critical two-tail	2.042272			t Critical two-tail	2.04227246	

Source: results of statistical data analysis with the SPSS product.

Specifically, these enterprises attain a cost profitability of 40.5%, demonstrating the economic benefits of a fully circular production model.

Table 4 displays the outcomes of the t-test analysis used to assess how circular economy principles affect sales revenue profitability. Through multiple comparisons across various enterprise groups, the study reveals consistent patterns in how circular practices influence revenue performance among the surveyed businesses.

Table 5. Results of statistical hypothesis testing regarding whether there is a difference between the individual groups of enterprises according to the indicator - "Profitability of sales revenue"

Comparison between→	**Level 1**	**Level 2**	**Level 1**	**Level 3**	**Level 1**	**Level 4**	**Level 2**	**Level 3**	**Level 2**	**Level 4**	**Level 3**	**Level 4**
Null hypothesis – there is a statistically significant difference	accepted		is rejected		accepted		accepted		accepted		accepted	
Alternative hypothesis - there is no statistically significant difference	is rejected		accepted		is rejected		is rejected		is rejected		is rejected	

Source: results of statistical data analysis with the SPSS product.

Table 6. Results of the application of the t-test method for comparing group averages, in this case profitability of investments in the studied enterprises

	Level 1	***Level 2***			***Level 1***	***Level 3***
Mean	-0.00704	0.019225		Mean	-0.00704	0.968775
Variance	0.011942	0.046639		Variance	0.011942	7.141467
Observations	31	31		Observations	31	31
Pearson Correlation	0.407478			Pearson Correlation	0.132074	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	-0.73717			t Stat	-2.04242	
P(T<=t) one-tail	0.233372			P(T<=t) one-tail	0.024992	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	0.466744			P(T<=t) two-tail	0.049984	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	
	Level 1	*Level 4*			*Level 2*	*Level 3*
Mean	-0.00704	1.632419		Mean	0.019225	0.968775
Variance	0.011942	0.680121		Variance	0.046639	7.141467
Observations	31	31		Observations	31	31
Pearson Correlation	0.049346			Pearson Correlation	-0.0999	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	-11.0438			t Stat	-1.9563	
P(T<=t) one-tail	2.16E-12			P(T<=t) one-tail	0.029898	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	4.31E-12			P(T<=t) two-tail	0.059796	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	
	Level 2	*Level 4*			*Level 3*	*Level 4*
Mean	0.019225	1.632419		Mean	0.968775	1.632419
Variance	0.046639	0.680121		Variance	7.141467	0.680121
Observations	31	31		Observations	31	31
Pearson Correlation	-0.07943			Pearson Correlation	-0.16007	
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
Df	30			df	30	
t Stat	-10.3366			t Stat	-1.26536	
P(T<=t) one-tail	1.05E-11			P(T<=t) one-tail	0.107741	
t Critical one-tail	1.697261			t Critical one-tail	1.697261	
P(T<=t) two-tail	2.1E-11			P(T<=t) two-tail	0.215482	
t Critical two-tail	2.042272			t Critical two-tail	2.042272	

Source: results of statistical data analysis with the SPSS product.

The summarized results of the t-test analysis, presented in Table 5, indicate which hypotheses are confirmed (accepted).

The analysis demonstrates that in all intergroup comparisons—except for the comparison between enterprises at Level 1 and Level 3—there is a statistically significant difference in the average value of the "Profitability of Sales Revenue" indicator.

These findings suggest that enterprises implementing technologies enabling over 75% reuse of recycled resources in subsequent production and technological cycles achieve significantly higher profitability of sales revenue compared to enterprises at Level 1.

In these enterprises, the profitability of net sales revenue reaches 14.4%, further emphasizing the economic advantages of integrating circular economy principles in the wine industry.

The comparison of enterprise groups was further conducted concerning the "Return on Investment (ROI)" indicator. Table 6 presents the t-test results, illustrating the systematic impact of circular economy principles on the profitability of sales revenues in the analyzed enterprises.

Using the multiple comparison method of group averages at a statistical error level of ά = 0.05, a statistically significant difference was observed between the average ROI values when comparing the four enterprise groups. To confirm the Null Hypothesis, the P (two-tail) value must be lower than the statistical indicator ά, indicating a significant difference between the enterprise levels with respect to Return on Investment.

These results support the strong link between greater adoption of circular economy practices and enhanced investment returns within the wine industry.

Table 7 displays the results of testing the working hypotheses.

The findings indicate that there is a statistically significant difference in the average values of the "Return on Investment" (ROI) indicator across all comparisons, except for the comparisons between enterprises at level 2 versus level 3, and between level 3 versus level 4. It can be concluded that, in the majority of the comparisons, a significant difference in investment profitability is observed.

This indicates that a more widespread adoption of circular economy principles within the examined enterprises is associated with higher investment profitability, highlighting the positive impact of circular economy practices on investment returns.

Table 7. Results of statistical hypothesis testing regarding whether there is a difference between the individual groups of enterprises according to the indicator - "Return on investment"

Comparison between:	**Level 1**	**Level 2**	**Level 1**	**Level 3**	**Level 1**	**Level 4**	**Level 2**	**Level 3**	**Level 2**	**Level 4**	**Level 3**	**Level 4**
Null hypothesis - there is a statistically significant difference	accepted		accepted		accepted		is rejected		accepted		is rejected	
Alternative hypothesis - there is no statistically significant difference	is rejected		is rejected		is rejected		accepted		is rejected		accepted	

Source: results of statistical data analysis with the SPSS product.

CONCLUSIONS

The statistical analysis of the data generated from the survey and financial accounting documents of the enterprises reveals several important conclusions regarding the impact of the circular economy principles on the profitability of wine-making enterprises:

-*Investment Activity and Efficiency*. Based on the statistical analysis of key indicators such as investments, operating income, and net sales revenue, it is evident that level 4 enterprises exhibit the highest levels of investment activity and operating expenses. These enterprises also report the highest net sales revenue. It is clear that enterprises that have integrated

technologies to close the production cycle through recycling and resource reuse demonstrate high efficiency in managing cash flows derived from investment activity.

-*Profitability Trends Based on Circular Economy Implementation*. Other factors being constant, enterprises that have made the most progress in implementing the principles of the circular economy achieve the highest profitability in terms of investments, revenues, and expenses.

-*Cost Profitability*. Enterprises that have adopted technologies allowing them to achieve 100% closure of the production cycle via recycling and reuse of resources exhibit significantly higher cost profitability compared to enterprises at level 1 and level 2. In these enterprises, the profitability of operating costs reaches 40.5%.

-*Sales Revenue Profitability*. Enterprises that have introduced technologies enabling them to recycle and reuse over 75% of resources in the next production cycle show significantly higher profitability in terms of sales revenue when compared to level 1 enterprises. In these enterprises, the profitability of net sales revenues reaches 14.4%.

-*Investment Profitability*. In the majority of the comparisons made between the surveyed enterprises, a significant difference in investment profitability is observed. The more circular economy principles are implemented, the higher the profitability of investments in the enterprises.

- The combined data, analyses, and findings indicate that the sector presents favorable conditions for the adoption of circular economy principles. Specifically, the wine industry holds promise as a model for other sectors, showcasing the advantages of implementing circular economy practices.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF FUNCTIONAL FOODS AND TRENDS IN THEIR DEVELOPMENT

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Abstract

This study explores the role of functional foods within contemporary nutrition and health-oriented lifestyles. It discusses their scientific foundations, technological innovations, and regulatory frameworks, while offering a detailed SWOT analysis based on examples from countries such as Germany, France, Bulgaria, Japan, and the United States. The analysis draws on a range of sources, including scientific literature and institutional data from EFSA, WHO, and FDA. Methodologically, the work combines literature review, comparative analysis, and assessment of market trends. The findings suggest that functional foods contribute positively to metabolism, immune response, and cognitive health, though the sector faces notable challenges such as high production costs, strict regulations, and significant investment requirements. The study concludes that sustainable development in this field will require greater transparency, cross-border collaboration, and ongoing innovation.

Key words**:** *functional foods, health benefits, technology and inovation, market trends and economic dynamics, regulatory framework.*

INTRODUCTION

Functional foods have increasingly attracted attention from researchers and health professionals because of their potential to support human health and reduce the prevalence of chronic diseases. These products are being integrated into modern diets as consumers seek ways to enhance wellness through daily nutrition [3]. According to the scientific literature, functional foods are those that offer benefits to health that go beyond their basic nutritional value [4]. They are associated with improved physiological functions and may help to prevent various chronic conditions.

[24] considers the role of probiotics and prebiotics as essential components of functional foods, emphasizing their importance in the prevention of chronic diseases such as cardiovascular diseases and diabetes. In addition, [12] and [23] highlight the importance of probiotic foods in maintaining a healthy intestinal microflora, which is crucial for immune function. According to [9], functional foods not only improve physical health, but can also positively affect cognitive function and mental well-being. Recent analyses reveal that probiotic and prebiotic foods are crucial in maintaining gut health and preventing conditions such as cardiovascular disease and diabetes. Their role in modulating the intestinal microbiota is especially important for immune response [14]. In addition, [19] and [16] examine the role of functional foods in the context of nutrigenomics and personalized nutrition, highlighting their potential to adapt to individual genetic needs. Functional foods are considered an important component of modern lifestyles, where disease prevention and maintenance of good health take center stage. The growing interest in functional foods is due to both scientific findings regarding their effectiveness and the increased attention to healthy eating and well-being [2]. In the past few years, as noted in the analysis by [14], the functional food sector has grown considerably, largely due to heightened public awareness of how diet influences overall health. The findings of [29] further confirm this expansion and reveal evolving consumer perceptions, reinforcing the conclusions drawn by [14]. In addition, [13] emphasizes the importance of functional foods for cognitive health and brain function. This growing interest in functional foods not only reflects the global trend towards a healthy lifestyle, but

also highlights the need for continued research and innovation in the field. [10] Understanding the complex interactions between food components and human health will be key to the development of future functional products that can effectively address the specific needs of different population groups.

In this context, the purpose of this article is to The aim is to present the scientific basis, innovative technologies and regulatory aspects of these foods, as well as an in-depth SWOT analysis, including examples from various countries.

MATERIALS AND METHODS

The materials include scientific articles, data from EFSA, WHO, FDA and BFSA, as well as market research from OECD, Statista and Euromonitor. The methods include a systematic literature review, analysis of regulatory documents and SWOT analysis of functional foods. The study period covers 2014-2024, with the main focus on Europe, the USA, Japan and Bulgaria.

RESULTS AND DISCUSSIONS

Definition and classification

Researchers have documented a connection between functional foods and enhanced metabolic health, including better blood lipid profiles and reduced inflammatory markers, making them valuable in chronic disease prevention strategies. According to the World Health Organization (WHO) [31], functional foods are "foods that have the potential to positively affect health beyond their basic nutritional content, while being consumed as part of the usual diet" [31]. Recent progress in areas such as nutrigenomics and individualized nutrition has made it increasingly feasible to design functional foods that reflect the biological characteristics of different consumer groups. This approach opens new possibilities for addressing distinct health priorities based on personal traits [6]. In the United States, the Food and Drug Administration (FDA) uses the term "foods with established health claims" to refer to ingredients with proven health benefits. The Japanese Food for Specific Health Purposes (FOSHU) system was the first formal regulatory framework for functional foods, adopted in 1991 by the Japanese Ministry of Health and Welfare. This system requires scientific evidence of the health benefits of products and strict safety criteria before they can be approved for labeling as FOSHU. The criteria include clinical trials, toxicological analyses, and stability evaluation of active ingredients. The achievements of the FOSHU system have inspired the development of comparable regulatory approaches in other nations, including the European Union and the United States, both of which have adopted the Japanese framework as a foundation for their own standards on safety and effectiveness in functional foods. In Bulgaria, functional foods are regulated under the European Union regulatory framework and are recognized by the Bulgarian Food Safety Agency (BFSA). Under Regulation (EC) No 1924/2006 of the European Parliament and the Council, all functional foods marketed in Bulgaria are required to comply with stringent rules concerning labelling and health-related claims. In Bulgaria, the Food Safety Authority oversees the evaluation and authorization of health claims on functional food products, ensuring that they meet both European Union legislation and relevant national regulatory standards. According to the categorization systems of the European Food Safety Authority (EFSA) [6] and the World Health Organization (WHO) [31], functional foods fall into several core groups. 1. Probiotic and prebiotic products, which either supply live beneficial microorganisms or promote their proliferation within the gut. 2. Fortified foods - added vitamins, minerals or other bioactive compounds. 3. Functional beverages - contain antioxidants, vitamins or plant extracts. 4. Foods with a reduced content of harmful ingredients - for example, reduced content of saturated fat, salt or sugar. This classification allows a clear distinction between different types of functional foods and facilitates the understanding of their impact on health and their role in the diet.

Functional foods are emerging as an important part of the modern food industry, supported by research and innovation. A brief introduction

to this section highlights the importance of these foods for health and the economy, which will be discussed in detail below.

Health Benefits

Functional foods exert a wide range of beneficial effects on human health — a fact consistently demonstrated by scientific research and acknowledged by leading health authorities. The World Health Organization (WHO) notes that incorporating such foods into the daily diet can play a substantial role in lowering the risk of chronic diseases and enhancing overall health outcomes [31]. 1. Digestive health support: Products enriched with probiotics like Lactobacillus and Bifidobacterium contribute to a balanced intestinal microbiota. In turn, prebiotics such as inulin and fructooligosaccharides (FOS) serve as substrates that promote the proliferation of these beneficial microbes, thereby aiding digestion and nutrient absorption [12]. 2. Supporting immune health: A number of functional foods contain compounds with antioxidant properties—such as vitamins C and E, various carotenoids, and polyphenols—that contribute to the body's ability to manage oxidative processes. Their presence may help the immune system function more effectively and reduce the impact of inflammation [2]. 3. Cardiovascular protection: Ingredients such as omega-3 fatty acids, plant sterols, and dietary fiber have been linked to improved lipid profiles and regulated blood pressure. Regular intake of these components has been associated with a lower incidence of heart attacks and strokes, as supported by clinical findings [17]. 4. Bone health maintenance: Functional foods fortified with calcium and vitamin D contribute to the preservation of bone density and dental integrity. Their role in reducing the likelihood of conditions such as osteoporosis is well-documented in nutritional science literature [30]. 5. Weight management and metabolic regulation: Functional foods that are high in dietary fiber and low in energy density can enhance the feeling of fullness and help stabilize blood glucose levels. Such effects are particularly valuable for individuals struggling with excess weight or managing type 2 diabetes [27]. 6. Cognitive and psychological benefits: Certain functional food components — notably omega-3 fatty acids and B-group vitamins — have demonstrated potential in supporting brain health and lowering the risk of neurodegenerative conditions like Alzheimer's disease [13].

Beyond their nutritional value, functional foods contribute significantly to disease prevention and overall well-being, establishing themselves as a cornerstone of contemporary health-conscious lifestyles.

Production technologies

The creation of functional foods requires the application of advanced technologies and innovative methods that guarantee the preservation and effectiveness of active ingredients. The development of these technologies is key to the production of products with high biological value and stability. 1. Microencapsulation: This technology involves encapsulating bioactive compounds in microscopic capsules that protect the active substances from degradation during processing, storage and consumption. This allows for the controlled release of the active ingredients into the body [11]. 2. Nanotechnology: The use of nanoparticles to improve the bioavailability and effectiveness of nutrients is becoming increasingly common in the production of functional foods. Nanotechnology allows the creation of foods with improved texture, taste and digestibility [25]. 3. Biotechnology: Genetic modification and the use of biocatalysts to produce functional ingredients such as enzymes, probiotics and vitamins are among the leading biotechnological methods in this field [26]. 4. Fortification and enrichment: The addition of vitamins, minerals and other bioactive compounds to food products is a common method for creating functional foods. This process ensures that the products provide additional health benefits [1]. 5. Fermentation processes: Traditional and modern fermentation techniques are used to create probiotic products and foods with improved nutritional properties. Fermentation increases the bioavailability of some nutrients and improves the palatability of the products [18]. 6. Extrusion and texturization: Technologies such as extrusion are used to create foods with

the desired texture and shape, while maintaining the functional properties of the added ingredients [15]. By incorporating these advanced technologies into the manufacturing process, producers are able to develop innovative functional food products that align with contemporary consumer expectations for health-oriented and nutritionally enhanced choices.

Regulatory aspects

Regulating functional foods is a multifaceted task that differs across jurisdictions and encompasses a wide range of standards concerning product safety, labelling practices, and permitted health claims. The primary objective of regulatory authorities is to ensure that functional foods are safe to consume and that the health benefits claimed are scientifically substantiated. 1. European Union (EU): In the EU, functional foods are regulated under Regulation (EC) No 1924/2006 on nutrition and health claims made on foods [5]. The European Food Safety Authority (EFSA)[6] is responsible for evaluating the scientific evidence related to functional foods before they are approved for labeling. Health claims must be supported by reliable clinical studies and meet strict criteria for accuracy and clarity. 2. United States of America (USA): In the United States, the Food and Drug Administration (FDA) is responsible for regulating functional foods. Products bearing approved health claims must adhere to the standards established by the Food, Drug, and Cosmetic Act. In addition, the Federal Trade Commission (FTC) monitors the accuracy of marketing claims related to functional foods. 3. Japan: The Japanese Food for Specific Health Purposes (FOSHU) system was the first formal regulatory framework for functional foods, introduced in 1991. The Japanese Ministry of Health, Labor and Welfare requires scientific evidence of the safety and effectiveness of products before they can be approved for labeling. 4. Bulgaria: In Bulgaria, functional foods are regulated in accordance with the EU regulatory framework. The Bulgarian Food Safety Agency (BFSA) is responsible for overseeing the production, labeling and marketing of functional foods in the country. All health claims must comply with European regulations and be supported by scientific evidence. 5. International standards: The Codex Alimentarius, a joint initiative of the WHO and FAO, offers internationally recognized standards and guidelines for the safety and labeling of functional foods. These standards serve as the basis for national regulations in many countries around the world. Regulating functional foods plays a vital role in safeguarding consumer health and verifying the safety and effectiveness of such products. Adherence to both international and national standards is essential for building consumer trust and supporting the growth of the functional foods market.

Market Trends and Innovations

Over the last ten years, the functional food market has expanded significantly, largely driven by growing public interest in the relationship between diet and health. Data from the OECD [22] indicate that the global market reached around USD 282 billion in 2023, with projections suggesting it could exceed USD 400 billion by 2027. In Europe, the sector is expected to grow from EUR 80 billion to approximately EUR 110 billion over the same period, reflecting steady annual growth of about 7–9%.According to the Organization for Economic Cooperation and Development (OECD), the consumption of functional foods in Europe grew by 6% per year between 2018 and 2023, with the highest growth observed in Western European countries. Leading markets in Europe are Germany, France, Italy and Spain, where consumer demand for healthy products continues to grow. 1. Rising interest in sustainability and environmentally conscious production has led more consumers to opt for plant-based and organic functional foods. According to data from Statista [28] and Euromonitor [7], demand for such products in Europe and North America rose by 12% in 2022—a trend that is expected to persist in the coming years. With increasing attention to sustainability and environmentally friendly production, consumers are increasingly choosing plant-based and organic functional foods. This trend is particularly strong in Europe and North America, where there are strict regulations and consumer demand for organic certified products. 2. Personalized

nutrition: The rise of genetic-based dietary approaches has led to a noticeable shift in consumer demand for foods designed to reflect personal health data. Industry reports from 2021 indicate that companies offering such customized nutrition solutions have seen sales increases of around 15%, reflecting a growing market interest in precision-based dietary interventions. Advancements in nutrigenomics and personalized healthcare have sparked growing consumer interest in functional foods designed to match individual genetic profiles and metabolic characteristics. Today, the industry delivers tailored nutritional solutions informed by DNA testing and personal health data. 3. Adoption of emerging technologies: The incorporation of nanotechnology and biotechnology into functional food production enables the development of products with enhanced nutrient absorption and increased physiological impact. Data from Statista shows that investments in nanotechnology for the food industry have increased by 10% in the last three years. The use of nanotechnology and biotechnology in functional food production enables the development of products with enhanced nutrient absorption and greater physiological impact. In addition, these technologies help improve flavor profiles and prolong shelf life, making the products more appealing and commercially viable. 4. Expanding product categories: While traditional functional foods like yogurt and fortified cereals remain widely consumed, the market has expanded to include newer formats such as drinks, snack items, and dietary supplements. Statista reports that functional beverages, in particular, have shown the most dynamic growth globally, with an average annual increase of 11%. Traditional functional foods such as yogurt and breakfast cereals are being complemented by new categories such as functional beverages, snacks and supplements. This diversification meets the different needs and preferences of consumers. 5. Emphasis on mental well-being: As public understanding deepens regarding the connection between diet and mental health, the market has seen a notable rise in functional food products targeting cognitive enhancement, stress reduction, and mood improvement. According to Euromonitor, sales of such items in Europe increased by 9% in 2022 [7]. 6. Increasing investment and strategic partnerships: Global companies and startups are investing significant resources in the development of innovative functional products. According to Statista, investment in innovation in the functional food sector increased by 14% between 2020 and 2023. Global companies and startups are investing significant resources in the development of innovative functional products. Strategic partnerships between scientific institutions and industry are accelerating the introduction of new technologies and products to the market. These developments suggest that functional foods are poised to remain a key segment within the food industry, providing innovative approaches to enhance health and quality of life both globally and within specific regions. Different countries around the world are taking specific approaches to developing and marketing functional foods: • Germany: Manufacturers are focusing on probiotic and prebiotic-enriched products, such as yogurts and fermented dairy products, popular with consumers seeking improved digestive health.

• France: Food manufacturers focus on products enriched with omega-3 fatty acids—such as margarine and dairy items—designed to support heart health.

• Bulgaria: Traditional fermented dairy products like yogurt are recognized for their probiotic effects. In addition, local producers have introduced herbal teas with functional properties, often created in collaboration with phytotherapy experts to address specific health concerns.

• Japan: A global pioneer in functional nutrition, Japan developed the FOSHU system and markets a variety of fiber-rich beverages for digestion and products aimed at managing blood pressure.

• USA: Characterized by a highly diverse and innovation-driven market, the United States offers functional products ranging from vitamin-fortified cereals to antioxidant-rich beverages aimed at holistic well-being.

These examples illustrate the wide variety of strategies employed worldwide in the functional food sector. To better understand the

current market status and future potential, the following SWOT analysis outlines core strengths and weaknesses, as well as the primary opportunities and threats facing the industry today.

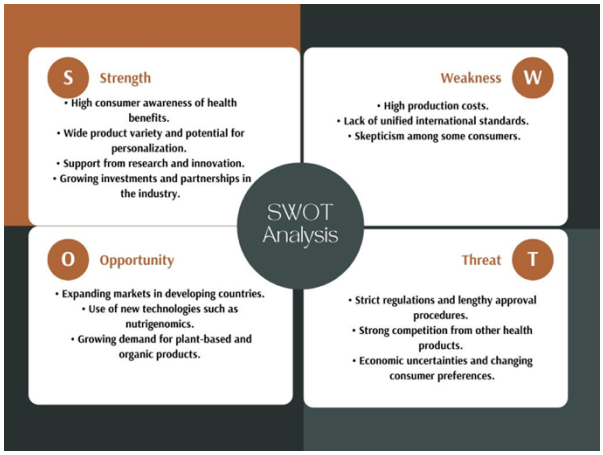


Fig.1. SWOT Functional food
Source: Own design and conception.

The SWOT analysis (Fig. 1) of functional foods highlights the significant potential of this market segment, driven by high consumer awareness and scientific support for the benefits of these products. Despite high production costs and the lack of globally uniform standards, innovation and growing demand create a favorable environment for development. Regulatory challenges and competition require strategic decisions but expanding markets and the introduction of new technologies offer sustainable growth opportunities. Companies that invest in transparency, quality and adaptability will be best positioned to succeed in this dynamic sector.

Economic Dynamics of the Functional Food Market in Bulgaria (2014–2024)

The Bulgarian functional food market has shown consistent growth over the 2014–2024 period. This upward trend is largely driven by growing public awareness of the link between diet and health, the expanding influence of organic and vegan lifestyles, and an overall increase in product availability from domestic producers. Although still modest compared to Western Europe, the Bulgarian market shows potential in several key segments (Table 1).

Table 1. Market Indicators of Functional Foods in Bulgaria (2014–2024)

Product Group	Indicator	2014	2019	2024	Average Annual Growth (%)
Fruits	Consumption (thousand tons)	450	560	630	3.5%
	Raspberry production (thousand tons)	5	12	18	13%
Nuts	Market volume (million BGN)	50	85	120	8%
	Cashew imports (thousand tons)	1.2	2.5	3.8	9%
Seeds	Market volume (million BGN)	10	25	40	12%
	Chia imports (tons)	50	200	350	15%
Vegetables	Broccoli consumption (thousand tons)	2	5	8	11%
	Organic vegetables market (mil. BGN)	15	30	50	10%
Legumes	Market volume (million BGN)	20	35	55	9%
	Chickpea imports (thousand tons)	0.5	1.5	2.5	14%

Sources: Own design and conception by data from NSI (https://www.nsi.bg)[21], MAF (https://www.mzh.government.bg) [20], Eurostat (https://ec.europa.eu/eurostat) [8], Euromonitor [7], Statista (https://www.statista.com)[25].

Functional Fruits (berries, apples, pears, oranges, bananas, etc.)

Over the past decade, the market for functional fruits in Bulgaria has shown consistent positive dynamics. Reports by NSI [21] and Eurostat [8] indicate that the consumption of fresh fruits increased by over 25% during 2014–2023, with the most significant growth seen in berries and bananas, recognized for their high antioxidant and fibre content. Imports of berries (blueberries, blackberries, raspberries) more than doubled, while domestic raspberry production tripled (from 5 thousand tons in 2014 to over 15 thousand tons in 2022).

Apples and pears remain leading in terms of domestic production volume, although their

export share has declined due to low competitiveness. On the other hand, demand for organic-certified fruits and local varieties rich in polyphenols has increased, particularly in urban centres.

Nuts (almonds, cashews, etc.)

Nuts are positioned as a "superfood" in Bulgaria, with the market for almonds, cashews, and hazelnuts growing by an average of 8% annually between 2014 and 2023. As reported by BFSA and Euromonitor, imports of raw and unsalted nuts used in muesli and functional snacks have tripled. The largest increase is observed in cashews and pistachios, while traditional walnuts maintain a stable share, primarily from local production.

This growth is driven by increased consumption in the healthy and vegan food sectors, as well as the incorporation of nuts in functional bars and dairy alternatives (e.g., almond and cashew milk).

Seeds (sunflower, sesame, etc.)

Sunflower seeds are traditional in Bulgaria, but the past decade has seen diversification toward dehulled sunflower seeds and organic sesame, used in functional products. The seed market, including chia and flaxseed, has experienced exponential growth since 2017, particularly in urban areas.

Reports by retail chains and organic stores show that sales of functional seed mixes (granolas, smoothies, functional breads) have more than tripled over the decade.

Vegetables (broccoli, spinach, cauliflower, tomatoes, etc.)

Vegetables with proven antioxidant properties such as broccoli, kale, spinach, and tomatoes have become a focal point of consumer interest. In 2014, broccoli imports to Bulgaria were under 2 thousand tons, while in 2022 they exceeded 6 thousand tons. Local production is also increasing, albeit at a slower pace due to labour-intensive cultivation.

As reported by NSI and BFSA, demand for fresh and frozen functional vegetables rose by more than 40%, with main consumers being high-income families, restaurants, and catering services. The organic vegetable market is growing at 12% annually.

Legumes (beans, peas, lentils, etc.)

Bulgaria has a tradition of growing legumes, but the production of functional varieties with high protein and fibre content (e.g., red beans, black lentils) has developed only after 2018. Imports of high-protein peas and chickpeas have doubled over the period, with an increasing number of producers incorporating them into vegan alternatives – burgers, spreads, and flours.

Growth in this segment is supported by the popularity of vegan diets and sustainable eating. The market for chickpea-based products (e.g., hummus, falafel) has grown by 19% annually between 2019 and 2023.

Behavioural and Market Factors Influencing the Development of the Functional Food Market in Bulgaria

Shifts in consumer perceptions and habits have played a crucial role in driving the increased demand for functional foods in Bulgaria throughout the 2014–2024 period. Over this decade, several distinct transformations have emerged, shaped both by global processes and by specific internal dynamics within the socio-economic environment.

First, contemporary Bulgarian society demonstrates increasing health awareness, reflected in interest toward foods with proven or perceived benefits for strengthening the immune system, regulating metabolism, improving digestion, and enhancing cognitive function. This interest intensified as a result of the epidemiological crisis caused by COVID-19, which catalysed a shift in attitudes toward prevention through nutrition. As a result, the consumer base for functional foods has expanded beyond niche groups such as athletes, vegans, and individuals with specific dietary needs.

Second, demographic and social characteristics play a significant role in shaping market behavior. Analysis shows that the typical consumer of functional foods in Bulgaria is a member of the urban middle class, aged between 25 and 45, with higher education and an active interest in new dietary practices and innovations. Women dominate among regular consumers, with a ratio of approximately 3:2 compared to men. A relatively higher concentration of consumers is observed in the capital and major university cities (Plovdiv,

Varna, Veliko Tarnovo), where access to specialized stores, organic-certified products, and information channels is more developed.

Third, new distribution and marketing channels have emerged in the market context, enhancing the accessibility and recognition of functional foods. Alongside the expansion of organic sections in large retail chains, increasing significance is seen in:

-online food delivery platforms and "functional food box" services;

-farmers' markets with short supply chains;

-influencer marketing via social networks, which strengthens the emotional connection between product and consumer.

Finally, market trends show substantial flexibility among producers, who adapt their offerings to changing demand through innovative formats: mini packages, "on-the-go" food options, probiotic desserts, beverages with bioactive ingredients, and more. This adaptation contributes to the differentiation of functional products from mass-market goods and to the enhancement of their market value.

Institutional Support and Regulatory Environment

The development of the functional food market in Bulgaria cannot be considered in isolation from the institutional framework that defines the conditions for production, certification, marketing, and consumption. Between 2014 and 2024, a gradual evolution has been observed in national policies and regulations aimed at promoting sustainable agriculture, innovation in the food industry, and encouragement of biodiversity in diets.

A significant role is played by the Rural Development Programme (RDP), which in the 2014–2020 and 2021–2027 programming periods provides targeted financial support for:

-transitioning to organic agriculture;

-investments in modernization of production and processing facilities;

-support for young farmers, including in the fruit, nut, and legume sectors.

As reported by data from the Ministry of Agriculture, by the end of 2022, over 280 projects related to organic production of functional crops had been funded, with nearly 40% concentrated in Southwestern and South Central Bulgaria- regions with favorable climatic and agronomic conditions. A significant portion of these projects have led to the creation of new jobs, improved environmental standards, and the achievement of high added value through certified functional products.

In regulatory terms, the Bulgarian Food Safety Agency (BFSA) implements EU legislation (Regulation (EC) No 1924/2006), which defines the requirements for nutrition and health claims. However, the absence of a national register of functional foods and the lack of a coordinated information platform hinder informed consumer choices and complicate market orientation for producers.

It is necessary to establish a more clearly defined institutional environment that:

-defines the concept of "functional food" in the national context;

-accelerates the procedures for evaluation and registration of new products;

-provides incentives for research in the fields of nutrigenomics and clinical evaluation of functional effects.

Only through strategic synergies between agricultural, health, education, and scientific policies can Bulgaria realize the full potential of functional foods as a driver of economic growth, public health, and ecological sustainability.

The analysis of market dynamics of functional foods in Bulgaria during 2014–2024 reveals several key conclusions outlining the current state, specific trends, and strategic development opportunities in this segment of the agri-food industry.

First, a clear acceleration of market growth for functional foods is observed, especially in the segments of fresh fruits, nuts, and legumes. This is due both to increasing consumer demand driven by a desire for healthy living and to structural changes in supply—including the expansion of organic-certified production areas and the introduction of innovative product formats (e.g., functional snacks and drinks, fortified breads, and smoothies).

Second, the integration of new groups of functional foods—such as chia seeds, flaxseed, baby spinach, and chickpeas—reflects not only a shift in consumer attitudes but also producers' adaptability to global trends in

sustainable, plant-based, and personalized nutrition. It is especially notable that this growth is occurring under conditions of still limited processing infrastructure, highlighting the latent potential for increasing domestic added value.

Third, it was found that the main success factors for functional foods in Bulgaria include access to organic certification, effective communication of health claims, innovative commercial vision (including online channels and short supply chains), and the ability of producers to combine traditional agricultural crops with new technological solutions.

In light of these findings, evidence-based recommendations for sustainable sector development can be formulated as follows:

First, it is necessary to establish an institutional framework for functional foods in Bulgaria that clearly defines the criteria for health claims, harmonizes labelling with European requirements, and ensures control over market transparency. This would help increase consumer trust and create more effective links between producers, distributors, and end customers.

Second, efforts to support organic farming and the processing industry should be strengthened through the promotion of public-private partnerships, targeted investment tools, and innovation hubs for functional foods. Priority should be given to small and medium-sized producers who demonstrate the ability to implement sustainable, eco-friendly, and socially responsible practices.

Third, it is recommended to conduct systematic multidisciplinary research to validate the health effects of local functional foods, using methods from nutrigenomics, metabolomics, and functional medicine. This will enhance the scientific value and international competitiveness of Bulgarian products.

Finally, it is essential to invest in educational and information campaigns aimed at improving the population's health literacy and fostering a culture of informed food choices. Only through an integrated approach combining science, economy, regulation, and consumer interests can the sustainable development of the functional food sector in Bulgaria be achieved.

CONCLUSIONS

Functional foods are an important component of modern nutrition, offering healthy solutions and market opportunities. This analysis provided an in-depth overview of the sector, highlighting challenges such as high costs and regulatory requirements, but also opportunities for innovation and growth. Successful development depends on continuous scientific research, adaptation to dynamic consumer needs and effective regulation. Synergy between industry, regulators and consumers is essential to create a transparent and sustainable environment. The analysis showed that functional foods can be a driver of innovation in the food industry, combining health benefits, technological advancements and effective market positioning. Expanding markets, especially in emerging economies, and adapting to environmental and social requirements are key for future development. Increased cooperation between manufacturers, regulators and the scientific community is recommended, as well as greater investment in education and consumer awareness. Successful implementation of these strategies will ensure sustainable development and long-term success, meeting expectations for quality, safety and innovation.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE ROLE OF ASSOCIATIVE FORMS IN STIMULATING AGRICULTURAL INNOVATION AND INCREASING ECONOMIC PERFORMANCE - A BIBLIOMETRIC APPROACH

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Abstract

In this article, we have analyzed how innovation in agriculture is reflected and articulated in the international scientific literature, with a special focus on the role of associative forms, such as cooperatives and producer groups. The main goal was to understand how types of agricultural innovation are defined and disseminated and to what extent they are influenced or facilitated by collective farmer organizational structures. The approach was guided by two objectives: identifying the main types of innovation applied in agriculture and carrying out a bibliometric analysis that would highlight the structure and dynamics of scientific knowledge in this field. The methodology was based on querying the Scopus database, using relevant terms such as agricultural innovation, farmer associations and economic performance. The data obtained were processed using VOSviewer, to generate thematic maps that analyze networks of co-citation, keyword co-occurrence, international collaboration and bibliographic coupling. The results obtained show that, although the topic of agricultural innovation is intensively treated, the relationship with associative forms remains peripheral in the specialized literature. The bibliometric networks show a pronounced conceptual fragmentation, with thematic clusters evolving in isolation, some focused on technology and adoption, others on rural development or sustainability, without a coherent integration of the organizational dimension. In addition, the lack of common theoretical sources and insufficient standardization of terminology affect the coherence of the scientific field and its capacity to produce transferable explanatory models. The general conclusion emphasizes the need for interdisciplinary and integrative approaches, which more clearly connect technological innovation with social and institutional processes in agriculture. It is also recommended to valorize associative forms as active vectors of innovation, not just as an organizational background, in order to advance towards a more complete understanding of the transformations in contemporary agriculture.

Key words: *innovation, agriculture, association, economic performance, bibliometric analysis*

INTRODUCTION

In a global context marked by major transitions, climate change, demographic pressure, food crises and accelerated technological transformations, agriculture remains not only a strategic sector, but also a space in which the dynamics of innovation become vital for sustainability and competitiveness [13]. At the same time, the excessive fragmentation of agricultural holdings, the lack of individual resources and the asymmetry of access to technology have led to the need for forms of cooperative or associative organization, which allow the aggregation of interests, resources and innovation capacity. This dual framework, the need for innovation and the imperatives of collaboration, underpin the present scientific approach, which explores the interdependencies between innovation in agriculture and associative forms.

Agricultural innovation is not only about introducing new technologies, such as high-performance machinery, digital monitoring systems or innovative biological solutions [15, 16, 17]. It also includes organizational processes, new cooperation models, access to knowledge and support services for farmers. Innovation is thus both a technological and a social and institutional process [19, 20]. Associative forms, such as cooperatives,

producer groups or inter-farmer partnerships, can be essential catalysts for these processes. They reduce the isolation of farmers, facilitate the exchange of good practices and increase the absorption capacity of European funds for investment and innovation [4].

In Romania, innovation challenges are exacerbated by the structural specificity of agriculture. High fragmentation, the dominance of subsistence farms and weak organization in associative forms have long limited the sector's capacity to adopt modern technological solutions. Despite the high agricultural potential, the economic performance of Romanian farms remains modest compared to the European Union average [5, 7]. Also, the innovation rate is significantly lower among individual farms than those organized in associative forms, according to data from international sources. These discrepancies justify a deeper analysis of how association forms influence the adoption of innovation and, implicitly, the economic performance of the sector.

In the specialized literature, there is a growing consensus on the idea that associative forms constitute a favorable framework for innovation. Agricultural cooperatives in particular are frequently cited as examples of success in facilitating access to markets, technologies, vocational training and financing. By sharing risks and costs, they can stimulate the process of adopting new technologies and transitioning to sustainable agricultural practices. However, the effect of these forms of organization on economic performance is not always linear or guaranteed. Success depends on factors such as the quality of internal governance, the level of trust between members, institutional support and the regional socio-economic context.

A first objective of the research is to identify the main types of innovation that can be adopted in the agricultural sector – from technological innovations (precision farming systems, drones, sensors, etc.) to organizational innovations (e.g. short supply chains, collective contractual models, digital sales platforms). In parallel, the research aims to assess the degree of diffusion of these innovations in Romania and other European countries, focusing on the differences between individual and associated farms.

The second objective aims to carry out a bibliometric analysis to understand how this topic is approached in the international scientific literature. Thus, a map of key concepts (agricultural innovation, farmer associations, profitability) will be built, the main authors, citation networks and existing research gaps will be identified.

The relevance of the topic is also given by the current context of European policies. The new Common Agricultural Policy (CAP 2023–2027) emphasizes innovation, digitalization and cooperation as pillars of the sustainable development of European agriculture. Initiatives such as the European Innovation Partnership in Agriculture (EIP-Agri), Smart Villages or the Horizon Europe programs offer concrete opportunities for promoting associative forms as vectors of innovation. Romania, with an agriculture marked by structural polarization and underutilization of associative potential, has the chance to capitalize on these directions through a strategic and integrated approach. At the same time, it is important to understand that innovation is not a neutral process, but a deeply contextual one. The adoption or rejection of innovations depends not only on their technical efficiency, but also on cultural, institutional and economic factors. Thus, in an agricultural community with a low level of mutual trust or with negative experiences related to forced cooperatives from the communist period, associative forms develop with difficulty, and innovations penetrate fragmentedly. Therefore, a deep analysis must take into account both objective and perceived barriers to the process of innovation and association.

The approach to this topic also has an important practical component. Understanding how agricultural innovation is supported by cooperation can underpin more effective public policies, support programs adapted to local realities, and bottom-up interventions, in which farmers become active agents of transformation. Also, highlighting the performance differences between associative and individual farms can constitute a solid argument for promoting voluntary

cooperativization and for consolidating the agricultural associative sector in Romania.

MATERIALS AND METHODS

To achieve the established objectives, the present research was structured in two main methodological stages: an empirical-descriptive one, based on the exploration and classification of relevant statistical data sources, and a documentary-analytical one, based on the bibliographic analysis of international scientific production in the field.

In the first stage, the emphasis was placed on understanding how innovation is conceptualized and applied in the agricultural context. Not only the technological side was taken into account, such as the adoption of modern equipment, the digitalization of farms, precision agriculture, but also the organizational, institutional and social dimensions of innovation, being analyzed secondary data sources, such as thematic databases, but also public policy documents.

To support the theoretical approach and calibrate the directions of empirical analysis, an applied bibliometric component was integrated, aiming to evaluate the current state of scientific research in the targeted field. At this stage, the Scopus database was used, recognized for the accuracy and timeliness of indexing scientific publications in fields such as social sciences, economics, agriculture, rural development and innovation. The search conducted on July 25, 2025 targeted three key terms, strategically selected for their relevance to the objectives of the paper: agricultural innovation resulting in 18,334 identified articles; farmer associations, resulting in 219 articles and economic performance, with 6 identified articles (in combination with the other terms).

These results reflect a significant contrast between the intense interest shown by the academic community for agricultural innovation in the broad sense and the still limited presence of research that analyzes in depth the role of associative forms in this process. The low number of articles that simultaneously integrate the three dimensions – innovation, association and economic performance – signals the existence of a conceptual and applicative void that can be capitalized on through research oriented towards the relational analysis of these phenomena.

The query was performed on the standard Scopus fields (title, abstract, keywords), with minimal delimitations regarding the publication period, precisely in order to obtain the most complete picture of the conceptual dynamics over time. The resulting articles were subsequently qualitatively filtered, based on relevance to the research object, and were to be analyzed in depth in the section dedicated to the literature review and bibliometric synthesis.

To visualize thematic relationships and scientific networks, bibliometric data were processed using the VOSviewer software, which allows the graphical representation of concept clusters, co-citations and institutional or international collaborations. Thus, bibliometric analysis was not used only as a descriptive tool, but as a mechanism for mapping the scientific field, providing a clear picture of the hard core of research in the field, but also of emerging or poorly covered frontiers.

This dual approach allowed us to anchor the research in the existing literature, while providing us with starting points for a critical analysis of the degree of thematic coverage, consolidated research directions and existing gaps in the field of innovative associative agriculture. Through this methodology, the research proposed a contextualized and integrated understanding of the phenomenon of innovation in agriculture, in a framework in which forms of collective organization become not only logistical supports, but essential vectors of transformation of the contemporary agri-food sector.

RESULTS AND DISCUSSIONS

The bibliometric analysis of the 219 selected articles and the results of the application of the 2 key terms used aimed to identify the main concepts, trends and scientific networks that structure the field, providing a systematic perspective on how the topic is treated in the

specialized literature. The results visualized in the form of thematic maps allow not only to highlight active subfields, but also to delimit research gaps. In the study, 9 conceptual maps were constructed, each focusing on a specific aspect of agricultural innovation and cooperation in this field, including the analysis of the co-occurrence of keywords, co-authorship networks and the way in which these important fields have developed.

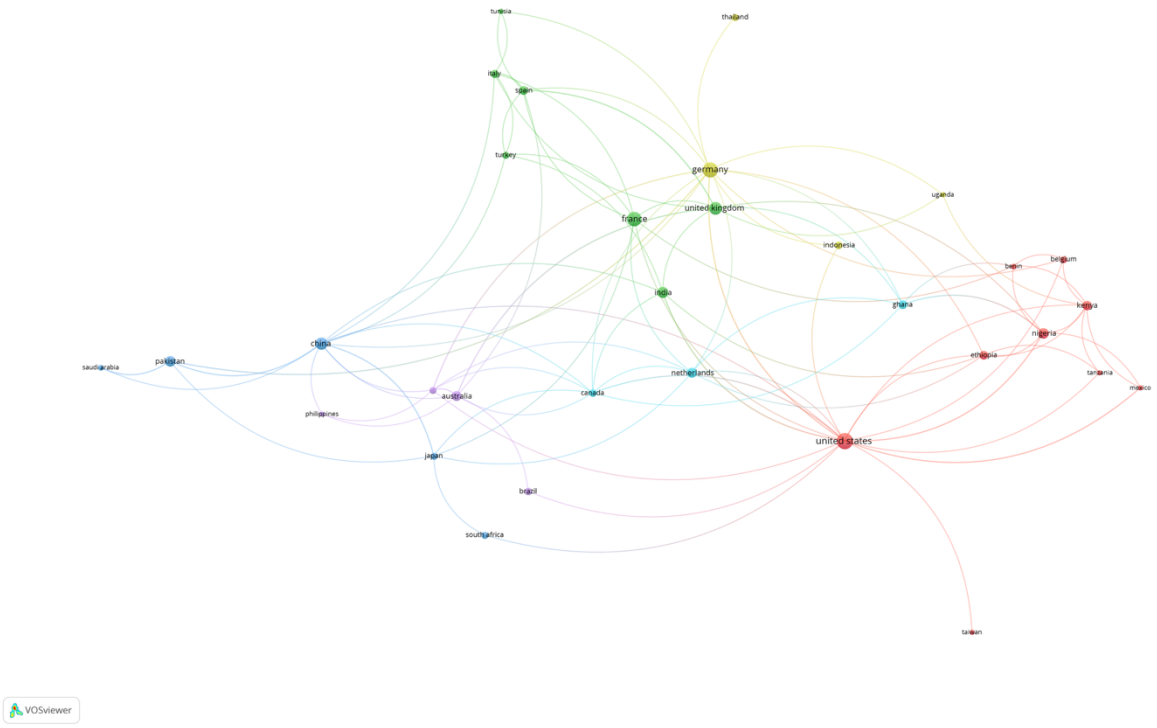


Fig. 1. Geographical distribution of scientific collaboration on innovation in agriculture: bibliometric analysis of countries
Source: own processing [18].

The map of international scientific collaborations highlights the co-authorship networks between countries in the field of agricultural innovation research. The analysis shows the existence of well-defined scientific centers of gravity, dominated by a few states with a high volume of academic production and a high capacity for transnational collaboration. The United States of America occupies a central role in the collaboration network, acting as a major interconnection node, especially with countries in Africa (Kenya, Nigeria, Tanzania, Ethiopia) and Western Europe (Belgium, the Netherlands). This position reflects both the capacity to coordinate international projects and the strategic interest in emerging agriculture and global rural innovation. China forms an important pole in the east of the network, with strong collaborative relationships in Asia (Pakistan, Philippines, Japan), but also with Australia and South Africa. Unlike the USA, Chinese collaborations are more strongly anchored in the Asia-Pacific area, indicating a regional dimension of research. France, Germany and the United Kingdom are emerging as a European research cluster, interconnected with Italy, the Netherlands and Turkey. These countries demonstrate intense domestic and cross-border scientific activity, in line with European policies on rural development and the green transition. The European cluster is also visibly connected with states in Africa and Southeast Asia, which shows a dual interest: fundamental and applied research, with a development cooperation component. Countries such as Kenya, Ghana, Nigeria and Ethiopia frequently appear in connection with researchers from the USA and Europe, which also indicates an orientation of research topics towards the context of developing agriculture. At the same time, African countries play a rather passive role in the network, being included in collaborations,

but rarely acting as independent poles of co-authorship. Australia and Canada have moderate links with China, the USA and Europe, but without significant centrality in the network, which demonstrates a selective involvement in international consortia.

This structure highlights the asymmetry in the production and dissemination of scientific knowledge in the field of agricultural innovation and indicates the need to strengthen institutional capacities in underrepresented countries.

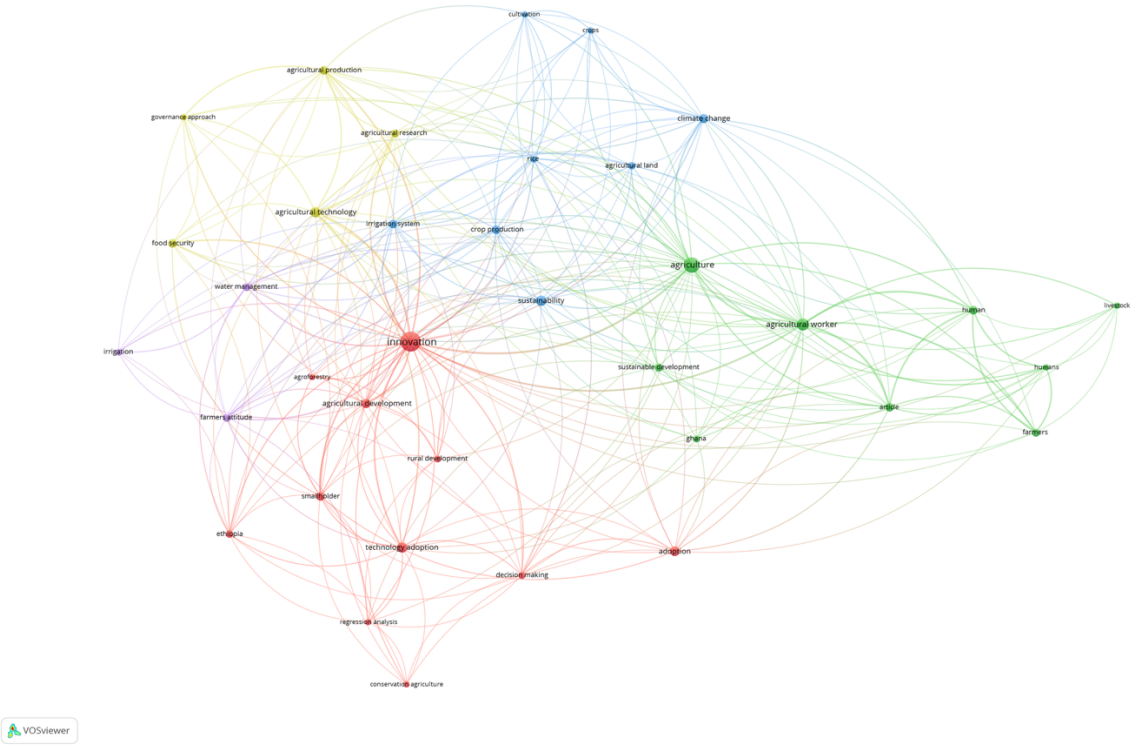


Fig. 2. Terminological structure of the scientific literature on agricultural innovation
Source: own processing [18].

The keyword co-occurrence map (Figure 2) highlights the conceptual organization of the scientific literature on agricultural innovation. The central term, "innovation", is connected to a variety of sub-themes, signaling a complex and interdisciplinary approach. Several thematic clusters are emerging around it. The first major cluster, dominated by terms such as "agricultural development", "technology adoption", "rural development" and "smallholder", shows that innovation is understood in direct relation to the modernization of small-scale agriculture. The emphasis falls not only on technology, but also on the decision-making, adoption and adaptation processes at the farmer level, which reflects an applied and pragmatic orientation of the research. Implicitly, innovation is perceived as a tool for reducing vulnerability and stimulating local development. A second relevant cluster, focused on terms such as "agriculture", "farmers", "gender" and "livestock", brings to the fore the social dimension of agriculture. The presence of gender and agricultural worker themes indicates an increasingly visible concern for equity, inclusion and the differential impact of innovation on different categories of rural actors. Innovation is thus not only a technical process, but a social one, with implications for the structure of communities and roles on the ground. A third cluster groups terms such as "sustainability", "climate change", "agricultural land" and "crop production", reflecting the integration of innovation into the discourse on sustainability and climate change. Here, innovation appears as a response to environmental crises, especially in the context of smart agriculture and resource conservation.

Fig. 3. Co-occurrence network of authors' keywords in the literature on agricultural innovation
Source: own processing [18].

The co-occurrence map of the author keywords reveals an extremely fragmented thematic network, with only a few weakly connected nodes, which reflects a low level of conceptual convergence in the scientific literature dedicated to the relationship between agricultural innovation and associative forms. The terms present, such as "technology adoption", "smallholders", "innovation", "climate change", "sustainable agriculture", appear grouped in linear chains, not in dense clusters, which demonstrates the lack of a consolidated thematic core.

This dispersion has multiple causes. First, the researched themes are often treated in isolation: innovation is studied predominantly from a technological perspective, and associative forms rarely appear as explicit vectors of it. Second, the relevant literature is fragmented between several disciplines (agronomy, economics, rural development, public policies), which reduces terminological coherence between authors.

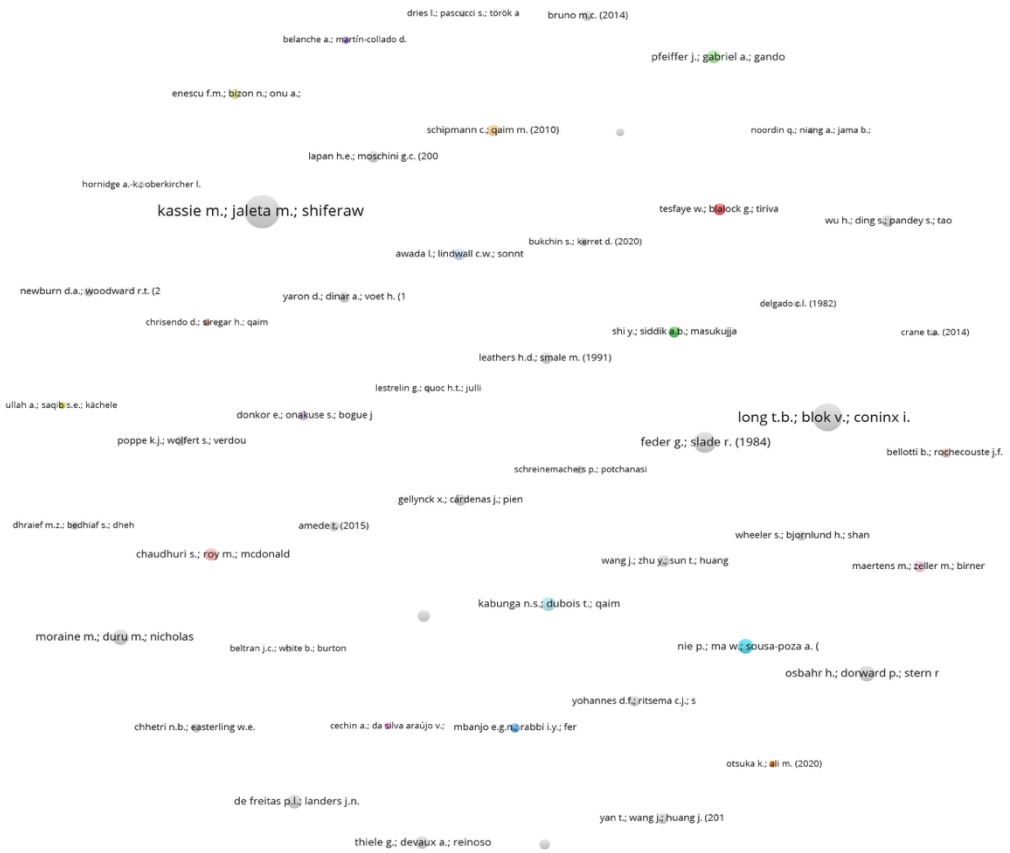


Fig. 4. Citation network in agricultural innovation and cooperation research
Source: own processing [18].

The consequence of this dispersion is the absence of a common language that facilitates the accumulation of knowledge and solid theoretical construction in the field. Without recurring terms and strong semantic correlations, the field remains poorly integrated and with reduced academic visibility.

To correct this fragmentation, a gradual standardization of thematic vocabulary, a better anchoring in theoretical concepts and a stimulation of interdisciplinary research that integrates technological innovation with organizational and social aspects are required. International initiatives such as EIP-Agri or European networks for rural development can be fertile environments for the development of a common research core, in which terms such as "cooperation", "farmer organizations" or "collective innovation" become part of the frequently used vocabulary.

The map of the most cited articles (Figure 4) highlights a series of seminal works that have shaped major research directions in the field of agricultural innovation. The most prominent papers, such as those by Kassie et al., Long et al. [10], and Feder et al., indicate recurrent and converging themes, with a clear focus on technology adoption, farmer behavior, and the economic efficiency of innovation. The work by Kassie et al. (focused on Africa and smallholder farmers) is notable for its high network connectivity, which signals a sustained interest in innovation in subsistence agriculture and the determinants of adoption [8]. The frequently cited papers by Feder and Umali played a founding role in the formulation of theoretical models of the adoption decision and are still relevant in the contemporary literature [6].



Fig. 5. Cross-country citation network in agricultural innovation and cooperation research
Source: own processing [18].

The most cited articles are predominantly anchored in empirical contexts from the global South (Asia and Africa), which indicates a dominant concern for rural development, poverty reduction and the adaptation of technologies at the local level [3, 12]. In contrast, the dimension related to associative forms appears marginal and works focused on

agricultural cooperatives or partnerships do not figure among the most influential, which shows a thematic space under-represented in the impact literature [2, 21]. This concentration of citations around topics such as technology adoption, economic behavior, and farm-level analysis reflects the dominant orientation towards efficiency and economic performance, rather than towards the institutional, social, or collaborative dimensions of innovation [1, 9, 11, 14].

To balance this thematic imbalance, we believe it is necessary to promote research that analyzes the role of associative forms as a medium for the production and diffusion of innovation, integrating indicators of collaboration, trust, governance, and social capital. Such approaches could complement the current literature, offering a more systemic and inclusive perspective on the innovation process in agriculture.

Figure 5 highlights that, although several countries are active in publishing relevant research (United States, China, India, United Kingdom, Nigeria), there is no consolidated co-citation network between them. Each country seems to operate in isolation, without significant bibliographic interdependence. This lack of connections signals a global fragmentation of the scientific field: researchers from different countries do not frequently read the same reference works or build on common literature bases. In practice, this reflects the existence of several "academic islands", where themes and approaches are developed in parallel, but do not converge in a coherent international dialogue.

The causes can be multiple: language barriers, regional differences in research priorities, unequal access to indexed publications, but also different institutional orientations (they place greater emphasis on local empirical studies in the Global South vs. theoretical research in the Global North).

The absence of a solid co-citation network reduces the chances of theoretical synthesis, fragmenting the global understanding of agricultural innovation. Furthermore, associative forms, often dependent on local contexts, remain poorly connected between international studies, which limits the transferability of good practices and successful models. Solutions could include promoting international collaborative projects (Horizon Europe, ERANet), creating meta-analyses and synthesis articles with transregional visibility, and encouraging publications with international co-authorship and cross-citation.

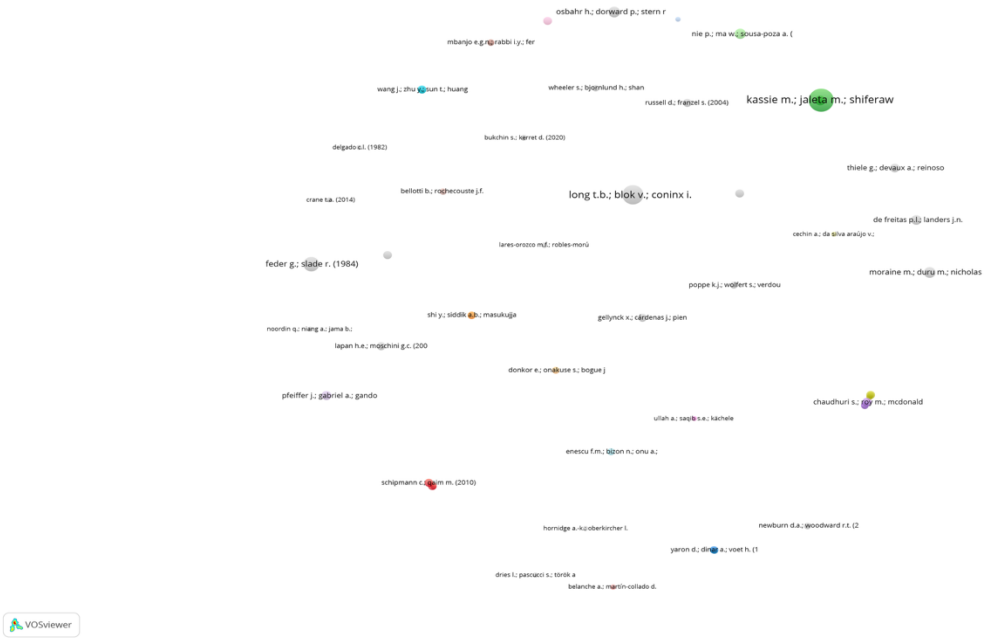


Fig. 6. Bibliographic linking network of documents in agricultural innovation and cooperation research
Source: own processing [18].

The analysis of bibliographic coupling provides a picture of how documents in the scientific literature are linked to each other through common cited sources, reflecting the intellectual proximity and thematic convergence of research. In Figure 6, the network highlights the formation of several distinct groups of works that share similar bibliographic bases, suggesting the existence of consolidated subdomains within the general theme of agricultural innovation and cooperation. A first group is shaped around research focused on the adoption of technologies in small-scale farms, with an emphasis on economic variables, farmer attitudes and access to resources. A second cluster is centered on sustainable development practices and conservative agriculture, and a third on institutional models of cooperation and rural governance. These subthemes show a healthy diversification of research directions, but also the tendency of authors to work with common sources within a narrow framework, which may limit the dialogue between complementary perspectives.

However, the absence of dense connections between clusters indicates a fragmentation of the literature. Works in the field of agricultural cooperation appear weakly linked to those oriented towards technological innovation, which shows a dissociation between the social-organizational and the technical-economic dimensions of research. This thematic gap is due to the excessive specialization of the authors, the lack of integrative theoretical frameworks or the underrepresentation of associative forms in dominant studies. The result is an active scientific field, but one that risks evolving into disciplinary clusters, without a coherent vision on how agricultural cooperation influences, and is influenced by, innovation processes. Therefore, we believe that there is a need to promote interdisciplinary research and synthesis studies that connect the fields of governance, innovation and rural development. International initiatives and European policies can provide the right context for the emergence of an integrative sector of literature.



Fig. 7. Bibliographic coupling network of sources in agricultural innovation and cooperation research
Source: own processing [18].

The bibliographic coupling network of sources reflects the connectivity between scientific publications based on the common references used by the authors. In Figure 7, a linear network is observed, made up of a few isolated or weakly interconnected nodes, signaling a low degree of bibliographic cohesion in the field of agricultural innovation and cooperation.

The presence of several Authors, such as Beltrán, Lestrélin, Kächele, Awada, in intermediate positions, but with few links between clusters, indicates independent thematic groups, each operating with its own set of sources. This fragmented structure reflects a lack of theoretical consensus and common framework sources, which limits the development of an integrative scientific discourse.

In the long term, this dispersion may reduce the visibility and impact of research related to agricultural cooperation, especially if it does not connect to well-consolidated bibliographic corpora. It is necessary to consolidate central reference sources and promote synthesis works that connect isolated research and facilitate the formation of a clear epistemological identity in this emerging field.

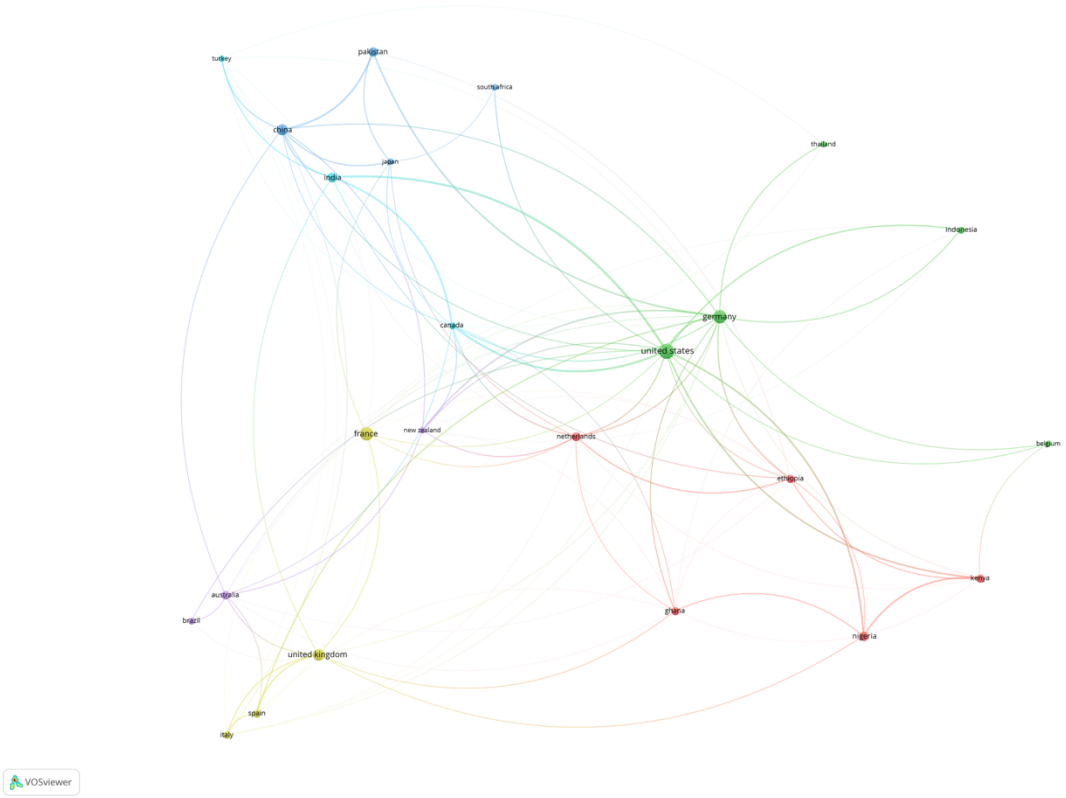


Fig. 8. Bibliographic coupling network between countries in agricultural innovation research
Source: own processing [18].

Figure 8 highlights a bibliographic coupling network between countries, in which countries are connected according to the similarity of bibliographic sources used in their publications. Unlike co-authorship maps, this network shows the extent to which researchers from different countries read the same sources and, implicitly, participate in the same global scientific conversations. The network shows a polarized structure around highly connected countries, such as China, the United States, Germany, and the United Kingdom, which act as central nodes. These countries frequently share the same reference sources, suggesting an epistemic and thematic convergence among researchers in these academic spaces. Other regional groups, such as African or Asian countries (Nigeria, India, Pakistan), appear indirectly connected, with a more modest participation in the common bibliographic corpus, but with visible links to dominant centers. This shows an assimilation of the "central" literature without sufficiently visible theoretical contributions of their own, reflecting an imbalance in global scientific influence.

It was found that from the perspective of agricultural innovation, only certain geographical spaces actively participate in shaping a common scientific discourse, while others remain in peripheral areas, despite the growing volume of scientific production. We consider it essential to promote transnational collaborative research and relevant local bibliographic sources, in order to reduce dependence on dominant literature and balance theoretical influences in the field of innovative agriculture.

The network highlights the conceptual structure of the scientific literature by analyzing authors who are frequently cited together, suggesting theoretical, methodological, or thematic affinities. The presence of several densely connected clusters, each represented by a distinct color, indicates a diversity of schools of thought or emerging subfields. The central, red cluster brings together fundamental authors in the theory of agricultural technology adoption and rural economics, while the green and blue clusters integrate authors associated with sustainable development, agricultural policies, and rural

governance. The presence of an isolated group on the far left, purple, indicates a minority line of research or an alternative approach, possibly from another geographical region or discipline. The co-citation network shows a growing scientific coherence around canonical authors, which indicates the stabilization of the thematic field. However, the fragmentation into several clusters also reflects a lack of transversal integration between technological innovation and associative forms, which often remain treated separately. We believe that strengthening the dialogue between clusters through synthesis research and interdisciplinary works can facilitate the articulation of a unitary paradigm on agricultural innovation in associative contexts, capable of underpinning more efficient and inclusive public policies.

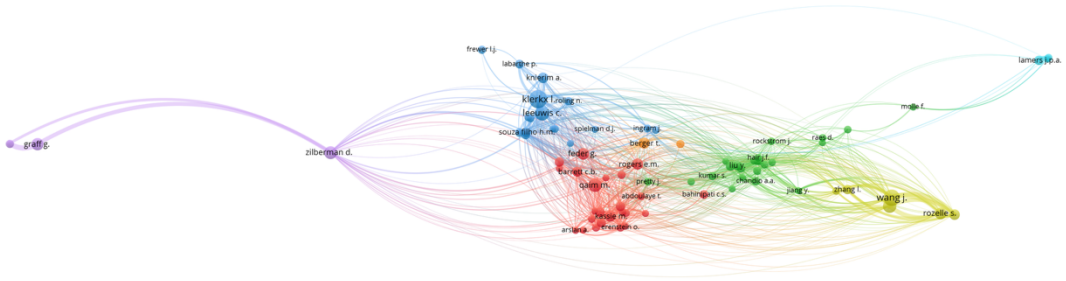


Fig. 9. Co-citation network between authors in the literature on agricultural innovation and cooperation
Source: own processing [18].

The network highlights the conceptual structure of the scientific literature by analyzing authors who are frequently cited together, suggesting theoretical, methodological, or thematic affinities. The presence of several densely connected clusters, each represented by a distinct color, indicates a diversity of schools of thought or emerging subfields. The central, red cluster brings together fundamental authors in the theory of agricultural technology adoption and rural economics, while the green and blue clusters integrate authors associated with sustainable development, agricultural policies, and rural governance. The presence of an isolated group on the far left, purple, indicates a minority line of research or an alternative approach, possibly from another geographical region or discipline. The co-citation network shows a growing scientific coherence around canonical authors, which indicates the stabilization of the thematic field. However, the fragmentation into several clusters also reflects a lack of transversal integration between technological innovation and associative forms, which often remain treated separately. We believe that strengthening the dialogue between clusters through synthesis research and interdisciplinary works can facilitate the articulation of a unitary paradigm on agricultural innovation in associative contexts, capable of underpinning more efficient and inclusive public policies.

CONCLUSIONS

The bibliometric analysis carried out in this research allowed us not only to explore the quantitative structure of scientific production in the field of agricultural innovation and its associative forms, but also to conduct an in-depth investigation of how knowledge is organized, disseminated and connected internationally. The results obtained from the networks of co-authorship, co-citation, co-occurrence and bibliographic coupling highlight some defining features of the analyzed field.

The literature on agricultural innovation is expanding, but dominated by a few geographical and epistemic centers, especially in the United States, Western Europe and East Asia. Countries from the global South are active mainly in applied and contextual research, but rarely contribute to the formulation of dominant theoretical frameworks, which reflects an imbalance

between the generation and application of knowledge.

Another aspect found shows that, despite a high density of works and active authors, the field suffers from conceptual fragmentation. Clustering by themes, sources and authors highlights a lack of integration between complementary dimensions, such as technological and organizational innovation, digitalization and agricultural cooperation, sustainable development and economic efficiency. This fragmentation affects the theoretical coherence of the field and limits the transferability of results to practice and public policies. Another important observation concerns the absence of standardized terminology, especially regarding associative forms in agriculture. Keywords such as cooperation, farmer organizations, collective action, associative structures are used inconsistently, and this makes it difficult to retrieve information and build a solid thematic core. Also, associative forms are not treated as autonomous vectors of innovation, but rather as secondary or contextual factors.

At the same time, the bibliographic coupling analysis highlighted a lack of common theoretical sources in the specialized literature, which may indicate an emerging, not yet settled field, but also a lack of synthesis works or meta-analyses that connect existing approaches. In this sense, the absence of theoretical “bridges” between applied studies and normative or critical ones is felt, which reduces the literature’s capacity to formulate coherent paradigms for understanding agricultural innovation in associative contexts.

From a methodological perspective, the results indicate a high dependence on local case studies and applied quantitative analysis models, to the detriment of comparative, transnational or historical-institutional approaches, which could contribute to explaining the differences in performance between agricultural cooperation models and levels of innovation adoption.

Last but not least, the bibliometric maps show a desynchronization between scientific production and its applicability in contemporary agricultural policies, especially those promoted at European level. The lack of integration between academic literature and policy documents indicates a gap between theoretical research and the operational dimension of innovation in agriculture.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DIRECTIONS FOR SUSTAINABLE DEVELOPMENT OF TOURISM AND CIRCULAR ECONOMY IN GIURGIU COUNTY, ROMANIA AND THEIR IMPACT ON THE LOCAL ECONOMY

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Abstract

The purpose of this research was to assess the structure and dynamics of tourist accommodation capacity in Giurgiu County during the period 2015–2024 and to identify its implications for the implementation of circular economy principles in local tourism. The analysis followed both the structural characteristics of the market and its potential to support a sustainable development model, based on diversification, efficiency and integration into the local economy. The methodology was quantitative, descriptive-analytical, based on official data from the sources of the National Institute of Statistics. The data set included the total accommodation capacity broken down by type of structure. The processing involved the calculation of absolute and percentage variations, weights by type, as well as synthetic indicators of evolution, coefficient of variation, average annual growth rate, CAGR, and structure, Herfindahl–Hirschman index, Simpson index, Shannon entropy, effective number of types and Pielou equilibrium index. The results highlighted a high and constant concentration of accommodation capacity around the hotel segment, a low typological diversity and an unbalanced distribution between the types of structures. The low coefficient of variation indicated structural stability, and the positive but low CAGR suggested a slow pace of expansion. These characteristics limit the flexibility of the market and reduce the capacity for a balanced distribution of tourist flows and pressure on resources. The resulting conclusions indicate the need for a deliberate transition towards a circular tourism model, capable of reducing the degree of concentration, diversifying the typology of structures and integrating local economic chains. The proposed model, structured on six strategic components, typological diversification, optimizing resource consumption, circular waste management, integration into the local economy, community and tourist involvement, as well as performance measurement and reporting, provides an applicative framework for increasing the resilience and sustainability of tourism in Giurgiu County.

Key words: *circular economy, tourism, sustainable development, Giurgiu*

INTRODUCTION

The circular economy has emerged as a central idea in European and worldwide sustainable development goals in recent decades [2, 20]. By proposing strategies that increase the usable life of resources, stop losses, and maximize the value of goods and materials, it provides an alternative economic model to the linear one, based on the concepts of extract, create, consume, and discard [13]. According to this viewpoint, the circular economy is not just an environmental strategy but also a comprehensive framework for restructuring economic processes that may foster innovation, competitiveness, and community resilience [10, 24].

In tourism, the integration of circular economy principles has a strategic role, as this industry involves a significant consumption of natural and material resources, generates large waste streams and directly influences ecosystems and local communities [14, 18, 21]. Transforming tourism into a circular sector means implementing practices such as reducing energy and water consumption in accommodation units, responsible waste management, sourcing food from local sources, using green infrastructure and developing tourism offers that emphasize the conservation of natural and cultural heritage. [7, 16].

The link between the circular economy and sustainable development in tourism is obvious:

sustainable tourism, based on reuse, efficiency and respect for resources, contributes not only to protecting the environment, but also to creating long-term economic and social benefits [3, 5, 23]. By implementing these ideas, local communities may achieve stable incomes, promote entrepreneurship, and minimize reliance on imports, resulting in a model of balanced economic growth. By making responsible decisions and acting responsibly, tourists also take an active role in the shift towards sustainability [25]. Several studies highlight the need for an integrated strategy when implementing the circular economy in the tourist industry, where communities, public authorities, and economic operators work together to develop local and regenerative value chains [6, 8]. Practices such as reusing materials in the construction and furnishing of accommodation units, reducing water consumption through efficient technologies, or transforming organic waste into locally usable compost have a direct impact on reducing the carbon footprint and improving environmental quality [11, 17].

According to research, the circular economy in tourism encompasses both the sociocultural and technological facets of resource management: heritage conservation, revitalization of traditional crafts and promotion of local products [19]. These elements not only diversify the tourism offer, but also strengthen the cultural identity of the destination, attracting segments of tourists interested in authentic and responsible experiences [12]. Moreover, the specialized literature emphasizes the importance of education and professional training for the success of the transition to circular tourism [1, 4]. Staff in the field must be prepared to adopt and promote sustainable practices, and tourists must be informed and encouraged to actively participate in reducing negative environmental impacts. Eco-certification programs, green labels and awareness-raising campaigns are key tools identified as having a decisive role in changing behaviors and strengthening the circular culture [15].

In Romania, the circular economy has gradually started to be integrated into regional and local development strategies, including in the field of tourism, but the pace of implementation varies significantly between regions [22]. In areas with low or insufficiently exploited tourism potential, such as Giurgiu County, the application of circular economy principles can be a catalyst for revitalizing the sector. By capitalizing on local resources – from natural and cultural heritage to traditional agri-food products – and through the active involvement of the community, tourism can become a driver of economic growth and social cohesion [26]. Giurgiu County, located in southern Romania, benefits from a strategic position on the Danube and the border with Bulgaria, with access to international trade and tourism routes. However, the tourism infrastructure is still limited and tourist flows are modest compared to the existing potential. This backdrop provides a chance to design the development of the tourist sector from the start using circular economy logic, avoiding growth paradigms that have resulted in environmental degradation or economic imbalances in other locations.

The goal of this research is to assess the existing condition of tourism in Giurgiu County based on available statistical data and highlight the ways in which the circular economy principles might assist to the sustainable growth of this sector. In this way, the aim is not only to describe an economic reality, but also to formulate a set of strategic directions that support the transition towards a competitive, sustainable and community-adapted tourism model.

MATERIALS AND METHODS

With the aim of examining the dynamics and structure of Giurgiu County's tourist lodging capacity in relation to the possibility of incorporating the circular economy's tenets, the current study used a quantitative, descriptive-analytical methodology. The database used comes from official statistics published by the National Institute of Statistics for the period 2015–2024 and includes information on the total accommodation capacity, expressed in number of places, broken down by the main types of structures: hotels, tourist and agro-tourism guesthouses, hostels, motels, tourist

villas, campsites, ships and other similar structures.

Data processing involved centralizing and organizing annual series in a tabular format and calculating basic quantitative indicators, such as absolute and percentage variations from one year to the next, the share of each type of structure in the annual total capacity and the average growth rate. To characterize the general evolution, the average annual growth rate, CAGR, and the coefficient of variation, CV, were determined, useful for assessing the stability and trend of the sector during the analyzed period.

The market structure was investigated through established concentration and diversity indicators: the Herfindahl–Hirschman index, HHI, for measuring the degree of concentration by type of structures; the Simpson diversity index, for the probability that two randomly selected units are different; Shannon entropy and the effective number of types, for assessing functional diversity; the Pielou equilibrium index, J, for the uniformity of capacity distribution between types. These indicators were calculated annually, to capture short-term variations, and synthesized over the entire period, to outline a stable structural profile.

The interpretation of the results was carried out by integrating the circular economy perspective, assessing how the degree of concentration, typological diversity and structural balance influence resource consumption, waste management and the potential for integration into local economic chains. Finally, based on the findings, a theoretical-applicative model of circular tourism for Giurgiu County was formulated, structured on six strategic components: typological diversification, optimization of resource consumption, circular waste management, integration into the local economy, community and tourist involvement, continuous performance measurement and reporting. This model is proposed as an adapted response to the identified structural particularities, with the objective of increasing the resilience and sustainability of the local tourism sector.

RESULTS AND DISCUSSIONS

The examination of the growth of tourist accommodation capacity in Giurgiu County is significant not only for analyzing the sector's development potential, but also for finding chances for incorporating circular economy concepts. Data on accommodation structures allow us to understand how the tourist infrastructure has developed over time and how it can be optimized to use resources efficiently, reduce environmental impact and capitalize on local potential. Correlating development trends with energy efficiency measures, responsible waste management and local sourcing can contribute to shaping a sustainable tourism model, adapted to market requirements and community needs.

The analysis of the time series related to the total tourist accommodation capacity (Figure 1) highlights a moderately upward trend in Giurgiu County during the period 2015–2024, with occasional oscillations determined by structural and cyclical factors. From an initial level of 589 accommodation places in 2015, the indicator recorded a sustained increase until 2017 (817 places), which can be associated with initial investments in the tourist infrastructure, including the diversification of the typologies of structures. During the period 2018–2020, the values presented a relative stability, followed by a constant advance until 2023, when the maximum of the period was reached with 952 places. The decrease from 2024 to 873 places reflects processes of temporary withdrawal from the market of some units, changes in classification and adjustments of the nominal capacity for economic or legislative reasons.

From a circular economy perspective, this development is important, as changes in accommodation capacity directly influence the pressure on local resources and determine the need for integrated solutions for managing material and energy flows. The progressive increase in capacity implies both opportunities to attract a larger number of visitors and the responsibility to implement sustainable operating measures, energy efficiency, waste reduction, local sourcing, in order to prevent imbalances between economic potential and environmental resilience. In this sense, planning for the development of

accommodation infrastructure must be correlated with circular economy strategies, so that the expansion of capacity does not generate long-term environmental and social costs.

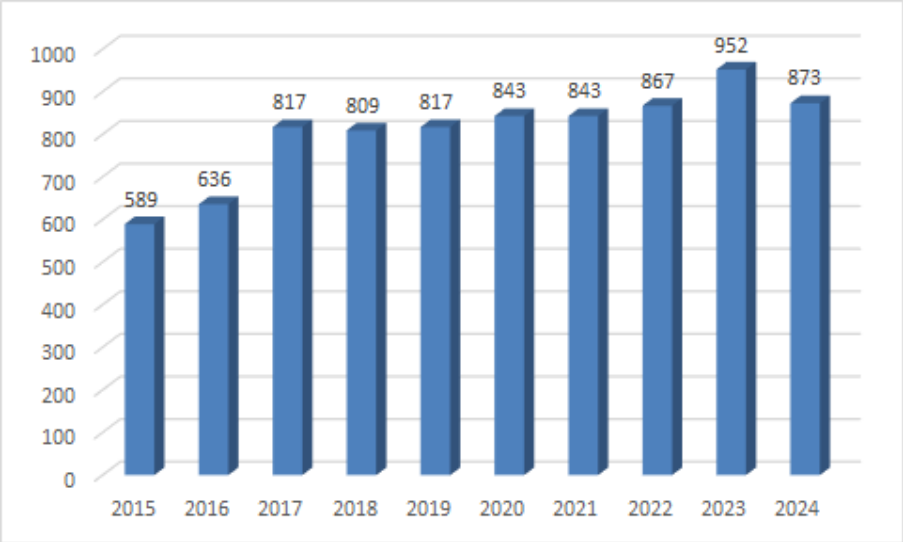


Fig. 1. Evolution of the total existing tourist accommodation capacity in Giurgiu County during 2015-2024 (number of places)
Source: own processing [9].

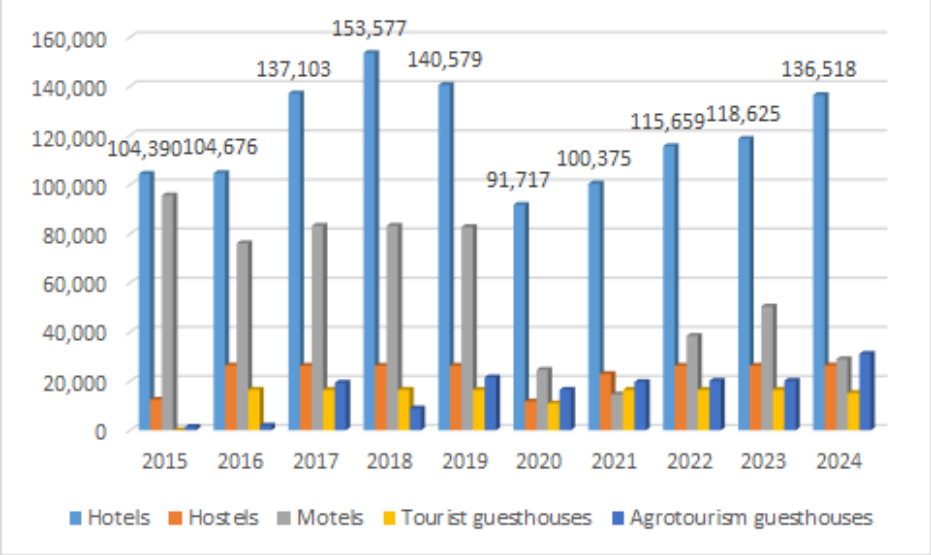


Fig. 2. Accommodation capacity, by type of structure in the period 2015-2024 (number of overnight stays)
Source: own processing [9].

The analysis of the accommodation capacity structure shows a significant concentration of the tourist offer in certain types of units, which outlines the functional profile of the tourism sector in Giurgiu County. Throughout the analyzed period, hotels represented the dominant category, with consistently high shares in the total number of accommodation places, indicating that the local market is mainly oriented towards organized tourism and towards visitor segments that prefer standardized facilities. Motels and guesthouses had a variable, but lower contribution, suggesting a limited diversification of accommodation typologies and a low concentration on alternative forms of tourism, such as agrotourism, ecotourism, etc. The presence of distinctive units, such as lodging ships or other unconventional constructions, indicates the potential to capitalize on natural resources for the creation of differentiated

tourist goods, but their relative share remains modest in relation to the potential of the area.

From a circular economy perspective, the analysis of weights is relevant for sizing the interventions needed to reduce the impact on the environment. For example, hotels, with their large capacity, concentrate higher energy and water consumption, as well as larger volumes of waste, which requires the adoption of energy efficiency practices, selective waste management and the implementation of water saving solutions. Smaller structures, such as guesthouses, can play an important role in stimulating short supply chains and integrating local products and services into the tourism offer, which contributes to strengthening the economic resilience of the community. In the medium and long term, a balanced strategy would involve not only increasing the number of accommodation places, but also adjusting the weights between types, in favor of structures that can more easily implement circular and sustainable operating models. Thus, the diversification of accommodation types, correlated with the integration of green technologies and responsible practices, can contribute to transforming tourism in Giurgiu County into a vector of sustainable development and regional competitiveness.

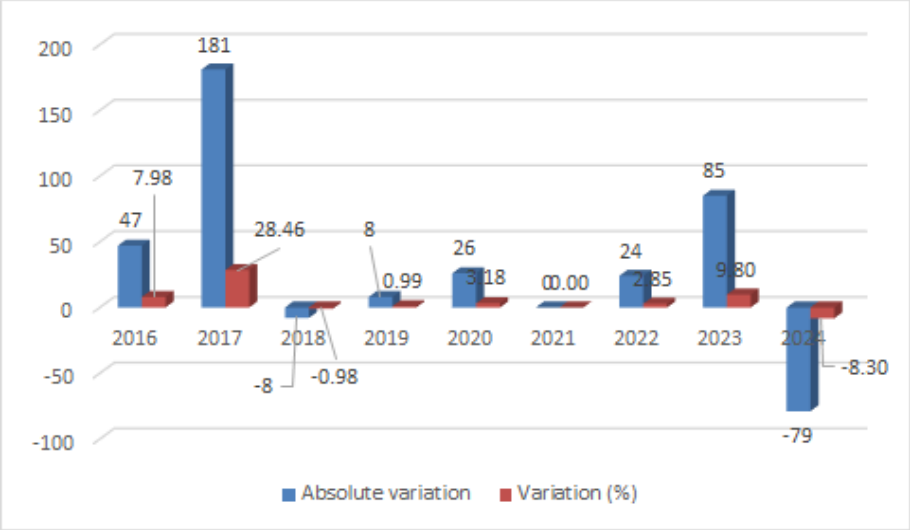


Fig. 3. Evolution of the absolute and percentage variation of the total tourist accommodation capacity in Giurgiu County during 2015-2024
Source: own processing [9].

The analysis of absolute and percentage variations highlights two distinct phases in the evolution of accommodation capacity (Figure 3). The first phase, between 2015 and 2017, is characterized by significant increases, with an absolute advance of over 200 places and an annual growth rate of over 10%, which denotes an accelerated process of infrastructure development. This period most likely coincides with the opening of new structures and the expansion of existing ones, possibly supported by investment programs or non-reimbursable funds. The second phase, between 2018 and 2020, reflects a relative stagnation, with minor fluctuations, followed by a new increase in 2021–2023, culminating in a historical maximum in 2023 (952 places). The decrease in 2024 (-79 places, respectively -8.3%) shows a temporary withdrawal of some units from the tourist circuit or capacity adjustments determined by economic factors, legislative changes or the reorientation of some spaces towards other functions.

From a circular economy perspective, monitoring these variations is essential for planning resource consumption and related infrastructure (water, energy, waste management). Rapid increases require proactive planning to prevent environmental overload, while decreases can create opportunities for ecological rehabilitation and upgrading of facilities to green standards, paving the way for a sustainable tourism model.

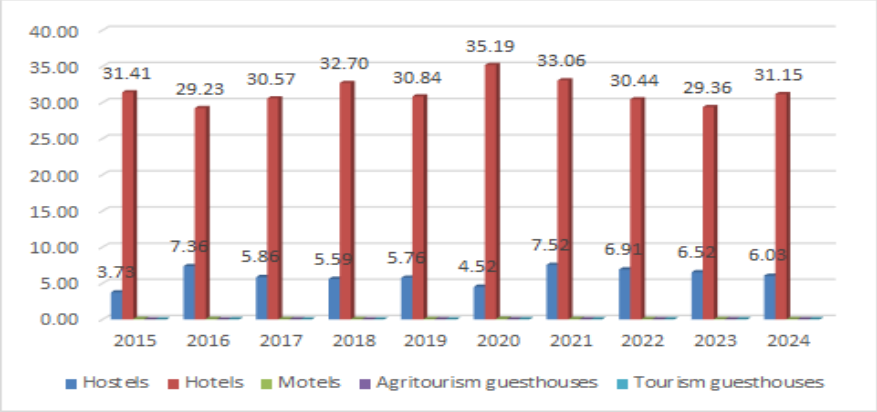


Fig. 4. The share of accommodation units by type in the total tourist capacity in Giurgiu County in the period 2015-2024 (%)
Source: own processing [9].

The structure by type of accommodation units remained relatively stable during the period under review, with the constant predominance of hotels, which hold the largest share in the total number of available places (Figure 4). This configuration indicates a concentration of supply in the classic tourism segment, oriented towards standardized services and a less diversified audience. Pensions, motels and other types of structures (including accommodation ships) had variable but significantly lower shares, which suggests a limited exploitation of the potential for niche, rural or ecological tourism.

From the circular economy point of view, the analysis of weights provides a basis for supply balancing strategies. Hotels, due to their large number of places, also concentrate the highest resource consumption, which requires the implementation of energy efficiency technologies and sustainable management systems. On the other hand, smaller structures, with a low weight, can be developed as responsible tourism poles, integrated into local production and service networks, reducing dependence on external supply chains and increasing local economic resilience.

Diversifying the accommodation structure and increasing the weight of units that adopt circular operating models (use of renewable sources, waste reduction, community involvement) can contribute to creating an image of a sustainable destination for Giurgiu County, with a positive impact on its competitiveness on the tourism market.

The Herfindahl–Hirschman index values for the period 2015–2024 (Table 1) indicate a high concentration of tourist accommodation capacity in Giurgiu County, oscillating between approximately 0.57 and 0.60. This level exceeds the threshold of 0.25 generally considered a signal of a concentrated market, which confirms the dominance of a single category – hotels – in the structure of the offer. In a circular economy logic, this concentration can amplify the impact on resources (water, energy) and waste management infrastructure, given that large structures usually have a more intense and less flexible consumption. The Simpson diversity index and Shannon entropy highlight a low diversity of types of accommodation structures, with values corresponding to an effective number of only 2.1–2.4 active types in weighted terms. This shows that, although there are several registered categories, only two have a significant share in the total capacity. This limited structure reduces the possibilities of adapting supply to demand for alternative forms of tourism (ecotourism, rural tourism, accommodation in units with a low carbon footprint). The Pielou equilibrium index, constantly below 0.8, confirms the uneven distribution of capacity between existing types, which implies a high dependence on the dominant segment. From a circularity perspective, such dependence reduces the resilience of the tourism system: disruptions in the dominant segment can affect the entire sector, and the absorption capacity of sustainable innovations remains limited.

Table 1. Annual indicators of concentration and diversity of the structure of tourist accommodation capacity in Giurgiu County in the period 2015-2024

Year	HHI	Diversity Index Simpson	Entropy Shannon	Number of types	Balance Index Pielou
2015	0.511803	0.488197	0.777054	2.175056	0.482811
2016	0.484892	0.515108	0.849791	2.339157	0.474277
2017	0.494394	0.505606	0.825262	2.282479	0.460587
2018	0.484772	0.515228	0.832372	2.298765	0.464556
2019	0.493841	0.506159	0.824996	2.281873	0.460439
2020	0.478546	0.521454	0.82704	2.286542	0.425015
2021	0.458796	0.541204	0.882439	2.416787	0.453484
2022	0.482334	0.517666	0.849474	2.338416	0.436543
2023	0.494236	0.505764	0.832216	2.298407	0.427675
2024	0.488594	0.511406	0.833684	2.301782	0.465288

Source: own processing [9].

The findings indicate that to shift to a circular tourism model, there is a need to increase the proportion of small and medium-sized businesses that are integrated into local production and consumption chains in order to decrease the degree of concentration. Diversifying the typology of units would allow for the distribution of pressure on resources, encourage the use of local materials and services, and faster implementation of energy efficiency and small-scale waste reduction measures. In addition, a more balanced accommodation structure could support innovation and experimentation with new business models, from the collaborative economy to closed circular systems for resource management.

Table 2. Synthetic statistical indicators of the structure and concentration of tourist accommodation capacity in Giurgiu County

Indicator	Value
CV (total capacity)	0.136
CAGR (total capacity)	0.045
Average HHI	0.487
Min HHI	0.459
Max HHI	0.512
Simpson diversity index (average)	0.513
Shannon entropy (average)	0.833
Effective number of types (average)	2.302
Pielou equilibrium index (average)	0.455

Source: own processing [9].

The synthetic statistical indicators calculated for the period 2015–2024 highlight some essential structural and dynamic features of the tourist accommodation capacity in Giurgiu County (Table 2). The relatively low coefficient of variation, CV, indicates a moderate fluctuation of the total capacity over time, which suggests a stability of the supply in the medium term, without sudden variations determined by massive investments or significant closures of units. The accommodation infrastructure is gradually expanding, as indicated by the positive but modest trend shown by the average annual growth rate, or CAGR. The high average Herfindahl-Hirschman index and the closely spaced minimum and maximum values show a steady supply concentration around a small number of building types, primarily hotels. This characteristic is correlated with the relatively low levels of diversity indices, Simpson and Shannon, which show that although there are several typological categories recorded, their distribution is unbalanced and dominated by a few major segments.

The effective average number of types of structures, of 2.3, and the sub-unit Pielou equilibrium index confirm that the local accommodation market operates almost as a typological oligopoly, which limits both the options for tourists and the capacity of the sector to integrate circular economy practices. From a sustainable development perspective, reduced diversity can mean vulnerability to economic shocks or changes in tourist preferences, as well as a disproportionate concentration of pressure on resources in a few large types of structures.

These findings demonstrate that in order to support the transition to a tourism model based on the principles of the circular economy, local and regional policies that encourage typological diversification, the integration of small and medium-sized businesses into local economic circuits, and the adoption of waste management and energy efficiency technologies at a scale appropriate for each type of structure are all required.

A significant concentration of supply around a small number of unit types, particularly hotels, and a decreased variety of the typology of available structures are highlighted by the study of the structure and dynamics of tourist accommodation capacity in Giurgiu County. From a circular economy perspective, this configuration limits the sector's flexibility in adopting sustainable practices and increases the pressure on resources and infrastructure.

To respond to these challenges, it is necessary to implement a circular tourism model that simultaneously aims to diversify the supply, optimize resource consumption and integrate short supply chains, with the active involvement of the community.

First of all, the typological diversification of accommodation structures is an essential condition. Reducing the degree of concentration and increasing the share of small and medium-sized units – guesthouses, agro-pensiones, ecological campsites, farm accommodation – would contribute to a more uniform distribution of tourist flows and would allow for a more flexible implementation of resource-saving solutions. Small-sized units can more easily adopt modular technologies, adaptable to seasonal requirements and with low energy consumption, such as photovoltaic panels, heat pumps or water recovery systems.

Optimizing resource consumption must become a strategic objective for tourism operators. This involves installing smart water and energy monitoring systems, implementing renewable sources, and promoting efficient lighting and air conditioning solutions. At the same time, integrating sustainable construction standards and using materials with a low carbon footprint can reduce the long-term environmental impact of tourism infrastructure.

Circular waste management is another central component. In practice, this means separate waste collection, composting the organic fraction from food operations, and repurposing materials and equipment when they become unusable. By partnering with local recycling companies and public authorities, accommodation establishments can transform waste streams from a problem into a resource.

Integration into the local economy completes the circular framework. Prioritizing local suppliers for food, construction materials and services not only reduces emissions associated with transport, but also stimulates the economic development of the community. In addition, collaboration with agricultural producers, artisans and cultural operators can lead to the creation of integrated tourism packages with high added value, responding to the demand for authentic experiences.

The involvement of the community and tourists in the transition to circular tourism is essential. Information and education campaigns, facilitating collaborative platforms for the exchange of resources between operators and encouraging responsible behavior among visitors can accelerate the adoption of good practices. At the same time, tourists can become promoters of sustainability through their consumption choices, preferring establishments that apply green standards and services with a low environmental impact.

An effective circular tourism model requires continuous measurement and reporting. Establishing key indicators – average water and energy consumption per tourist, share of recycled waste, degree of local supply – and publishing the results annually would allow monitoring progress and adjusting strategies. This openness can boost market and community trust while encouraging healthy rivalry among industry players.

By putting this approach into practice in Giurgiu County, the tourist industry would be transformed into a force for sustainable development that can distribute financial gains fairly, lessen environmental stress, and boost community resilience to socioeconomic shifts. An integrated strategy built on cooperation, diversity, and efficiency might make local

tourism a useful illustration of how the circular economy's tenets can be implemented.

CONCLUSIONS

The analysis of the structure and dynamics of tourist accommodation capacity in Giurgiu County for the period 2015–2024 reveals a profile characterized by high concentration and low diversity of accommodation unit types. Concentration indicators (HHI) remain at high values throughout the period, indicating a persistent dominance of the hotel segment, while diversity indices (Simpson, Shannon) and balance indices (Pielou) confirm the existence of a typological oligopoly, with only two types of structures having a significant share. The low coefficient of variation and the moderate average annual growth rate (CAGR) suggest a relatively stable market, without major fluctuations, but also with a slow rate of expansion.

From the perspective of the circular economy and sustainable development, this structural configuration has important implications. High concentration limits the flexibility of the tourism sector in adapting to new demands and reduces the capacity for balanced distribution of pressure on natural resources and infrastructure. In addition, low diversity restricts the possibility of developing alternative forms of tourism with a low carbon footprint, such as ecotourism, agrotourism or community tourism.

The circular tourism model proposed in the study provides a strategic direction for the transformation of the local sector, based on six major components: typological diversification of structures, optimization of resource consumption, circular waste management, integration into the local economy, community and tourist involvement, as well as performance measurement and reporting. The application of these principles could lead to a reduction in the degree of concentration, stimulation of the local economy, increased resilience and improved sustainability of the tourism sector in Giurgiu County.

Therefore, the data and analysis carried out indicate the need for a deliberate transition towards a circular tourism, based on diversity and efficiency, in which economic, social and environmental benefits are distributed equitably in the community. The implementation of coherent local policies and strategies, supported by public-private partnerships and the active involvement of all actors in the field, can transform Giurgiu tourism into an example of good practice at regional and national level.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EFFICIENCY OF PIG FATTENING USING FEED WITH LOW-DIGESTIBLE PROTEIN AND ADDING THE AMINO ACID SUPPLEMENT AMINOPRO

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Abstract

The study aimed to assess the economic efficiency in pig fattening using a new feed ration based on a low-digestible protein and adding the amino acid supplement AminoPro. For this purpose, the experiment included different levels and degrees of protein digestibility in diets supplemented with amino acids. In this way, it was possible to evaluate the fattening qualities of hybrid pigs. The experiment was conducted at the "Ryabushkivsky Bacon" pig complex in the Sumy region with F_1 hybrid pigs (VBxL sows x PIC-337 boars). Six groups of 20 pigs, divided by live weight and sex, were fed diets with varying protein digestibility. After a 30-day equalization period, five pigs with extreme weight gains were excluded, leaving 15 animals per group. Over 16 days, pigs were fed either quickly or poorly digestible protein diets with the AminoPro supplement. Dry compound feed was used throughout the experiment. Lightweight piglets on conventional diets with easily digestible protein achieved a final weight of 2.10 kg (1.56%) higher than those with AminoPro. Medium-weight pigs on conventional diets outperformed the experimental group by 2.60 kg (1.84%). Absolute weight gain in pigs fed AminoPro diets was 4.60 kg (6.03%) higher than those on conventional diets. Average daily gains increased by 53 g (6.04%) in medium-weight pigs consuming AminoPro. Feed conversion rations improved in lightweight pigs on conventional diets by 0.07 kg per gain, while medium-weight pigs on AminoPro consumed 0.27 kg less feed per kg of gain. Pigs fed AminoPro diets demonstrated higher fattening quality indices across all weight groups, with significant correlations between initial and final weights. The findings provide valuable insights for optimizing feeding strategies, improving growth performance, and reducing feed costs, contributing to greater profitability in pig production.

INTRODUCTION

The composition of the diet is one of the most critical factors determining the production efficiency in pig farming. Optimal feeding contributes to the rapid growth of pigs and their health, improved meat quality, and reduced environmental impact [30, 33, 35]. Modern livestock farming emphasizes balanced diets that provide the necessary nutrients in optimal ratios [32]. This reduces feed costs and increases animal productivity, which is critically important in the growing demand for high-quality meat [10, 22]. The pigs' diet affects key indicators such as growth rate, feed conversion, health status, and reproductive capabilities. In addition, fine-tuning the composition of feeds using proteins, amino acids, vitamins, and minerals contributes to achieving environmental goals, such as reducing nitrogen emissions. Thus, competent ration formulation is the foundation of

sustainable and profitable pig farming [23, 24, 31].

Any modification to the feeding system influences the efficiency of pig rearing and fattening [21].

The protein content in a pig's diet is a crucial factor in determining growth and overall productivity [33]. As a primary source of essential amino acids, protein plays a vital role in muscle tissue development, metabolic regulation, and maintaining overall animal health [3, 13]. Maintaining an optimal protein level in the diet ensures maximum live weight gain, whereas both deficiencies and excesses can have adverse effects on productivity [15, 29]. A diet with a high protein content promotes active muscle mass gain, especially in young pigs in the initial stages of fattening. However, excessive amounts of protein can be inefficiently utilized by the body, leading to increased feed costs and nitrogen emissions into the environment. This can reduce production profitability and create environmental problems [14, 18]. Low protein levels in the diet lead to slower growth rates, lower feed conversion, and a weakened immune system. Pigs spend more energy on maintaining essential body functions than on growth, which negatively affects performance and increases the duration of fattening [9, 25].

Balanced protein diets provide optimal growth rates, support animal health, and reduce feed costs [7, 28]. Feed additives such as amino acids (lysine, methionine, threonine) allow for efficient protein absorption even when total crude protein levels are reduced. This ensures rapid muscle mass gain and reduces the negative impact on the environment [5, 15, 19].

The digestibility of protein in the diet is an important factor affecting the growth rate of pigs, as it determines what proportion of the protein consumed can be absorbed by the animal's body to ensure growth, maintain health, and regulate metabolic processes. High protein digestibility ensures more efficient use of nutrients, while low digestibility limits their availability and can lead to reduced gains [6, 16, 38].

Diets with easily digestible proteins contribute to maximum muscle growth, reduced feed consumption, and reduced nitrogen excretion. Amino acids derived from easily digestible protein are used for body protein synthesis, stimulating intensive growth of live weight. Because protein is digested more efficiently, less of it is wasted, which reduces the total amount of feed needed to achieve the desired results. Undigested protein is excreted from the body, which can lead to increased nitrogen emissions into the environment. High protein digestibility minimizes these losses [2, 8, 34, 34]. If protein in the diet has low digestibility, this can lead to reduced growth rates, increased feed consumption, and negative health effects. The pig body does not receive enough essential amino acids, which limits protein synthesis and slows down growth. To compensate for the deficit of available protein, larger feed volumes are required, which increases feeding costs. Undigested protein components can stimulate the development of pathogenic microflora in the intestine, which can cause gastrointestinal disorders. In particular, studies conducted [37] showed that pigs that received diets with low protein digestibility showed a decrease in average daily gains by 15–20% compared to those whose diets contained highly digestible protein. In addition, the feed conversion ratio increased since the animals needed more feed to achieve the desired results.

It was found [28] that low-digestible protein in diets led to accumulating undigested protein residues in the intestine. This stimulated the growth of pathogenic microflora, causing inflammatory processes and digestive disorders, which negatively affected the overall health of the animals and reduced growth rate.

Other studies [11] showed that diets with low protein digestibility increased nitrogen emissions by 20–30%. This created environmental problems and indicated a low efficiency of nutrient use in pig diets.

According report [26], young pigs with diets with low-digestible protein had significantly slower growth rates and delays in reaching slaughter weight. This is due to insufficient available amino acids for muscle tissue synthesis.

According to research [17], farmers who used cheaper protein components with low digestibility suffered losses due to the need to

increase the amount of feed by 10–15%. As a result, the cost of feeding became higher than when using high-quality protein components.

The digestibility of protein in the diet directly affects the growth rate of pigs. Diets with high digestibility provide efficient absorption of amino acids, contributing to maximum growth, reduced feed costs, and reduced environmental impact. On the contrary, low digestibility limits animal productivity and increases production costs [27].

To manage the growth rate of pigs with different initial weights, diets are adapted: for lighter animals, the protein and energy content is increased, and for heavier ones, it is reduced to avoid fat accumulation [1, 4]. In the case of a deficiency of natural protein, amino acid supplements are used to increase the digestibility of the diet, stimulate growth, and reduce feed costs [12].

The addition of limiting amino acids, such as lysine, methionine, threonine, and tryptophan, increases the efficiency of protein use, reduces the need for expensive protein feeds, and optimizes diets at different stages of pig development [17]. Amino acids help control the ratio of proteins and fats in animals and improve meat quality, making it leaner and more attractive to consumers [20].

Research into the use of indigestible protein with the addition of amino acids in pig fattening is relevant due to its significant impact on economic efficiency, livestock productivity, and environmental sustainability. Modern market conditions require reducing production costs, optimal use of resources, and minimizing environmental impact. At the same time, the increasing dependence on synthetic additives and the risk of ration imbalances highlight the need for accurate feed balancing and assessment of their impact on animal health and performance.

Research on this topic will help develop scientifically based recommendations for the efficient use of resources in pig farming, which is important for the industry's sustainable development in the face of modern economic and environmental challenges.

The study aims to determine the effectiveness of using indigestible protein by adding amino acids in fattening pigs to ensure optimal performance and reduce feed costs.

MATERIALS AND METHODS

To accomplish the study's objectives, an experiment was carried out to evaluate the fattening performance of F1 hybrid pigs, produced by crossing breed sows (GW×L) with terminal high-yielding PIC-337 boars. The research took place at the industrial pig farming complex LLC "RYABUSHKIVSKY BAKON" in Sumy region, Sumy district, under conditions involving varying levels and degrees of protein digestibility in the diet (Table 1).

The experiment accounted for different initial weights at the start of fattening and the pigs' sex. The animals were divided into six groups of 20 pigs each, with varying live weights during a 30-day equalization period in the enterprise's fattening facilities.

During the equalization period, all livestock received the same regular diet. Upon completion of the equalization period, five pigs with growth retardation and excessive gain were removed from each group.

During the next 16 days of fattening, the pigs were fed the same feed as during the equalization period to achieve a target weight of 110 kg.

On the 47th day of fattening, all animals were divided into groups based on live weight and kept in pens of 15 animals on a solid slatted floor at a rate of 1.04 m^2 per animal until the 87th day, after which they were sent for slaughter.

The first three groups of 15 animals each, I – with an average weight of 58 kg, II – with an average weight of 66 kg, III – with an average weight of 77 kg, were fed with diets containing easily digestible protein (Table 2).

Table 1. Research scheme

Groups	I	II	III	IV	V	VI
First equalization period						
Number of animals in the group, pig	20	20	20	20	20	20
Duration, days	30	30	30	30	30	30
Ration	Normal diet					
Second equalization period						
Number of animals in the group, pig	15	15	15	15	15	15
Duration, days	16	16	16	16	16	16
Ration	Normal diet					
Experimental period						
Number of animals in the group, pig	15	15	15	15	15	15
Duration, days	41	41	41	41	41	41
Ration	A ration with highly absorbable protein.	A ration with highly absorbable protein.	A ration with highly absorbable protein.	A feeding regimen containing low-digestibility protein and the AminoPro additive	A feeding regimen containing low-digestibility protein and the AminoPro additive	A feeding regimen containing low-digestibility protein and the AminoPro additive
Average weight at the beginning of fattening, kg	58	66	77	58	66	77

Source: own calculations.

Table 2. Composition of compound feeds for fattening pigs

Ingredient	Control Composition I	Experimental Composition II
Quantity of compound feed	1,000	1,000
Barley	246	214
Wheat	250	250
Corn	300	300
Bran	54	100
Soybean meal	130	115
Novacid	1	1
Chalk	7	7
Salt	4	4
Monocalcium phosphate	4	4
Trace elements	0.6	0.6
Vitamins	0.15	0.15
Kenzaim	0.278	0.278
Hadox	0.1	0.1
Betasorb	0.5	0.5
Lysine	2.25	2.25
Methionine	0.2	0.2
Aminoton		1
Licetin	0.2	0.2

Source: own calculations.

The remaining pigs were distributed according to their weight in the same way: Group IV – animals weighing 58 kg, Group V – pigs weighing 66 kg, VI – animals weighing 77 kg. The pigs of groups IV, V and VI, which were kept in a group pen of 15 animals, were fattened using feed with low protein digestibility, but with the addition of the feed additive AminoPro under other, identical housing conditions for the specified time (Table 3).

Table 3. Composition of the AminoPro feed vitamin supplement for fattening pigs

Ingredients	Units	Quantity
Vitamin A, min	MO	25,000.00
Vitamin D_3, min	MO	3,750.00
Vitamin E, min	mg	62.50

Source: own calculations.

The primary difference between the feeds lay in the proportion of indigestible and easily digestible protein, with the digestibility of the latter being adjusted through the influence of the AminoPro feed additive.

Throughout the experimental period, all groups were fed a dry compound feed produced on-site. It was formulated using BMVD as a base, supplemented with finely chopped formula

ingredients, and manually distributed twice daily via an automatic feeder (60×30×600 cm) with partitions, allowing fifteen pigs to feed simultaneously. After distribution, the feed was moistened in the drinker at a ratio of 1 part feed to 2 parts water (Photo 1). The amount of feed at each distribution corresponded to the fat content, age, daily requirements of the pigs and the specified intensity of average daily weight gain and allowed ad libitum consumption between each distribution.

It is important to mention that the daily feed mixing rate was continuously monitored by assessing the leftover feed in the feeders. As the pigs grew, the feed amount was gradually adjusted in response to their increasing consumption. The feed intake was recorded for each group by calculating the difference between the distributed feed mixture and the remaining feed after 24 hours.



Photo 1. General view of pig fattening sections
Source: Original.

Watering was carried out using nipple drinkers. Manure removal was done through underfloor baths with a drain frequency every 42 days. The microclimate of the premises was provided by supply-exhaust ventilation with air circulation through fans in window openings, drawing air into the interior of the premises in the warm season and extracting it in the cold.

The experiment results were biometrically processed using the MS Office Excel 2016 program. The reliability of differences between the mean values of the groups was determined using the Student t-test.

Any handling of experimental pigs met the requirements of EU legislation regarding their humane use during animal experiments. All procedures and manipulations during the experiment were aimed at avoiding the pain and suffering of the pigs.

The hypothesis suggests that incorporating feeds containing indigestible protein along with the AminoPro supplement in fattening pigs enhances both absolute and average daily weight gains compared to traditional feeds. This, in turn, leads to higher fattening productivity and improves the overall efficiency of pig farming operations.

RESULTS AND DISCUSSIONS

The most significant statistical differences were found in average daily gain, relative gain, age at reaching 100 kg, and feed consumption for groups with an average initial weight at the start of fattening (Table 4). Regarding the final weight at the end of fattening, piglets with medium initial weight consuming hard-to-digest protein with an amino acid supplement showed a 4.1 kg (2.89%) increase ($p<0.05$) compared to those consuming feed with easily digestible protein. Additionally, both light-weight gilts and medium-weight piglets exhibited a higher average daily gain: light-weight gilts gained 16 g (1.81%) more ($p<0.05$), while medium-weight piglets and gilts gained 63 g (7.11%) ($p<0.05$) and 56 g (6.34%) ($p<0.05$) more, respectively. Piglets with average initial weight whose feed contained the AminPro supplement showed a 4.0% ($p<0.05$) higher relative gain compared to piglets with normal feed.

Both the lightweight gilts and the lightweight boars fattened on the experimental diet reached a weight of 100 kg faster than their peers consuming feed with easily digestible protein, by 12.0 days (8.96 %) ($p<0.05$) and 11.1 days (8.34 %) ($p<0.05$) respectively.

The analysis of feed consumption per kilogram of gain revealed higher values for this indicator in piglets with average initial weight, which were fed a diet with easily digestible protein, compared to those that received an amino acid supplement, with a difference of 0.27 kg (5.64%). Additionally, medium-weight pigs fed a standard diet had a 0.25 kg (5.24%) higher feed conversion ratio than those on the experimental diet. Other factors, such as initial and final weight, absolute gain, and feed consumption in groups of pigs with low and high initial weights at the start of fattening, did not show significant statistical differences, but only a trend toward differences in fattening performance.

Table 4. Fattening performance of pigs at different initial weights and different diets during fattening

Groups	I	II	III	IV	V	VI
	Weight at the beginning of fattening. Kg					
Boars	58.1±0.04[a]	65.9±0.10[a]	72.2±1.01[a]	58.0±0.51[a]	64.2±0.43[a]	69.9±0.35[a]
Gilts	58.2±0.07[a]	65.1±0.22[a]	71.1±1.10[a]	57.3±0.56[a]	63.3±0.38[a]	69.4±0.69[a]
	Weight at the end of fattening. Kg					
Boars	135.0±0.67[a]	142.1±0.52[a]	148.5±2.13[a]	133.4±1.81[a]	146.2±1.85[b]	146.1±1.73[a]
Gilts	134.8±0.91[a]	141.3±0.75[a]	146.8±1.91[a]	132.6±2.14[a]	143.8±2.01[a]	145.3±1.70[a]
	Absolute gain. G					
Boars	77.1±0.47[a]	77.1±0.61[a]	77.1±1.10[a]	76.2±1.76[a]	81.9±1.36[a]	76.3±2.01[a]
Gilts	76.5±0.91[a]	75.9±0.33[a]	75.7±2.94[a]	75.2±1.90[a]	80.5±1.72[a]	76.0±2.26[a]
	Average daily gain. G					
Boars	885±0.01[a]	886±0.01[a]	883±0.02[a]	885±0.01[a]	949±0.02[b]	881.0±0.03[a]
Gilts	884±0.01[a]	883±0.01[a]	879±0.03[a]	868±0.02[b]	939±0.02[b]	871.0±0.02[a]
	Relative growth. %					
Boars	79.9±0.37[a]	73.8±0.29[a]	68.9±1.43[a]	79.8±1.18[a]	78.8±0.83[b]	71.0±1.63[a]
Gilts	79.2±0.56[a]	73.7±0.32[a]	69.4±1.41[a]	79.0±1.17[a]	77.7±0.85[b]	70.6±1.74[a]
	Number of days in fattening					
Boars	87.0	87.0	87.0	87.0	87.0	87.0
Gilts	87.0	87.0	87.0	87.0	87.0	87.0
	Age of reaching 100 kg weight. Days					
Boars	133.9±0.54[a]	126.9±0.63[a]	121.9±1.65[a]	121.9±2.08[a]	124.0±1.60[a]	125.2±1.47[a]
Gilts	133.1±0.89[a]	127.3±0.68[a]	122.8±2.36[a]	122.0±2.21[b]	125.2±1.76[a]	122.9±1.41[a]
	Feed consumption per 1 kg of gain. Kg					
Boars	4.77	4.78	4.79	4.84	4.51	4.79
Gilts	4.72	4.77	4.75	4.80	4.52	4.78

Notes: Different lowercase letters (a, b) indicate statistical difference between fattening parameters at the $p<0.05$ level or higher.
Source: own calculations.

A two-factor analysis of variance was conducted to evaluate the impact of initial weight and diet on the fattening characteristics of pigs (Fig. 1). The analysis revealed that only relative gain was significantly affected by these factors, with the initial weight contributing 78.5% and the diet contributing 3.6%. However, there was no such dependence observed for absolute and daily gains. The age at which pigs reached a live weight of 100 kg was influenced by the initial live weight by 83.1%, while the final weight was influenced by the initial weight by 82.6%, with no effect from the other factors.

Comparing the performance of the groups of lightweight pigs fed the easily digestible protein diet and low-starting pigs fed the poorly digestible protein diet supplemented with AminoPro, the initial weight in both groups was the same at 58.0 kg.

The final weight of the pigs in the first group was 1.6 kg (1.2%) higher (135.0 kg vs. 133.4 kilograms). The cost of fattening pigs in the fourth group was 2.2 EUR (2.4%) higher, and the feed cost was 1.6 EUR (2.4%). The income of the lightweight pigs was 2.9 EUR (1.2%) higher, and the profit was 5.1 EUR (3.5%). The profitability in the first group was 1.4% higher than in the fourth (62.4% and 61.0%) (Table 5).

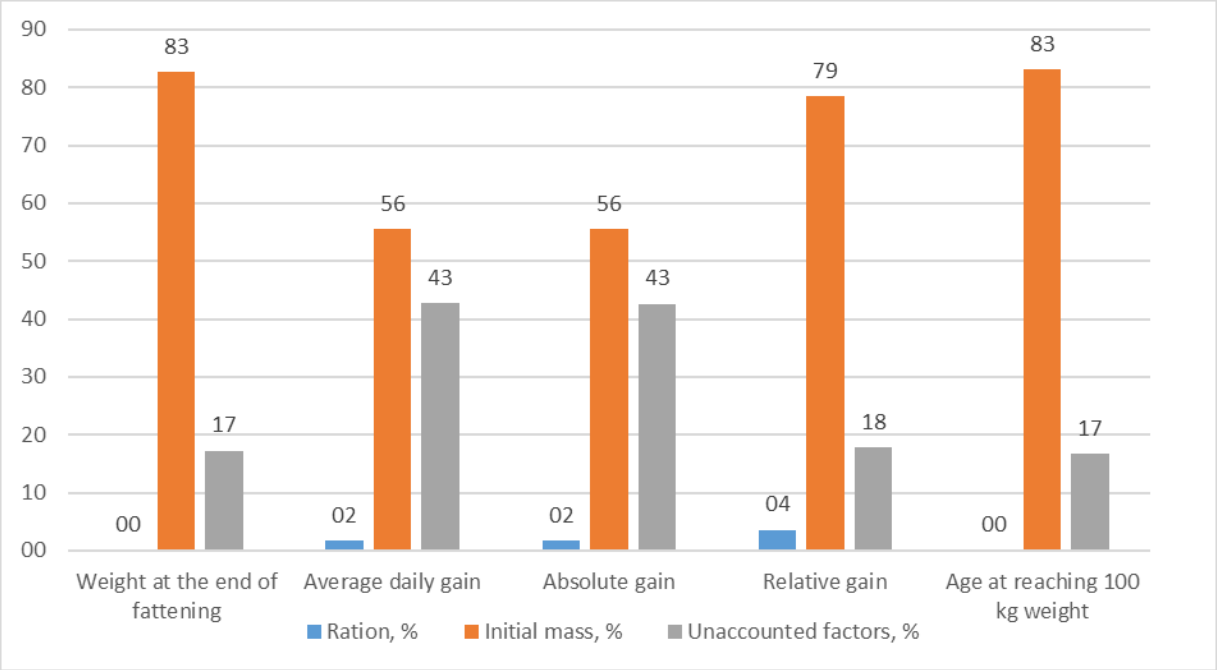


Fig. 1. The influence of weight at the beginning of fattening and diet on the fattening qualities of pigs
Source: own calculations.

Table 5. Economic efficiency of fattening pigs when using easily digestible and difficult-to-digest protein in the feed

Indicator	I	II	III	IV	V	VI
	A ration with highly absorbable protein			A feeding regimen containing low-digestibility protein and the AminoPro additive		
Initial live weight, kg	58.0	66.0	77.0	58.0	66.0	77.0
Live weight price, EUR/kg	1.8	1.8	1.8	1.8	1.8	1.8
Cost of fattening 1 pig in the experiment, EUR	90.7	95.5	103.8	92.9	97.5	104.3
Including the cost of feed spent on fattening 1 pig, EUR	67.2	70.8	76.9	68.8	72.2	77.2
Percentage of feed spent on fattening in the total cost of 1 pig, %	74.1	74.1	74.1	74.1	74.1	74.1
Average live weight at the end of fattening, kg	135.0	142.1	148.5	133.4	146.2	146.1
Income from the sale of one piglet (excluding VAT), EUR	241.1	253.8	265.2	238.2	261.1	260.9
Profit from fattening 1 pig, EUR	150.4	158.2	161.4	145.3	163.6	156.6
Profitability of fattening 1 pig, %	62.4	62.3	60.9	61.0	62.7	60.0

Source: own calculations.

The average-weight pigs fed the easily digestible protein, and their counterparts fed the indigestible protein and AminoPro supplement had the same initial weight of 66.0 kg. However, the average weight of pigs on the experimental feed had a final weight that was 4.1 kg (2.9%) higher (146.2 kg vs. 142.1 kg). The cost of fattening in group 5 was 2.0 EUR (2.1%) higher, and the feed cost was 1.4 EUR (2.0%). The income in the fifth group was 7.3 EUR (2.9%) higher than in the second, and the profit was 5.4 EUR (3.4%). The profitability in the fifth group was 0.4% higher than in the second (62.7% vs. 62.3%).

A comparison of heavy pigs fed conventional feed and counterparts fed the indigestible protein with AminoPro supplement showed that their initial weight was the same - 77.0 kg. However, the final weight of pigs in the third group was 2.4 kg (1.6%) higher (148.5 kg vs. 146.1 kg). The cost of fattening in the sixth group was 0.5 EUR (0.5%) higher, and the feed cost was 0.3 EUR (0.4%) higher. The income in the third group exceeded the similar indicator in the sixth by 4.3 EUR (1.6%), and the profit by 4.8 EUR (3.1%). The profitability of fattening in the third group was 0.9% higher (60.9% vs. 60.0%).

Thus, medium-weight pigs receiving the experimental feed recorded the highest profitability and cost-effectiveness indicators.

In general, our results confirm the importance of a rational approach to the design of pig diets, considering both initial live weight and the use of protein supplements.

As reports [1] mention, the diet should consider the animals' initial weight to ensure optimal growth and avoid excessive fat accumulation. In our studies, the average daily gain was significantly higher in pigs of the medium-weight group fed hard-to-reach proteins with amino acid supplements. In particular, the gain in these animals was 63 g (7.11 %) higher in boars and 56 g (6.34 %) higher in gilts, which is consistent with the statement that optimizing the protein content in the diet promotes intensive growth of muscle mass [17].

According to [37], low available protein without amino acids can reduce animal performance and prolong the fattening period. According to our data, using experimental feed shortened the time to reach 100 kg by 12.0 days (8.96%) in gilts and 11.1 days (8.34%) in boars in the lightweight group. These results show that adding amino acids makes it possible to compensate for the inadequacies of hard-to-access protein and increase its digestibility and performance.

Similar to the widely reported data [7] that a balanced diet helps to reduce feed costs, we found confirmation of the statement that feed costs per 1 kg gain were 0.27 kg (5.64 %) lower in medium-weight pigs fed diets containing amino acids than in pigs fed easily digestible protein. This our finding indicates the economic feasibility of using protein supplements.

In our study, the relative gain was 4.0 higher in medium-weight boars fed a hard-to-access protein with amino acids, confirming the role of amino acids in stimulating growth, similar to the results of [28], which indicates that the balance of amino acids and proteins ensures an effective increase in muscle mass.

Therefore, most of our results align with the literature sources and confirm the effectiveness of using hard-to-access proteins with amino acid supplements to increase pig performance, especially in pigs with an average initial weight.

CONCLUSIONS

The inclusion of hard-to-digest proteins along with the amino acid supplement AminoPro enhances pig productivity by increasing average daily gain, shortening the time to reach a live weight of 100 kg, and reducing feed costs per unit of gain.

At the start of fattening, piglets in the average weight group that received these proteins with amino acids demonstrated significantly higher weight gains, reached slaughter weight more quickly, and required less feed per kilogram of gain. The use of cheaper protein components in combination with amino acid supplements reduces feeding costs without compromising animal productivity.

The initial live weight of pigs plays a key role in determining feeding efficiency and weight gain. Animals with an average weight at the beginning of fattening showed the best results in terms of productive indicators.

The highest profitability and cost-effectiveness rates were recorded in medium-weight pigs fed a feed of indigestible protein supplemented with AminoPro. However, this feed did not provide a positive economic effect on financial indicators in light-weight and heavy-weight pigs.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SUNFLOWER CULTIVATION TECHNOLOGY OPTIMIZING BASED ON THE "GENOTYPE*PLANT DENSITY" INTERACTION IN YIELD

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Abstract

The optimization of crop technologies is a continuous necesity, driven by theintroduction of new genotypes, changing climatic and soil conditions, farm sustainability. The study analyzed the performance of 23 sunflower genotypes (G1 to G23), cultivated in three densities (Ad – 40,000 plt ha^{-1}; Bd – 60,000 plt ha^{-1}; Cd = 80,000 plt ha^{-1}). The field experiment was located in the specific conditions of the Western Plain of Romania, within the ARDS Lovrin, agricultural year 2023 – 2024. The mean yield value was $\overline{Y_{Ad}}$ = 2,006.71 kg ha^{-1}, (Ad plant density), $\overline{Y_{Bd}}$ =2,293.29 kg ha^{-1}, (Bd plant density) and $\overline{Y_{Cd}}$ = 2,298.39 kg ha^{-1} (Cd plant density). A several-samples test confirmed significant differences between densities (Ad, Bd, Cd), and within each group (p = 0.00549). Dunn's post hoc Test validated the differences between Ad and Bd, respectively Ad and Cd. In the Ad group seven genotypes presented values above the mean, with statistical safety, G6, G8 (p<0.05), G23 (p<0.01), and G15, G19, G20, G21 (p<0.001). In the Bd group, six genotypes performed above the group mean, G8 (p<0.05), G10 (p<0.01), G19, G20, G21, and G23 (p<0.001). In the Cd group seven genotypes performed above the group mean, G8 (p<0.05), G4, G9, G19, G20, G21, and G23 (p<0.001). According to Cluster and Ranking analysis, in relation to all three densities, the genotypes G21, G20, G19, G23, G8 and G6 were grouped in the upper quartile. In some genotypes performing at any density (e.g. G21, G20), small differences in yield between densities were recorded, so choosing the density with lower input costs of biological material, at equal performance, is recommended.

Key words: *comparative analysis, crop management, genotype performance, plant density, sunflower, technologies optimization, yield*

INTRODUCTION

The optimization of agricultural technologies remains a constant focus for farmers, researchers, input suppliers, service providers, and agricultural consultants. This is due to the ever-changing nature of production factors and environmental conditions [10, 11, 29, 37].
Starting with the biological material, newly introduced genotypes have specific biological potential to respond to nutritional and vegetative factors, photosynthetic capacity, and yield potential. These genotypes will also respond differently to technological inputs [13, 15, 36, 43].
Understanding the interaction between "genotype × environment × technology" is essential for selecting the appropriate genotypes for specific regions and for adjusting their requirements in relation to target yields [4, 8, 32, 35].
Changing climate conditions lead to water deficits and heat stress during certain growth stages of crops, which in turn influences how technological inputs are used and impacts final yields [23, 30, 33, 39, 40, 41, 42].
The costs associated with achieving sustainable yields are also of interest, varying by type of agricultural system, farm category, and farmer profile [2, 16, 25].
Controlling input use in crop technologies is crucial for optimizing the production process, reducing crop-specific costs, enhancing farmer performance, and ensuring farm sustainability [5, 18, 26, 45].
Among agricultural crops, sunflower is a crop of major importance globally, in Europe, and particularly in Romania [7, 31, 34, 38]. The dynamics of sunflower cultivation have been analyzed in relation to various factors – especially ecological and economic – that have influenced the cultivated area, yields, and the

sunflower production market [1, 19, 22, 30, 44].

New sunflower genotypes have been developed and introduced into cultivation, and testing them under different agricultural systems, pedoclimatic conditions, and cultivation technologies is essential [3, 6, 9, 14].

In order to optimize sunflower cultivation technologies, this study evaluated the performance of 23 sunflower genotypes grown at three different plant densities. Through a comparative yield analysis, the study identified optimal density variants and high-performing genotypes as a result of the "genotype × plant density" interaction.

MATERIALS AND METHODS

This study comparatively analyzed 23 sunflower genotypes cultivated at three different plant densities, focusing on yield performance. The field experiments were located within the ARDS Lovrin, in specific pedoclimatic conditions of the Western Plain of Romania. The comparative trial was set up on flat terrain, with chernozem soil, under non-irrigated conditions. The climatic conditions during the experimental period are presented in Figure 1.

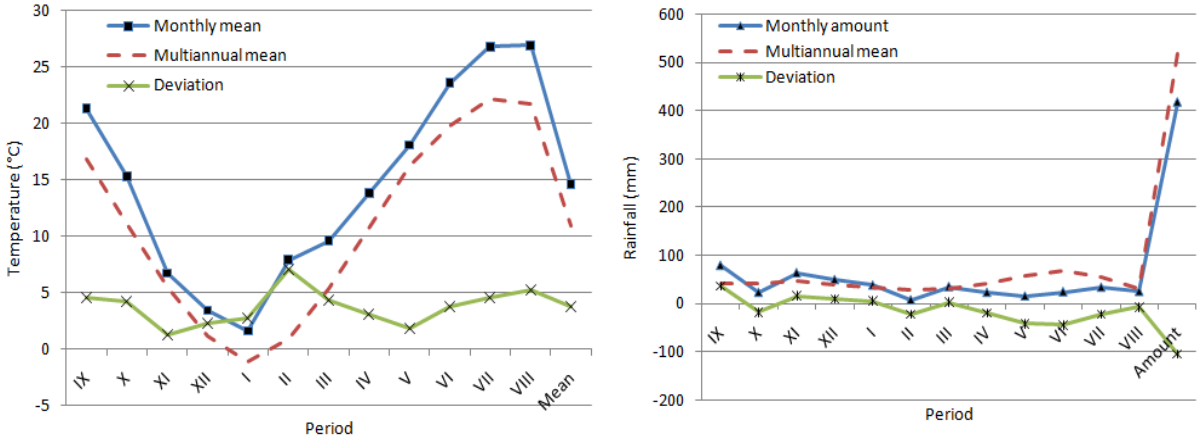


Fig. 1. Climatic conditions
Source: ARDS Lovrin Weather Station.

The sunflower genotypes used in this study were provided by ARDS Lovrin's collaboration partners: Bayer ('Hudson' – G1), Corteva ('P64HE144' – G2; 'P64HE244' – G3; 'P64LE280' – G4; 'P64LE163' – G5; 'P64LE162' – G6), KWS ('Suvex' – G7; 'Arnetes' – G8), Mass Seed ('MAS 85 SU' – G9; 'DT 3402TT' – G10), NOVI SAD ('24AN44LE' – G11; '24AN19LE' – G12; '24AN65LE' – G13), Novi Sad Institute ('NS H 8002' – G14; 'NS H 8005' – G15; 'NS Kruna' – G16; 'NS Ronin' – G17; 'NS Sanol HO' – G18), Syngenta ('Subaro HTS HO' – G19; 'Sureli HTS' – G20; 'Subeo' – G21; 'Suomi' – G22; 'NX 32122' – G23); G1 to G23 represent the genotype codes used in this article. Each genotype was cultivated under three plant density variants: 40,000 plt ha^{-1} (Ad), 60,000 plt ha^{-1} (Bd), 80,000 plt ha^{-1} (Cd); Ad, Bd, and Cd are the density codes referenced in this article. The soil was prepared using a conventional system (plowing followed by discing and a combinator pass). Sowing was carried out at the optimal time, in early April. Specific technological operations were applied uniformly across all plots. At physiological maturity (BBCH code 99) [24], harvesting was performed mechanically. Yield data were recorded for each genotype and plant density.

The experimental workflow, data analysis, and interpretation of results were conducted according to the schematic diagram shown in Figure 2.

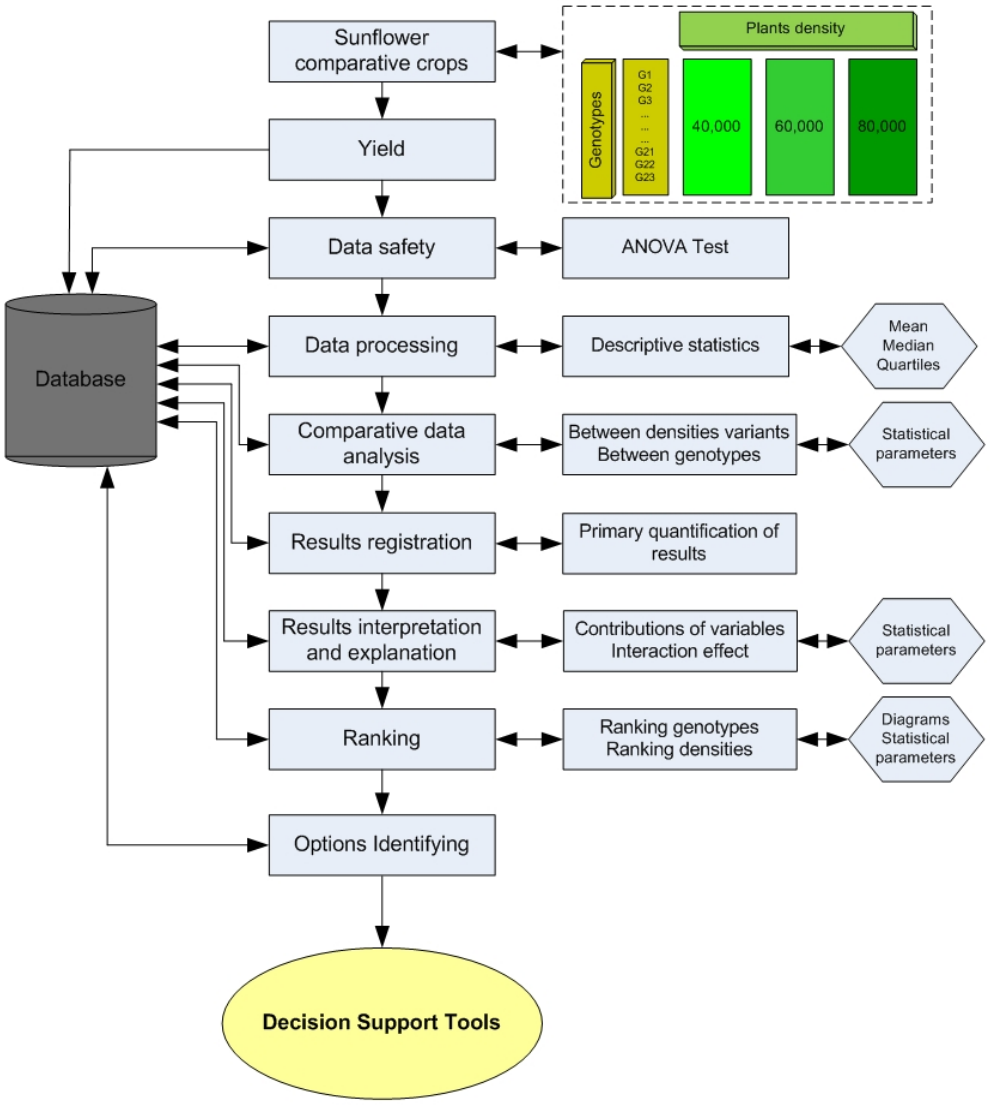


Fig. 2. Workflow diagram
Source: Original.

The recorded yield data were analyzed using mathematical and statistical methods to compare the performance of the genotypes at each planting density, as well as across the three cropping systems defined by those densities. Data analysis was conducted using PAST software [12] and Microsoft Excel's calculation modules.

RESULTS AND DISCUSSIONS

Yield values were recorded for each sunflower hybrid, at the three plant densities (Ad, 40,000 plt ha^{-1}; Bd, 60,000 plt ha^{-1}; Cd, 80,000 plt ha^{-1}). The presence of variance within the dataset, as well as the reliability of the experimental data, was confirmed through ANOVA testing, as shown in Table 1.

Table 1. ANOVA Test results

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	6,260,119	22	284,550.85	10.052	7.94E-11	1.789
Columns	1,282,110	2	641,054.95	22.645	1.73E-07	3.209
Error	1,245,580	44	28,308.63			
Total	8,787,809	68				

Source: Original data.

The performances resulting from the three sunflower planting densities, as well as the performance of each hybrid within each density level, were comparatively analyzed. The mean yield value, at the Ad density level (40,000 plt ha^{-1}), was $\overline{Y_{Ad}}$ = 2,006.71 kg ha^{-1}, at the Bd density level (60,000 plt ha^{-1}) was $\overline{Y_{Bd}}$ = 2,293.29 kg ha^{-1}, and at the Cd density

level (80,000 plt ha^{-1}) was $\overline{Y_{Cd}}$ = 2,298.39 kg ha^{-1}.

The calculated mean values showed differences between the three culture densities (as mean values). The performance generated by the culture densities was analyzed comparatively (Ad with Bd; Ad with Cd; Bd with Cd) through several types of tests.

According to the pairwise comparative analysis (each variant with each), the Bd density variant performed better compared to the Ad variant, with a difference of ΔY = 286.58 kg ha^{-1} ($p<0.001$), and the Cd variant performed better compared to the Ad variant, with a difference of ΔY = 291.68 kg ha^{-1} ($p = 0.0001$), (Table 2). In the case of the comparative analysis of the Bd and Cd variants, a difference of ΔY = 5.09 kg ha^{-1} (for the Cd variant) resulted, but without statistical certainty ($p = 0.9096$), (Table 2).

Table 2. Two-sample paired test

Parameter	Ad	Bd	Ad	Cd	Bd	Cd
Mean	2,006.71	2,293.29	2,006.71	2,298.39	2,293.29	2,298.39
Median	1,960.00	2,257.10	1,960.00	2,325.70	2,257.10	2,325.70
Mean diff	286.58		291.68		5.09	
t	-7.1819		-4.7170		-0.1148	
95% confidence	(203.83 369.34)		(163.44 419.92)		(-86.928 97.116)	
p	3.37E-07		0.0001		0.9096	

Source: Original data.

Comparative analysis by ANOVA, Several-samples Test, and the values in Table 3 resulted.

Table 3. Test for equal means results for sunflower density variants

Parameter	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	1.28E+06	2	641,061	5.637	0.005493
Within groups:	7.51E+06	66	113,722	Permutation p (n=99999)	
Total:	8.79E+06	68	0.0057		

Source: Original data.

The results showed that there were significant differences between groups (culture densities), as well as within each group (Ad, Bd, Cd) given the culture density, ($p = 0.005493$).

Within this analysis, according to Dunn's post hoc, the values in table 4 resulted, which validated the differences in the case of comparisons between the density variants Ad and Bd, and Ad and Cd, respectively. In contrast, the differences between the Bd and Cd variants were not confirmed (Table 4).

Table 4. Dunn's post hoc Test results for densities

	Ad	Bd	Cd
Ad		0.0043	0.0023
Bd	0.0043		0.8427
Cd	0.0023	0.8427	

Source: Original data.

The results confirmed the justification of Bd and Cd densities compared to Ad density. In contrast, the results showed that Cd density compared to Bd density was not justified, under the study conditions, through additional input costs (higher seeding quantity per sowing), given that the yield increase (ΔY) was insignificant.

Following confirmation of the differences within the groups (Ad, Bd, Cd), table 3, the performance of each hybrid in each crop density was analyzed, tables 5, 6, and 7. Within the Ad density, the comparative analysis of the performance of the hybrids led to the results in table 5. Compared to the mean yield value at Ad density ($\overline{Y_{Ad}}$ = 2,006.71 kg ha^{-1}), seven genotypes presented values higher than the mean, with statistical certainty, $p<0.05$ (G6, G8), $p<0.01$ (G23), respectively $p<0.001$ (G15, G19, G20, and G21). Seven genotypes recorded values lower than the mean, with statistical certainty (Table 5).

Within the Bd density (60,000 plt ha^{-1}), the comparative analysis highlighted the performance of the hybrids, according to table 6. Compared to the mean yield value at the Bd density level ($\overline{Y_{Bd}}$ =2,293.29 kg ha^{-1}), six genotypes presented values higher than the mean, with statistical certainty, $p<0.05$ (G8), $p<0.01$ (G10), respectively $p<0.001$ (G19, G20, G21, and G23). Seven genotypes recorded values lower than the mean, with statistical certainty (Table 6).

Table 5. Comparative analysis of genotypes under Ad density conditions (40,000 plt ha^{-1})

Genotype	Given mean:	Sample mean:	95% conf. interval:	Difference:	95% conf. interval:	t:	p (same mean):	Significance
G1	1,662.86			-343.850	(185.66 502.04)	4.5079	0.0002	ooo
G2	1,857.14			-149.570	(-8.6207 307.76)	1.9609	0.0627	ns
G3	1,822.86			-183.850	(25.659 342.04)	2.4103	0.0247	o
G4	1,960.00			-46.707	(-111.48 204.9)	0.6123	0.5466	ns
G5	1,798.57			-208.140	(49.949 366.33)	2.7287	0.0123	o
G6	2,182.86			176.150	(17.964 334.34)	-2.3094	0.0307	*
G7	2,045.71			39.003	(-119.19 197.19)	-0.5113	0.6142	ns
G8	2,171.43			164.720	(6.5345 322.91)	-2.1595	0.0420	*
G9	1,611.43			-395.280	(237.09 553.47)	5.1822	<0.001	ooo
G10	1,937.14			-69.567	(-88.621 227.76)	0.9120	0.3716	ns
G11	1,411.43			-595.280	(437.09 753.47)	7.8042	<0.001	ooo
G12	1,857.14	2,006.7	(1,848.5 2,164.9)	-149.570	(-8.6207 307.76)	1.9609	0.0627	ns
G13	1,920.00			-86.707	(-71.481 244.9)	1.1367	0.2679	ns
G14	2,000.00			-6.707	(-151.48 164.9)	0.0879	0.9307	ns
G15	2,405.71			399.000	(240.81 557.19)	-5.2310	<0.001	***
G16	1,605.71			-401.000	(242.81 559.19)	5.2571	<0.001	ooo
G17	2,005.71			-0.997	(-157.19 159.19)	0.0131	0.9897	ns
G18	1,708.57			-298.140	(139.95 456.33)	3.9086	0.0008	ooo
G19	2,314.29			307.580	(149.39 465.77)	-4.0325	0.0006	***
G20	2,731.43			724.720	(566.53 882.91)	-9.5012	<0.001	***
G21	3,005.71			999.000	(840.81 1157.2)	-13.0970	<0.001	***
G22	2,005.71			-0.997	(-157.19 159.19)	0.0131	0.9897	ns
G23	2,222.86			216.150	(57.964 374.34)	-2.8338	0.0097	**

Source: Original data.

Table 6. Comparative analysis of genotypes under Bd density conditions (60,000 plt ha^{-1})

Bd	Given mean:	Sample mean:	95% conf. interval:	Difference:	95% conf. interval:	t :	p (same mean):	Significance
G1	2,091.43			-201.860	(58.158 345.57)	2.9132	0.0081	oo
G2	2,348.57			55.278	(-88.426 198.98)	-0.7978	0.4335	ns
G3	2,285.71			-7.582	(-136.12 151.29)	0.1094	0.9139	ns
G4	2,257.14			-36.152	(-107.55 179.86)	0.5217	0.6071	ns
G5	2,120.00			-173.290	(29.588 317)	2.5009	0.0203	o
G6	2,382.86			89.568	(-54.136 233.27)	-1.2926	0.2096	ns
G7	2,394.29			101.000	(-42.706 244.7)	-1.4576	0.1591	ns
G8	2,451.43			158.140	(14.434 301.84)	-2.2822	0.0325	*
G9	1,971.43			-321.860	(178.16 465.57)	4.6450	0.0001	ooo
G10	2,514.29			221.000	(77.294 364.7)	-3.1893	0.0042	**
G11	1,560.00			-733.290	(589.59 877)	10.5830	<0.001	ooo
G12	2,142.86	2,293.3	(2,149.6 2,437)	-150.430	(6.7282 294.14)	2.1710	0.0410	o
G13	2,165.71			-127.580	(-16.122 271.29)	1.8412	0.0791	ns
G14	2,360.00			66.708	(-76.996 210.41)	-0.9627	0.3462	ns
G15	2,228.57			-64.722	(-78.982 208.43)	0.9340	0.3604	ns
G16	2,102.86			-190.430	(46.728 334.14)	2.7482	0.0117	o
G17	1,971.43			-321.860	(178.16 465.57)	4.6450	0.0001	ooo
G18	1,862.86			-430.430	(286.73 574.14)	6.2118	<0.001	ooo
G19	2,645.71			352.420	(208.71 496.12)	-5.0859	<0.001	***
G20	2,874.29			581.000	(437.29 724.7)	-8.3847	<0.001	***
G21	3,017.14			723.850	(580.14 867.55)	-10.4460	<0.001	***
G22	2,200.00			-93.292	(-50.412 237)	1.3464	0.1919	ns
G23	2,797.14			503.850	(360.14 647.55)	-7.2713	<0.001	***

Source: Original data.

Within the Cd density (80,000 plt ha^{-1}), the comparative analysis highlighted the performance of the hybrids, according to Table 7. Compared to the mean yield value at the Cd density level ($\overline{Y_{Cd}}$ = 2,298.39 kg ha^{-1}), seven genotypes presented values higher than the mean, with statistical certainty, $p<0.05$ (G8), respectively $p<0.001$ (G4, G9, G19, G20, G21, and G23). Seven genotypes recorded values lower than the mean, with statistical certainty (Table 7).

Table 7. Comparative analysis of genotypes under Cd density conditions (80,000 plt ha^{-1})

Cd	Given mean:	Sample mean:	95% conf. interval:	Difference:	95% conf. interval:	t :	p (same mean):	Significance
G1	2,194.29	2,298.4	(2,163.8 2,433)	-104.100	(-30.526 238.72)	1.6036	0.1231	ns
G2	2,320.00			21.614	(-113.01 156.24)	-0.3330	0.7423	ns
G3	2,377.14			78.754	(-55.869 213.38)	-1.2132	0.2379	ns
G4	2,560.00			261.610	(126.99 396.24)	-4.0302	0.0006	***
G5	2,371.43			73.044	(-61.579 207.67)	-1.1252	0.2726	ns
G6	2,325.71			27.324	(-107.3 161.95)	-0.4209	0.6779	ns
G7	2,240.00			-58.386	(-76.236 193.01)	0.8994	0.3782	ns
G8	2,480.00			181.610	(46.991 316.24)	-2.7978	0.0105	*
G9	2,651.43			353.040	(218.42 487.67)	-5.4387	<0.001	***
G10	2,337.14			38.754	(-95.869 173.38)	-0.5970	0.5566	ns
G11	1,760.00			-538.390	(403.76 673.01)	8.2939	<0.001	ooo
G12	2,120.00			-178.390	(43.764 313.01)	2.7481	0.0117	o
G13	1,891.43			-406.960	(272.33 541.58)	6.2692	<0.001	ooo
G14	2,422.86			124.470	(-10.149 259.1)	-1.9175	0.0682	ns
G15	2,154.29			-144.100	(9.4735 278.72)	2.2198	0.0370	o
G16	1,914.29			-384.100	(249.47 518.72)	5.9170	<0.001	ooo
G17	2,000.00			-298.390	(163.76 433.01)	4.5967	0.0001	ooo
G18	1,662.86			-635.530	(500.9 770.15)	9.7903	<0.001	ooo
G19	2,680.00			381.610	(246.99 516.24)	-5.8788	<0.001	***
G20	2,760.00			461.610	(326.99 596.24)	-7.1112	<0.001	***
G21	2,811.43			513.040	(378.42 647.67)	-7.9035	<0.001	***
G22	2,234.29			-64.096	(-70.526 198.72)	0.9874	0.3342	ns
G23	2,592.29			293.900	(159.28 428.53)	-4.5276	0.0002	***

Source: Original data.

Some genotypes showed statistically significant differences compared to other genotypes only under certain plant density conditions, while other genotypes showed significant differences compared to other genotypes consistently across all plant density conditions.

Dunn's post hoc test on yield data across all three plant density conditions, analyzed concurrently (together), showed genotypes that performed consistently with clear and statistically significant differences compared to other genotypes (Table 8 -bold values).

Multivariate analysis broke down the distribution of the 23 sunflower genotypes, in relation to the three plant densities (Ad, Bd, and Cd) (Figure 3). Component PC1 explained 83.776% of total variance, and component PC2 explained 12.62% of total variance. Some genotypes were associated with a certain density, and other genotypes were positioned intermediate between densities (e.g. G19, G20, G21, G23) depending on yield performance. There were also genotypes that were positioned independently of the three densities, with lower performances, regardless of crop density (Figure 3).

The two-way cluster analysis grouped the two categories of factors, density (Ad, Bd, Cd) and sunflower genotypes (23 genotypes), based on similarity, with Coph.corr. = 0.742 (Figure 4). In the case of densities, the association of Bd with Cd and the separate position of Ad density were observed. In the case of genotypes, these were associated in different subclusters, within the dendrogram (Figure 4).

Table 8. Dunn's post hoc Test results for genotype

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23
G1		0.4638	0.4700	0.3041	0.7066	0.1963	0.3041	0.1148	0.7141	0.2763	0.2674	0.9432	0.9270	0.2461	0.4098	0.6691	0.4154	0.2461	0.2763	0.2461	0.2587	0.6617	0.4700
G2	0.4638		0.9919	0.7679	0.7217	0.5757	0.7679	0.3984	0.7141	0.7217	0.0655	0.5084	0.4098	0.6691	0.6915	0.2419	0.4393	0.1195	0.2034	0.0626	0.9351	0.5149	0.0545
G3	0.4700	0.9919		0.7602	0.7294	0.5688	0.7217	0.3927	0.7141	0.7217	0.0670	0.5149	0.6397	0.6617	0.6840	0.2461	0.4454	0.1220	0.1998	0.0612	0.9432	0.7066	0.2339
G4	0.3041	0.7679	0.7602		0.5149	0.7914	1.0000	0.5827	0.5084	0.9513	0.7602	0.3388	0.2630	0.8948	0.9190	0.1429	0.2853	0.0640	0.3287	0.1171	0.0801	0.7066	0.3706
G5	0.7066	0.7217	0.7294	0.5149		0.3598	0.5149	0.2299	0.9919	0.4763	0.1374	0.7602	0.6397	0.4333	0.4515	0.4156	0.6765	0.2299	0.1035	0.0265	0.0163	0.7835	0.1220
G6	0.1963	0.5757	0.5688	0.7914	0.3598		0.7914	0.7757	0.2260	0.0163	0.1374	0.2221	0.1664	0.8948	0.8707	0.0837	0.1826	0.0343	0.4763	0.1928	0.1374	0.5215	0.5281
G7	0.3041	0.7679	0.7602	1.0000	0.5149	0.7914		0.5827	0.5084	0.3545	0.8387	0.3388	0.2630	0.8948	0.9190	0.1429	0.2853	0.0640	0.3287	0.1171	0.0801	0.7066	0.3706
G8	0.1148	0.3984	0.3927	0.5827	0.2299	0.7757	0.5827		0.2260	0.6253	0.9513	0.1321	0.0952	0.6765	0.6544	0.0439	0.1057	0.0163	0.6691	0.3089	0.2299	0.3545	0.7294
G9	0.7141	0.7141	0.7217	0.5084	0.9919	0.4763	0.5084	0.2260		0.4700	0.8387	0.7679	0.6470	0.4274	0.4454	0.4215	0.6840	0.2339	0.1014	0.0259	0.0159	0.7757	0.1195
G10	0.2763	0.7217	0.7141	0.9513	0.4763	0.8387	0.9513	0.6253	0.4700		0.0280	0.3089	0.2379	0.9432	0.9675	0.1269	0.2587	0.0558	0.3598	0.1321	0.0912	0.6617	0.4041
G11	0.2674	0.0655	0.0670	0.7602	0.1374	**0.0163**	**0.0326**	**0.0072**	0.1401	**0.0280**		0.2379	0.3089	0.0233	0.0252	0.5019	0.2853	0.7757	0.0018	0.0002	0.0001	0.0784	0.0024
G12	0.9432	0.5084	0.5149	0.3388	0.7602	0.2221	0.3388	0.1321	0.7679	0.3089	0.2379		0.8707	0.2763	0.2900	0.6109	0.9109	0.0532	0.0361	0.0116	0.0068	0.5619	0.0640
G13	0.9270	0.4098	0.2630	0.2630	0.6397	0.1664	0.2630	0.0952	0.6470	0.2379	0.3089	0.8707		0.2107	0.2221	0.7294	0.9594	0.4638	0.0361	0.0072	0.0041	0.4576	0.0439
G14	0.2461	0.6691	0.6617	0.8948	0.4333	0.2221	0.8948	0.6765	0.4274	0.9432	0.0233	0.2763	0.2107		0.9756	0.1102	0.2299	0.0472	0.1514	0.0024	0.0057	0.6109	0.4454
G15	0.6915	0.2419	0.3927	0.8948	0.2299	0.8948	0.8948	0.6544	0.4454	0.9675	0.0252	0.2900	0.2221	0.9756		0.1171	0.2419	0.0508	0.1429	0.0013	0.0093	0.6325	0.4274
G16	0.6617	0.1102	0.2461	0.0837	0.4515	0.1429	0.0837	0.0439	0.4215	0.1269	0.5019	0.6109	0.7294	0.1102	0.1171		0.6915	0.6990	0.0146	0.0024	0.0013	0.2763	0.0182
G17	0.4454	0.6840	0.4454	0.2853	0.6765	0.1826	0.2853	0.1057	0.6840	0.2587	0.2853	0.9109	0.9594	0.2299	0.2419	0.6915		0.4333	0.0408	0.0084	0.0048	0.2419	0.0496
G18	0.2461	0.2419	0.2461	0.6840	0.2299	0.1826	0.1429	0.0558	0.4215	0.1269	0.7757	0.0116	0.0072	0.1514	0.1429	0.6990	0.4333		0.0047	0.0006	0.0084	0.6325	0.1401
G19	0.4154	0.2419	0.2461	0.6840	0.2299	0.1826	0.1429	0.0439	0.4215	0.1269	0.5019	0.6109	0.7294	0.1102	0.1171	0.6915	0.4333	0.0047		0.0024	0.0013	0.2763	0.0182
G20	0.6691	0.2419	0.2461	0.6840	0.2299	0.1826	0.1429	0.0439	0.4215	0.1269	0.5019	0.6109	0.7294	0.1102	0.1171	0.6915	0.4333	0.0047	0.0024		0.0013	0.2763	0.0182
G21	0.2763	0.0626	0.1998	0.3287	0.1035	0.4763	0.3287	0.1014	0.3598	0.1321	0.0558	0.2587	0.1664	0.0640	0.0508	0.2034	0.1998	0.0640	0.2034	0.1028		0.0335	0.1928
G22	0.9351	0.5551	0.5551	0.8547	0.5551	0.4393	0.3927	0.3706	0.6691	0.5014	0.3598	0.8547	0.4393	0.6109	0.5551	0.4393	0.5551	0.4393	0.4393	0.5551	0.8547		0.5019
G23	0.0545	0.2339	0.2299	0.3706	0.1220	0.5281	0.3706	0.7294	0.1195	0.4041	0.0024	0.0640	0.0439	0.4454	0.4274	0.0182	0.0496	0.0060	0.9351	0.0520	0.5019	0.2034	

Source: Original data.

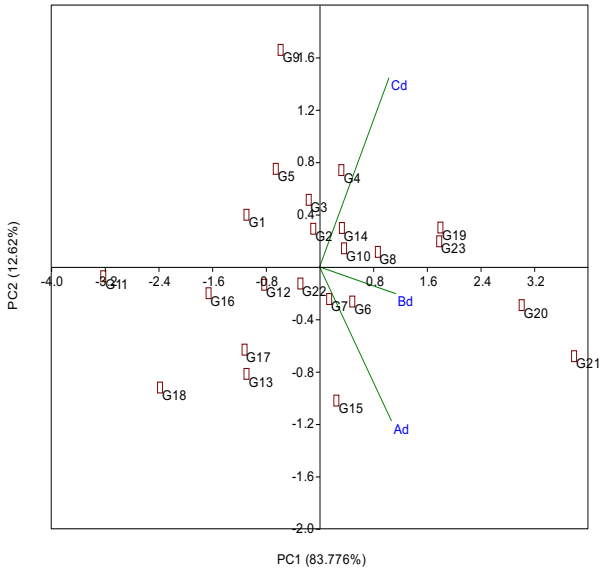


Fig. 3. PCA diagram, correlation, in relation to plant crop densities (Ad, Bd, Cd – as biplot)
Source: Original diagram.

In cluster C1, four high-performing genotypes were positioned in terms of yield, marked with warm colors (red – orange, predominant), according to the dendrogram legend.

The G21 genotype stood out with high performance, followed by the G20 genotype, grouped in a subcluster (G20,G21), with the SDI value = 313.5, cluster C1. In the same cluster (C1), the G19 and G23 genotypes were also positioned, with similar results, SDI = 196.56, subcluster (G19,G23).

Cluster C2 included 19 genotypes, grouped in different subclusters. The genotypes with the lowest yield values in all three densities were included in the subcluster (G11,(G16,G18)), on the right of the dendrogram, marked with cold colors (blue in different intensities), according to the dendrogram legend.

The other genotypes were positioned in the middle area of the dendrogram. With low yield performance, and invariably in relation to the sowing density, the genotype G17 was observed (Y = 2,005.71 kg ha^{-1} in Ad; Y = 1,971.43 kg ha^{-1} in Bd; Y = 2,000.00 kg ha^{-1} in Cd).

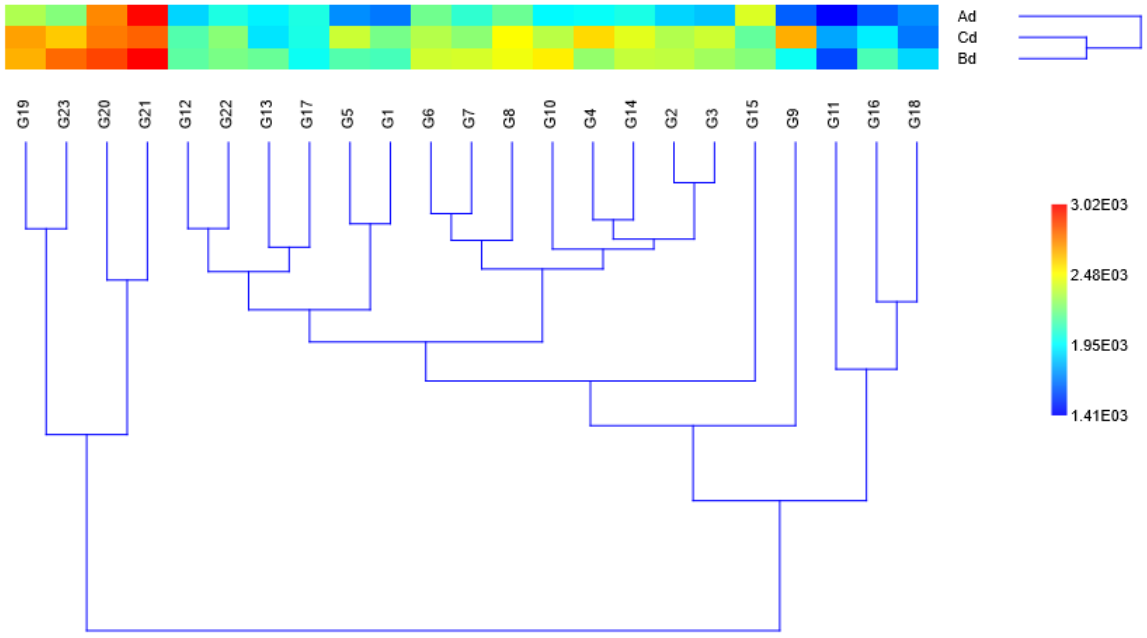


Fig. 4. Cluster dendrogram, with representation of density groups and genotypes based on similarity
Source: Original dendrogram.

Genotype rankings were made (descending order of yield performance), in relation to yield performance, at each seeding density as well as an overall one. In relation to Ad density (40,000 plt ha^{-1}), the genotypes G21, G20, G15, G19, G23, and G6 were grouped in the upper quartile. In relation to Bd density (60,000 plt ha^{-1}), the genotypes G21, G20, G23, G19, G10, and G8 were grouped in the upper quartile. In relation to Cd density (80,000 plt ha^{-1}), the genotypes G21, G20, G19, G9, G23, and G4 were grouped in the

upper quartile. In relation to the general situation, across all three densities, the genotypes G21, G20, G19, G23, G8 and G6 were grouped in the upper quartile.

The constant position of two genotypes on the first two positions (G21, followed by G20) in all rankings was observed. This showed the high performance of the two genotypes, regardless of the plant density. At the same time, it was observed that the yield differences between the three densities were minor, so that the cost difference due to the higher sowing rate at Bd and Cd densities would not be justified in the case of the two genotypes (G21, and G20). Similarly, other genotypes were identified.

Plant density in sunflower is important for crop performance and has been studied in relation to plant physiological indices [17], crop irrigation under mulching conditions [20], production under precision farming conditions [27], crop performance and yield compensation [28], and yield optimization [21].

Sunflower crop showed the capacity to compensate for yield in relation to plant density, either in conditions of density towards lower limits at sowing, or in conditions in which the high density of the planes was randomly affected (spatial variability) under the influence of some factors [27, 28].

Under the conditions of this study, the studied sunflower genotypes generated differentiated yield values in relation to the three densities ensured by sowing, some genotypes maintained close yield values, and others varied more widely in relation to plant density.

CONCLUSIONS

The sowing densities studied (40,000 plt ha^{-1} – Ad, 60,000 plt ha^{-1} – Bd, and 80,000 plt ha^{-1} – Cd) differentially influenced the 23 sunflower genotypes, under non-irrigated cultivation conditions, under the pedoclimatic conditions of the Western Romanian Plain, the comparative crop experimental field at ARDS Lovrin.

The Bd and Cd densities ensured, on mean, better yields compared to the Ad density, with statistically significant differences, and there were insignificant differences between the Bd and Cd densities (Dunn's post hoc Test).

In the Ad density variant, with mean yield $\overline{Y_{Ad}}$ = 2,006.71 kg ha^{-1}, seven genotypes presented values above the mean, in conditions of statistical safety, G6, G8 ($p<0.05$), G23 ($p<0.01$), respectively G15, G19, G20, and G21 ($p<0.001$).

In the Bd density variant, with the mean Bd yield $\overline{Y_{Bd}}$ =2,293.29 kg ha^{-1}, six genotypes presented values above the mean, in conditions of statistical safety, G8 ($p<0.05$), G10 ($p<0.01$), respectively G19, G20, G21, and G23 ($p<0.001$).

In the Cd density variant, with mean yield $\overline{Y_{Cd}}$ = 2,298.39 kg ha^{-1}, seven genotypes presented values above the mean, in conditions of statistical safety, G8 ($p<0.05$), respectively G4, G9, G19, G20, G21, and G23 ($p<0.001$).

The highest performance was observed for the G21 genotype, followed by the G20 genotype, grouped in a subcluster (G20,G21), with SDI = 313.5. The next best-performing genotypes were G19 and G23, in subcluster (G19,G23) with SDI = 196.56.

ACKNOWLEDGEMENTS

The authors thank Agricultural Research and Development Station-ARDS Lovrin and its partners for facilitating this study.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STUDY ON THE POSSIBILITY OF USING GIS IN THE MANAGEMENT OF AGROTOURISM CATTLE FARMS

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Abstract

This article explores the benefits and use of Geographic Information Systems (GIS) in agrotourism cattle farms management, aiming to highlight their impact on operational efficiency and agricultural sustainability. It presents the process of designing, implementing, and operating a GIS system customized for cattle farms, with details on its integration with modern technologies such as the Internet of Things (IoT), artificial intelligence, cloud computing, augmented reality, and remote sensing. The adopted methodology includes an analysis of how GIS can be used for land and pasture management, animal health monitoring, optimizing feeding, farm infrastructure planning, spatial analysis of assets, tracking animal vaccinations, monitoring staff locations, and disease management. The results obtained demonstrate that the use of GIS for agrotourism cattle farms management significantly improves resource management, reducing costs and risks. The GIS system enables the collection and analysis of geospatial data, providing precise information that aids in making informed decisions. The main conclusion of the research is that the use of GIS in cattle farms is essential for optimizing production and enhancing sustainability. The implementation of this system, combined with emerging technologies, will revolutionize agricultural management, contributing to the creation of more efficient, climate-resilient, and environmentally responsible farms.

Key words**:** *GIS, agrotourism cattle farms management, spatial analysis, livestock behaviour, land use planning*

INTRODUCTION

By integrating and using GIS technologies in agrotourism cattle farms management, they can contribute to a circular economy where resources are used more efficiently, and waste is significantly reduced. Thus, technology not only improves productivity but also helps protect the environment by offering innovative solutions for more sustainable agriculture [10]. Information technologies have had a significant impact on how agricultural activities are managed, and one of the most innovative tools in this field is the Geographic Information System (GIS). It enables the collection, storage, analysis, and visualization of geospatial data, providing farmers with essential information for making informed decisions [1, 5, 8, 13].

GIS represent a set of technologies that combine geospatial data and complex analysis to support decision-making across various fields, including agriculture. Over the past few decades, GIS technology has become an essential tool for farmers worldwide, and its application in cattle farms is a clear example of how technological innovations can transform the way agricultural activities are managed [1, 2, 16]. GIS allows the collection, processing, and analysis of data related to the location and distribution of different resources on the farm, making it possible to obtain critical information about land, animals, infrastructure, and other essential resources for agricultural production.

In an era where agriculture faces significant challenges such as climate change, dwindling natural resources, and increasing production demands, GIS becomes an indispensable tool for improving efficiency and sustainability in farm management. In this context, the use of GIS in cattle farms not only allows for better organization and management of resources but also helps optimize production and improve animal welfare. This has a direct impact on the economic growth of farms, reducing operational costs, and increasing the production of quality milk and meat [1, 10, 11].

Another example of modern technology used is digital feed management, through sensors and

automated systems that monitor the nutritional needs of animals, thereby optimizing feed use and reducing waste. Additionally, the use of smart systems for managing manure [7] allows its transformation into compost or biogas, contributing to soil fertilization or energy generation, instead of becoming a polluting waste.

Furthermore, the constant monitoring of animal health through telemetry technologies and the Internet of Things (IoT) helps prevent diseases, thus reducing the need for chemical treatments and interventions that may harm the environment [2, 14, 9]. These solutions allow for more efficient resource management and more sustainable production.

The use of modern technologies in cattle farms plays an essential role in implementing the principles of the circular economy. In this context, the circular economy involves maximizing the use of resources, minimizing waste, and creating a sustainable system where by-products are efficiently reused and recycled. In cattle farms, innovative technologies significantly contribute to these goals.

In this paper, we will explore the most common scenarios of GIS use in cattle farms, highlighting the interaction with other modern technologies and how this technology contributes to the development of more efficient and sustainable agriculture.

According to [5], "an information system includes technical, organizational, and personnel components, computing techniques, regulations, and imposed methodologies, with the goal of proper and efficient data management, from collection to CRUD operations (create-read-update-delete) and the presentation of final results." Therefore, it must be understood that the implementation and use of a GIS is a process that requires the allocation of financial and human resources both during development and implementation, as well as throughout its operational lifespan and usage.

In the context of modern and sustainable agriculture, any GIS must perform at least four basic functions, which are also applicable in cattle farms: monitoring, control, prediction, and logistics (Fig. 1).

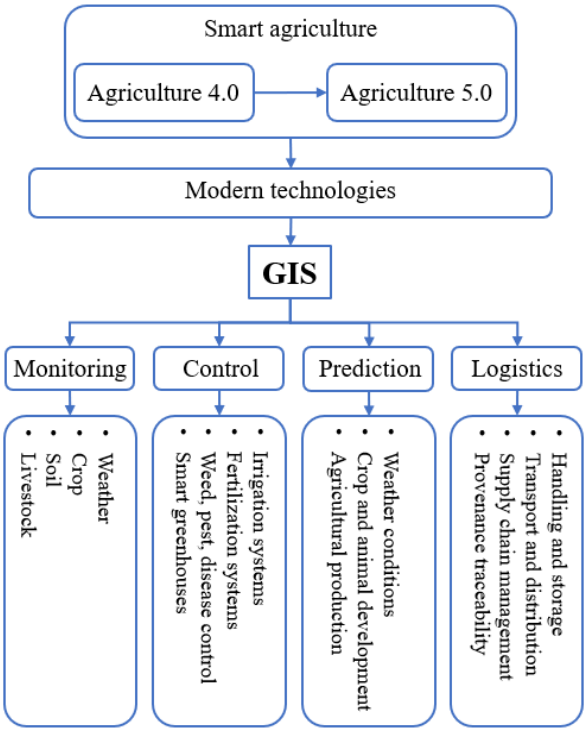


Fig. 1. The use of modern technologies in smart agriculture.
Source: Own elaboration, adapted from [9].

The methodology for designing and implementing a GIS (Fig. 2) involves several essential stages to ensure the effective integration of geospatial technologies into a project [14].

The first stage is the requirements analysis, which involves identifying user needs and defining the objectives of the GIS system. Next, the system architecture is designed, including the selection of the software platform, necessary hardware, and the definition of the data structure. After the design phase, the actual implementation follows, which consists of collecting and processing geographical data and integrating it into a GIS database. After implementation, system testing is crucial to verify its functionality and performance. Finally, user training is carried out, and a plan for system operation, results presentation [13], and system maintenance is established to ensure the long-term update and accuracy of the data.

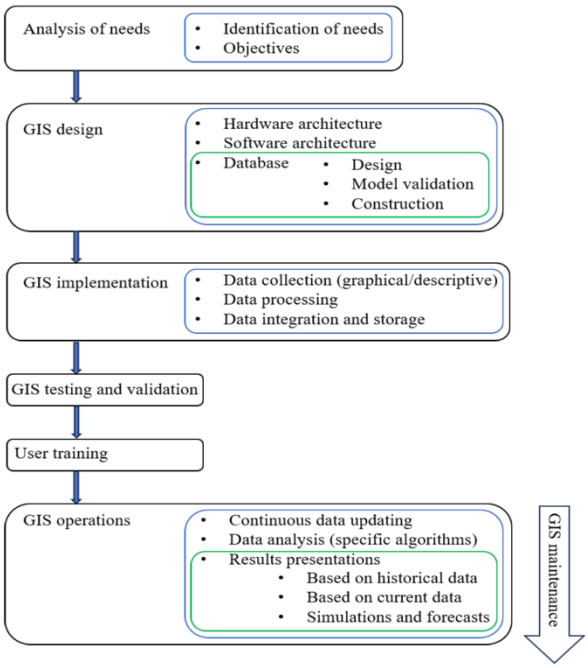


Fig.2. The methodology for designing, implementing, and operating a GIS.
Source: Own elaboration, based on literature review.

In this paper, we aim to analyze the possibility of integrating GIS with innovative technologies and identify the most common scenarios for applying GIS in livestock farm management.

MATERIALS AND METHODS

In this study, we aim to explore the feasibility, utility, and benefits of implementing and using GIS in cattle farm management. GIS provides a data-driven approach for monitoring and optimizing resources, enhancing decision-making in the livestock sector. The study focuses on identifying and analyzing how GIS integrates with advanced technologies. Additionally, it seeks to identify the most applicable scenarios for GIS implementation in cattle farms.

To achieve these objectives, we followed a structured methodology based on documentation, analysis, and direct interaction with industry specialists. The applied methodology is presented in Figure 3.

In the first stage, we established the study objectives. These aimed to identify the most common uses of GIS in cattle farms, its integration with modern technologies, and the evaluation of its impact on farm efficiency and sustainability.

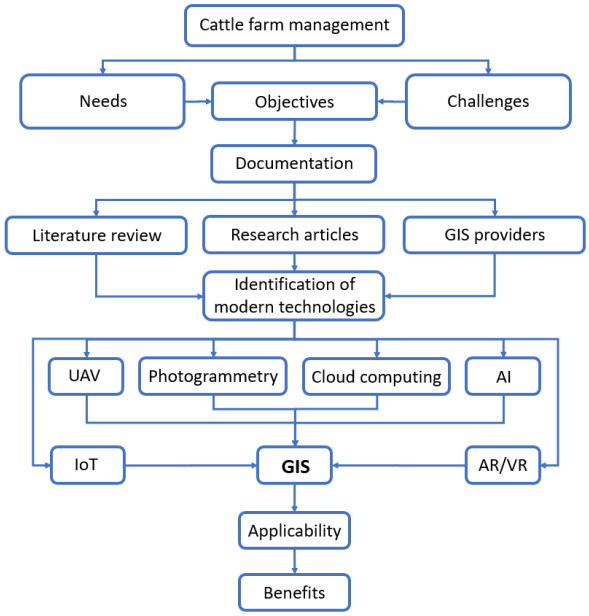


Fig. 3. The research methodology.
Source: Own elaboration, based on literature review.

The second stage involved in-depth documentation through a review of specialized literature and relevant scientific articles (academic databases such as Web of Science and Science Direct). We analyzed case studies and recent research exploring the implementation of GIS in agriculture and animal husbandry, focusing on resource management, feed optimization, animal health monitoring, and pasture management.

In addition to theoretical documentation, direct interaction with industry stakeholders was considered essential. Thus, we conducted discussions with companies that develop and implement GIS solutions for cattle farms. These interactions provided valuable insights into practical challenges, existing solutions, and future perspectives on the use of these technologies.

Based on the collected information, we proceeded to identify modern technologies that work alongside GIS to improve farm management.

The final stage of the study was determining the applicability and benefits of GIS in cattle farm management. Based on the conducted analyses, we determined that GIS contributes to resource optimization, operational cost reduction, productivity improvement, and increased sustainability. We also highlighted

existing challenges, such as high initial costs and the need for user training.

Through this methodological approach, the study provides a clear perspective on how GIS and complementary technologies can transform cattle farm management, supporting data-driven decision-making and optimizing agricultural processes.

RESULTS AND DISCUSSIONS

Definition of GIS and its importance in agriculture

By analyzing the basic characteristics, we can say that GIS is an information system designed to capture, store, analyze, and visualize data that has a geographic component (location) [2, 8, 11]. Through the integration of digital maps with information collected from various sources (such as satellites, soil sensors, mobile devices, and drones), GIS helps users better understand and manage the distribution and dynamics of available resources. In agriculture, this technology is used to track and analyze various aspects such as land use, water management, weather conditions, plant and animal health, and much more [7, 14, 13, 16].

In cattle farms, GIS plays a crucial role in supporting the management of natural resources and infrastructure, helping farmers make informed decisions in real-time [1, 8, 12, 13]. By integrating data on soil and pasture quality, farmers can plan grazing routes more efficiently for their cows, reducing land waste and maximizing production. Similarly, GIS data can be used to track the flow of resources and identify potential problems or inefficiencies in the farm's internal processes.

Integration of GIS with other technologies

GIS have become an essential tool in managing and analyzing geospatial data, widely used in fields such as urban planning, natural resource management, environmental protection, and public safety. These systems allow for the collection, processing, and visualization of geographic data, and their continuous evolution has been closely linked to technological progress. Today, the integration of GIS with other emerging and traditional technologies has opened new horizons in geospatial data analysis, bringing significant benefits to many fields of activity [4, 9, 17].

One of the most obvious examples of GIS integration is its collaboration with *Internet of Things* (IoT) technology [9]. IoT involves the interconnection of devices and sensors that collect real-time data and transmit it to central systems for processing. When this data is integrated into a GIS system, it adds a dynamic dimension to geospatial analysis, enabling decisions to be made more quickly and efficiently. Figure 4 illustrates how IoT interacts with other technological elements and systems.

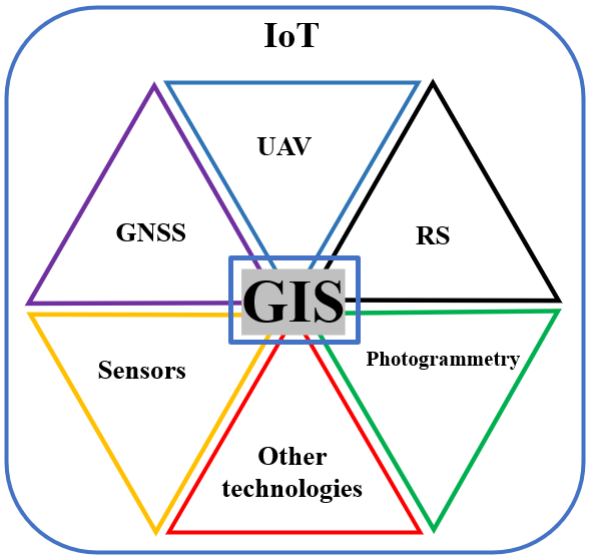


Fig. 4. IoT in the field of agriculture for smart farming.
Source: Own elaboration, based on literature review.

In animal farm management, sensors can be used to monitor soil quality, track weather conditions, place sensors on animals to collect data on their health and behavior, monitor staff locations, etc. Therefore, the integration of IoT with GIS not only improves real-time monitoring but also optimizes the management of stocks and resources.

Another field where GIS has found a natural integration is in *Artificial Intelligence (AI)* [9, 17]. Machine learning algorithms and neural networks, specific to AI, are used to analyze large amounts of data and extract patterns that would be difficult to identify using traditional methods. Within a GIS system, these technologies enable rapid analysis of geospatial data and prediction of long-term events or trends. In the field of natural resource management, AI can analyze geospatial data to

predict high-risk flood areas or assess the effects of climate change on specific ecosystems. AI algorithms can identify hidden patterns in geographic data, helping to make more informed and precise decisions.

Furthermore, *cloud computing technology* has revolutionized the way geospatial data is stored and processed. Instead of relying on local servers, which can be expensive and difficult to maintain, modern GIS platforms can store and process their data on external servers accessible via the internet. This brings significant benefits, especially in the context of large data volumes and collaboration between various organizations or government agencies managing the same geospatial data [3, 9]. For example, in disaster management, government institutions or rescue organizations can share geospatial data in real-time to coordinate interventions. Cloud computing not only reduces infrastructure costs but also enables global data accessibility, facilitating collaboration and information exchange between different entities.

Additionally, the integration of GIS with *augmented reality (AR)* and *virtual reality (VR)* opens up new possibilities for visualizing and interacting with geospatial data [7, 13, 15]. Augmented reality allows digital information to be superimposed on real images (Fig. 5), and in the context of GIS, this can help visualize in real-time how certain projects will impact a geographic area.

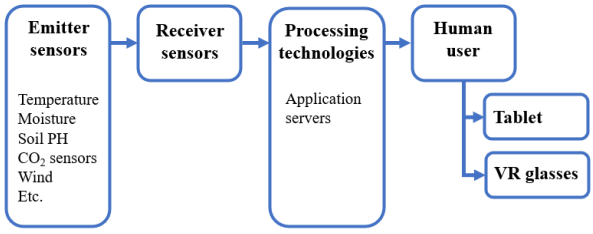


Fig. 5. Workflow for using AR
Source: Own elaboration, based on literature review.

For example, a specialist could use AR to visualize what a warehouse, land, or road would look like in a specific location, thus facilitating the planning, approval, and execution process of projects.

Moreover, virtual reality allows the creation of simulations of the geographic environment, and users can explore areas from a three-dimensional perspective. These technologies offer an interactive way to visualize and understand the complexity of geographic issues, thus contributing to better planning and decision-making.

Photogrammetry, a technology that uses aerial or satellite imagery to measure geospatial objects or phenomena, is another example of effective integration with GIS. It enables the creation of accurate models of terrain and objects within a geographic area and is essential in mapping and monitoring processes [1, 2, 15]. Figure 6 shows a photogrammetric processing model. In practice various processing models can be applied depending on the available data type and desired results.

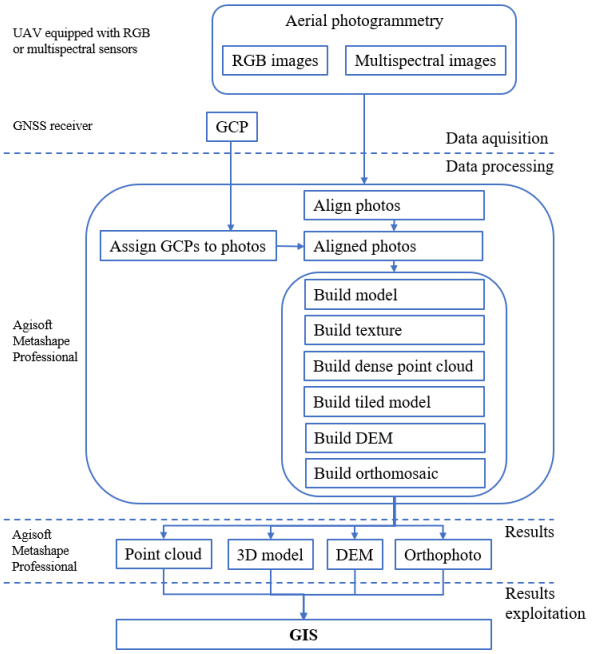


Fig. 6. Flow chart of image processing
Source: Own elaboration, based on literature review.

In combination with a GIS system, photogrammetry can add an extra level of detail to geographic analysis. Photogrammetry can be used to monitor changes in landscapes, such as soil erosion or deforestation, and this information can be processed in a GIS to create detailed maps that help local authorities better manage natural resources. Moreover, advanced photogrammetry techniques allow the creation of three-dimensional models of terrain [1], which contributes to more efficient project planning.

Similarly, remote sensing plays an important role in integrating with GIS [1, 2, 4, 9], allowing data collection from large

geographical areas using satellites or aircraft equipped with specialized sensors. Remote sensing can provide detailed information about the surrounding environment, including data on vegetation, water, soils, or urbanization. By integrating this data into a GIS system, complex analyses can be performed, and patterns that would not be easily observed from traditional sources can be identified. Through the use of satellite data and images, changes in the vegetation of a region can be detected, and this information can be used to assess the impact of climate change or human activities on ecosystems. Remote sensing and GIS enable continuous environmental monitoring and are essential in fields such as environmental protection, precision agriculture, and natural disaster management.

Another significant integration example is the use of GNSS measurements within GIS. These technologies provide precise coordinates of a geographical object or phenomenon, essential for creating accurate maps and collecting precise geospatial data [4, 6, 14, 17]. In fields like topography, cartography, and infrastructure management, GNSS measurements are crucial for obtaining accurate information about the positions of objects on the ground. A technician can use a GNSS receiver to measure the exact coordinates of a new construction or geographical feature, and this data can be integrated into a GIS system to create detailed maps or monitor the evolution of land over time.

Thus, we can appreciate that the integration of GIS systems with emerging and traditional technologies, such as IoT, AI, cloud computing, AR/VR, photogrammetry, remote sensing, and GNSS measurements, brings numerous benefits to the analysis and use of geospatial data. These technologies not only improve the ability to collect and process information but also contribute to making more informed [1, 8, 13] and faster decisions in essential fields such as natural resource management, urban development, environmental protection, and public safety. Their integration makes it possible to create more efficient and sustainable solutions to the challenges faced by contemporary society, and the future of GIS is undoubtedly closely linked to these technological advancements.

Benefits of using GIS in agrotourism cattle farms management

One of the main benefits of using GIS in cattle farms is the improvement of resource planning and management. Farmers can use maps and geospatial analyses to better assess land use and make informed decisions about how to utilize it. This includes determining the best areas for grazing, planting forage crops, or establishing irrigation zones. Additionally, the use of GIS can assist in efficiently monitoring water resources and managing irrigation systems, which are essential in farms facing droughts or extreme weather conditions [10, 6, 13, 16].

At the same time, GIS can help reduce costs by optimizing workflows and resource distribution. By analyzing animal flows and their movements within the farm [12, 14, 17], farmers can identify the most efficient routes for animal transportation, reducing energy consumption and saving time. This is a crucial application in large farms where effective management of animal transport can significantly reduce operational costs.

In addition to economic benefits, GIS helps ensure a safer and more sustainable working environment for farm employees and the animals they manage [14]. Geospatial analysis can help identify and prevent accident risks on the farm, such as areas with heavy traffic or high potential for soil erosion. Moreover, using GIS to monitor animal health can aid in preventing the spread of diseases and improving cattle welfare [8, 11].

Challenges and future perspectives of using GIS in agrotourism cattle farms management

Although GIS technology has enormous potential in modern agriculture, there are challenges associated with its implementation. One of the main difficulties is access to accurate and up-to-date data, which is essential for GIS analysis to be useful and efficient. Additionally, integrating GIS technologies with other farm management systems may require significant investments in IT infrastructure and staff training.

Despite these challenges, the use of GIS in agrotourism cattle farms management continues to grow, and emerging technologies such as drones and precision sensors are expected to deepen the impact of GIS in this field. In the future, GIS is expected to become a core tool in farm management, contributing to the development of more efficient, sustainable, and resilient agriculture in the face of global challenges [8, 11].

GIS application scenarios for agrotourism cattle farms management

Various GIS system use scenarios can be applied in a farm setting. Following a study of the specialized literature, the most applicable scenarios for cattle farms are presented below.

GIS in land and pasture management

One of the most important aspects of cattle farms is land management, especially pasture management. GIS can help farmers map and monitor vegetation distribution, analyze soil quality, and identify areas that require specific interventions [10, 14, 16, 17]. Using GIS can help determine the most fertile grazing areas that should be used for feeding cattle [13], as well as identify places at risk of erosion or drought. GIS enables monitoring vegetation changes over different seasons and adjusting grazing strategies accordingly.

Land cover analysis is essential in cattle farming to maximize the use of available land [10,16], ensuring a constant supply of grass and reducing the risks associated with improper land management. GIS can be used to create detailed maps of the farm showing grazing areas, access roads, animal shelters, and irrigation infrastructure.

Monitoring animal health and well-being

Another important application of GIS in cattle farms is monitoring animal health and well-being. By integrating data from sensors placed on animals (bracelets or collars that measure vital parameters such as body temperature, heart rate, or physical activity) [4,12,17], farmers can create detailed maps of animal behavior and health status [8, 12, 11, 17]. This allows them to quickly identify cows that may show signs of disease or stress and intervene promptly to prevent the spread of diseases or avoid significant economic losses.

GIS can also be used to track cattle movement within the farm, identifying areas where animals spend the most time, preferred shelter locations, and abnormal behaviors [12,17]. This information is crucial for maintaining a healthy environment for the cattle, which can contribute to increased milk and meat production of superior quality.

Optimizing animal nutrition and feed management

Animal feed management is another important GIS application in cattle farming. Feed distribution maps can be created with GIS [14] to track which areas of the farm require more attention regarding available food for the cattle. Additionally, data from other farms can be used to anticipate the animals' feed needs at different times of the year [8]. This helps farmers reduce feed waste, improve feeding efficiency, and increase production.

GIS can integrate information about available feed types in different areas of the farm and how they affect cow performance. As a result, farmers can make better-informed decisions regarding the addition of dietary supplements or diet adjustments to improve animal health and productivity.

Farm infrastructure planning and management

GIS also plays an important role in managing farm infrastructure [14]. Creating digital maps of the farm can help in optimal planning of access roads, animal shelters, feed storage areas, and other facilities. This information can be used to avoid conflict zones, reduce accident risks, and improve the efficiency of daily operations.

GIS can also be used to analyze transport routes for products from the farm to processors or markets, identifying the most efficient routes, saving time and fuel. These infrastructure plans can contribute to reducing operational costs and creating a safer and more efficient working environment.

Spatial analysis and asset mapping

Spatial analysis and asset mapping in an agrotourism cattle farms are essential tools for efficient resource management [4,14] and improving farm performance. Using modern technologies such as GPS and GIS, farmers can create detailed maps of land, infrastructure,

and available resources (water, feed, shelters, equipment, etc.). These maps enable monitoring of resource distribution and usage, optimizing the spatial management of the farm. Asset mapping contributes to efficient land management, risk prevention, and long-term sustainability of the farm. In this way, farmers can make informed decisions that support both productivity and environmental protection.

Moreover, GIS can include and utilize resources from external environments, such as veterinary clinics, artificial insemination centers, semen storage facilities, biological or feed analysis laboratories, feed depots, nearby farms, markets, fairs, and public institutions regulating cattle farming.

Feed production or cultivation

Feed production refers to the activities of cultivating and improving resources for animal feed, an indispensable resource in livestock management. Feed production involves the cultivation and proper management of various grass, legume, or other plant species used to feed animals.

GIS systems allow the integration of multiple datasets (soil types, pedological data, land topography, climatic data, water resources) [13], enabling the identification of the most suitable land for cultivating feed and efficient crop management (by integrating data on environmental conditions, treatments, and applied fertilizers, standard crop growth models) [1,14,17]. Additionally, GIS can include data for multispectral analyses or for managing equipment and staff, with direct benefits on productivity and staff safety.

Monitoring animal vaccination levels

Vaccinating animals is a critical aspect of managing their health. Administering appropriate vaccines at the right times protects animal health and prevents the spread of infectious agents. GIS systems allow the integration of vaccination data for livestock [11,14], including who, where, when, and to whom, providing an overview of vaccination levels and coverage. This dataset can be correlated with data from individual monitoring sensors [4, 17], allowing for the evaluation of vaccination effectiveness. Generally, integrating GIS into animal vaccination monitoring improves the efficiency and effectiveness of vaccination programs by ensuring accurate data capture, informed decision-making, and improved coverage rates.

Tracking personnel locations

GIS systems include tracking and real-time monitoring features for personnel [14] and equipment, allowing for activity optimization and increased productivity. By integrating location sensors, the position of personnel (veterinarians, caretakers, vaccination staff, other workers) within the farm can always be known, enabling optimal allocation of activities and guiding them to the location of interest.

Moreover, the integration and use of personnel and equipment location sensors allow the implementation of alert mechanisms, with direct benefits for the safety and protection of the staff.

GIS for disease management

Using GIS for managing epidemics in cattle farms can significantly improve disease control and prevention [9,11,14]. By collecting and analyzing geospatial data, farmers can identify disease outbreaks, track their spread, and anticipate risks. GIS allows integration of data regarding animal locations [4,12,17], disease types, climatic conditions, and animal movements, helping to identify high-risk areas. Additionally, it facilitates the creation of detailed maps that support quick decisions, such as isolation, vaccination, or treatment. Continuous monitoring and real-time data updates ensure a prompt and efficient response, reducing the impact of epidemics on animal health and production [11].

CONCLUSIONS

The use of GIS in cattle farms represents a revolution in managing and optimizing various agricultural activities, offering significant benefits in terms of both operational efficiency and long-term sustainability. The implementation and utilization of a well-designed GIS can transform the way farms are managed, enabling more precise planning and detailed monitoring of resources. Integrating this system with other modern technologies, such as IoT, artificial intelligence, cloud

computing, virtual reality, augmented reality, photogrammetry, and remote sensing, greatly enhances the ability to collect, analyze, and utilize complex data for making informed and quick decisions.

The benefits of GIS in cattle farms are diverse and extremely valuable. From land and pasture management, optimizing animal feed and forage, to monitoring animal health and farm infrastructure, GIS offers solutions that support more efficient and sustainable resource management. Spatial analysis of assets, monitoring vaccination levels, and tracking staff locations are just a few examples of applications that contribute to increased productivity and reduced risks. Additionally, GIS can be used for disease management, helping to prevent and combat outbreaks by quickly identifying hotspots and high-risk areas.

Therefore, the use of GIS in cattle farms not only improves their economic performance but also contributes to creating a healthier environment for animals, better land and resource utilization, and greater adaptability to climate and environmental challenges. As technologies evolve, the continuous integration of GIS with innovative solutions will open new opportunities for farmers who wish to adopt a more efficient and responsible business model. However, it should be noted that there are also challenges in implementing and using GIS in livestock farms. Among these, we mention: the need for financial resources (both for implementation and during operation), the staff must be continuously trained to use the system, and the GIS must be constantly adapted to the farm's activities and its development pace.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STUDY ON THE TOURISM POTENTIAL AND THE REACTION OF THE RURAL TOURISM AND AGROTURISM MARKET IN MEHEDINTI COUNTY TO THE EFFECTS OF THE PANDEMIC

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Abstract

The study aims to analyze the total tourism potential of Mehedinți County and the way the rural tourism market reacted and adapted to the effects and impact of the pandemic on it, during the period 2019-2023. It was mainly focused on the analysis and characterization of the adaptation of the specific structures of rural tourism and agrotourism. In the first part, the value of the tourism potential as a whole in this county was inventoried and analyzed, which contributed decisively to the return and readaptation of the tourism market to the new conditions imposed by the impact of the pandemic on the entire economic activity in the county, but especially on tourism activity. In the second part, a series of indicators were analyzed based on which the effects of the pandemic on the rural tourism market in the studied county were first established in 2019 and 2020, after which in 2021-2023, its reaction and adaptation to the new conditions and realities that emerged after the pandemic were observed. Based on the data analyzed in the tables included in the paper, a series of conclusions and recommendations were formulated that aimed at the possibility of rapid adaptation, so that the negative impact of the pandemic would be as low as possible and its effects on the circulation and tourism activity in the county would be as short-lived as possible.

Key words**:** *agritourism, the effects of the pandemic, management, tourist market*

INTRODUCTION

The current issue is that the national and regional tourism development strategy should be updated and adapted to the new context of international tourism development, generated by the COVID-19 pandemic and the economic crisis due to the armed conflicts in Eastern Europe and Gaza. The health crisis that began worldwide at the beginning of 2020, through its progressive restrictions up to the stage of total lockdown, has led to a drastic decline in tourism activities, a true "paralysis" of the entire field, a fact noted in the Report on the development of an EU strategy for sustainable tourism of the European Parliament's Committee on Transport and Tourism (2020) [1, 11, 13].

The revitalization and updating of the appropriate development of the tourism sector and the provision of services can only be guaranteed through quality education and training in the field. In order to better understand the skills and competences needed by the tourism sector in Romania, they must be analyzed in a broader socio-economic context. The European Commission estimates that less than 20% of high school and university graduates choose to work in the hotel and tourism sector. They work on a temporary basis and are mostly employed with short-term contracts [4, 8, 25]. On the other hand, there is another phenomenon, that of overqualified personnel working in the tourism sector, with university degrees, but in another field, not related to tourism. In this sector, the need for skills development is felt, at the level of execution but also of management [2, 5, 16].

For this reason, at the national and European level, due to the new challenges in the evolution of the tourism industry, the question of the role of the European Union in the field of tourism is raised in terms of how to approach and solve the new issues that have arisen in this field. The answer to this issue can be found by carefully following the evolution of the tourism market in particular, both at European and global level, correlated with monitoring tourist satisfaction which could be achieved in addition to consumer protection measures and

through those of diversifying and personalizing the tourism product (revitalizing and revitalizing cultural and rural tourism in particular).

It is also necessary for the European Union to continue to benefit from a legal framework through which to provide assistance to the tourism sector by creating a favorable environment for tourism, improving professional training in the field, protecting the environment [10, 12]. The future protection of the interests of the tourism market can be achieved through coherent, established and predictable policies in the field of taxes, infrastructure, competition, etc., while creating a basis for cooperation between Member States and stimulating dialogue in the future approach to tourism issues. Effective and continuous dialogue between all parties involved at regional, national or international level is the essential element of a common and efficient action plan [12, 18, 27].

The development of tourism represents a viable activity in the life of an area or a county, and it involves human, material and immaterial potential, having significant implications for the evolution of the entire local community. Rural tourism can be considered as one of the best businesses at the county level, it contributes to a large extent to increasing the local product, it is an important source of jobs and a very good capital investor. In the economic sense, rural tourism can be considered as a driver of progress in all related fields, in the rural areas where it was implemented. Rural tourism represents a priority sector for the area under study because, through the resources it involves and the interconnections with other branches of the local economy, it is the main factor of progress of rural localities, this depending on the ability to capitalize on the huge potential it has, on the ability to permanently adapt to the demands of tourists and to increase the quality of this activity from all points of view [7, 19, 26, 28].

In the new conditions that have emerged, a more careful and realistic assessment of the tourist potential of the areas under study, of the role of rural tourism in promoting local development, is required to think about sustainable and optimal development strategies for the future. In our country, with the increase in urbanization, areas that have significant natural potential (unique landscapes, rich cultural-historical values or biodiversity) have become increasingly attractive tourist destinations. At the same time, the resources indispensable to tourism, such as the quality of services and infrastructure, the transport network, waste management and others, must be managed properly in order to have a positive impact on local communities and the environment, so the principles of sustainable tourism must be applied [7, 19, 26, 28].

In order to show that the area under study (Mehedinți County) can quickly adapt to the new conditions outlined above, we have reevaluated in this briefer study, the natural and anthropic tourist potential by inventorying all the resources it has and analyzing very carefully their special value in supporting a tourism activity.

MATERIALS AND METHODS

The research method used was based on identifying the tourism potential of Mehedinți County, by inventorying and classifying all existing natural and anthropogenic resources, without insisting too much on it and analyzing the impact of the pandemic on rural tourism and agrotourism activity. Also, this study attempted to bring to the attention of small agricultural landowners in this county, that one of the complementary activities to the basic agricultural activity, with substantial and significant advantages, which can be successfully practiced in rural areas, is the activity of agrotourism and rural tourism [27].

An important issue addressed in this paper is that of the use of boats and river vessels in tourist accommodation, similar to the accommodation spaces in the Danube Delta. This aspect can be successfully used in this area, because it has the two largest water accumulations in our country, the Iron Gates I and II reservoirs and on the Danube navigable channel, aspects that must be exploited to their maximum potential. Based on data taken from the National Institute of Statistics (NIS) [17] and documentation from thematic monographs and maps analyzed, as well as from numerous

field studies, a well-documented radiography of the situation of tourism activities in Mehedinți County and the impact of the pandemic on this activity was also made.
By carefully and professionally evaluating the results obtained, several conclusions and recommendations were developed that would have the effect of revitalizing tourism and agrotourism activities in the area, especially after the pandemic, and that would also lead to awareness of the need to practice sustainable tourism, based on ecological principles, since the area abounds in reserves and protected natural areas [6].

RESULTS AND DISCUSSIONS

The study was conducted in Mehedinți County, which is located in the South-West of Romania, in the lower Danube River basin, on the border with Serbia and Bulgaria, between the counties of Caraș-Severin, Gorj and Dolj, crossed by the parallel of 45° north latitude and the meridian of 23° east longitude. In terms of accessibility, the county is crossed by the European road E70, and the commissioning of the Rhine-Main-Danube Canal put the county seat, the municipality of Drobeta Turnu Severin, in direct contact with all the riverside cities from the Black Sea to the North Sea. The bridge at the Iron Gates Hydropower and Navigation System shortened the road distances between Drobeta-Turnu Severin and various European cities [3, 9, 21].

3.1. Inventorying the natural tourist potential of the area.

The relief is dominated by the Danube River and its gorge, unique in the country. In addition, the Mehedinți Mountains are one of the major attractions. They have an average height of 1,200 meters, the highest being Stan's Peak (1,466 m), the highest being grouped in their central part. At the foot of the Mehedinți Mountains is the Mehedinți Plateau, with special characteristics, in structure and relief it is similar to mountains, and in altitude it is similar to hills. It is a plateau unit made up of crystalline schists and limestones, with altitudes between 400 and 600 m. The sinkholes, of great beauty are: the Topolnița karst complex, the Balta karst formations, the Bulba karst phenomena [14, 15, 22].

Climate and bioclimate are of increasing importance in the development of tourism in the area, the most important being the influence of the sub-Mediterranean climate that overlaps with the temperate continental climate characteristic of the entire country. Climatic conditions must be known by tourism operators in order to adapt their offers according to the most favorable periods, so that the viability of the tourism sector can be supported, generating economic and social benefits for local communities and improving the experience of tourists [3, 9,14].

The hydrography of the area is dominated by the Danube, the second river in Europe in length and flow, after the Volga. The lower sector of the Danube (the Romanian one), 1,075 km long, begins with the spectacular and impressive Iron Gates gorge, 144 km long, which crosses the southwest of the Southern Carpathians, having a 9 km long section with Cauldrons, steep limestone slopes. Another important component of the hydrographic network is the Cerna River, a tributary of the Danube, with a length of 84 km and a basin area of 1,433 km^2. The Motru River is a tributary of the Jiu River and is 120 km long and has a basin area of 1,900 km^2. In the subsoil of Mehedinți County, important groundwater resources have been identified, located in hydrogeological basins with important reserves of underground drinking water: Strehaia basin, Poiana Gruii, Jiana Mare-Vânju Mare, and with mineral and thermal water, Schela Cladovei-Gura Văii basin, Bala - Crainici. At the regional level, there are springs or outcrops with unexplored mineral waters, identified in the localities: Colibași, Lupșa, Baia de Aramă, Balta, Vârciorova [9, 21, 23].

The vegetation of the study area is composed of a rich variety, from mountain forests to plants adapted to the subcarpathian areas and river meadows. Mountain forests extend over a significant part of the county and they host a variety of tree species, such as firs, beeches, spruces, and spruces. Some species, such as the mountain carnation, are endemic to the Parâng Mountains. The hill forests of the

subcarpathian areas host deciduous forests, such as oak, hornbeam, hornbeam, and coniferous forests with fir and pine. These forests provide natural resources, but also recreation for local residents. The river meadows are populated by vegetation specific to alluvial areas [9,15, 24, 31].

Fauna. The area hosts a number of wild mammals, including species such as red deer, wild boar, fox, brown bear, wolf, and lynx. The red deer is an emblematic species of the mountainous areas of the Parâng Mountains. Wild boars and foxes are found in the forests and sub-Carpathian regions, and the brown bear is less common, but can be found in the higher areas. The area is an important birdwatching destination, with a variety of migratory and resident species. Numerous bird species can be observed here, such as the bald eagle, the falcon, the great owl, the magpie, the white-winged thrush and many others. The Iron Gates Natural Park offers diverse habitats for waterfowl, such as the common pelican and the great Corcovado. The fresh waters in the area provide habitat for various species of aquatic animals, such as crabs, snails and aquatic invertebrates, which contribute to the ecological balance of freshwater ecosystems. The Iron Gates Natural Park, located on the Danube River, is one of these protected areas and hosts valuable aquatic ecosystems and a variety of bird species [9,15, 24, 30].

3.2. Inventory of the anthropogenic tourism potential.

The area has a wide range of cultural facilities that contribute to the promotion and preservation of the cultural and historical heritage of the region. These cultural facilities include museums, theaters, libraries and other institutions that support and develop the cultural life of the county. The main museum objectives are; The Iron Gates Region Museum, the Drobeta-Turnu Severin Art Museum [3, 9, 22,23, 21, 30, 31].

Monasteries, cathedrals and churches. The wooden church "Saint Nicholas" - from Ponoarele is an important historical and architectural monument located in the commune of Ponoarele. Other representative churches are: The wooden church of the Holy Apostles Peter and Paul from Brebina - a historical monument and a popular religious architecture, representative of the wooden churches in Oltenia [9, 29]. The wooden church of the Holy Voivodes in Godeanu - a historical and folk religious architecture monument, dating from the period 1783 - 1786. The wooden church of the Holy Voivodes in Isverna - a historical and folk religious architecture monument. The Holy Trinity Monastery in Cerneți - a historical and religious architecture monument, The Church of the former monastery of the Holy 24 Voivodes in Baia de Aramă - a historical and religious architecture monument [3, 9, 21, 22, 23, 30, 31]. Gura Motrului Monastery - was founded in 1512 - 1521 by Neagoe Basarab. Vodița Monastery built in 1364 - 1370 by the monk Nicodim. The Strehaia Fortress Monastery was probably built around 1500 and rebuilt in its present form by Matei Basarab in 1645. The Topolnița Holy Cross Hermitage - was built in 1646 by Lupu Buliga, a captain in Matei Basarab's army.

Monuments and sites. Trajan's Bridge - built by Apollodorus of Damascus on the orders of Emperor Trajan - is a remarkable historical structure, located near the municipality of Drobeta-Turnu Severin, recognized as an important archaeological site and a historical monument, and was included on the UNESCO World Heritage List in 1982. The Statue of Decebalus - is one of the largest stone sculptures in Europe [9, 20, 22, 23, 31].

Ethnographic and Folkloric Values. The area is distinguished by its wealth of ethnographic and folkloric values, which represent an important part of the cultural identity of the region. These values reflect the traditions, customs and creativity of local communities and include aspects such as traditional architecture, folk installations and techniques, folk costumes, musical, choreographic and literary folklore, folk celebrations, festivals, village traditions and rituals. Wooden houses in the villages of the area, with hipped roofs, which preserve the architecture specific to the area. Pottery: An important part of the Mehedinte tradition and the ceramics of the area are known for their traditional patterns and handmade decorative vessels and objects [3, 9, 20, 21, 22, 23, 30, 31].

The folk costume is traditionally worn at cultural and festive events. Traditional Music - the area has a rich tradition in folk music, with instruments such as the flute, bagpipes and violin. These ethnographic and folkloric values contribute to the preservation and transmission of local traditions, as well as to the promotion of the cultural identity of the area. The immense treasure of the rural space of Mehedinti is highlighted through manifestations related to various religious or secular events, which bring together generations in exceptional manifestations [3, 9, 21, 22, 23, 30, 31].

3.3. Analysis of the impact of the pandemic on the tourism market

From the analysis of centralized data for Mehedinți County and Romania, we can observe several important trends and developments in the number of tourist reception structures with accommodation functions, both at the national level and specifically for Mehedinți County (Table 1).

In the context of the COVID-19 pandemic, these data allow us to observe the impact that restrictions and changes in tourists' behavior have had on tourism. General observations:

• At the national level, the total number of accommodation structures has steadily increased from 8,402 in 2019 to 12,697 in 2023 (+51.12%). This increase is a sign of the expansion of the tourism infrastructure in Romania, a phenomenon that has manifested itself much more strongly in Mehedinți County.

• In Mehedinți County, the number of structures has increased significantly, from 83 in 2019 to 170 in 2023 (+104.82%). This growth suggests that Mehedinți County has managed to diversify and enrich its tourism offer in recent years, with a positive trend that can also be attributed to the development of new types of accommodation units.

• If we analyze the dynamics from 2019-2023 according to the type of accommodation units, we can observe 3 distinct trends, as follows: o Tourist villas and Tourist cottages which have recorded a significant increase at the national level, a trend that is not maintained at the MH county level; o Tourist guesthouses which have recorded a significant decrease at the national level, a trend that has not been maintained at the county level; o Agritourist guesthouses which have recorded significant increases both at the national level (+15.75%) and at the county level (+73.17%).

Table 1. Evolution of the number of tourist reception structures with tourist accommodation functions, by type of structure in Romania/Mehedinți

Types of structures of tourist reception	Total	Years					
		1990	2019	2020	2021	2022	2023
TOTAL	Romania	3,213	8,402	8,610	11,736	12,201	12,697
	Mehedinți	22	83	96	146	165	170
Inns	Romania	:	3	3	3	4	5
Tourist villas	Romania	1,551	709	752	752	758	756
	Mehedinți	4	4	5	5	5	4
Tourist chalets	Romania	226	222	226	222	220	223
	Mehedinți	1	1	1	1	1	1
Holiday villages	Romania	:	9	8	8	8	10
Tourist cottages	Romania	:	82	92	112	127	155
	Mehedinți	:	:	:	1	1	2
Tourist guesthouses	Romania	:	1,669	1,729	1,745	1,696	1,642
	Mehedinți	:	13	14	14	14	12
Agritourist guesthouses	Romania	:	2,800	3,022	3,460	3,484	3,498
	Mehedinți	:	41	50	61	70	71
Accommodation on river ships	Mehedinți		24	27	25	24	29

Source: processing based on own data and from NIS [17].

• A particular specificity of MH county is represented by accommodation structures on cruise ships. Their number fluctuated slightly (from 24 in 2020 to 29 in 2023), which suggests a stability of this tourism segment, but also a possible post-pandemic revitalization, as tourism on the Danube recovers. Impact of the

COVID-19 pandemic on accommodation structures:

• During the period 2020-2021, against the backdrop of the pandemic and the distancing/isolation rules, there was stagnation or slight variations for classic accommodation structures, and a strong increase in structures positioned in rural areas, which facilitate access to nature and in areas with lower population density: Tourist cottages and Agritourist guesthouses. If for Tourist cottages a strong growth is observed only at the national level, which is not maintained at the county level, in the case of Agritourist guesthouses there were strong increases both at the national level (+14.49%) and at the MH county level (+22%).

• These trends have been maintained in the post-pandemic period, increasing the addressability for Tourist cottages and Agritourist guesthouses, while the addressability for Tourist guesthouses has steadily decreased, suggesting a trend of appreciation of rural tourism. It is noted that in the post-pandemic period, Mehedinți County has recorded a significant increase in the number of accommodation structures, especially in the agrotourism guesthouse sector, which reflects a tendency to adapt to the demands of a tourist market that seeks more peace, isolation and unforgettable experiences. The pandemic had a significant impact in the first part of the period, but with the relaxation of restrictions, tourism recorded a strong recovery, and Mehedinți County benefited from a diversification of the tourist offer. A greater preference for smaller and more intimate accommodation structures, such as agrotourism guesthouses and tourist cottages, can also be observed, which align with the general trends of sustainable tourism and proximity to nature. Analysing the dynamics of tourist accommodation capacity expressed in available accommodation places, both at the national level and for Mehedinți county, we observe significant developments, especially in the context of the COVID-19 pandemic. In this paper, we analyse the developments according to the types of accommodation structures and the impact that the pandemic has had on them.

Table 2. Dynamics of tourist accommodation capacity expressed in existing places by type of tourist reception structures Romania/Mehedinți

Types of structures of tourist reception	Total	Years					
		1990	2019	2020	2021	2022	2023
TOTAL	Romania	353,236	356,562	358,119	410,291	422,114	433,487
	Mehedinți	2,407	2,429	2,661	3,361	3,621	3,653
Inns	Romania	:	80	80	80	90	120
Tourist villas	Romania	46,757	16,665	17,124	17,325	17,457	17,450
	Mehedinți	400	24	48	48	48	42
Tourist chalets	Romania	12,430	6,216	6,331	6,356	6,256	6,067
	Mehedinți	110	10	10	10	10	10
Holiday villages	Romania	:	477	375	375	456	688
Tourist cottages	Romania	:	2,503	2,662	3,122	3,518	4,012
	Mehedinți	:	:	:	8	8	24
Tourist guesthouses	Romania	:	35,198	35,312	35,387	34,587	33,930
	Mehedinți	:	244	266	266	266	234
Agritourist guesthouses	Romania	:	49,053	52,389	55,778	56,850	58,086
	Mehedinți	:	716	830	928	1,032	1,048
Accommodation on river ships	Mehedinți		846	901	831	839	897

Source: processing based on own data and from NIS [17].

Increasing accommodation capacity in Romania and Mehedinți (Table 2)

At the national level, accommodation capacity has steadily increased from 356,562 places in 2019 to 433,487 places in 2023. This indicates a general expansion of the tourism infrastructure, which reflects the trend of diversification of the tourism offer in Romania. In Mehedinți county, accommodation capacity has increased from 2,429 places in 2019 to 3,653 places in 2023, with a very strong increase compared to 2021. This increase is significant and suggests that the county has invested in the development of tourism infrastructure, thus contributing to the increase

in the number of tourists and the diversification of the experiences offered.

The impact of the pandemic on accommodation capacity

Similar to the evolution of the number of accommodation units, during the pandemic period (2020-2021) there is a stagnation or slight variations for classic accommodation structures, and a strong increase in structures positioned in rural areas, which facilitate access to nature and in areas with lower population density: Tourist cottages and Agritourist guesthouses. For Tourist cottages, a strong increase is observed only at national level (+17.28%), a trend that is not maintained at county level, and in the case of Agritourist guesthouses, increases were recorded both at national level (+6.47%) and at MH county level (+11.81%). At the same time, a decrease in accommodation capacity on Accommodation on river ships (-7.77%) is observed.

Post-pandemic trends and adaptations

Agritourism guesthouses continue to be a significant growth area both in Romania and in Mehedinți. Nationally, the number of accommodation places in these units has increased steadily, from 49,053 places in 2019 to 58,086 places in 2023 (+18.41%). In Mehedinți, the growth is remarkable, from 716 places in 2019 to 1,048 places in 2023 (+46.37%), indicating that the county has capitalized on the increased interest in rural tourism and authentic experiences.

Tourist cottages have registered a significant growth in Romania, from 2,503 places in 2019 to 4,012 places in 2023 (+60.29%). In Mehedinți, however, this type of accommodation was much more limited in the period 2019-2021, with only 8 places in 2021, but their number increased significantly in 2023, to 24 places. This suggests a trend of adaptation to market requirements and a greater diversification of the tourist offer in the county.

Holiday cottages and tourist villas have recorded a stagnation or even a slight decrease in accommodation capacity, which may be related to the decrease in demand during this period, especially in the case of some types of accommodation that did not adapt quickly to the new realities of post-pandemic tourism.

The accommodation capacity on Danube cruise ships in Mehedinți County has had a relatively constant evolution, with a small decline in 2021 (from 901 places in 2020 to 831 places in 2021), but has returned slightly to higher levels in 2023 (897 places). This suggests that river tourism was affected, but has had a gradual recovery in the post-pandemic period, as restrictions have been relaxed.

From the analyzed data, it can be seen that in the post-pandemic period, tourism in Mehedinți County has recorded a strong recovery, with a significant increase in accommodation capacity in sectors such as agrotourism guesthouses and accommodation on cruise ships. This suggests a paradigm shift in the preferences of tourists, who have sought more tranquillity and safety, which has favored the development of rural tourism and authentic experiences. In contrast, larger accommodation structures, such as tourist villas and holiday cottages, have experienced slower growth or even a decrease in capacity, possibly due to changes in post-pandemic travel behaviors and the need for more privacy and isolation. Overall, Mehedinți County has managed to diversify its tourism offer in the post-pandemic period, and this has been reflected in the increase in accommodation capacity. This diversification could represent an important opportunity for the future, especially for attracting a more sustainable type of tourism oriented towards nature and local experiences.

By analyzing the data on tourist accommodation capacity expressed in places-per-day, both at the national level and for Mehedinți County, we can analyze the developments and trends in the tourism sector, taking into account the impact of the COVID-19 pandemic on it (table 3). We will observe in particular how accommodation structures have evolved during the period 2019-2023, a period marked by restrictions, changes in tourist behavior and adaptations to the new conditions.

Table 3. Tourist accommodation capacity in function by types of tourist reception structures in places - days, in Romania/Mehedinți

Types of structures of tourist reception	Total	Years					
		2001	2019	2020	2021	2022	2023
TOTAL	Romania	51,882,465	88,789,656	64,040,595	87,217,823	93,007,230	98,293,110
	Mehedinți	425,990	717,328	514,675	751,150	819,218	868,635
Inns	Romania	70,864	28,580	22,237	24,890	27,268	37,240
Tourist villas	Romania	2,488,256	3,753,539	2,780,569	3,485,815	3,590,100	3,588,609
	Mehedinți	:	3,480	8,616	11,514	11,514	11,514
Tourist chalets	Romania	1,880,532	1,494,759	995,642	1,371,743	1,378,194	1,361,159
	Mehedinți	:	2,340	1,610	2,140	1,590	1,830
Holiday villages	Romania	13,140	114,390	66,680	93,224	112,698	182,007
Tourist cottages	Romania	311,211	230,114	225,344	299,693	334,975	475,147
	Mehedinți	:	:	:	736	368	1,968
Tourist guesthouses	Romania	1,026,975	10,454,735	7,290,415	8,784,339	8,804,999	8,862,371
	Mehedinți	:	76,848	65,483	78,512	75,899	58,551
Agritourist guesthouses	Romania	1,105,724	12,615,982	9,195,563	12,228,257	13,269,082	13,973,610
	Mehedinți	:	157,775	139,469	209,743	235,816	252,446
Accommodation on river ships	Mehedinți	81,011	59,670	49,025	31,276	30,296	29,254

Source: processing based on own data and from NIS [17].

Total accommodation capacity in Romania and Mehedinți (Table 3)

At the national level, the total accommodation capacity expressed in places-per-day has steadily increased from 88,789,656 in 2019 to 98,293,110 in 2023. This suggests a significant expansion of the tourism infrastructure and a diversification of the accommodation offer, which has contributed to attracting an increasing number of tourists to Romania. In Mehedinți County, the accommodation capacity has increased from 717,328 places-per-day in 2019 to 868,635 places-per-day in 2023, reflecting a similar trend of expansion of the local tourism sector.

The impact of the pandemic on accommodation capacity

During the pandemic (2020-2021), there has been a significant decrease in accommodation capacity nationwide, especially in 2020, when capacity decreased to 64,040,595 places-per-day, compared to 88,789,656 places in 2019 (-27.87%). This reflects the direct effects of travel restrictions, accommodation closures and the decrease in tourism demand due to the pandemic. Mehedinți County followed the national trend, with a decrease in capacity from 717,328 places in 2019 to 514,675 places in 2020 (-28.25%). After this decrease, the county managed to recover and even increase accommodation capacity, recording an increase from 751,150 places in 2021 to 868,635 places in 2023, suggesting a strong return of local tourism in the post-pandemic period.

Specific trends according to the type of accommodation structure

Tourist villas: Nationally, the accommodation capacity in tourist villas decreased significantly during the pandemic, from 3,753,539 places in 2019 to 2,780,569 places in 2020. This can be attributed to a decrease in demand and the operating capacity of the units due to restrictions and temporary closures. After 2020, the capacity started to increase slightly, but did not return to 2019 levels until the end of 2023. In Mehedinți, on the other hand, the accommodation capacity in tourist villas was relatively constant during 2020-2023.

Agritourism guesthouses: Another type of accommodation that was positively influenced by the behavioral changes of tourists during the pandemic was rural tourism, especially in counties with agrotourism potential, such as Mehedinți. The accommodation capacity in agrotourism guesthouses continued to increase, both nationally (from 12,615,982 places in 2019 to 13,973,610 places in 2023, i.e. an increase of +10.76%) and in Mehedinți (from 157,775 places in 2019 to 252,446 places in 2023, i.e. an increase of +60%). This suggests a strong increase in demand for more isolated and safe destinations, aspects that were favored by the pandemic.

Tourist cottages: At the national level, the number of accommodation places in tourist

cottages increased significantly after 2020, reaching 475,147 places in 2023, which indicates a trend of diversifying the accommodation offer in more isolated and natural locations. In Mehedinți, this type of accommodation had a remarkable increase in the period 2022-2023, from 736 places in 2021 to 1,968 places in 2023. This shows an adaptation to the post-pandemic demands of tourists who prefer smaller and more isolated accommodation units.

Accommodation on cruise ships: In Mehedinți County, the accommodation capacity on cruise ships on the Danube had a significant decrease in 2020 and 2021, reaching 31,276 places in 2021, compared to 59,670 places in 2019. This reflects the direct impact of the pandemic on river tourism, but after 2021 the capacity remained relatively constant, with a slight decrease in 2023 (29,254 places), which suggests a gradual return of cruise tourism on the Danube.

In conclusion, it is noted that:

• ***Post-pandemic recovery:*** After significant declines in 2020, Mehedinți County and Romania in general have seen a significant recovery in accommodation capacity. This suggests that as restrictions were lifted and tourism demand increased, the tourism infrastructure responded positively, with a continued increase in the number of accommodation places in various types of structures.

• ***Search for safety and isolation:*** The pandemic has led tourists to seek more isolation and security, which has favored rural tourism and agrotourism, types of accommodation that have continued to grow in Mehedinți. More isolated and intimate accommodations, such as tourist cottages, have also experienced rapid expansion.

• ***Revitalization of river tourism:*** After a period of stagnation, river tourism in Mehedinți County is starting to recover, but is still below previous levels, suggesting that it will take time to regain confidence and tourist numbers in this sector.

Table 4. Dynamics of tourist arrivals in tourist reception structures by type of structure in Romania/Mehedinți

Types of structures of tourist reception	Total	Years					
		2001	2019	2020	2021	2022	2023
TOTAL	Romania	4,874,777	13,374,943	6,398,642	10,205,322	12,588,333	13,910,956
	Mehedinți	35,772	112,174	78,241	97,668	103,257	111,967
Inns	Romania	3,670	2,911	759	697	1,345	1,820
Tourist villas	Romania	174,956	463,600	267,338	382,473	420,838	437,492
	Mehedinți	:	336	2,763	3,638	4,089	3,671
Tourist chalets	Romania	104,049	153,374	95,370	130,051	131,805	137,390
	Mehedinți	:	921	484	536	309	474
Holiday villages	Romania	1,862	6,341	2,987	5,986	8,420	38,944
Tourist cottages	Romania	18,358	20,556	20,086	27,673	31,348	48,795
	Mehedinți	:	:	:	80	40	133
Tourist guesthouses	Romania	106,129	1,254,476	654,397	893,859	977,694	1,037,475
	Mehedinți	:	13,659	10,791	13,775	13,686	8,867
Agritourist guesthouses	Romania	41,658	1,272,878	755,436	1,087,327	1,181,699	1,306,683
	Mehedinți	:	33,323	27,997	32,262	33,967	33,490
Accommodation on river ships	Mehedinți	8,238	5,790	5,442	3,324	2,630	2,534

Source: processing based on own data and from NIS [17].

Analyzing the data on the number of tourist arrivals in tourist reception structures, several interesting trends can be observed, with a significant impact of the COVID-19 pandemic on tourism in Romania and Mehedinți County.

Total evolution of tourist arrivals in Romania and Mehedinți

• Romania recorded a significant increase in tourist arrivals between 2001 and 2019, from 4,874,777 in 2001 to 13,374,943 in 2019. However, the pandemic had a dramatic impact on tourism in 2020, when the number of arrivals decreased to 6,398,642 (-52.16%), due to travel restrictions and the closure of some tourist destinations. After 2020, the number of tourists has increased steadily, reaching 13,910,956 in 2023 (above the 2019 level), suggesting a strong recovery of the tourism industry in the post-pandemic period.

• Mehedinți followed a similar trend, with tourist arrivals falling from 112,174 in 2019 to 78,241 in 2020 (-30.25%). However, the county has seen a gradual increase in tourist arrivals in the following years, reaching 111,967 in 2023 (but significantly below the 2019 level). This suggests a fairly rapid recovery of local tourism.

The impact of the pandemic on types of accommodation structures

Tourist villas: Nationally, the number of tourist arrivals in tourist villas was quite affected by the pandemic, decreasing from 463,600 in 2019 to 267,338 in 2020 (a decrease of -42.33%). This reflects the fact that many accommodation units of this type were affected by travel restrictions and changes in tourist behavior, who began to opt for more isolated destinations. In Mehedinți, the number of arrivals in tourist villas was much lower, but gradually increased after 2020, reaching 3,671 in 2023.

Agritourism guesthouses: One of the most obvious trends that emerged during the pandemic was the increased interest in agritourism, especially in counties that benefit from this type of tourism, such as Mehedinți. Nationally, the number of arrivals in agritourism guesthouses decreased from 1,272,878 in 2019 to 755,436 in 2020 (a decrease of -40.65%), but recovered quickly after 2020, reaching 1,306,683 in 2023 (exceeding the 2019 level). In Mehedinți, the number of arrivals in agritourism guesthouses remained relatively constant, with a slight increase from 33,323 in 2019 to 33,490 in 2023, suggesting that this type of tourism was less affected by the health crisis and even benefited from higher demand from tourists looking for isolated and safer places.

Tourist cottages: In 2020, at the national level, tourist cottages recorded a significant decrease in arrivals (from 20,556 in 2019 to 20,086 in 2020), but this type of accommodation had a notable comeback, reaching 48,795 in 2023 (an increase of +137.38% compared to 2019). In Mehedinți, the number of arrivals in tourist cottages increased slightly, reaching 133 in 2023. This suggests that tourists have started to prefer smaller and more isolated accommodation units, which allow for better social distancing and reduced contact with other people.

Holiday cottages and holiday villages: In 2020, the number of arrivals in holiday villages and holiday cottages decreased nationally, but they recorded a rapid recovery in 2021 and 2022, with a significant increase in 2023. In Mehedinți, however, these structures recorded a very low number of arrivals in the period 2020-2023, which suggests that this type of accommodation is not as widespread in the county or has not been as requested by tourists in the post-pandemic period.

River tourism: The number of tourist arrivals in cruise ship accommodation in Mehedinți county decreased significantly throughout the period 2019-2023. This can be explained by the fact that water tourism was affected by travel restrictions and port closures. After 2021, the number of arrivals remained low, reaching 2,534 in 2023, suggesting a continued and slow decline for river tourism during this period.

From the same table 4 it can be seen that:

• ***Significant recovery after 2020:*** After the dramatic drop in arrivals in 2020, the tourism sector in Romania and Mehedinți showed a strong recovery in the following years. This suggests that tourists have gradually returned to their preferred destinations, and their preferences have changed to include more safety and isolation.

• ***Adaptation of tourist behavior:*** The pandemic has led to a change in tourist behavior, favoring more isolated and safer destinations, such as agrotourism and accommodation in smaller and less crowded places (tourist cottages, agrotourism guesthouses). This change has been reflected in both national and local (Mehedinți) trends.

• ***River tourism and other structures:*** Despite the general trend of recovery, river tourism and certain types of accommodation structures (such as holiday villages) have not recovered as quickly as the number of arrivals from the pre-pandemic period, suggesting that certain sectors of tourism are still facing post-pandemic challenges.

Table 5. Dynamics of overnight stays of tourists in tourist reception structures by type of structures and number, in Romania/Mehedinți

Types of structures of tourist reception	Total	Years					
		2001	2019	2020	2021	2022	2023
TOTAL	Romania	18,121,688	30,086,091	14,579,140	22,747,562	27,044,372	29,691,592
	Mehedinți	119,801	232,325	154,106	206,199	221,047	230,973
Inns	Romania	6,142	3,622	1,415	1,651	2,288	2,432
Tourist villas	Romania	792,519	1,039,641	593,440	865,471	885,701	949,886
	Mehedinți	:	828	4,100	5,241	5,886	5,474
Tourist chalets	Romania	211,024	266,010	161,230	214,004	218,605	240,108
	Mehedinți	:	1,755	1,158	1,210	881	1,137
Holiday villages	Romania	4,863	16,318	7,225	14,432	19,847	71,657
Tourist cottages	Romania	68,994	44,298	49,824	60,127	64,706	93,546
	Mehedinți	:	:	:	120	60	241
Tourist guesthouses	Romania	187,533	2,324,217	1,201,697	1,605,766	1,754,388	1,837,049
	Mehedinți	:	19,813	17,302	21,343	23,446	14,005
Agritourist guesthouses	Romania	88,349	2,518,605	1,515,305	2,089,781	2,265,633	2,529,052
	Mehedinți	:	67,477	61,463	67,901	67,892	67,373
Accommodation on river ships	Mehedinți	57,516	16,272	14,380	7,586	6,332	5,149

Source: processing based on own data and from NIS [17].

Analyzing data on tourist arrivals and accommodation capacity in tourist structures in Romania and Mehedinți during 2019-2023, several significant trends and changes are observed in the context of the COVID-19 pandemic, which have affected the tourism industry.

Total evolution of the number of overnight stays in Romania and Mehedinți (table 5)

• ***Romania:*** The total number of overnight stays reached 30,086,091 in 2019. The COVID-19 pandemic had a significant impact on tourism in 2020, with a drastic decrease in the number of overnight stays (-51.54%), which reached 14,579,140. This decrease was the result of travel restrictions, isolation measures and the closure of accommodation units. After 2020, there was an increase in the number of overnight stays, reaching 29,691,592 in 2023 (significantly below the level of 2019), suggesting a significant recovery of tourism post-pandemic.

• ***Mehedinți:*** The number of overnight stays followed a similar pattern, with a sharp drop in 2020 to 154,106 compared to 232,325 in 2019 (-33.67), in the context of the pandemic. However, the county has shown a steady recovery in the post-pandemic years, with 230,973 overnight stays in 2023, suggesting a gradual return of local tourism, although not yet reaching the level of 2019.

Evolution of types of accommodation structures

Agritourism guesthouses: These structures have shown a continuous increase in the number of overnight stays, both nationally and in Mehedinți. During the period 2020-2023, the preference for isolated destinations made agritourism a favored option. At the national level, the number of overnight stays in agritourism guesthouses decreased from 2,518,605 in 2019 to 1,515,305 in 2020 (-39.84%), but recovered significantly, reaching 2,529,052 in 2023 (an increase of 66.90% compared to 2020, and a similar level to 2019). In Mehedinți, the number of overnight stays in agritourism guesthouses remained stable during 2019-2023, with a decrease in 2020 to 61,463 overnight stays, but with a rapid recovery in 2021 and subsequent maintenance at a constant level.

Tourist villas: At the national level, overnight stays in tourist villas suffered a major decrease in 2020 (-42.92%), falling from 1,039,641 in 2019 to 593,440. This can be explained by travel restrictions and the preference for accommodation in more isolated locations. However, the number of overnight stays gradually increased after 2020, reaching 949,886 in 2023, still below the level of 2019. In Mehedinți, the number of overnight stays in tourist villas was relatively low, but has been increasing steadily since 2020, reaching 5,474 in 2023. Although not at the same levels as in other areas of Romania, villas in Mehedinți have become a more attractive option in the post-pandemic period.

Tourist cottages and chalets: In 2020, overnight stays in tourist cottages and chalets suffered significant decreases, from 266,010 in 2019 to 161,230 in 2020 (-39.39%), followed by a gradual recovery until 2023. These accommodation structures, usually having a smaller number of places and located in more isolated areas, started to gain popularity in the post-pandemic period. In Mehedinți, overnight stays in tourist cottages remained almost non-existent in 2020-2021, but increased significantly in 2023, reaching 241 overnight stays.

Cruise ship tourism: Mehedinți has seen a significant and continuous decrease in cruise ship overnight stays (from 16,272 in 2019 to 14,380 in 2020), and in 2021 and 2022, the number remained at a low level. In 2023, cruise ship overnight stays continued to be well below the 2019 level, suggesting that river tourism has not fully recovered from the impact of the pandemic.

• *Overall, but slower recovery in Mehedinți:* After the significant impact of the pandemic, tourism in Romania and in Mehedinți has started to recover since 2021, and in 2023 an overall increase in overnight stays is observed. However, in Mehedinți, this recovery has been slower, especially in terms of tourism in certain types of accommodation, such as villas and tourist cabins.

• *Increased demand for agritourism and remote locations:* The pandemic has changed the behavior of tourists, who have started to appreciate more isolated, safe places that allow for social distancing. This is why agritourism has become an increasingly popular option, even in Mehedinți, a county with significant agritourism potential.

• *Decrease in river tourism:* Cruise ship tourism in Mehedinți has suffered due to the pandemic and has not returned to 2019 levels until 2023. This may be a consequence of international travel restrictions and changes in tourist preferences post-pandemic.

• *Diversification of the offer:* Since 2021, the accommodation offers in Romania and Mehedinți have diversified, with an increase in demand for smaller and more isolated structures, such as tourist cottages and agrotourism. This can be an opportunity to better capitalize on local resources and support the development of more sustainable and environmentally friendly forms of tourism.

Table 6. Dynamics of the net utilization index of tourist accommodation capacity in operation in %, since August, by types of tourists reception structures, in Romania/Mehedinți

Types of structures of tourist reception	Total	Years				
		2019	2020	2021	2022	2023
TOTAL	Romania	52.1	39.1	48.5	45.1	45.7
	Mehedinți	57.1	60.7	49.6	50.3	46.3
Inns	Romania	11.9	7.8	3.7	6.4	8.4
Tourist villas	Romania	49.6	37.6	49	43	43.1
	Mehedinți	:	100	92.2	88.6	80.9
Tourist chalets	Romania	29.7	29	27.4	29.2	28.8
	Mehedinți	100	100	100	97.7	100
Holiday villages	Romania	31	15.7	36.7	34.8	62.2
Tourist cottages	Romania	36	39.2	35.8	28.2	30.2
	Mehedinți	:	:	:	:	12.1
Tourist guesthouses	Romania	35	28.1	33.3	31.5	32.2
	Mehedinți	47.9	46.5	44.9	42.1	37.2
Agritourist guesthouses	Romania	34.7	31.8	32.4	30.5	31.5
	Mehedinți	68.4	72.3	58.7	63.1	57.1
Accommodation on river ships	Mehedinți	35.4	42.4	28.2	28.2	28.5

Source: processing based on own data and from NIS [17].

Analyzing the net occupancy rate of accommodation capacity in operation in percentage terms, both at the national level (Romania) and for Mehedinți county, during the period 2019-2023, we observe several significant trends, especially in the context of the COVID-19 pandemic (Table 6). These data are useful for understanding the impact of the pandemic on tourism and how different types of accommodation structures have been affected during this period.

Overall evolution of the occupancy rate of accommodation capacity in Romania and Mehedinți:

Romania: In 2019, the occupancy rate of accommodation capacity was 52.1%. In 2020, during the pandemic, it decreased significantly to 39.1%, reflecting the direct impact of travel restrictions and isolation measures. In 2021, the index increased slightly to 48.5%, but did not fully return to 2019 levels. In 2022 and 2023, the index remained relatively constant, at 45.1% and 45.7%, indicating a partial recovery of tourism, but still below the pre-pandemic level.

Mehedinți: In Mehedinți county, the accommodation capacity utilization index was higher than in the rest of the country in 2019 (57.1%), and even increased in 2020, reaching 60.7%. This suggests a better adaptation of the county to the crisis, possibly due to a more

limited tourism offer, which may be easier to manage under pandemic conditions. After 2020, the index recorded a significant decrease in 2021 (reaching 49.6%) and an increase in 2022, reaching 50.3%. In 2023, the accommodation capacity utilization index reached 46.3%, reflecting a slower recovery compared to other areas of the country.

Evolution by type of accommodation structures

Inns: • Romania: The occupancy rate of inns was very low in 2020 (7.8%) and remained below normal in the following years. In 2023, it reached 8.4%.

• Mehedinți: Data for inns are not available for Mehedinți explicitly, but it is clear that this type of accommodation was less in demand, especially during the pandemic, and does not seem to have experienced a significant recovery.

Tourist villas: • Romania: The occupancy rate of tourist villas was affected by the pandemic, falling from 49.6% in 2019 to 37.6% in 2020. After 2020, occupancy of these structures increased slightly to 49% in 2021 and 43% in 2022, but remained below the 2019 level.

• Mehedinți: The occupancy rate of tourist villas was much higher in 2020 than in the rest of the country, suggesting a high demand for these types of accommodation during the pandemic, when tourists preferred more isolated destinations. Occupancy gradually decreased in the following years, reaching 80.9% in 2023, but remaining significantly higher than the national average.

Chalets: • Romania: The capacity utilization rate in chalets was relatively constant, ranging between 27.4% in 2020 and 29.7% in 2019, suggesting that these types of structures were less affected by the pandemic.

• Mehedinți: Chalets in Mehedinți had a very high utilization rate in 2020, suggesting high demand during that period. After 2020, utilization decreased slightly in 2023, indicating a continued preference for these isolated and safer accommodation structures.

Tourist guesthouses: • Romania: Guesthouses had a significant decrease in utilization in 2020 (28.1%), but recovered slightly to 33.3% in 2021 and 31.5% in 2022. In 2023, utilization increased to 32.2%.

• Mehedinți: Tourist guesthouses in Mehedinți had a relatively constant and higher than the national average occupancy rate, of approximately 46.5% in 2020 and 44.9% in 2021. This decreased slightly in 2023 to 37.2%, suggesting a relatively lower occupancy rate compared to 2020 and 2021.

Agritourism guesthouses: • Romania: The occupancy rate of agritourism guesthouses was approximately 31.8% in 2020, with a slow recovery in the following years, reaching 31.5% in 2023.

• Mehedinți: Agrotourism guesthouses in Mehedinți had a very high occupancy rate in 2020 (72.3%), reflecting the increased preference for agritourism during the pandemic. In 2023, this rate decreased to 57.1%, well above the national average.

Ship accommodation: • Mehedinti: The utilization of cruise ship accommodation capacity has decreased from 42.4% in 2020 to 28.5% in 2023. This is a direct consequence of travel restrictions and the decrease in interest in water-based tourism in the post-pandemic period.

Analyzing data on the arrivals of foreign visitors to Romania during 2019-2023, coming from various continents and countries of origin, significant trends can be observed, especially in the context of the COVID-19 pandemic (Table 7).

Table 7. Arrivals of foreign visitors in Romania by continent and country of origin - thousands of persons

Continents and countries	2019	2020	2021	2022	2023
Total	12,815	5,023	6,789	12,697	14,777
Europe	11,878	4,830	6,480	11,929	13,868
European Union	6,254	2,593	3,114	4,397	5,197
Other European countries	127	46	83	145	169
Africa	43	17	25	49	52
Egypt	10	5	8	13	16
North America	281	38	94	230	289
USA	214	29	73	173	218
South and Central America	40	9	12	27	34
Asia	545	126	175	446	507
Israel	309	43	65	226	234
Australia, Oceania and other territories	27	3	3	15	26
Unspecified countries and territories	1	0	0	1	1

Source: processing based on own data and from NIS [17].

General evolution of foreign tourist arrivals (Total)

• *In 2019,* Romania received a significant number of foreign tourists, with 12,815 thousand arrivals.
• *In 2020*, the COVID-19 pandemic led to a major decline in tourism, with the number of foreign tourist arrivals dropping sharply to just 5,023 thousand, reflecting the immediate impact of travel restrictions and isolation measures.
• *In 2021*, the number of arrivals increased to 6,789 thousand, suggesting a partial recovery in tourism as restrictions were eased and vaccinations began to be implemented on a large scale.
• *In 2022*, tourism continued to grow significantly, reaching 12,697 thousand arrivals, almost at the level of 2019.
• *In 2023*, foreign tourist arrivals exceeded this level, reaching 14,777 thousand tourists, indicating a complete recovery and even an increase in the number of tourists compared to the pre-pandemic period.

Interpretations and comments

• ***Impact of the pandemic:*** 2020 was clearly a disastrous year for tourism in Romania, and the pandemic affected all regions of the world, leading to significant decreases in tourist numbers. There was also a shift of interest to geographically closer destinations, such as countries in the European Union and other parts of Europe, to the detriment of more distant destinations.
• ***Recovery in 2021-2023:*** After 2020, tourism began to gradually recover. In particular in 2022 and 2023, Romania experienced a significant increase in the number of foreign visitors, exceeding 2019 levels, suggesting a solid return of confidence and demand in the tourism market.
• ***Regional trends****:* Europe remained the main source of tourists for Romania, and within Europe, the European Union was the most important market. After a significant decline in 2020, European tourism returned to near-normal levels in 2023, suggesting a rapid recovery in regional tourism.
• ***Slower recovery in other regions:*** Regions such as Africa, South America and Asia have seen slower and more modest recoveries, and visitor numbers in these areas have not yet reached pre-pandemic levels.
• ***Preference for destinations closer to home:*** As seen in the case of tourists from the European Union and Israel, the general trend in the post-pandemic period has been to choose more geographically accessible and safer destinations, to minimize the risks associated with long-haul international travel.

CONCLUSIONS

From the analysis and inventory of the natural tourism potential, we came to the conclusion that Mehedinți County has rich and valuable natural resources that played a very important role in attracting tourists, both during the pandemic and in the following years 2021-2023, contributing greatly to combating the negative effect of the pandemic on tourism activity in general, in the studied area. The multitude of extremely valuable anthropogenic tourism resources, represented by historical monuments, churches and monasteries, archaeological sites, memorial houses and architectural ensembles with a unique character, crafts, village customs and rituals of inestimable value, and others, also had positive effects on attracting tourists. Thanks to this, it can be seen from the data presented in tables 1-7 that the pandemic had an extremely negative impact on tourism activity only in 2020, the year in which restrictions on the movement and health safety of tourists were the most drastic.
Also, from these tables it can be seen that in the first year of the pandemic 2019, the tourist activity in the county took place due to inertia, without visible negative effects. The greatest negative impact on all the indicators studied, as can be seen from the same table, was manifested in 2020, the year of grace of the pandemic. Subsequently, due to effective measures taken both at the local and county level, as well as at the management level of the main tourist reception structures in the field of rural tourism, the values of the indicators studied began to increase slightly, in the first year 2021, these increases were very timid, their values increasing very little compared to 2020. Significant and visible increases in all these indicators were achieved in 2023, the year in which the rural tourism market in Mehedinți county showed signs of revival and

readaptation to the new realities and challenges imposed by the passage through the crisis period during the pandemic.

An interesting aspect identified in this study is that the occupancy rate of Agritourist guesthouses was highest in August 2020, at 72.3%, which indicates that these tourist reception structures, due to the family-oriented nature of their activity and the management more focused on the specific, personalized needs of customers, led to a faster reaction and adaptation capacity to new conditions arising in the context of the pandemic.

It can also be seen from the data recorded in tables 1-3 that the number of agrotourism reception structures has increased considerably by over 75%, reaching from 41 in 2019 to 71 in 2023, and the number of accommodation places in these structures in operation has increased from 157775 place-days in 2019 to 252446 place-days in 2023. These data attest to the fact that these structures are responding very well to the new challenges and that local people have understood that this activity can bring jobs and additional income for the family, both in more difficult conditions such as those during the pandemic, and afterwards.

Regarding the more specific aspect of this county, that of Accommodation on river ships, it can be seen from Table 1 that their number increased from 24 in 2019 to 29 in 2023, but regarding the number of tourists arriving in these structures, it decreased considerably by over 50%, from 5,790 tourists in 2019 to only 2,534 in 2023, the same phenomenon of considerable decrease is also manifested in the dynamics of overnight stays, which decreased from 16,272 in 2019 to only 5,149 in 2023, a fact that shows that these structures, due to their specificity and the additional conditions imposed, could not quickly readjust to the increasingly greater competition in the tourism market.

We also studied Arrivals of foreign visitors in Romania by continent and country of origin - thousands of persons, in table 7, from which it can be clearly seen that the tourism market at the national level has reacted well to the new conditions, because the total number of foreign tourists who visited Romania has increased year by year after the pandemic, exceeding the number of 12,815 thousand in 2019, reaching 14,777 thousand tourists in 2023, the majority of whom arrived from Europe, 13,868 thousand tourists, the rest under 1,000 thousand, coming from other continents.

Comparing the evolution of tourism activity in Mehedinți County with that at the national level, it is found that at this level, the evolution of the tourism market had a positive trend, the same as at the national level, attracting more and more domestic tourists, but constantly focusing on improving management and services and personalizing the tourist offer, to attract more and more foreign tourists.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE DYNAMICS OF THE EUROPEAN AND ROMANIAN BEER MARKETS: CONSUMPTION, PRODUCTION, AND MARKET EVOLUTION

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Abstract

The purpose of this paper is to analyze the dynamics of the Romanian beer market during the period 2019–2023, in the broader context of European trends. The study relies on official statistical data from national and international sources, applying quantitative methods such as time series analysis, growth indices, the coefficient of variation, Compound Annual Growth Rate (CAGR), and the Pareto cumulative method. In addition, a SWOT framework was employed to evaluate the internal strengths and weaknesses of the sector, alongside external opportunities and threats.The results highlight a moderate but steady decline in Romania's key market indicators—consumption, production, imports, and exports—registering annual decreases between -1% and -4%. Despite this contraction, Romania remains among the top beer consumers in Europe, with an average of approximately 85 liters per capita. Production, averaging 16 million hectoliters annually, has ensured strategic self-sufficiency, while imports (mainly from EU countries) reflect consumer demand for diversification rather than production deficits. Exports, however, remain marginal and highly volatile. The analysis further shows that the HoReCa sector was severely affected by the pandemic, while fiscal pressure (notably the 2022 excise duty increase) negatively influenced demand. Conversely, segments such as craft, premium, and non-alcoholic beers recorded growth, driven by urban demand, digitalization, and health-oriented consumption trends.The study concludes that, although challenged by economic pressures and regulatory constraints, the Romanian beer industry demonstrates resilience and adaptive capacity. Strategic directions include portfolio diversification, digital channel development, promotion of sustainability, fiscal dialogue with policymakers, and targeted expansion into external markets.

Key words: *beer market, Romania, beer consumption, beer production, imports, exports, SWOT analysis, CAGR, Pareto method*

INTRODUCTION

The European brewing industry reflects the cultural, economic, and social transformations shaping the continent. In the face of major challenges – from the global pandemic to economic instability and armed conflicts – its role and relevance are increasingly evident.

Agriculture underpins the brewing value chain, as key raw materials – barley, malted barley, and hops – are cultivated primarily for beer production. Barley and malted barley are converted into malt, the main source of fermentable sugars, while hops provide bitterness and stability. Consequently, agricultural performance directly determines the volume, quality, and continuity of brewing output.

Beer is a fermented alcoholic beverage produced from water, malt (usually barley), hops, and yeast (*Saccharomyces cerevisiae* or S. *pastorianus*). It is one of humanity's oldest fermented products, documented in ancient Mesopotamia (~5,000 BC) [1]. Beer contains over 800 volatile compounds, with its nutritional profile shaped by raw materials, yeast metabolism, and storage [23].

Moderate consumption has been linked to improved HDL cholesterol, endothelial function, and lower inflammatory markers while hop-derived polyphenols enhance antioxidant capacity and may reduce oxidative stress. Conversely, chronic excessive intake contributes significantly to alcoholic liver disease, due to caloric density and consumption volume [29].

The brewing industry is a major economic sector, generating employment and contributing to GDP through production, distribution, and exports [10]. While domestic output covers most internal demand, Romania both imports and exports considerable volumes, reflecting its integration into European trade [8].

At EU level, the beer market is mature, with average per capita consumption of ~70 liters annually, though with strong national variations. Germany, the Czech Republic, Austria, and Poland are among the largest producers and consumers [4]. The sector is highly diverse, from multinationals dominating market share to thousands of microbreweries and craft producers expanding rapidly [22]. Current trends highlight demand for low- or non-alcoholic products, sustainability initiatives, and innovation in styles and techniques [3].

Strict EU-level regulations on production, labeling, and taxation coexist with national specificities, influencing competitiveness [26]. The industry is also a pillar of agriculture, relying on local barley and hops, and plays a vital role in rural economies [4].

Romania stands as one of the largest beer markets in Eastern Europe, with a long tradition of brewing and consumption. In the past decade, the market has been dominated by four large companies but also shaped by the dynamic growth of craft breweries targeting younger urban consumers [7].

The four main players are Ursus Breweries (Asahi Group), producing Timișoreana, Ursus, Stejar, Kozel, and Ciucaș; Heineken Romania with Ciuc, Silva, and international brands; Bergenbier (Molson Coors); and United Romanian Breweries Bereprod, which brews Tuborg and Carlsberg. Alongside them, dozens of microbreweries focusing on quality and innovation have emerged, including Hop Hooligans, Ground Zero, Zăganu, Wicked Barrel, and Clinica de Bere.

In this context, the goal of this research was to analyze the evolution of the Romanian beer market in the broader extent of European trends, in the interval of the five years 2019–2023.

MATERIALSAND METHODS

The data used in this study were obtained from official and reliable sources, including:

• Databases on beverage consumption for the period 2020–2023, provided by the National Institute of Statistics [14], [15], [16].

• European Beer Trends – Statistics Report [30], which provides aggregated data and analyses on beer production and consumption at the European level.

For the interpretation of the collected data, the following statistical methods and analytical tools were employed:

1. Time Series Analysis

The evolution of beer production, consumption, as well as exported and imported volumes was analyzed through time series using:

• Annual growth rates;

• Variation ratios [12].

2. Growth Index (%)

To evaluate annual changes, the growth index was calculated using the formula:

$$I_t = \frac{X_t}{X_{t-1}} \times 100 \quad \text{.....(1)}$$

where:

I_t= growth index for year t,

X_t = indicator value in year t,

X_{t-1} = indicator value in the previous year.

This method is widely applied in the statistical analysis of socio-economic dynamics [32].

3. Coefficient of Variation (CV)

To assess fluctuations in the beer production, consumption, as well as exported and imported volumes, the coefficient of variation was employed, calculated as:

$$CV=\sigma/\mu \quad \text{.....(2)}$$

where:

σ = standard deviation,

μ= arithmetic mean of the data series.

A CV below 0.2 indicates low variability, and a CV above 0.5 indicates high variability.

4. Compound Annual Growth Rate (CAGR)

To analyze the growth dynamics of beer output, consumption, and trade flows, the Compound Annual Growth Rate (CAGR) was employed, as it represents an essential indicator for long-term sectoral assessments. In the context of the brewing industry, CAGR is particularly relevant for:

• Evaluating the performance of the beer market over time, highlighting production and demand trend;
• Estimating long-term growth prospects for both domestic and European beer sectors;
• Comparing development trajectories between different countries or regional markets within the EU.
The formula is [6]:

$$CAGR = \left(\frac{V_f}{V_i}\right)^{\frac{1}{n}} - 1 \text{.....(3)}$$

where:
V_f= the final value of the indicator,
V_i = the initial value of the indicator,
n = the number of years under review.

5. Pareto Cumulative Method

The Pareto cumulative method is based on the empirical observation that, within a given system, a relatively small proportion of causes generates the majority of effects [18]. This method provides deeper insights into the relative distribution of production among different states and highlights structural inequalities in each country's contribution to the European total. By applying the Pareto cumulative method, the graphical representation offers a dual perspective:
•Quantitative – through the individual values of each country;
•Cumulative – by emphasizing the progressive share in the European total.
Thus, this method becomes an essential tool in formulating sectoral policies, allocating resources, or identifying strategic markets in the European brewing industry [20],[25].

6. SWOT Analysis

The SWOT analysis is a method used to evaluate the strengths, weaknesses, opportunities, and threats of a sector, organization, or strategy. In this study, focused on the brewing industry in Romania and its integration within the European market, the SWOT framework was applied to identify internal and external factors influencing the development and competitiveness of the beer sector [19],[13].

RESULTS AND DISCUSSIONS

The analysed chart provides an overview of beer production in the member states of the European Union in 2023, expressed in thousands of hectoliters (hl). The data highlight significant disparities among member states regarding production volumes, outlining a clear hierarchy of the main producers in the region (Figure 1).

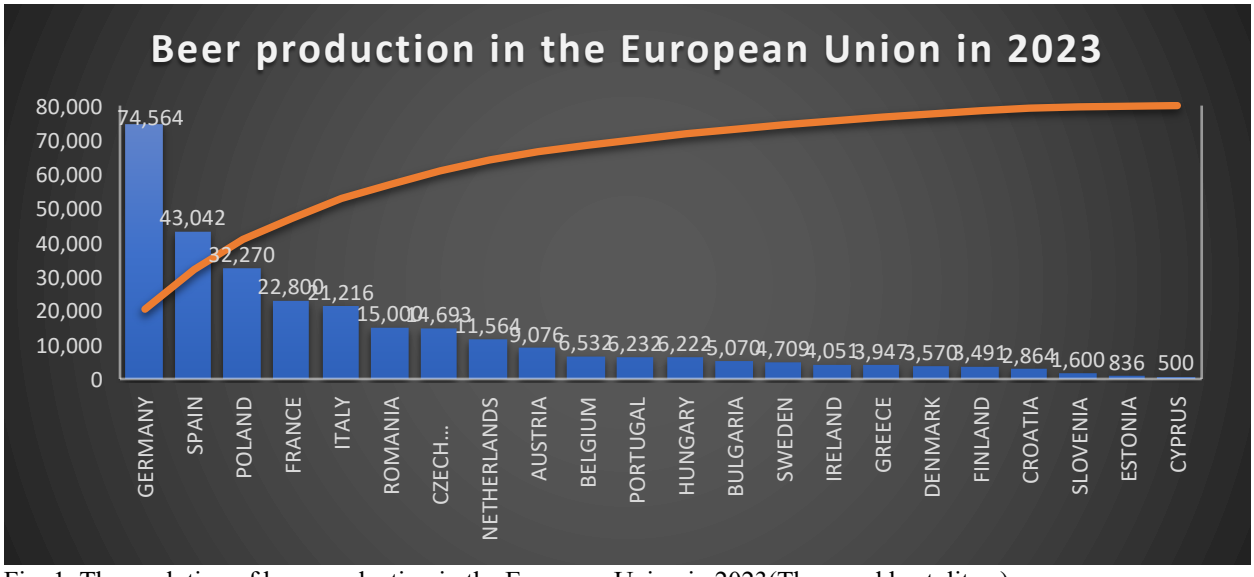


Fig. 1. The evolution of beer production in the European Union in 2023(Thousand hectoliters)
Source: European Beer Trends – Statistics Report (The Brewers of Europe, 2023) [30].

Germany ranks first by a wide margin, with a production volume of 74,564 thousand hl, consolidating its position as the most important beer producer in the EU. It is followed by Spain (43,042 thousand hl) and Poland (32,270 thousand hl), completing the top three. These

three countries make a substantial contribution to the Union's overall beer production, concentrating a considerable share of the total volume.

France (22,800 thousand hl) and Italy (21,216 thousand hl) occupy the next positions, confirming the upward trend of beer production and consumption in Southern European states. Romania ranks sixth, with a production volume of 15,000 thousand hl, highlighting its active role in the European beer industry, even surpassing countries with a longstanding brewing tradition such as the Czech Republic (14,693 thousand hl) and Belgium (6,532 thousand hl).

In the middle range of the ranking we find the Netherlands (11,564 thousand hl), Austria (9,076 thousand hl), Portugal (6,232 thousand hl), Hungary (6,222 thousand hl), and Bulgaria (5,070 thousand hl), reflecting stable but smaller-scale production compared to the major markets. At the opposite end are countries such as Slovenia (1,600 thousand hl), Estonia (836 thousand hl), and Cyprus (500 thousand hl), which record the lowest production levels in the Union.

The orange line superimposed on the chart suggests a Pareto-type cumulative curve, emphasizing the concentration of production within the first few member states. This representation confirms that a relatively small proportion of countries generate the largest share of total beer production in the European Union.

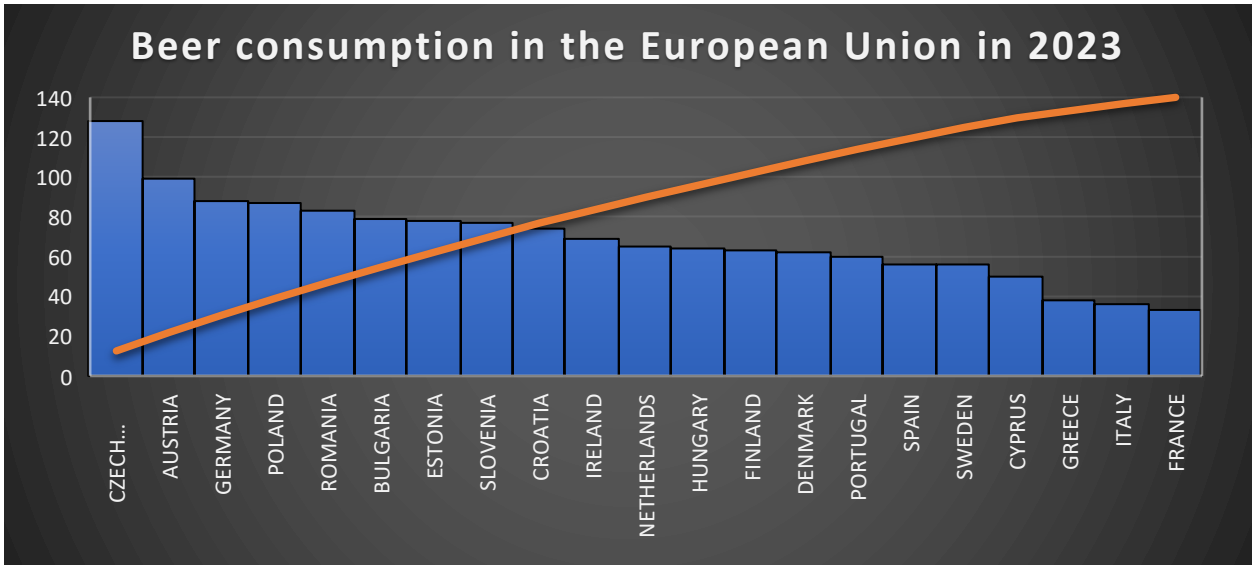


Fig. 2. The evolution of beer consumption in the European Union in 2023 (Liters per capita/year)
Source: European Beer Trends – Statistics Report (The Brewers of Europe, 2023) [30].

The Czech Republic ranks first in terms of consumption, with approximately 130 liters per capita, thus maintaining its status as the European leader in individual beer consumption. Austria and Germany follow, each with a consumption level exceeding 90–100 liters per capita.

This situation reflects a strong beer-drinking culture, typical of the Central European region, where beer is deeply embedded in social, festive, and everyday life.

A considerable segment of the European Union records an annual consumption of 65–85 liters per capita. These include Poland, Romania, Bulgaria, Estonia, Slovenia, and Croatia, as well as Western and Northern countries such as Ireland, the Netherlands, Finland, and Denmark (Fig. 2).

Such values can be linked to the wide availability of the product, the presence of local industries, and balanced dietary preferences between beer and other alcoholic beverages.

At the bottom of the ranking are France (~35 liters per capita), Italy, Greece, and Cyprus, all below 50 liters per capita. These countries are distinguished by their dominant viticulture traditions, where wine remains the primary alcoholic beverage, which explains the

relatively low levels of beer consumption (Fig. 2).

The orange line on the consumption graph represents the cumulative distribution, expressing the aggregated shares of each country in the EU total. This representation highlights a phenomenon of concentration in consumption across a limited number of states: the first 5–6 countries, including the Czech Republic, Austria, Germany, Poland, and Romania, account for a significant proportion of total per capita consumption in the EU. Toward the end of the chart, the curve flattens, indicating that the remaining countries contribute marginally to the cumulative total.

Thus, the Pareto model illustrates the inequality in the distribution of individual consumption, confirming the hypothesis that a small group of states sustain a large part of regional demand.

According to Brewers of Romania (2023), the annual average per capita consumption was approximately 85 liters in the period 2019–2023, positioning Romania among the significant beer consumers at the European level. However, consumption recorded a slight decline in recent years, caused by factors such as the pandemic, increased excise duties, and lifestyle changes.

Table 1. Statistical indicators

	Standard deviation	Mean	Coefficient of variation (%)	2023/2019 (%)	Annual growth rate (%)
Beer consumption (liters)	3.33	85.74	0.04	90.24	-2.54
Beer production (thousand hl)	706.85	16,489.58	0.04	89.56	-2.72
Import (thousand hl)	99.25	610.26	0.16	95.55	-1.13
Export (thousand hl)	38.35	492.52	0.08	84.49	-4.13

Source: Own calculations based on beverage consumption data.

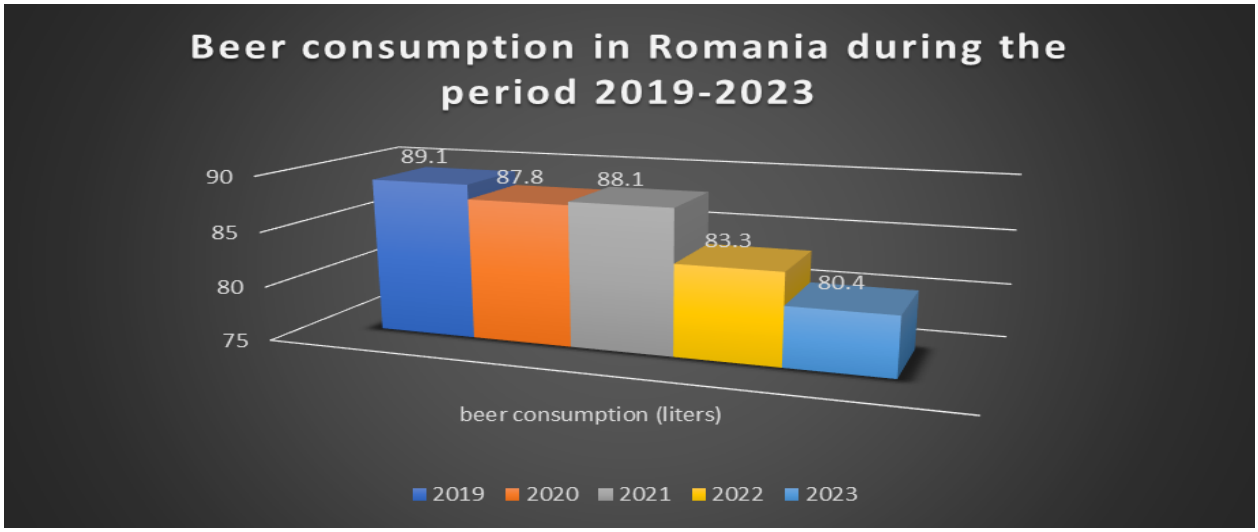


Fig. 3. The evolution of beer consumption in Romania during 2019–2023
Source: Official statistics regarding agriculture and consumption [14], [15], [16].

The statistical indicators for beer production, consumption, export and import are sown in Table 1.

Analyzing beer consumption in Romania during 2019–2023, a downward trend can be observed (Figure 3). The annual average per capita beer consumption decreased steadily, with an average annual rate of -2.54%. This declining trend is consistent with findings in the literature, which highlight the negative impact of the COVID-19 pandemic, inflation, and rising excise duties on alcohol consumption in Romania [24], [21]. Nevertheless, the low coefficient of variation (0.04) shows that the decline was gradual, without major annual fluctuations.

The main causes of this decline include reduced purchasing power, unfavourable weather, and shifts in consumer behavior (greater orientation toward health and non-alcoholic products). Consumption was directly affected by the fall in real incomes, accentuated during the pandemic and subsequent inflation. It should also be noted that in 2022, excise duties rose considerably through Government Ordinance 16/2022, and were subsequently adjusted automatically to inflation plus 5% annually. The HoReCa sector was severely hit by lockdowns in 2020–21, with its share of total beer consumption dropping to 8–9%, from ~15–20% before the pandemic.

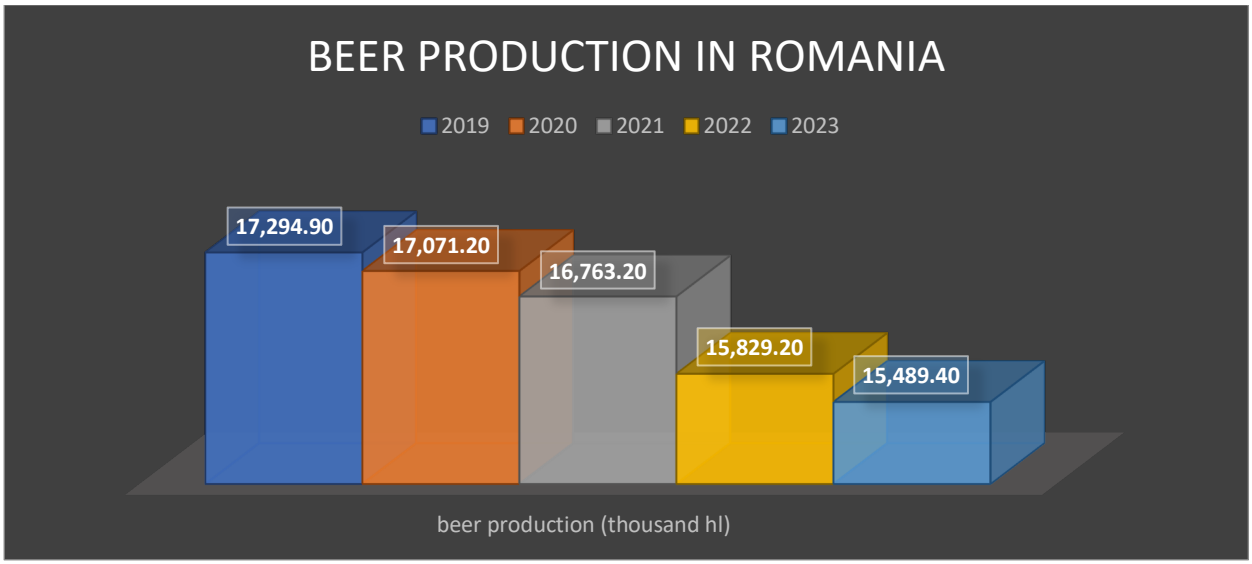


Fig. 4. The evolution of beer production in Romania during 2019–2023
Sources: Official statistics regarding agriculture and consumption [14], [15], [16].

Domestic beer production decreased on average by 2.72% annually during the analyzed period, reflecting declining domestic demand and economic pressures (Fig. 4).

This trend has also been observed in other economic studies of the Romanian agri-food sector, where production contracted under pandemic restrictions and rising production costs [17].

The stability of the coefficient of variation indicates a continuous and uniform decline.

Beer imports are predominantly sourced from EU countries such as Germany, the Czech Republic, Poland, and Belgium, driven by consumer preferences for unusual, international, or premium beers, as well as low logistical costs within the Common European Market.

Studies show that in Central Europe, major markets encourage imports mainly for novelty and diversification, not for substituting local production.

Imports recorded a more moderate decline, with an annual rate of -1.13%.

The higher variability (coef. 0.16) reflects significant year-to-year fluctuations, possibly caused by supply chain changes, logistical costs, and consumer preferences [9].

Part of this relative stability may be explained by the import of premium or craft assortments that are not widely produced domestically [7] (Fig. 5).

Beer exports in Romania remain marginal and stable, representing 2–3% of production.

The current strategy relies on strong domestic consumption and niche demand from the diaspora rather than large-scale exports.

Exports were the most affected, registering an average annual decline of over 4%. This decline may be associated with international logistical difficulties during the pandemic, reduced competitiveness in external markets, and shifts in consumption preferences [24], [21]. The coefficient of variation indicates higher volatility, characteristic of export markets sensitive to external factors.

Compared to other Central European nations, Romania is not a significant exporter, and

imports/trade balance remain predominantly local (Fig. 6).

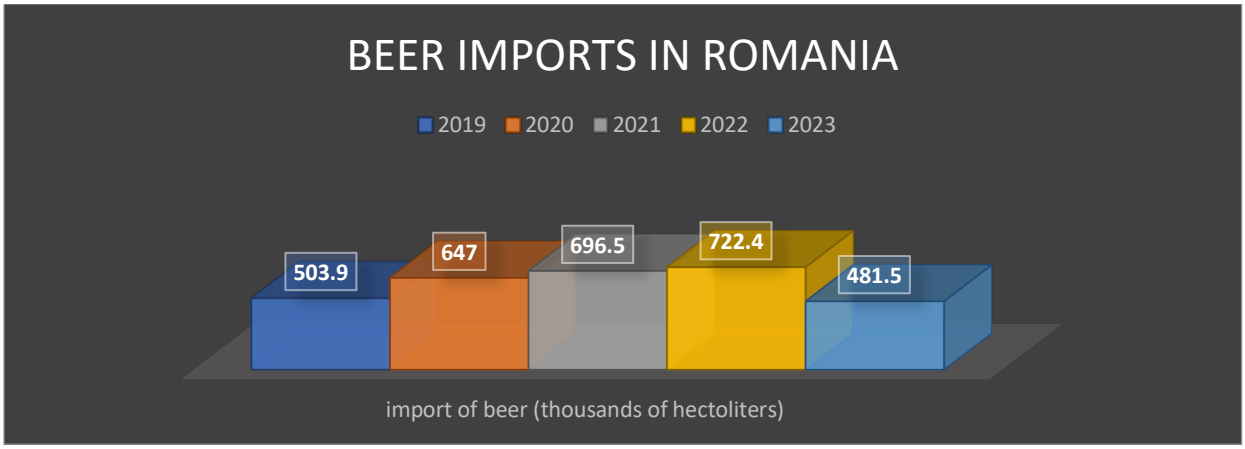


Fig. 5. The evolution of beer imports in Romania during 2019–2023
Sources: Official statistics regarding agriculture and consumption [14], [15], [16].

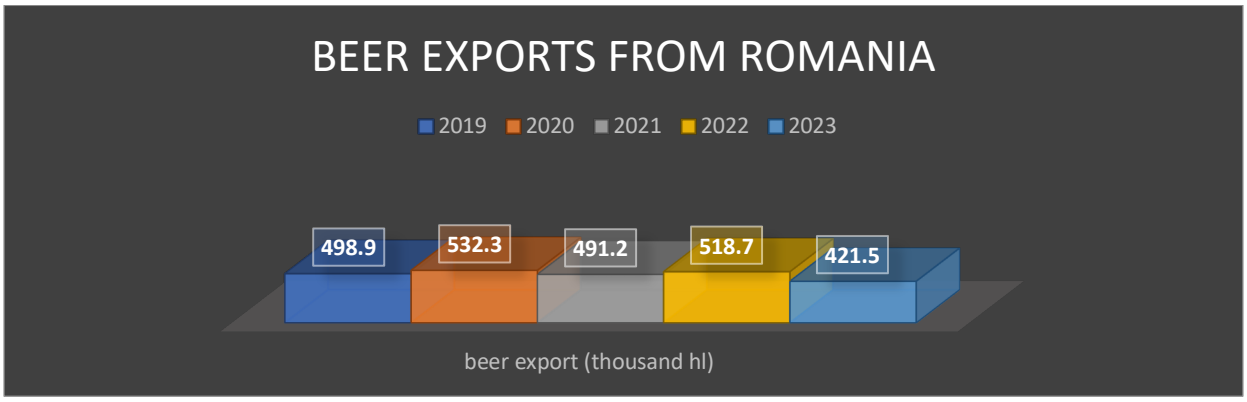


Fig. 6. The evolution of beer exports from Romania during 2019–2023
Sources: Official statistics regarding agriculture and consumption [14], [15], [16]/

SWOT Analysis

Strengths

1. Consistent local production

Romania is one of the main beer producers in Eastern Europe, with an average annual production of approximately 16 million hectoliters during 2019–2023, covering most of domestic consumption [5]. This consistent production supports internal market stability, even during crises. Popescu et al. (2022) highlight the resilience of the beer industry to recent economic shocks [24].

2. Strong beer consumption culture

Per capita consumption, although declining, has remained high compared to other countries in the region, indicating a well-established tradition [9]. This culture provides a stable consumer base. [2] emphasized Romanian consumers' traditional preferences for local beer.

3.Development of the craft and premium segment

Although still small in share, the craft beer segment has grown rapidly, offering new market opportunities [7]. This attracts young, urban consumers willing to pay more for quality and diversity.

Weaknesses

1. Decline in consumption and production

Data reveal a constant downward trend in consumption and production during 2019–2023, with negative annual rates of approximately 2.5–2.7% [14].This decline is due to the negative economic impact of the pandemic and changing consumer behavior.

2. High fiscal pressure

The increase in excise duties and alcohol taxes during the analysed period led to higher prices and reduced consumption, particularly in the mainstream beer segment. Georgescu & Pavel

(2022) demonstrate that high taxation reduces demand elasticity and negatively impacts the beer market [11].

3. Dependence on the HoReCa sector

The HoReCa segment was severely affected by pandemic restrictions, which negatively influenced draft and premium beer sales [5]. This dependency makes the market vulnerable to external shocks. In the absence of diversification, external shocks can lead to abrupt declines in sales volumes, difficulties in maintaining cash flow, and long-term competitive vulnerability. [28]

Opportunities

1.Expansion of the craft and premium segment

Demand for craft, non-alcoholic, and flavoured beers is increasing, stimulating innovation and portfolio diversification [7], [27]. This can raise profit margins and attract new consumer segments.

2. Digitalization of sales

E-commerce channels and home delivery developed significantly during the pandemic and continue to represent an opportunity for market expansion [31]. Adapting to digital commerce can improve accessibility and convenience for consumers.

3. Trends toward responsible and healthy consumption

The growing interest in non-alcoholic and low-alcohol beer opens new markets and can help counterbalance the overall decline in alcohol consumption [27].

Threats

1. Difficult economic context and inflation

Rising production costs and declining purchasing power negatively affect demand in the beer market. Georgescu & Pavel (2022) emphasize the negative impact of inflation on discretionary spending [11].

2. Strict fiscal and legislative regulations

Fluctuating tax policies and rising excise duties reduce investment attractiveness and may discourage consumption [2]. Popescu et al. (2022) mention that legislative instability is a barrier to long-term development [24].

3.Growing competition from imports and alternative beverages

Beer imports, as well as rising consumption of other alcoholic or non-alcoholic beverages, can affect the market share of local producers [9]. Pantiu et al. (2024) show that changes in preferences and access to international brands intensify competition [21].

4. Impact of climate change on raw materials

Risks related to the supply of hops and barley can generate cost volatility and affect production [28]. Dumitru et al. (2022) draw attention to the industry's vulnerability to environmental factors [7].

CONCLUSIONS

The Romanian beer market has experienced a steady yet moderate decline across its main indicators—consumption, production, imports, and exports—registering negative annual rates between -1% and -4%. This trend reflects not only macroeconomic pressures such as the pandemic, inflation, and higher excise duties, but also long-term structural changes in consumer behaviour.

With an average annual consumption of approximately 85 liters per person, Romania continues to rank among the top beer consumers in Europe, despite an annual decline of -2.54%. The shift in consumer preferences-toward health-oriented choices and non-alcoholic beer-combined with the erosion of real incomes, represent key drivers of this downward trend.

Beer production declined at an average rate of -2.7% per year, reaching an annual average of 16 million hectoliters. Nevertheless, production levels remained sufficient to cover nearly the entire domestic demand, reflecting a strategic self-sufficiency of the industry. This resilience underscores the ability of domestic producers to balance supply and demand, even under adverse economic conditions.

Beer imports originate primarily from EU member states such as Germany, the Czech Republic, and Belgium. They are driven largely by consumer demand for diversification-particularly in the craft and premium segments-rather than by any insufficiency in local production capacity. Although imports show greater variability than production, their overall medium-term trajectory has remained relatively stable, reflecting a niche-oriented but persistent demand.

Exports of Romanian beer have been the most affected indicator, registering an average annual decline of -4.13% and accounting for only 2–3% of total production. Romania does not play a major exporting role within the European beer market, with external trade largely confined to niche demand, particularly from the diaspora or for traditional specialty products.

The HoReCa segment (hotels, restaurants, cafés) was severely impacted by the restrictions imposed during the pandemic, while the increase in excise duties introduced through Government Ordinance 16/2022 led to higher retail prices and reduced consumption, especially within the mainstream beer segment. These combined effects contributed to the contraction of both volume and value in domestic sales.

Despite the overall downturn, the market has shown dynamism in certain sub-segments. Craft, flavored, and non-alcoholic beers are recording steady growth, supported by demand from urban consumers, the expansion of digital sales channels, and the rise of responsible and health-conscious consumption trends. This emerging demand highlights the capacity of the Romanian beer industry to adapt and innovate in response to shifting consumer expectations, offering a potential path for future resilience and growth.

Strategic Recommendations for the Beer Market

Diversification of product portfolio

Given the decline in traditional consumption and the growing interest in craft, non-alcoholic, and premium beers, companies should expand their offerings to include innovative products tailored to new consumer preferences [7]. This can enhance attractiveness and strengthen customer loyalty.

- ***Development of digital sales channels***

The COVID-19 pandemic accelerated digital transformation, and online commerce is becoming increasingly important for consumers [31]. Investments in e-commerce platforms, delivery services, and digital marketing can broaden customer access and convenience, boosting sales.

- ***Promotion of sustainability and social responsibility***

Consumers are increasingly concerned with environmental impact and responsible consumption [8]. Companies should invest in sustainable practices (reducing packaging, saving energy) and awareness campaigns on moderate drinking, which can strengthen brand image and public trust.

- ***Collaboration with authorities for balanced fiscal policies***

Given the high fiscal pressure negatively impacting consumption, the beer sector should develop a constructive dialogue with policymakers to support fiscal policies that stimulate growth and market competitiveness [11]

- ***Expansion into external markets***

Exports represent an important growth opportunity, particularly in regional (Central and Eastern European) and EU markets [10]. Companies should invest in international marketing and product adaptation to capitalize on these opportunities.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STUDIES REGARDING THE STORAGE CAPACITY AND ECONOMIC EFFICIENCY OF SOME SWEET POTATO VARIETIES CULTIVATED IN ROMANIA, IN THE CONTEXT OF THE EXPANSION IN CULTIVATION AS A CONSEQUENCE OF GLOBAL WARMING

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Abstract

Sweet potato consumption worldwide, but particularly in some African and South-East Asian countries, is second only to the potato as an important source of food for the population. Additionally, given the soil and climate requirements and the ongoing impacts of climate change, including global warming, sweet potato is a crop expected to increase in cultivation. This paper discusses the findings from studies on post-harvest management and the economic assessment of sweet potato cultivars in the marketing process. The duration of the quality keeping depends of the environmental conditions during storage, mainly temperature and relative humidity levels. The shelf-life was extended when stored at 13°C and 90% relative humidity (climatic room), lasting between 180 and 192 days, depending on the variety. In contrast, under ambient conditions of 18°C and 60% relative humidity, the shelf-life was shorter, ranging from 115 to 130 days, also depending on the variety. Overall losses at the end of storage were lower in the climatic chamber, ranging from 16% for Koretta to 23% for RO-CH-M.
It was also ascertained that over 98% of the output of the sweet potato cultivars correspond to the specific quality standard and the tubers production have a homogenous structure by quality categories, the value of quality category coefficient (Q) having values between 2.56 and 2.65.

Key words**:** *postharvest, storage period, weight losses, quality keeping, quality coefficient*

INTRODUCTION

Sweet potato (Ipomoea batatas) is a tropical tuber crop grown in warm seasons, ranking as the second most economically significant tuber crop worldwide, after the potato. It is a key food crop in numerous countries, mainly in Africa and Sud East Asia [6, 9, 13]. Sweet potato's ability to thrive in marginal environments, its role in enhancing household food security, and its adaptability in mixed farming systems make it a vital livelihood strategy for smallholder farmers. Sweet potato takes only a short period to maturity making it possible to produce food in areas with short rainfall seasons, aspect very important in the actual context of climate changes and global warming [1, 2, 3]. The sweet potato cultivar, growing conditions, maturity and storage conditions have a big influence on the nutrient composition and production [12].

Although the roots are mostly consumed soon after harvest, a properly cured sweet potato held under optimal temperature and relative humidity conditions can be stored for many months. Various types of sweet potatoes are planted in the world. Skin color, flesh color, dry matter, sweetness, and flavor differ among cultivars. However, the postharvest care and handling recommendations are identical for all types. Numerous pre-harvest factors influence the potential storage life of sweet potatoes. Heavy rainfall and saturated soil conditions prior to harvest may cause root fermentation and storage decay, especially if the vines have been removed before harvest. The amount of pre-harvest disease and insect pressure also influences postharvest life [7, 8].

Sweet potatoes do not mature as fruits do but continue to grow as long as conditions allow. Harvest time is determined by market price, expected total yield, and root size. Sweet potatoes should be harvested when most of the roots have attained the desired size for the target market. This typically requires between 3 to 3.5 months from the time of transplanting. After harvest, the storage of tubers may occur in short time, in order to have a good quality preservation of the product [4, 5].

The sweet potatoes should be kept in a separate well-insulated storage room at 13 °C ± 1 °C and 90 to 95 percent RH. Under these conditions, a storage life of 6 to 10 months is expected, although sprouting may begin after approximately 6 months, depending on the cultivar. Temperatures above 15°C lead to more rapid sprouting and weight loss. Roots can be stored up to a year without sprouting under optimal conditions [10,11].

In this context, the purpose of the paper is to present the results of the studies carried out regarding the post-harvest management process and the economic characterization of the sweet potato cultivars in the marketing process.

MATERIALS AND METHODS

Sweet potato tubers of the varieties Hayanmi, RO-CH-M, Dabu 23 and Koretta were harvested at the beginning of October 2023, from the experimental field of Research Station for Crop Culture on Sands (SCDCPN) Dăbuleni, Dolj County, Romania.

After harvesting, the tubers were kept in the laboratory of Horticultural Products Technology - Faculty of Horticulture Bucharest, under different environmental conditions, which constituted the 2 experimental variants:

V1 - T = 13°C and RH 90%, using climatic chamber (Photo 1, Photo 2).

V2 - T = 18°C and RH 60%, under ambient conditions, in a space away from light and heat.

Sweet potato tubers were weighed both before and after storage to assess weight loss. After harvest, only tubers in excellent phytosanitary condition were selected for storage. At the end of the storage period, the quality degradation (such as spoilage or sprouting) was evaluated. The SUS content of the tubers was measured using an Atago electronic refractometer at both harvest and the end of storage. The shelf-life was also determined, with the end of storage marked as the point when the sweet potato tubers lost their commercial value.



Photo 1.The temperature of climate chamber
Source: Photo taken by authors (Own source).



Fig. 2. Relative humidity of the climate chamber
Source: Photo taken by authors (Own source).

The economic efficiency of sweet potato valorization was determined by establishing the structure of production by quality categories (Q) using the formula:

Q = Kq/100, where K= 3 for extra quality; 2 for 1st quality; 1 for 2nd quality and 0 for that

intended for industrialization, and q is the percentage of the quality category.

According to American Standard No 51.1600/2005, sweet potato tubers are classified into quality classes according to physical parameters as follows:

- *Extra quality*: tuber length 7.5 - 23 cm, maximum diameter 8.2 cm, minimum diameter 4.5 cm and maximum weight 0.51 kg.
- *Grade 1*: tuber length between 7.5 - 23 cm, maximum diameter 9 cm, minimum diameter 4.5 cm and maximum weight 0.56 kg.
- *2nd quality*: tuber length between 7.5 - 18 cm, diameter between 3.8 and 5.7 cm.

RESULTS AND DISCUSSIONS

From the values presented in Table 1 , the following results were highlighted:

Soluble dry matter (SDM) content

At harvest, SDM content values ranged from 8.3% for Dabu 23 to 14.4% for Hayanmi. Koretta and RO-CH-M had intermediate values of 12.6% and 14.2% respectively. During storage, both due to further hydrolyzation of starch and its conversion into soluble carbohydrates and loss of water through transpiration (concentration), the SDM content increased.

Table 1. Behavior of sweet potato varieties during storage according to storage conditions

Variety	Storage variant	SDM (at harvest) %	SDM (end of storage) %	Storage period days	Weight loss %	Qualitative loss %	TOTAL LOSS %
HAYANMI	V1	14.4	15.2	192	11	7	18
	V2	14.4	15.8	130	16	10	26
RO-CH-M	V1	14.2	15.0	185	14	9	23
	V2	14.2	15.4	120	18	12	30
DABU 23	V1	8.3	9.0	185	14	7	21
	V2	8.3	9.6	125	20	10	30
KORETTA	V1	12.6	13.2	180	10	6	16
	V2	12.6	13.7	115	16	9	25

Source: Own results. V1 – T=13° C; UR= 90% V2 – T = 18° C; UR = 60%

Thus, under V1 conditions, the determined values ranged from 9% for Dabu 23 (Photo 3), 13.2% for Koretta (Photo 4), 15% for RO-CH-M (Photo 5), and 15.2% for Hayanmi (Photo 6).



Photo 3. Dabu variety - 23 SUS 9%
Source: Authors' s source.



Photo 4. Koretta variety - SUS 13.2%
Source: Authors' source.



Photo 5. RO - CH - M variety - SUS 15%
Source: Authors' s source.



Photo 6. Hayanmi variety - SUS 15.2 %
Source: Authors' source.

In sweet potato tubers stored at a higher temperature and lower relative humidity (V2), metabolic activity was more intense, so that SUS values at the end of storage were higher compared to V1. They ranged from 9.6% in Dabu 23, 13.7% in Koretta, 15.4% in RO-CH-M and 15.8% in Hayanmi, respectively.

Storage duration

Sweet potato tubers stored under the two experimental variants showed different behavior depending on variety and storage conditions. It was observed, as expected, that the longest storage period was observed at V1, practically under the environmental conditions recommended in the literature. Thus, the storage time under V1 conditions ranged from 180 days for Koretta variety, 185 days for Dabu 23 and RO-CH-M varieties and 192 days for Hayanmi variety, respectively.

Under ambient storage conditions (V2), the shelf-life was reduced compared to V1 by 60-65 days. The results obtained showed a storage life of 115 days for Koretta, 120 days for RO-CH-M, 125 days for Dabu 23 and 130 days for Hayanmi.

Weight loss

Due to the metabolic activity of sweet potato tubers but mainly due to water loss by transpiration during storage, weight losses were higher under ambient storage (V2) compared to cold storage (V1).

Weight losses, even after a longer storage period were lower in V1 compared to V2. Thus, under V1 conditions, losses were 10% for Koretta, 11% for Hayamni and 14% for RO-CH-M and Dabu 23. In tubers stored under ambient conditions (V2), weight losses were 16% for Hayanmi and Koretta, 18% for RO-CH-M and 20% for Dabu 23, respectively.

On a monthly average basis, weight losses under V1 storage conditions ranged from 1.66% to 2.33% depending on the variety, and from 2.66% to 3.33% for V2, also depending on the variety.

Quality scores

Quality downgrading caused by microbiological spoilage or sprouting of tubers was higher in sweet potato tubers stored under ambient conditions (V2) than in the climatic chamber (V1).

The values obtained under V1 conditions ranged from 6% for Koretta, 7% for Hayanmi and Dabu 23 and 9% for RO-CH-M.

The highest values recorded for tubers stored under V2 conditions ranged from 9% for Koretta, 10% for Dabu 23 and Hayamni and 12% for RO-CH-M.

It should be noted that in Dabu 23 and Hayanmi, at the end of storage under ambient conditions (V2), the tubers showed sprouting (Photo 7 and 8).



Photo 7. Dabu 23 variety, sproute
Source: Authors' s source.



Photo 8.Hayanmi variety, sprouted
Source: Authors' source.

Total losses

The total losses resulting from the sum of weight losses and quality downgrades were higher in the environmental storage conditions (V2) than in the climatic chamber (V1).

Thus, under V1 conditions, the values recorded were 16% for Koretta, 18% for Hayanmi, 21% for Dabu 23 and 23% for RO-CH-M, respectively.

The higher values recorded for tubers kept in the climate chamber (V2) ranged from 25% for Koretta, 26% for Hayanmi, 30% for Dabu 23 and RO-CH-M, respectively.

Economic efficiency of sweet potato tubers valorization

The structure by quality categories of sweet potato varieties cultivated in the experimental field of SCDCPN Dăbuleni is presented in Table 2.

It results that 98 - 99.3% of the total production of all varieties meet the requirements of the quality standard for fresh sweet potatoes.

The coefficient of the quality categories, which characterizes the homogeneity of the variety from the qualitative point of view, in the three cropping systems ranged between 2.56 and 2.65. The close values of this coefficient indicate the qualitative homogeneity of the cultivated varieties.

Table 2. The quality structure of sweet potato, in the valorization process

Variety	Quality structure - %-				Total according quality standard	The coefficient of the quality category
	Extra class	First quality class	Second quality class	Industry class		
HAYANMI	75.0	13.0	10.8	1.2	98.8	2.62
RO-CH-M	74.5	9.4	14.2	1.9	98.1	2.56
DABU 23	76.2	10.8	12.3	0.7	99.3	2.65
KORETTA	73.8	12.6	11.6	2.0	98.0	2.58

Source: Own results.

CONCLUSIONS

The optimal storage conditions recommended for the storage of sweet potato tubers are: temperature of 13°C and RH of 90%.

SUS content at harvest ranged from 8.3% in Dabu 23 variety to 14.4% in Hayanmi variety.

At the end of storage, the values were higher than at harvest, ranging from 9% - 15.2% (V1) and 9.6-15.8% (V2), respectively, depending on the variety.

The shelf-life was longer under storage conditions in climatic chamber V1, with values of 180-192 days, depending on the variety, and

lower values under ambient conditions (V2), ranging from 115 to 130 days, also depending on the variety.

The total losses at the end of storage were lower in the climatic chamber (V1), where they ranged from 16% for Koretta to 23% for RO-CH-M.

When stored under ambient conditions (V2), the highest values of total losses ranged from 25% for Koretta to 30% for Dabu 23 and RO-CH-M.

Analyzing the results as a whole, it can be seen that the best keeping capacity (shelf life correlated with total losses) was shown by the Hayanmi variety and the lowest by the Koretta variety.

Economic quality indicators of sweet potato varieties show that:

- 98 - 99.3% of the total production falls within the quality standard specific to the valorization of fresh sweet potato tubers,
- the coefficient of the quality categories (Q) had values between 2.56 and 2.65, which indicates the homogeneity of the quality structure of all 4 studied varieties

ACKNOWLEDGEMENTS

This research work was supported by an ADER 5.1.3 program granted by the Romanian Ministry of Agriculture and Rural Development, contract
number 113/13.07.2023.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CONCEPTUALISATION OF HUMAN CAPITAL AND SUSTAINABLE RURAL DEVELOPMENT

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Abstract

The aim of this paper is to conceptualise the human capital starting from early approaches to the present day. The human capital concept has been a constant in the economic and social thinking and practice even since classical economics, followed by the approaches in the post-war period and those specific to the recent and contemporary period. The intensity of human capital research has fluctuated over time, yet the interest has remained permanent and acquired new dimensions and valences. The present period comes with a series of new challenges and opportunities for the accumulation of human capital. Human capital is an important pillar in economic growth and sustainable rural development. In the current context, characterised by geo-political instability, pressure of climate change, economic instability and technological changes, human capital is subject to pressures that it has to face, both on the labour market and in social life, which presupposes the increase of resilience through the accumulation of new knowledge and skills.

Key words**:** *population health and education, sustainable development*

INTRODUCTION

The first approaches to the theory of human capital date back to antiquity, and belong to the philosophers Plato and Aristotle, starting from the knowledge and production capacities of individuals. William Petty continued the approach in 1863 and considered the individuals as fixed capital and their production capacities as circulating capital. He assessed the value of a human life in monetary terms, as the earnings obtained throughout an active life [18]. Adam Smith, in his work "The Wealth of Nations" (1776) [19], had a significant contribution in defining human capital, considering that the division and specialisation of labour could be achieved through adequate training; the capabilities of the individual are elements of a nation's wealth; investments in education are considered future sources of income; knowledge and experience are elements of fixed capital, etc.

The modern theory of human capital was developed in the second half of the 1900s by the exponents of the University of Chicago, the pioneers of the theory being T.W. Shultz, G. Becker and G. Stigler (Nobel Prize winners in economics). The human capital topic was approached from the point of view of economic growth. For the first time, the components of human capital (educational capital, biological capital respectively) appeared in an incipient form [1].

In the recent/current period, an increased importance is given to theories on human capital, through the impact of innovation, research, education, health or environmental protection on improving the quality of people's lives [14].

In this context, the objectives of the present paper are: identification of the temporal evolution of the concept, the main theories regarding human capital, its component elements and quantification methods.

MATERIALS AND METHODS

Over time, the human capital concept has raised a series of debates on the definition of the notion, quantification and establishment of component elements. The complexity of this issue will generate certain obstacles in encompassing all the facets of the concept, and thus a special attention will be paid to those approaches that treat human capital in terms of

economic growth and sustainable development.

The scientific approach of this paper is based on a summary review of the literature regarding the concept of human capital and the theories related to it, as well as the implications for economic growth and sustainable development.

The course of the research will stop at present, in the Romanian countryside, and the new perspectives and challenges from the perspective of human capital and sustainable rural development will be highlighted, which emerge from the study of the literature and evaluation reports of policies, plans and sectoral action strategies in relation to human capital.

RESULTS AND DISCUSSIONS

Definition of human capital

Adam Smith, long before the conceptualisation of human capital by the representatives of Chicago University, in his book "*The Wealth of Nations*", *viewed the human being as a machine that generated costs, but also with the ability to generate income, yet without offering a method to estimate the value of human capital*" [26]. He defined four types of fixed capital: equipment, buildings, land and the acquired and useful abilities of members in the society.

The pioneers of human capital were **Jacob Mincer, Theodore Schultz and Gary Becker** [1]. In the 1960s, they first applied the concept of human capital to economics. In their approach human capital represents means of production, and investments in human capital involves spending on education and professional training, that will generate an increase in productivity.

In the 21st century, capital was defined in the literature, from the economic point of view, as a multidimensional term, consisting of: "*organisational capital, intellectual-human capital, relational capital, financial capital, social capital and innovation capital*" [4].

According to the **dictionary of economic sciences**, human capital is defined as "*the combination of social and juridical characteristics that institutionalise the participation of individuals in the production of goods and services that are socially evaluated"* [2]

Human capital was treated by economists in close relation to education, health and human capacities and abilities, that is those elements that can generate productivity growth [30].

Frank and Bemanke, in the year 2007, defined human capital as an *"amalgam of factors, such as education, experience, training, intelligence, energy, work habits, trustworthiness, and the initiative that affects the value of a worker's marginal product"* [6].

Human capital is defined by **OECD** as the stock of knowledge, abilities, skills and other personal characteristics that generate individual, economic and social well-being [15]. Human capital is also an intangible asset that can support productivity, innovation and employment opportunities [16].

Table 1. Temporal evolution of the definition of human capital

Definition	Author
"as man's productive force that is due to his professional training, educational system and state of health" *"knowledge and skills form capital and this capital is the product of deliberate investment"* *"the ability, knowledge and capabilities of all that lead to increased labour productivity"*	Th. Schultz, 1961 [28]
"includes educational capital, biological capital, migration capital" *"stock of knowledge, abilities and skills incorporated into an individual resulting from his genetic inheritance, and subsequently, from investments in education, training and experience"*	G.Becker, 1964 [1]
"the skills and knowledge of a person that facilitate change in action and economic growth"	James Coleman, 1988 [28]
Fundamental source of productivity	P. Romer 1990 [22]
"the set of productive capacities of an individual, including his/her operational skills in the broadest sense: general or specific knowledge, skills, experience..."	Bernard Gazier, 1992 [28]
"the value of knowledge, skills and experience of the employees of the company"	Leif Edvinsson, 1997 [28]
"individual-specific human capital refers to the knowledge applicable to a wide range of companies and industries, it includes managerial and entrepreneurial experience"	Pennings, Lee&Von Witteloostujin, 1998 [28]

"knowledge, skills competences and other attributes acquired by individuals that are relevant for the economic activity" *"stock of knowledge, abilities, skills and other personal characteristics that facilitate the creation of personal, social and economic well-being."* *"intangible asset with the ability to drive and sustain productivity, innovation and employment"*	OECD, 1998 [15]
"human capital includes the level of academic education and professional training"	Hinz&Jung Hauer – Gans,1999 [28]
"accumulated stock of skills and talents and their manifestation in an educated and qualified workforce in the region"	Mathur, 1999 [12]
Innate abilities and knowledge and skills acquired by individuals throughout their lives	Laroche, Merette, and Ruggeri, 1999 [9]
"a hidden concept, a valorisation of the skills of individuals. A simple definition describes it as the value of a person's productive, marketable skills"	Joop Hartog, 2000 [28]
know-how, information, relationships and connections, general capabilities that individuals carry on behalf of the firm, as a result of salary relationships	Galunic, D. C., & Anderson, E. (2000). [7]
"… all the intangible assets that people bring to their workplace"	Thomas Davenport, 2001 [28]
Human capital is not limited to formal education, but encompasses experience, practical on-the-job learning, as well as non-traditional training methods that contribute to the development of skills	(Davidsson, Honig, 2003). [3]
A set of skills and accumulated experience that result in making employees more productive	Joseph Stiglitz (2007) [29]
"Additional production factor, consisting of the sum of the stock of knowledge, qualifications and experiences acquired both in formal education and in the post-school period during the process of on-the-job learning ("learning by doing").	C. Russu, 2012 [24]

Source: author's own selection from the literature [28, 1, 22, 15, 12, 9, 7, 3, 29, 24].

Modern human capital theory – in brief

The human capital theory was developed by the representatives of the Chicago School, and the models dealing with the impact of human capital on economic growth started from the neoliberal ideological framework. The human capital theory targeted several approaches, not only from the economic considerations of the educational process, but also of health, and they consider the development of individuals, but also public spending on health, education, social policies, and training expenses in the workplace [17].

The human capital theory has been subjected to a series of ideological, pragmatic and technical criticisms. Representative ideas of the human capital critics have been related to the fact that all human capital-related expenditures are treated as investment, even though some of them are consumption expenditures. Another criticism comes from the fact that not all the non-monetary benefits on the workplace are taken into consideration – related to better working conditions, increased job satisfaction – which cannot be reflected in higher incomes, and the rate of return on investment is uncertain [5].

Ideological criticism refers to the excessive use of the term capital, thus giving the impression that people are positioned on the same level with machines, physical capital.

Pragmatic criticisms refer to the fact that the social organization of school (example: educational differences between a bourgeois school and a scientific school) foreshadows the future educational-professional training of individuals.

Technical criticism refers to the fact that education and training of individuals are not directly conditioned by the level of productivity, but they condition potential productivity of individuals in the future.

Human capital in the theory of economic growth

Education has been perceived as having an impact on economic growth, through the increase of innovation and technological and knowledge diversification. And the improvement of technology and knowledge (skills) translates to increased productivity, which generates economic growth over time [21]. Combining this approach with the educational spending issue leads the scientific approach to two significant theories: the neoclassical theory of economic growth and the new theory of endogenous growth.

The neo-classical theory of economic growth

The neo-classical theory was developed by Robert Solow and Trevor Swan, in the year 1959. Robert M. Solow addressed investment in human capital at macro-economic level to stimulate growth and factor productivity, as

well as national wealth. He emphasised the idea that human capital growth is an investment, not a cost [27].

The neo-classical growth model assumes that capital accumulates in the economy, and how people use this capital is a determinant of economic growth. This model emphasises the link between capital and labour, which is reflected in production.

The Solow growth model was initially based on a quantitative approach to human capital – labour factor – based upon the Cobb-Douglas production function, in which the capital and labour factors have an elasticity substitution equal to 1 (to achieve the same volume of production, a 1% reduction in capital must be offset by a 1% increase in labour).

This instrument proved to be insufficient to explain the high economic growth rate in Western countries in the first years after the Second World War and continued in the 1950s. Thus, as an improvement to the model, R. Solow (Nobel Prize in Economic Sciences in 1987) introduced a third factor into the Cobb-Douglas function: the "*residual factor*", represented by technical progress, scientific knowledge, people's creative capacity, etc. [27]. This appears as an "endogenous" factor in relation to the economic growth process, but which incorporates a series of "exogenous" elements capable to increase the effectiveness of production processes. In this way, a qualitative approach to the labour factor was prefigured. Theoretical analyses and empirical studies on technical progress have led to a clarification of the role of human capital in economic growth.

This research highlights the acceleration of technical progress and the increasing complexity of production processes, which creates a new necessity in contemporary economies, i.e. the need to have as many qualified workers as possible. The only modality to increase the qualification level that would increase labour productivity, as well as social welfare, is the large-scale training of workforce. Thus, the emergence of human capital theory is imposed by the economic and social realities of the 21st century world.

The new theory of endogenous growth

The main contributors to the economic endogenous growth theory were P. Romer and R. Lucas (Nobel Prize laureate in Economic Sciences in 1995) [23], [10]. This theory is based on the principle of self-sustaining economic growth, unlike previous theories (R. Solow theory, which explains economic growth through "exogenous" factors); thus, investments in education represent an important accelerator of economic growth, which makes it possible to eliminate the so-called "Solow paradox" (denotes the discrepancy between the evolution of the volume of investments in information technology and GDP evolution).

Romer, P. (1994) and Stonier and Hague (1972) agree with Solow's hypotheses, arguing that technology should be an endogenous rather than exogenous determinant, because investments, research and development, knowledge and capital accumulation are reflected in the long-run economic growth. Investments in physical and human capital generate economic growth, which indicates that in the balanced state, growth derives from the development of human capital [22], [21].

In this regard, a series of recent studies have focused on measuring the stock of human capital from the perspective of economic growth theory, highlighting the mission of human capital in increasing well-being, as well as identifying the most appropriate means to eradicate endemic poverty in the countries with emerging economies. These theories show that starting from minimum investments in the accumulation of human capital, significant increases of production, and improvements of labour productivity can be generated [11].

However, the economic growth rate of a country depends on initial conditions, so that in a country with a low level of physical capital and human capital, the positive effects of education are not strong enough to generate and sustain economic growth. The human capital stock needs to be integrated into a production system capable to use the capabilities of individuals.

A consultation of the websites of organizations such as the World Bank, the Organization for Economic Cooperation and Development (OECD), the United Nations Educational,

Scientific and Cultural Organization (UNESCO) etc. reveals the importance given to theories that analyse the impact of innovation, research, education, healthcare or environmental protection on economic growth and improving the people's quality of life [13].

Components of human capital

There are several approaches to human capital in the scientific research, namely ***at macroeconomic level and at microeconomic level.*** At the microeconomic level, the approach considers the accumulation of knowledge, skills and abilities by the individuals in order to increase the level of personal or collective well-being (boosting productivity/efficiency at the firm level). The human capital thus accumulated is not transmissible, and the individual is the bearer of such capital, independently of the structures that have formed it; reaching a certain level of human capital can generate well-being, both at micro and macro levels. In this context, according to Becker's theory, the individual might be tempted to invest in personal education and training to reach a higher satisfaction scale [20].

Firm-specific human capital refers to those skills and knowledge that can be used only within the firm that has invested in their creation. In other words, these skills represent a competitive advantage for the firm, but they have a limited impact outside the unit. At the same time, the firm can also invest in the development of non-specific skills, through training and professional development courses, which will also have an effect on increasing firm's competitiveness, as well as on improving overall productivity at society level [20].

Most experts treat ***Human Capital*** as consisting of ***educational capital*** (skills acquired by the individual in the formal education process, as well as outside it) and ***biological capital*** (health status transposed in the physical abilities of individuals) [25].

Educational capital is composed of formal education (institutionalised education and training) and non-formal education. Education can be of several types depending on the type of investment, namely: a) informal parental education (education received from parents); b) formal education (knowledge received in primary, lower and upper secondary education); c) tertiary education: specific skills acquired in universities); d) formal and informal adult education (skills acquired by adults outside their work environment); e) continuous learning (skills acquired at work).

Biological capital is represented by the physical abilities of individuals, most often summarised by their state of health.

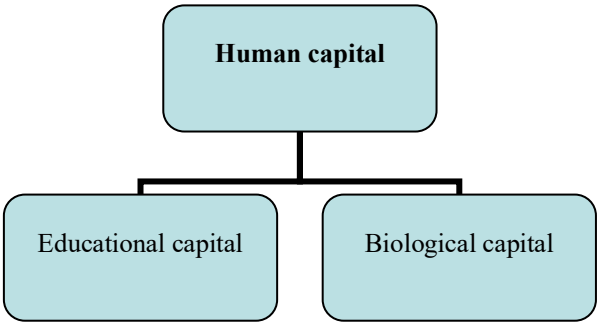


Fig. 1. Componence of Human Capital
Source: author's own conception.

Characteristics of human capital

Human capital is a multi-dimensional and multifactorial concept. It is *multidimensional* because it includes a series of elements such as: knowledge and qualifications; skills and abilities; character traits; personality; reputation and social status; mobility; state of health; level and quality of consumption, etc.

Human capital is also *multifactorial*, as a multitude of factors contribute to its formation and development, namely [19]:

-demographic data (population number, structures by genders and age, residence areas)

-economic situation and education level of family, which refer to the investment made by the family for education, nurturing and developing children's talents

-public spending for education and initial and continuous vocational training; healthcare and social assistance; culture; arts; environmental protection; housing etc.;

-public expenditure of economic operators for human resource development;

-personal expenditures made by individuals for their professional development throughout their lives.

Investment in human capital is a long-term investment both in terms of the period when it is made as well as of the period when its effects

are felt for individuals or community to which they belong (family, society). Investment in the production and use of human capital generates comparative and competitive advantages; winners are those individuals, those communities/nations that have in view and act to preserve, protect and develop the human capital stock [19].

As J. S. Mill highlighted in 1848, a fact confirmed by recent history, the speed and capacity with which a country recovers from devastating phenomena (natural disasters), economic disasters (economic crises) and military disasters (riots/wars) is faster the more modest the losses of human capital were.

Measuring human capital

It is quite difficult to measure human capital, given its multidimensional and multifactorial nature. Among the conventional ways to measure human capital, one of the three methods listed below can be used [8]: a) *The evaluation of results* takes into account a series of indicators, including: the enrolment rate in the educational system, the graduation rate of different education cycles, adult literacy and the average number of years of education; b) *The evaluation of costs* takes into account the calculation of educational and training costs; c) *The evaluation of income* takes into account the monetary benefits achieved by each individual following investments in education and vocational training. Regardless of the method chosen, there are a series of limitations deriving from the different way of assessment, evaluation or calculation of certain indicators used by each country.

Brief evolution of rural human capital in Romania

The post-communist period has brought about major changes in the way rural human capital is used on the labour market; thus, several stages can be noticed:

-***The first transition period (immediately after the Revolution, 1990-2000)***: Drastic decrease of the number or rural-urban commuters for work due to the restructuring or bankruptcy of many industrial and production units from towns, which has resulted in non-employed active population in rural areas or underemployed population in subsistence agriculture. This period of transition to market economy is a period of learning, of accumulation of human capital, yet with losses that are difficult to recover (human capital losses through school dropout, disqualification, poorer health condition, poverty expansion, destructuring of family institution) [19].

-***The second transition period (2000-2006):*** Emergence of a flow of urban residents who lost their jobs in industry coming back to rural areas. Unfortunately, the only occupational variant of those who remained in rural areas or who returned to the countryside was agriculture, namely subsistence agriculture due to the process of property restitution and dismantling of the cooperative and state farm system [19].

In the transition period, the processes of human capital growth (professionalisation) coexisted with the processes of human capital loss (de-professionalisation), the latter seeming to prevail. Thus, at least in certain socio-professional segments, we can notice significant losses of components, as well as loss of motivation for continuous learning. And this is taking place at the very moment when continuous lifelong learning becomes the main axis of learning and professional training reforms in the developed countries.

-Migration has intensified – which is also the main cause of human capital losses – mainly international migration as an alternative to subsistence farming, specific to the ***Period 3 (after Romania's accession to the EU);***

Besides the negative effects linked to the displacement of human capital from the Romanian countryside, the massive post-accession migration can also have positive effects in the short term, such as those associated with migrant remittances, capital accumulation, as well as long-term effects related to migrants' return home, which has been a more frequent phenomenon after the pandemic; migrants are coming home with a more developed entrepreneurial spirit, with a new development vision for their native area (***Period 4 – after the pandemic***).

The dynamics of rural area was different, where the lack of employment opportunities led to external migration over time, but also to internal rural-urban migration, generating a

decrease in the stock of human capital in rural areas, with a negative impact on the development of rural communities. The post-accession period has brought many financial resources to rural areas mainly through the rural development programmes implemented in this period, yet nowadays we are facing large development gaps between different rural spaces. Thus, we have peri-urban areas that have been informally assimilated to urban areas - around urban poles, as well as in tourist areas - these draw in human capital, while isolated areas, as well as rural areas located at a greater distance from urban centers, experience losses of human capital.

CONCLUSIONS

Human capital is an important component of economic growth and sustainable development, which must have the necessary knowledge and skills in order to face current and future challenges. Particular attention must be paid to it to reach a certain development level, so as to further contribute to the development of communities to which they belong. The development of human capital can be achieved by ensuring quality lifelong educational and healthcare services.

There is an obvious rural/urban divide in terms of human capital development, but lately, a significant gap has been also noticed between different rural areas. The higher development level of certain rural areas is correlated with obvious advantages that more developed areas benefit from: proximity to urban development poles (which facilitates access to education and healthcare, as well as access to non-agricultural jobs), existence of technical and utility infrastructure, existence of quality public infrastructure and services, relatively short distance (up to 30 km) to larger cities, etc. Thus, at present, there are rural areas where the living standard of the population is close to that in urban areas and poor and isolated rural areas, forgotten by the world. However, one of the EU's mottos is "Nobody will be left behind", which implies a lot of societal responsibility.

Romania's sustainable rural development vision should be an integrated vision, taking into consideration that in the absence of developed human capital (healthy, educated and informed), the solid foundations of development of a community, of society respectively, cannot be laid. Ideally, the rural identity (habits, traditions, crafts) should be preserved, alongside with adaptation to new technological trends.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE IMPACT OF TREATMENT WITH KALAM AND FOCUS ULTRA HERBICIDES IN VARIOUS DOSES ON YIELD, GROSS REVENUE AND PROFIT IN BIRD'S-FOOT-TREFOIL GRASSLAND

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Abstract

Weeds have a negative impact on the productive, quality and economic indicators in the production of bird's-foot-trefoil forage. The control against them is increasingly becoming a general ecological problem, which necessitates the need to look for new approaches to eliminate them. The implementation of systems and activities for sustainable agriculture is related to control over the use of plant protection preparations. This necessitates consideration of issues related to the application of appropriate agrotechnical practices to improve soil fertility and preserve useful cultivated species in grasslands from an economic point of view. Correlation dependences and derived regression equations were calculated on the sown grass from bird's-foot-trefoil treated with the herbicides Kalam in a dose of 20 and 40 g/da and Focus ultra in a dose of 100 and 200 ml/da. It was found that imported herbicides authorized for use showed a high positive correlation between yield with gross revenues (r=1.0000) and profit (r=0.9999). Graphical models have been developed to predict the main economic indicators based on the yield obtained after treating the grass with herbicides.

Key words**:** *grass forage, herbicide treatment, correlation dependences, regression equations, statistical analysis*

INTRODUCTION

Recently, weeds have covered large areas of arable land in plains and mountainous regions. The self-cultivation of crops using reduced tillage and intensive chemical protection, taking into account the herbicide resistance of weeds, is a cause of ecological and economic losses [8]. Ways to increase the profitability of agricultural crop production are being explored by reducing agronomic treatments [2] and intensifying chemical methods of weed control. Weeds cause severe economic losses to farmers and livestock producers. The increasing intensification of agriculture is leading to the emergence of herbicide-resistant weeds. This is limiting their adoption in sustainable agricultural practices [11; 20]. For many years, the strategies associated with herbicide application science experiments have been dependent on herbicide resistance [1; 14]. The increasing intensification of agriculture has led to a rapid increase in the incidence of herbicide-resistant weeds [19]. Chemical weed control is the most appropriate method to achieve high yields in forage crops [12]. Properly selected crop management technology [18], combined with the selection of the most suitable hybrids for a particular region, is a prerequisite for achieving sustainable yields and high economic results [3]. Elimination of weed competition by herbicide application increases productivity and income [9; 10; 16]. By analysing the economic results of herbicide treatments for weed control, it is possible to suggest the most appropriate one for use under specific soil and climatic conditions [21], according to its availability on the market. Properly selected herbicides for weed control are a cost-effective agronomic intervention that increases labour productivity and production efficiency and reduces production costs [23]. Weed control and fertilization [5, 6] are key elements of technology affecting yield, gross revenue and profit. A global strategy is needed to increase national capacity for herbicide resistance research. The aim of the study is to calculate correlations and derive regression equations for grass fodder produced from bird's-foot trefoil (Churkova, 2019) [4] after herbicide treatment based on yield and economic performance.

MATERIALS AND METHODS

In a research experiment in the experimental field of Research Institute of Mountain Stockbreeding and Agriculture-Troyan in the period 2020-2023 two herbicides were tested on bird's-foot trefoil grassland and their effect on weedy vegetation under the following variants: Kalam (dicamba 600 g/kg and tritosulfuron 125 g/kg) - 20 g/da; 2. Kalam (dicamba 600 g/kg and tritosulfuron 125 g/kg) - 40 g/da; 3. Focus ultra - 100 ml/da (active substance cycloxydim 100 g/l); 4. Focus ultra - 200 ml/da (active substance cycloxydim 100 g/l). The trial was laid out using the block method in 4 replications with a harvest plot size of 5 m².

Herbicides were selected from the "List of plant protection products, registered fertilizers and enhancers authorised for marketing and use" during the study period. Soil preparation for sowing was carried out according to generally accepted technology for the establishment of artificial grassland. Sowing was carried out in March at a rate of 1.2 kg/da with a row spacing of 12.5 cm and the area was irrigated before and after sowing. Herbicides were applied annually with a backpack sprayer at the 2-4 leaf stage of bird's-foot trefoil at a working solution rate of 50 l/da.

A statistical analysis based on economic indicators is applied. From the average dry matter yield (kg/da) data submitted to the Agricultural Academy in the ZFTK 7 project [22] over a four-year period, the economic indicators: production costs (BGN/da), cost price (BGN/kg), gross revenue (BGN/da), gross profit (BGN/da) and profitability (%) of dry matter yield of bird's-foot trefoil fodder production after herbicide treatment were calculated.

Correlation and regression analyses are presented. A tabular method was used to present the correlation dependences and a graphical method was used to derive the regression equations [13].

Correlation analysis is a numerical expression of the yield and the main economic indicators (production costs, cost price, gross revenue, gross profit and profitability of production). Data analysis of correlations and regressions is usually performed simultaneously as in this case [15].

The regression coefficient is a measure of the change by (+/-) when the i-th factor changes by the same unit [24].

In order to achieve the objective, the following indices were reported: Dry matter yield was reported as the average over the period (kg/da). The mathematical treatment of the yield was carried out using the method of analysis of variance by calculating statistically proven differences [17].

RESULTS AND DISCUSSIONS

Dry matter yield (Table 1) averaged over the study period was highest when bird's-foot trefoil grassland was treated with the herbicide Focus Ultra at 100 ml/da (1,017.4 kg/da).

Productivity was also high after application of the herbicide Kalam at 40 g/da (956.6 kg/da). Of the two herbicides tested, Focus ultra had a greater positive effect on productivity.

The application rate showed a higher effect with Focus Ultra herbicide than with Kalam herbicide.

Table 1. Dry matter yield of grassland of bird's-foot trefoil treated with herbicides in kg/da average over the period 2020-2023

Variants	*Dry matter yield (kg/da)*
Kalam 20 g/da	861.4
Kalam 40 g/da	956.6
Focus ultra – 100 ml/da	1,017.4
Focus ultra – 200 ml/da	868.0
LSD 5%	123.9
LSD 1%	180.2
LSD 0.1%	270.3

Source: Data from ZFTK7 Project to the Agricultural Academy of Bulgaria [22] and publication of Churkova and Churkova, 2024 [7].

Herbicide treatment of bird's-foot trefoil grassland had a significant effect on both the variation in average yield values and the economic indicators of forage production.

The highest positive correlation (Table 2) was found between yield and the gross revenue indicator (r=1.0000) and a negative correlation with costs (r=-0.9976).

Table 2. Correlation dependencies between yield and main economic indicators of bird's-foot trefoil production treated with herbicides

	Yield	Costs	Cost price	Gross Revenue	Gross Profit	Profitability
Yield	1					
Costs	0.9881	1				
Cost price	-0.9976	-0.9753	1			
Gross Revenue	1.0000	0.9881	-0.9976	1		
Gross Profit	0.9999	0.9878	-0.9977	0.9999	1	
Profitability	0.99943	0.9824	-0.9993	0.9994	0.9994	1

Source: Own calculations.

The theoretical regression line and the regression equation between the dry matter yield and the gross revenue of forage obtained after herbicide application on the bird's-foot trefoil stand are shown in Figure 1, where y=0.19x+0.0018 with an extremely high coefficient of determination, R^2=1. The obtained profit showed a positive, also very high positive correlation with the realized yield (r=0.9999), which proves the very strong correlation between these two indicators. The very strong correlation of yield with gross profit and gross revenue also determined the strong correlation dependence of yield and profitability with the effect of herbicide treatment and forage production obtained.

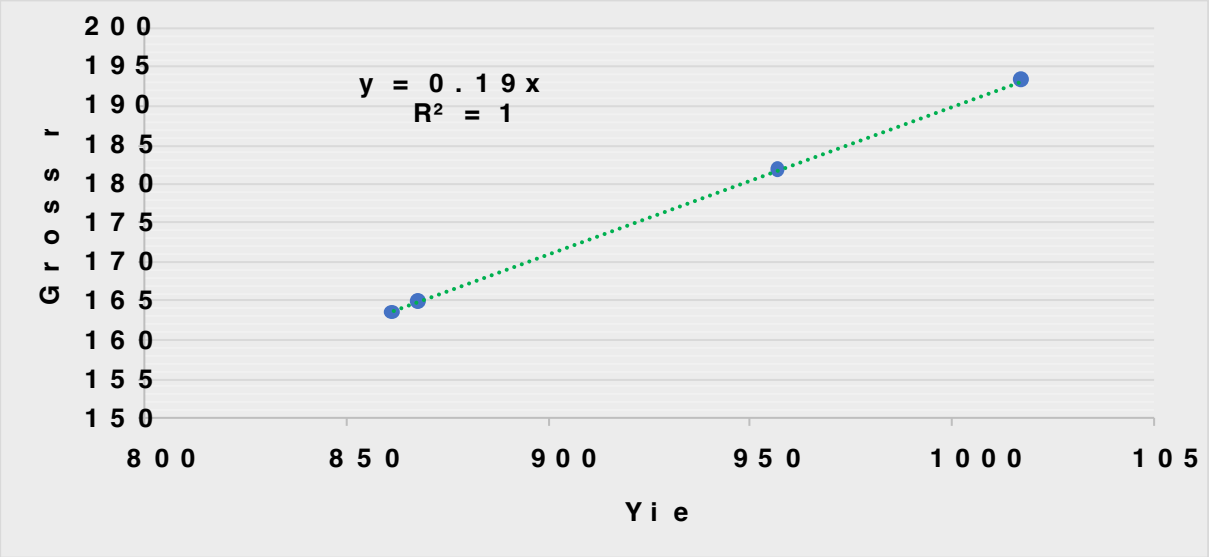


Fig. 1. Theoretical regression line and regression equation between dry matter yield and gross revenue
Source: Own calculations.

The efficiency of the herbicide treatment is a numerical expression of the resulting high value of the correlation coefficient between production costs and gross revenue, which is r=0.9881. The high values of production costs with profit (r=0.9878) and profitability (r=0.9824) were also found. Cost prices negatively correlated with gross revenue (r=-0.9976), gross profit (r=-0.9977) and profitability (r=-0.9993).

The very strong correlation between gross revenue and gross profit (r = 0.9999) determines the very high coefficient of determination shown in Figure 2 (R^2 = 0.9998) and the derived regression equation (y = 0.9767x - 11.256).

The high correlation between production costs and gross revenue (r=0.9881) determines the possibility of predicting gross revenue depending on the production costs of herbicide inputs and other production activities in the realization of forage production.

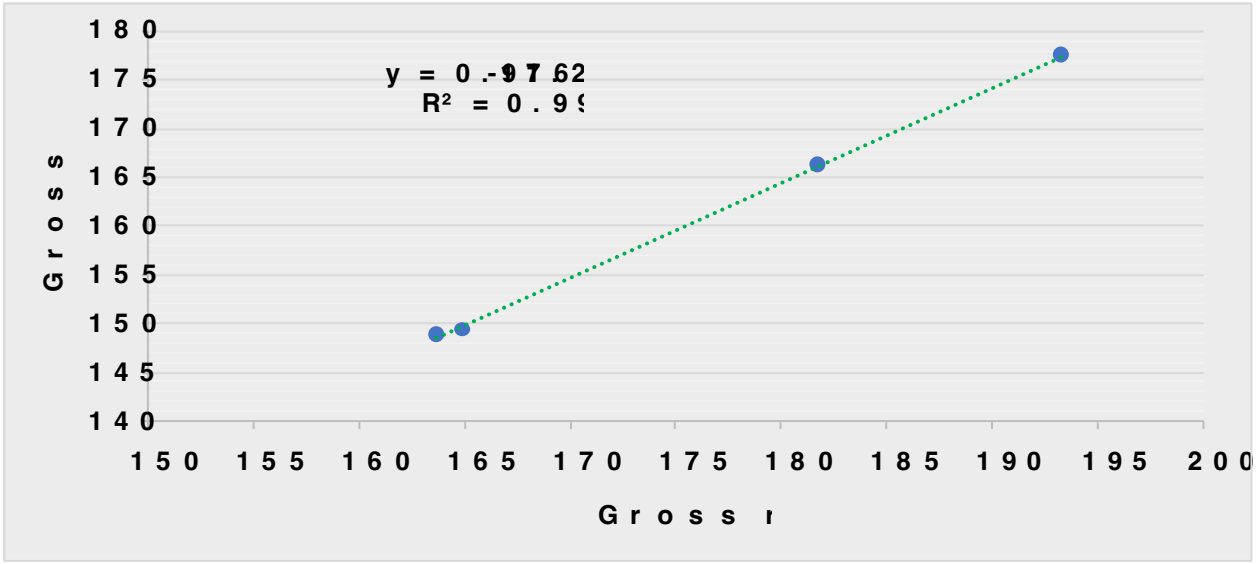


Fig. 2. Theoretical regression line and regression equation between gross revenue and gross profit
Source: Own calculations.

This also determined the derivation of the regression equation y=30.245x-288.57 with the coefficient of determination (R^2=0.7051) shown in Figure 3.

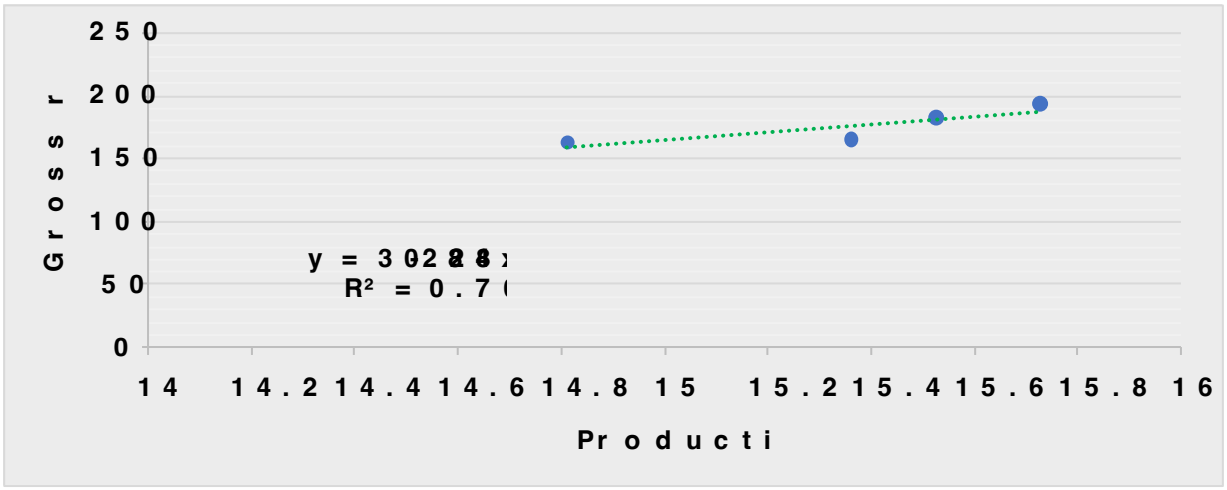


Fig. 3. Theoretical regression line and regression equation between production costs and gross revenues
Source: Own calculations.

The results of the analysis show a positive correlation (r=0.9994) between gross profit and profitability.

The high correlation allows the derivation of a regression equation (Figure 4), which is y=4.8697x+262.65, with a coefficient of determination R^2=0.9574.

The high correlation between the indices presented above determined the relationship between yield and the economic indicators in forage production. In the graphical regression models developed on this basis, the coefficients of determination are statistically proven and allow them to be used for indicative prediction of the economic effect of the agrotechnical interventions applied, as in this case the application of herbicides to obtain weed-free crops in the production of bird's-foot trefoil fodder.

Herbicide treatments on a self-seeded bird's-foot trefoil crop had the greatest influence on the change in yield values and thus on the economic indicators and the relationship between them. The established correlations show a good possibility of approximating the yield as a function of the production costs, and

the graphical models in Figure 3 determine, using the mentioned equation, the possibility of forecasting the gross revenue of the obtained fodder as a function of the magnitude of the production costs.

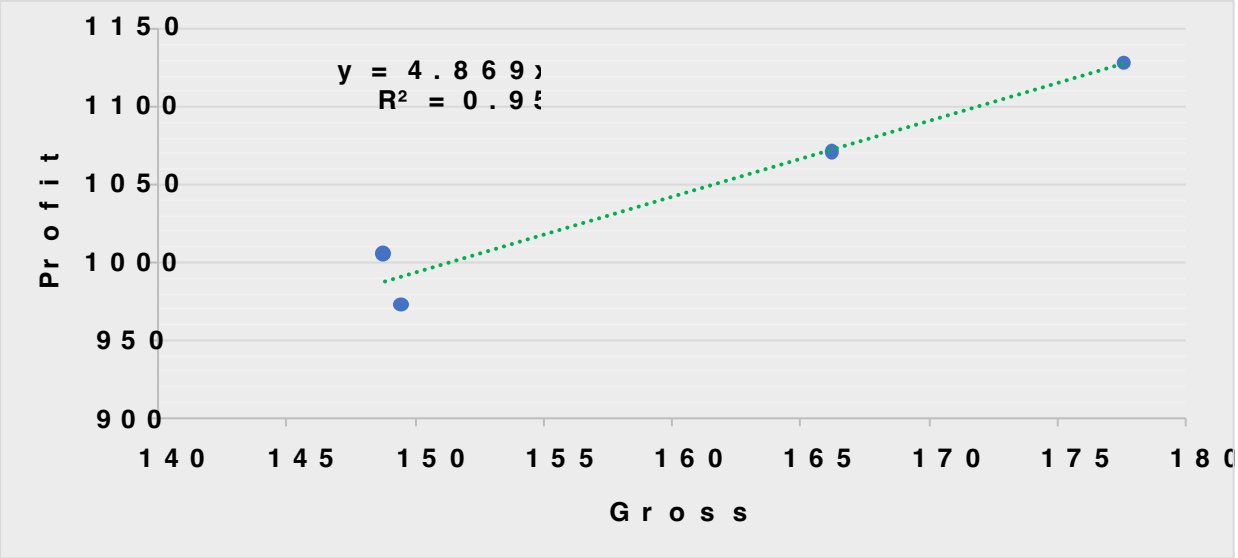


Fig. 4. Theoretical regression line and regression equation between gross profit and profitability
Source: Own calculations.

CONCLUSIONS

The treatment of a self-seeded grassland of bird's-foot trefoil with Kalam and Focus Ultra herbicides determined the high positive correlation between yield and gross revenue (r=1.0000) and gross profit (r=0.9999).

The very strong correlation relationship between gross revenue and gross profit (r=0.9999) determined the very high coefficient of determination (R^2= 0.9998) and is a prerequisite for the derivation of the regression equation (y=0.9767x - 11.256). The developed graphical regression models of the indicators showed high correlation relationships, can be used to determine and predict economic parameters related to the implementation of important agrotechnical measures for grass forage production.

The data analysis made it possible to predict the gross income in relation to the production costs of herbicide inputs and other production activities for fodder production realization.

The statistical treatment of the presented data proved the profitability of reducing agronomic treatments and intensifying chemical methods of weed control.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EVALUATION OF FORAGE PRODUCTION FROM GRASS MIXTURES IN THE MOUNTAIN REGIONS OF BULGARIA

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Abstract

Forage production from mixed grasslands is closely related to their productivity and quality. In this context, the correct selection of components in grass mixtures ensuring an environmentally acceptable grass association is essential, linked to the realization of cost-effective grass forage under sustainable management of natural resources. The object of the analysis is the characteristics of the main economic indicators in a scientific research experiment involving the following grass species: bird's foot trefoil + cock's foot; bird's foot trefoil and red fescue; bird's foot trefoil+ timothy; bird's foot trefoil + cock's foot + red fescue + timothy. The agrotechnical measures used and the costs involved are relevant to the amount of gross income, cost and profit of forage production. The high economic efficiency of the mixture of bird's foot trefoil + red fescue (82.65%) makes it the most suitable for hay in mountain regions. The realized forage production from it has the lowest production costs (19.57 BGN/da) and the lowest cost (0.018 BGN/kg). The high coefficient of economic efficiency makes it extremely profitable and suitable for practical application.

Key words**:** *sustainable agriculture, grass mixtures, economic indicators, economic efficiency*

INTRODUCTION

The production of forages based on modern technologies in line with climate change trends requires the introduction of new approaches and methods. Perennial grass species have a major role in creating high-quality forage for livestock [1]. Due to their well-developed root systems, they absorb nutrient and moisture from deeper soil layers more efficiently than other crops. Their rate of growth and development and their multi-year production cycle account for the lower material and production costs associated with basic and pre-sowing soil preparation, sowing, and crop care during the growing season [2]. The possibility of harvesting grasslands several times during the year and the low cost of forage make perennial grasses a suitable source of hay for ruminants [14].

Fertilization is an important agronomic measure affecting the efficiency of the forage produced by grasslands. Organic and mineral fertilizer inputs increase the productivity of grass species but increase production costs and reduce profitability. This is associated with higher fertilizer prices leading to rising forage prices [7].

The economic efficiency of mixed grasslands is largely determined by the type of components [16]. Legumes included in the composition of mixtures reduce the cost of forage and increase its profitability [6]. This is due to reduced nitrogen fertilizer costs because of the ability of legume grasses to fix nitrogen from the air [13, 17]. The gross and exchange energy of the obtained forage determines the energy cost structure of livestock production and depends on the animal breed and forage quality. Therefore, to assess the energy balance, it is essential to consider the criterion of economic evaluation of process technology in feed production, which is inextricably linked to the rational use of non-renewable and renewable energy [9].

Karbivska et al. (2020) [10] in a study of the economic and energy efficiency of forage from perennial legume grasses depending on fertilizers proved that forage without mineral fertilizers in the Carpathian region has a net profit of 11.1-21.9 thousand UAH/ha, the profitability level is 151-210%, and the cost of

1 ton of forage units is 1.6-2.0 thousand UAH/ha, BEC is 2.8-3.7 GJ/ha, CEE is 6.4-8.5 GJ/ha, energy cost for 1 ton of feed units is 3.1-4.3 GJ. The inclusion of bird's foot trefoil in mixed crops with perennial provides the highest economic and energy efficiency (Wysokiński et al., 2020) [17], and among the fertilizer options the best options for economic efficiency are with the application of phosphorus-potassium fertilizers at $P_{60}K_{60}$ rates.

Karbivska et al. (2021) [11] found the best economic and energy efficiency indicators for *Lolium perenne* L. and the lowest for *Festuca rubra* L., while *Dactylis glomerata* L., *Festuca orientalis*, *Bromus inermis* L., *Phalaris arundinacea* L. and *Phléumpraténse* L. occupied an intermediate position. Among the fertilizer options, the most effective is the full application of mineral fertilizer at a rate of $N_{90}P_{60}K_{60}$.

Studies related to the determination of economic efficiency and environmental effect in the production of forage from sown mixed grasslands are insufficient. This made it requirement to analyze the economic efficiency of forage production from a grass mixture including bird's foot trefoil and perennial forage grasses grown under mountain conditions.

The aim of the study is to make an economic evaluation of forage production from four variants of grass mixtures grown in the Central Balkan Mountains region in Bulgaria.

MATERIALS AND METHODS

In a field experiment on light grey pseudopodzolic soil during 2016-2019 in the experimental field of Research Institute of Mountain Stockbreeding and Agriculture - Troyan the following grass species were tested in mixed grasslands: bird's foot trefoil (*Lotus corniculatus* L.), cock's foot (*Dactylis glomerata* L.), red fescue (*Festuca rubra* L.) and timothy (*Phleum pratense* L.). It was sown bird's foot trefoil (variety *"Targovishte 1"*) and cock's foot (variety *"Loke"*), red fescue (variety *"Ryder"*), and timothy (variety *"Erecta"*). Bird's foot trefoil (100% - control); bird's foot trefoil + cock's foot (50:50); bird's foot trefoil + red fescue (50:50); bird's foot trefoil + timothy (50:50); bird's foot trefoil + cock's foot + red fescue + timothy (25:25:25:25). Sowing was carried out at a seed rate of 1.2 kg/da for bird's foot trefoil and 2.5 kg/da for all cereal grasses. Fertilization was carried out as a single stock fertilizer application at $P_{40}K_{40}$ rates and nitrogen fertilizer was applied annually at 6 kg/da. The main soil treatments deep ploughing, disking, milling, sowing and raining we carried out according to the technology adopted at the Research Institute of Mountain Stockbreeding and Agriculture for creating artificial grasslands [3]. The main forage harvesting activities included: cutting, hay turning, baling, transporting and storage.

Economic indicators were calculated based on the average dry matter yield over a four-year period (kg/da) and the obtained results analysed. For this purpose, process maps [12] were developed to calculate the production costs (BGN/da), cost price (BGN/kg), gross revenue (BGN/da), gross profit (BGN/da) of dry matter yield of sown mixed grasslands. Economic efficiency was determined by gross revenue and production costs. The analysis was carried out on data from the above economic indicators. A tabular and graphical method was applied [8].

RESULTS AND DISCUSSIONS

Table 1 shows that, on average, all the mixed grasslands exceeded the self-seeded crop of bird's foot trefoil in dry matter yield over the study period.

The highest value was recorded in the mixture of bird's foot trefoil + cock's foot, realizing a dry matter yield of 1,212.77 kg/da with an excess over the Control of 23.17%.

The second most productive mixture was bird's foot trefoil + red fescue (1,105.14 kg/da), which out-yielded the bird's foot trefoil self-seeded crop by 12.2%.

All other mixtures were also more productive than the Control, which proves the statement of Churkova (2010) [3] and Churkova and Churkova (2023)[5] that mixed grasslands of bird's foot trefoil are more productive than growing them in pure condition.

Table 1. Dry matter yield (kg/da) of mixed grasslands averaged over the period

Variants	*Average over the period*	
	kg/da	*%St*
1.Bird'sfoot-trefoil (100% - control)	984.57	100.00
2.Bird'sfoot -trefoil +cock's foot(50:50)	1,212.77	123.17
3.Bird'sfoot-trefoil + redfescue (50:50)	1,105.14	112.2
4.Bird'sfoot-trefoil + timothy (50:50)	1,051.49	106.79
5.Bird'sfoot-trefoil +cock'sfoot + redfescue+ timothy(25:25:25:25)	1,078.47	109.53
GD 5%	149.22	13.15
GD 1%	209.46	18.45
GD 0.1%	295.70	26.05

Source: Data from annual reports of Project P 163 of the Agricultural Academy of Bulgaria [15] and publication of Churkova and Churkova, 2021 [4].

In the production of grass mixtures, the largest inputs are made in the first year, i.e. at the establishment of the grassland. A large number of manual and mechanised activities are involved, which explains the increased production costs. The phosphorus and potassium fertilization carried out in the first year alone also increased the production costs. It should be noted that the cost of seed is most important in the first year of sowing and is the most important factor in determining the cost of each individual grass mixtures.

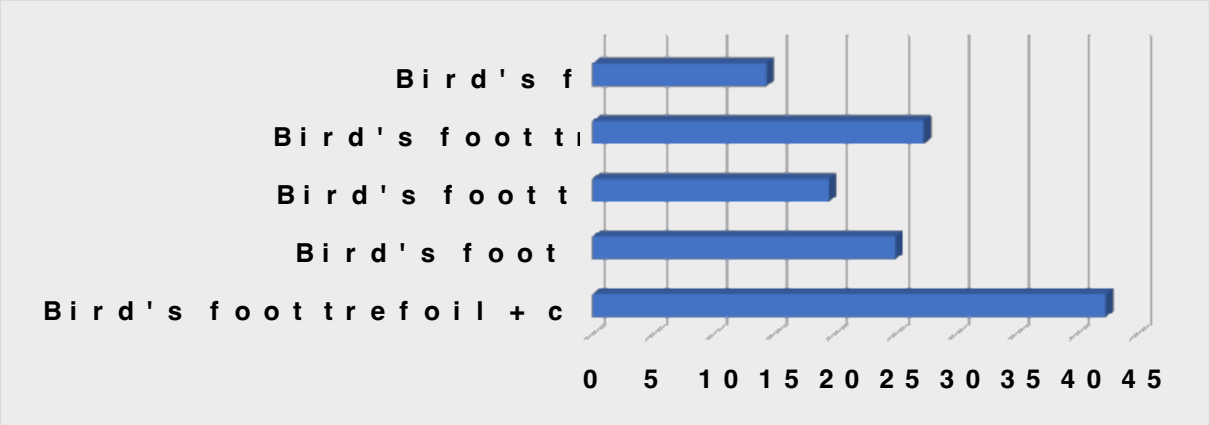


Fig. 1. Production costs (BGN/da) of forage production from grass mixtures on average over the period
Source: Own calculations.

From Figure 1, it can be seen that the combination of all grass mixtures studied had the highest costs on average over the study period. For the mixture composed of bird's foot trefoil + cock's foot + red fescue + timothy (var. 5), the costs were 42.45 BGN/da due to the seed inputs of the four components grass mixture. Similarly, this is the lowest cost value in the control, where we only have inputs for the purchase of bird's foot trefoil (*Lotus corniculatus* L.) seeds. In the other variants of bird's foot trefoil mixtures, the only influence is the price of the seed. Because of this fact, the mixture of bird's foot trefoil with cock's foot has a higher production cost (27.39 BGN/da) than that of bird's foot trefoil + timothy (25.07 BGN/da) and even higher than that of bird's foot trefoil + red fescue (19.57 BGN/da). All the other operations are identical and they cannot give such a large reflection in forming the costs of the different grass mixtures.

Table 2. Cost price (BGN/kg) of forage from grass mixtures production averaged over the period

Variants	*Cost price (BGN/kg)*
1.Bird's foot trefoil (Control)	0.015
2.Bird's foot trefoil + cock's foot	0.023
3.Bird's foot trefoil + red fescue	0.018
4.Bird's foot trefoil + timothy	0.024
5.Bird's foot trefoil + cock's foot + red fescue + timothy	0.039

Source: Own calculations.

The cost price of production was determined based on yield and production costs, with the

mixture *Lotus corniculatus* L. + *Dactylis glomerata* L. +*Festuca rubra* L. + *Phleum pratense* L. (var. 5) showing the highest values, respectively 0.039 (BGN/kg). Quite predictably, the control had the lowest cost price (0.015 BGN/kg), followed by the combination of bird's foot trefoil and red fescue (0.018 BGN/kg). The calculated cost values for bird's foot trefoil + cock's foot and bird's foot trefoil + timothy are similar, respectively 0.023 BGN/kg and 0.024 BGN/kg.

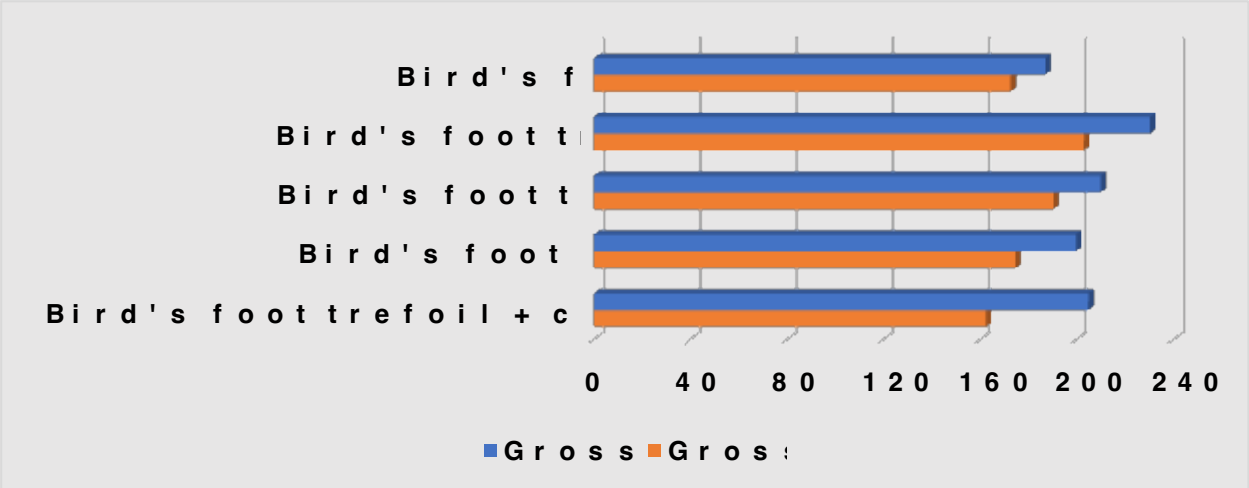


Fig. 2. Gross revenue (BGN/da) and gross profit (BGN/da) in the production of forage from grass mixtures averaged over the period
Source: Own calculations.

Gross revenues are most strongly influenced by the yield obtained. Averaged over the study period, the highest yield was recorded for the forage obtained from the mixture of bird's foot trefoil with cock's foot, which determined the highest revenues obtained, respectively 230.43 BGN/da (var. 2). The relatively high yield of forage from the mixture of bird's foot trefoil with red fescue, marked high revenues (209.98 BGN/da) due to the high productivity, respectively 1,105.14 kg/da. Similarly, the gross profit was the highest for the mixture of bird's foot trefoil and cock's foot, at 203.04 BGN/da (var. 2), followed by the mixture of bird's foot trefoil + red fescue, at 190.41 BGN/da (var. 3).

When calculating the gross profit, the close values of the control and the mixture of bird's foot trefoil + timothy, 172.66 BGN/da and 174.71 BGN/da, respectively, are remarkable, which is explained by the close values of the dry matter yield obtained. However, it should be noted here that the grass mixture of bird's foot trefoil + cock's foot + red fescue + timothy had the lowest realized profit of 162.46 BGN/da, which is due to the highest production costs incurred during the period analyzed.

Table 3. Economic efficiency of production of forage from grass mixtures

Variants	K_{ef}	*%*
1.Bird's foot trefoil (Control)	12.98	100.00
2.Bird's foot trefoil + cock's foot	8.41	64.80
3.Bird's foot trefoil + red fescue	10.73	82.65
4.Bird's foot trefoil + timothy	7.97	61.39
5.Bird's foot trefoil + cock's foot + red fescue + timothy	4.83	37.18

Source: Own calculations.

This type of mixture does not produce a high dry matter yield and, on this account, the inputs involved in its creation are not justified as they cannot ensure and guarantee a good profit for the farmers.

The economic efficiency ratio represents the economic efficiency of grass forage production represented by the ratio of revenue to costs. The difference between the values of the efficiency ratios for production of fodder for individual grass mixtures ranges from 4.83 to 10.73%, without taking into account the control, which is 100%. The mixture with the highest percentage of economic efficiency, approaching that of the control, was the mixture of bird's foot trefoil + red fescue (82.65%), and the lowest for the mixture of bird's foot trefoil + cock's foot + red fescue + timothy (37.18%). The variants of the grass mixtures bird's foot trefoil + timothy and bird's foot trefoil + cock's foot had efficiency coefficients of 7.97% and 8.41%, which were approximately similar.

CONCLUSIONS

From the analyzed economic indicators of forage production from four grass mixtures, it can be concluded that the grass mixture of bird's foot trefoil + red fescue has the lowest production costs and the lowest cost price, but the mixture of bird's foot trefoil + cock's foot realizes the highest revenue – 230.43 BGN/da and the highest gross profit – 203.04 BGN/da. In practice the most unsuitable mixture for rearing was bird's foot trefoil + timothy, with gross revenue of 199.78 BGN/da and profit of 174.71 BGN/da. This same grass mixture also stands out with the lowest total yield of the other grass mixtures at 1051.49 kg/da.

ACKNOWLEDGEMENTS

This research is supported by the Bulgarian Ministry of Education and Science under the National Program “Young Scientists and Postdoctoral Students – 2”.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

INEFFICIENCY AMID SUSTAINABILITY? EVALUATING TECHNICAL EFFICIENCY IN MOLDOVA'S ORGANIC FARMING SECTOR

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Abstract

This study investigates the technical efficiency of organic farms in the Republic of Moldova, aiming to assess how efficiently certified organic farms utilize available resources to produce economic outputs. The research draws on primary data collected through a structured survey conducted between March and June 2023, covering 63 farms managing a total of 19,456 hectares, including 5,320 hectares under certified organic farming. Due to data consistency requirements, 35 farms with complete and non-zero input-output records were selected for the technical efficiency analysis. To evaluate efficiency, a non-parametric methodology was applied using an input-oriented Data Envelopment Analysis (DEA) under Variable Returns to Scale (VRS). The results reveal a low average technical efficiency (TE) score of 0.32 indicating that most farms operate significantly below their potential. Only 8.6% of farms were found to be highly efficient (TE > 0.7), while over 60% fell into the low-efficiency category (TE ≤ 0.4). High-efficiency farms tend to exhibit leaner input structures, better cost control, and more consistent revenue streams, while low-efficiency farms often manage substantial organic land without generating proportional output. Spatial disparities were also observed in certain districts (Falesti, Telenesti, and Singerei) outperforming others (Riscani and Edinet). The findings suggest that technical efficiency in Moldova's organic farming sector is constrained not by land area or subsidies, but by managerial practices, input-output alignment, and market integration. A shift from uniform subsidy programs to performance-based support, combined with peer learning from high-performing farms and targeted training for underperforming districts, is essential to improve technical efficiency across the organic farming sector.

Key words**:** *agriculture, economic performance, technical efficiency, organic farming*

INTRODUCTION

Organic farming is increasingly promoted as an environmentally friendly alternative to conventional agriculture, aligning with broader sustainability goals such as biodiversity conservation, reduced chemical use, and improved soil health. However, from point of view of efficiency, particularly technical efficiency there are both advantages and disadvantages compared to traditional/ conventional agricultural systems.

Some research points out empirical evidence that organic farms generate lower yields and revenues comparing to conventional agriculture due to the existing restrictions on input use [16, 17]. Despite organic farms can exhibit higher technical efficiency comparing to its out-production frontier, but still behind conventional agricultural systems in absolute terms. Also, organic farms can experience a lower efficiency during the conversion period, as more applied knowledge on organic practices and experience is accumulated [12, 14, 18].

There is evidence that organic agricultural systems can be more efficient than conventional ones due to better input use in terms of labor and costs [11]. In some cases, organic agriculture experienced higher efficiency and profitability due to market premiums for organic products [1, 9].

Organic agriculture efficiency can be increased from innovation and knowledge transfer. Thus framers that adopt innovative practices tend to achieve higher total factor of productivity (TFP) [10]. A great role in improving efficiency has the diffusion of knowledge, particularly during conversion phase. At the same time, geographical location and clustering effects can be crucial to improve efficiency of organic farms, as those that are located in regions with higher density of organic farms benefit from localized

economies of scale, better market access and knowledge spillovers [12].

While organic farming is often perceived as less efficient in terms of output maximization, its sustainability benefits challenge traditional metrics of technical efficiency. By integrating ecological services—such as soil regeneration and reduced pollution—into efficiency assessments, some studies argue that organic systems may exhibit a different kind of "multi-dimensional efficiency" that conventional systems lack [10, 13]. Some studies [10] provided more evidence into the source of inefficiencies. Using DEA, they found that while both organic and conventional households showed suboptimal economic efficiency, the primary constraint for organic producers was allocative inefficiency. These findings are consistent with previous research [6], who emphasized that allocative inefficiency is often rooted in market imperfections or lack of managerial know-how**,** particularly relevant for organic farmers who operate under different regulatory and input constraints. Although organic farms may have lower productivity and efficiency indicators, these can result from the limited and less intensive use of inputs, which aligns with the ecological objectives of organic agriculture. However, inefficient input combinations can undermine the economic sustainability of organic farming systems. This dual challenge calls for targeted policy interventions: improving farmer education and access to tailored advisory services, while promoting organic input markets and appropriate pricing mechanisms.

In the context of Moldova, organic farming has received policy support through several legal and institutional initiatives. Financial support mechanisms, such as post-investment subsidies and compensation for conversion costs, have been introduced to encourage ecological farming. Nevertheless, challenges remain, particularly the limited recognition of Moldovan certification on the EU market, insufficient trained specialists, and reduced land conversion to organic production in recent years [4].

At the international level, organic agriculture has expanded rapidly. The EU-27 has shown a consistent increase in organic land in countries such as Spain, Italy, Germany, and France [15].

The aim of this research is to analyze the performance of organic farms in Moldova based on estimating farms technical efficiency. This research tries to assess if under sustainability aims, organic farms are desirable from ecologic point of view and/or efficient use of resources in terms of input-output conversion.

MATERIALS AND METHODS

The assessment of technical efficiency (TE) in organic farming has become increasingly significant in recent years due to the dual emphasis on sustainability and economic viability. While organic farming systems contribute to environmental preservation and the reduction of chemical inputs, they often face challenges related to optimizing resource use and minimizing production costs. Evaluating efficiency in this context provides critical insights into how well farms utilize their available resources to achieve maximum outputs without compromising their ecological goals.

Efficiency analysis in production economics assumes that the overall efficiency of a firm can be decomposed into two primary components: technical efficiency (TE) and allocative efficiency (AE) [8]. Technical efficiency reflects how effectively a farm utilizes its available inputs to achieve the highest possible output, or conversely, how efficiently it can use the least amount of inputs to produce a given level of output.In contrast, allocative efficiency reflects the farm’s capability to combine inputs in optimal proportions, taking into account the relative prices of those inputs and the prevailing production technology. Together, TE and AE form economic efficiency (EE), which represents the overall cost-effectiveness of production [7, 3]. In organic agriculture, both TE and AE play a crucial role because farms often operate under constraints that affect input choices, such as limited availability of certified organic inputs, higher labor requirements, and market imperfections. Results of previous research observe that inefficiencies in organic

farms often are more from allocative inefficiencies—misalignments in input use relative to price signals—than from purely technical inefficiencies [3].

Various approaches have been developed in the literature to estimate TE, broadly classified into parametric and non-parametric methods. Parametric approaches like Stochastic Frontier Analysis (SFA) rely on a predetermined functional form for the production function and allow for the separation of inefficiency effects from statistical noise. In contrast, non-parametric techniques, such as Data Envelopment Analysis (DEA), build the efficiency frontier directly from the observed data, without imposing assumptions about the underlying production technology [5]. DEA is widely used in agricultural research due to its flexibility in dealing with diverse farm types and its capability to incorporate multiple inputs and outputs simultaneously.

For this study, DEA was chosen due to its suitability for small to medium-sized samples and its capacity to evaluate farms relative to a "best-practice" frontier. DEA is advantageous when production processes are diverse or poorly defined, as is often the case with organic farming systems [6,7]. Moreover, DEA facilitates both input-oriented and output-oriented models, making it adaptable to different research objectives.

An input-oriented DEA model under Variable Returns to Scale (VRS) was applied. This specification is appropriate for the organic farming sector in Moldova for two main reasons. First, farmers typically have greater control over input use—such as land allocation, labor hours, and input purchases—than over output levels, which are often influenced by weather conditions and market demand. Second, the VRS assumption accounts for differences in scale efficiency across farms, which is essential given the structural diversity ranging from smallholder family farms to larger enterprises. Using a Constant Returns to Scale (CRS) assumption would have ignored these scale variations and potentially distorted the efficiency estimates [2]. This study is based on primary data collected through a survey conducted between March and June 2023, targeting certified organic farms in the Republic of Moldova. The initial sample included 63 farms, managing a total of 19,456 hectares of agricultural land, of which 5,320 hectares were cultivated under certified organic practices. The reference period for data collection was 2020–2022.

The sample reflects the sector's diversity in terms of legal form, size, and regional distribution. Limited Liability Companies (LLCs) represent the majority (73%) and manage 89% of the surveyed agricultural land, with 87.7% of it under organic production. Family farms (individual farms and enterprises) account for the remaining share. Regionally, 51% of the farms are located in the north, 38% in the center, and 11% in the south. Farms also vary widely in size, with 29% cultivating under 20 hectares and 17% managing more than 500 hectares.

For the technical efficiency (TE) analysis, the number of farms was reduced to 35, excluding those with missing or zero values for critical input or output variables such as land area, labor, costs, or revenue. This step ensured the reliability of the results and avoided computational errors related to undefined or skewed efficiency scores. DEA calculates an efficiency score for each farm—ranging from 0 to 1. A score of 1.0 indicates that the farm lies on the efficiency frontier, meaning it is fully technically efficient relative to its peers. Scores below 1.0 signal that the farm is inefficient and could proportionally reduce input use while maintaining the same output level. The decomposition of efficiency can also reveal the relative importance of technical versus allocative inefficiencies, though this study focuses primarily on TE [3].

To capture spatial variations, the TE scores were aggregated and analysed at the district level. This spatial mapping helps identify high-performing regions and potential problem areas, offering insights into where policy interventions and capacity-building programs might be most needed.

RESULTS AND DISCUSSIONS

To examine technical efficiency (TE) of organic farms were selected 35 farms from the survey data set.

The average registered TE score is 0.32 which suggests that surveyed farms produce only 23.3 percent of the output given the existing input levels. A score of 0.25 for the median suggests that above 50 percent of farms are operating at or below one quarter of their optimal efficiency (Table 1).

Table 1. Descriptive statistics

Statistic	Value
Count	35
Mean	0.323
Median	0.250
Standard Deviation	0.239
Minimum	0.020
25th Percentile	0.120
75th Percentile	0.520
Maximum	0.840
Skewness	0.98
Kurtosis	2.74

Source: Own calculation.

Standard deviation had a value of 0.239 which assumes large variation across farms, indicating a heterogenous farm sector, most of which are underperforming or near-efficient farms.

Minimum value is 0.02 which assumes extreme inefficiency, while maximum value of 0.84 indicated that the farm operates at 84% of their potential, almost approaching the efficiency frontier.

The TE scores are positively skewed (skewness = 0.98), revealing that most farms cluster at the lower end of the efficiency spectrum, while a smaller number perform relatively well.

The kurtosis of 2.74 further indicates that the distribution is leptokurtic — characterized by a sharp peak and heavier tails — pointing to the presence of outliers on both extremes.

This asymmetric distribution suggests that while a few farms have achieved notable efficiency gains, the majority face operational inefficiencies, possibly due to suboptimal input use, lack of technical knowledge, or limited market access.

To further interpret the variability in performance among the surveyed organic farms, the computed technical efficiency (TE) scores were categorized into three performance categories: high efficiency (TE > 0.7), moderate efficiency (0.4 < TE ≤ 0.7), and low efficiency (TE ≤ 0.4) (Table 2). This classification framework allows for a better understanding of the relative positioning of farms along the efficiency spectrum and facilitates the identification of specific intervention needs.

Table 2. Technical efficiency of organic farms in Moldova

Efficiency Category	Number of Farms	Percentage
High Efficiency (TE > 0.7)	3	8.6%
Moderate Efficiency (0.4 < TE ≤ 0.7)	10	28.6%
Low Efficiency (TE ≤ 0.4)	22	62.9%

Source: Own calculation.

The majority of farms (62.9%) fall into the low-efficiency category, meaning they operate at less than 40% of their potential output, given current input levels. This finding is consistent with the earlier observation that the mean technical efficiency for the sample is approximately 0.323. The moderate-efficiency group comprises just under a third of the sample (28.6%), reflecting farms with some capacity for optimization but still falling significantly short of best-practice benchmarks. Only 3 farms (8.6%) exhibit high efficiency, suggesting that a very limited number of operators are successfully managing inputs and resources to maximize output.

The analysis reveals a cluster of farms at the lower end of the efficiency distribution, with technical efficiency scores ranging from 0.02 to 0.07. Despite managing large areas of certified organic land (between 100 and 195 hectares), these farms demonstrate minimal or even negligible revenue generation from organic production In contrast, the top 10% of performers had TE scores above 0.68, with notably different operational patterns. These farms vary in scale — from 22 ha to over 333 ha — but share common traits: better conversion of costs into organic revenue, consistent productivity levels, and lean input structures. The disparity between top and bottom performers within Moldova's organic farming sector underscores a pronounced heterogeneity in both operational structure and outcomes. High-efficiency farms tend to

exhibit several defining characteristics. These farms generally operate with well-optimized input structures, allowing for cost-effective resource use and relatively stable, consistent revenue streams. Despite often being small or medium-sized in scale, they manage to sustain profitability, largely due to superior managerial capacity, access to markets, and perhaps closer integration with consumer preferences or international demand. Their performance reflects strategic decision-making and an ability to align certification with actual production and marketable output, maximizing the value derived from their organic status.

In contrast, low-efficiency farms experience a different case. Although some of these farms manage or possess large tracts of certified organic land, they often fail to translate this advantage into meaningful economic returns. Many such farms generate extremely low income levels, which suggests fundamental inefficiencies in how land and resources are utilized. There are clear signs of underutilization of certified areas, with production either insufficient, inconsistent, or poorly aligned with market opportunities. This is compounded by evident disconnects between the processes of certification, actual production practices, and the capacity to market or sell organic products at a premium. These disparities indicate that organic certification alone is not a sufficient predictor of performance; rather, success hinges on the effective integration of land, management, production strategies, and access to appropriate sales channels.

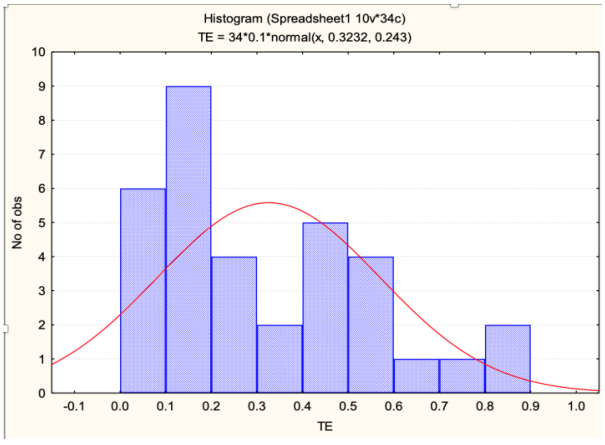


Fig.1. Distribution of technical efficiency (TE) among organic farms
Source: own processing.

The histogram (Fig. 1) clearly illustrates a strongly right-skewed distribution of technical efficiency (TE) scores among organic farms in Moldova. This skewed pattern reveals a sector where the vast majority of farms operate with relatively low efficiency, while only a small number manage to achieve high performance. The calculated skewness coefficient of 0.98 quantitatively confirms the presence of asymmetry, indicating that a significant concentration of farms performs far below the efficiency frontier. The average TE score across all farms stands at approximately 0.32, suggesting that, on average, farms convert only about one-third of their available inputs—land, labor, and capital—into productive organic output. Even more telling is the median TE score of 0.25, which implies that more than half of the farms perform below the already modest average. The range of scores, spanning from a low of 0.02 to a high of 0.84, underscores the stark variability in performance across the sector, from extreme inefficiency to near-optimal use of resources.

This distribution has several significant implications for understanding the structure and dynamics of Moldova's organic farming sector. First, the pronounced clustering of farms in the lower efficiency bands (TE < 0.4) points to a widespread problem of underperformance. Such inefficiencies may stem from poor managerial practices, inadequate training or technical support, suboptimal allocation of inputs, or limited access to profitable markets for organic products. Many farmers may lack the necessary knowledge, tools, or incentives to improve efficiency, resulting in low productivity.

Second, the presence of a small group of isolated high performers—those with TE scores above 0.75—suggests that it is indeed possible to operate organic farms efficiently in Moldova, but that success remains the exception rather than the rule. These top-performing farms may benefit from better technical expertise, stronger organizational capacity, closer alignment with certification and organic standards, and superior access to infrastructure or market networks. Their ability to operate near the efficiency frontier serves as

a benchmark for what is achievable in the sector under the right conditions.

Third, the relatively thin middle tier of efficiency (TE between 0.4 and 0.7) highlights a missing ladder of progressive improvement. This absence of a critical mass of moderately efficient farms suggests that many producers are either unable to overcome initial inefficiencies or are hindered by structural barriers that prevent incremental gains in productivity. It indicates a polarized landscape where farms tend to remain stuck in low-efficiency traps or, in rare cases, leap to high performance, bypassing intermediate stages of development. This gap challenges policymakers and development practitioners to identify and address the specific constraints—whether technical, financial, institutional, or infrastructural—that hinder the broad-based improvement of organic farming efficiency in Moldova. Bridging this gap could be key to unlocking more inclusive and sustainable growth within the sector. The geographic distribution of technical efficiency (TE) among organic farms in the Republic of Moldova reveals notable disparities. Based on the obtained results (Table 3), TE values vary significantly across districts, indicating that the efficiency of converting inputs into economic outputs is not uniform nationwide.

Table 3. Economic performance of organic farms based on TE score, by districts

District	Technical efficiency (TE)
Anenii Noi	0.59
Causeni	0.11
Drochia	0.16
Dubasari	0.17
Edinet	0.09
Falesti	0.66
Floresti	0.2
Glodeni	0.375
Hincesti	0.29
Ialoveni	0.12
Orhei	0.49
Rezina	0.29
Riscani	0.03
Singerei	0.46
Soroca	0.12
Stefan-Voda	0.14
Telenesti	0.46

Source: own processing.

According to the efficiency scores, the top-performing districts include Falesti (0.66), Anenii Noi (0.59), Orhei (0.49), Telenesti (0.46), and Singerei (0.46). These regions demonstrate a relatively high capacity to utilize land, labor, and capital efficiently in organic farming. The consistent performance of these districts likely reflects the presence of more structured farm management, better access to extension services, and stronger integration into organic value chains. Their role as regional efficiency hubs could be further leveraged to support peer learning and capacity-building initiatives.

In contrast, several districts continue to underperform, with TE values well below the national average. Notably, Riscani (0.03), Edinet (0.09), Causeni (0.11), and Ialoveni and Soroca (both 0.12) report the lowest efficiency scores. These low values suggest that farms in these areas face structural or operational challenges—such as limited market access, weak technical knowledge, or ineffective use of support programs—which hinder their ability to generate proportional economic returns from their organic production efforts. The persistence of such inefficiencies highlights the need for targeted interventions tailored to district-specific constraints.

Some districts occupy a middle ground. For instance, Glodeni (0.375), Hincesti and Rezina (both 0.29), and Floresti (0.20) present moderate efficiency scores. These regions may benefit from targeted training and advisory services to help transition farms from moderate to higher efficiency levels. Moreover, the moderate averages could also reflect a mix of well-managed and struggling farms within the same district, indicating internal variability and potential for improvement through localized support strategies.

Overall, the data show that central and northern regionsgenerally perform better in terms of efficiency, while eastern and southern regions appear to lag. This geographic representation adds a spatial dimension to the farm-level analysis, helping to identify efficiency clusters and priority areas for intervention. Policymakers and development agencies could use this information to prioritize technical training, infrastructure investment, and subsidy

optimization in underperforming districts, while also scaling up best practices from high-performing ones.

CONCLUSIONS

This study investigated the technical efficiency of certified organic farms in the Republic of Moldova, utilizing a non-parametric analytical approach based on a DEA-style input-output ratio adjusted through log transformation. Drawing on detailed farm-level data, the results reveal that the organic farming sector in Moldova currently operates well below its productive potential. The average technical efficiency (TE) score across the sample is only 0.32 indicating that most farms are producing less than one-third of the output they could achieve with existing resources. These findings point to a widespread underutilization of inputs suggesting critical inefficiencies not just in production but also in resource allocation, market integration, and knowledge application. A key pattern identified is the high proportion of low-performing farms. Over 60% of all surveyed farms fall into the low-efficiency category, with TE scores below 0.4. Many of these farms manage considerable organic areas and receive state subsidies but generate very limited revenues from organic products. This highlights a misalignment between certification status and effective participation in organic markets. Furthermore, efficiency does not appear to be strongly correlated with the scale of production or the volume of subsidies received. Several farms with large input volumes—including those with over 100 hectares of certified land—appear in the bottom 10% of the efficiency distribution, often reporting very low revenues. Conversely, the top-performing farms—representing only 8.6% of the total sample—tend to have leaner cost structures, moderate landholdings, and consistent, even not exceptionally high, revenues. These farms demonstrate that technical efficiency is not simply a function of input scale but rather of managerial capability, cost control, and effective market engagement. District-level analysis reveals clusters of higher-efficiency farms in areas such as Falesti, Anenii Noi, and Orhei**,** while consistent underperformance is evident in Riscani, Edinet, and Causeni**.** These geographic patterns likely reflect a combination of infrastructural, institutional, and informational factors, including proximity to markets, access to training, and the quality of local extension services. The variation observed within individual districts—such as Glodeni and Hincesti—also suggests that intra-regional disparities, possibly tied to farm-level managerial differences or social capital, play a significant role in shaping outcomes.

The findings highlight the need to shift from input-based subsidies to performance-based support**,** rewarding farms for outcomes like revenue, yield, and improved efficiency. Low-performing farms should receive targeted assistance, including training, diagnostics, and advisory services, while top-performing farmscan serve as models for peer learning. Addressing spatial disparities requires prioritizing underperforming districts for investment in infrastructure and human capital. In conclusion, the low average technical efficiency observed across Moldova's organic farms signals a critical need for reform in both farm management practices and public support policies. However, the presence of a small but significant group of highly efficient farms demonstrates that achieving high performance under organic principles is possible. Unlocking this potential will require a dual strategy: investing in underperforming farms to build capacity and scaling up the success factors evident in leading farms. Through regionally differentiated interventions, performance-based incentives, and a stronger knowledge-sharing infrastructure, Moldova can enhance the viability and competitiveness of its organic agriculture sector while advancing broader sustainability goals.

ACKNOWLEDGEMENTS

This research was developed within the framework of Subprogram 030101 „Strengthening the resilience, competitiveness, and sustainability of the economy of the Republic of Moldova in the context of the accession process to the European Union", institutional funding.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SUSTAINABLE DEVELOPMENT OF RURAL AREAS: STRATEGIC MANAGEMENT APPROACHES FOR THE MUNICIPALITY OF SNAGOV, ILFOV COUNTY, ROMANIA

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Abstract

This article examines the potential of Snagov commune, situated in Ilfov county, from the perspective of implementing a sustainable development strategy tailored to the local and regional specificities. In the first part, the geographical, historical, and socio-economic context of the area is analyzed, as well as the natural and cultural heritage that constitutes an important competitive advantage in the development process. Subsequently, the paper addresses the principles of sustainable development applicable in rural areas, identifying the specific challenges of their implementation in Romania, with an emphasis on structural, institutional, and economic issues. Through an integrated approach, clear strategic objectives, concrete measures, and actions are proposed, structured in a phased operational plan, with performance indicators and monitoring mechanisms. The study emphasizes the importance of involving the local community, inter-institutional partnerships, and accessing European funds in the process of sustainable transformation of Snagov commune. The conclusions highlight the economic, social, and environmental benefits of the strategy, while also providing practical recommendations for local authorities to ensure the sustainability and continuity of the development process.

Key words: *sustainable development; rural community; territorial strategies; heritage; sustainable tourism*

INTRODUCTION

Snagov commune is located in the northern part of Ilfov County and forms part of the Romanian Plain. The area is defined by the presence of Lake Snagov, the largest natural body of water in Romania, covering approximately 5.75 km², with a length of about 16 km. On the shores of the lake lies the remnant of the Codrilor Vlăsiei forest, today established as a nature reserve. Snagov is also distinguished for its ecological richness, including avifauna, diverse aquatic and terrestrial vegetation, as well as by its cultural heritage, represented by the medieval Snagov Monastery and the interwar Snagov Palace.

The study aims to evaluate the tourism potential of Snagov commune, in the perspective of sustainable development. The methodology combines several components: a bibliographical review of the specialized literature (tourism, geography, history), analysis of primary sources (monographs, field studies), as well as dialogue with local stakeholders (authorities, community representatives and economic actors). The emphasis is on applying sustainable development criteria — ensuring a balance between economic, social, and environmental needs — and on identifying strategic directions through which tourism can generate sustainable benefits.

The sustainable development of tourism in Snagov is crucial for the conservation of natural resources (including the lake and the forest) and cultural values (Snagov Monastery, Snagov Palace), while simultaneously stimulating the local economy and strenghthening community cohesion. By promoting ecotourism, agrotourism, and cultural tourism practices, integrated with modern infrastructure and high-quality services, the area holds the potential to become a regional model of sustainable tourism [10].

The commune of Snagov has a long history, with archaeological traces attestinghuman presence since the Bronze Age. Discoveries made in the area of Snagov Lake and the surrounding forest indicate the existence of stable settlements in the Dacian and Roman periods, thereby granting the region considerable archaeological value [2].

During the Middle Ages, the town of Snagov gained spiritual and strategic importance with the founding of the Snagov Monastery, located on an island in the middle of the lake. Most likely founded in the 14th century, it was rebuilt and expanded in the 15th century under the reign of Vlad the Impaler. According to tradition, he was also buried here, although the existence of his tomb on the island remains a matter of dispute among historians [8], [5].

Snagov was, in the Middle Ages, both a religious center and a place of refuge and defense, benefiting from its isolated yet accessible position relative to the capital. During the Phanariot era and until the 19th century, the domain of Snagov Monastery was under the administration of the Orthodox Church, undergoing a gradual economic and cultural decline. It was only during the interwar period that the area experienced a revitalization, becoming a favored recreation spot for Bucharest's political and cultural elites [1].

During the communist period, Snagov was transformed into an exclusive space, reserved for the communist nomenclature. The Snagov Palace, originally built as a royal residence, was nationalized and adapted for the needs of the state leadership. During this period, public access to the area's natural and cultural resources was severely limited. After 1989, the Snagov commune went through a slow process of reopening to public tourism and valorizing its heritage, but many restoration and promotion initiatives remained partially implemented [18].

Snagov commune has a cultural and natural heritage of exceptional value, which provides the region with distinct tourism potential and real prospects for integration into a sustainable development model. Natural resources are concentrated around Snagov Lake and Snagov Forest, both classified as protected areas under national and international legislation. The lake, of tectonic origin, is considered the longest natural lake in Romania, with a remarkable biodiversity: over 20 species of fish, rare waterfowl, and specific lacustrine vegetation. Snagov Forest, a relic of the Codrilor Vlăsiei forest, constitutes a forest ecosystem with a major ecological role in regulating the area's microclimate and preserving local biodiversity [3] [13].

The elements of intangible heritage — local legends, traditions related to holidays and fishing, stories about Wallachian rulers — are still insufficiently documented, yet they can form a solid basis for cultural and educational tourism projects [16].

MATERIALS AND METHODS

The concept of sustainable development emerged as a response to the negative effects of accelerated industrialization and uncontrolled urbanization on the environment, natural resources, and quality of life. Its classic definition, provided in the Brundtland Report (1987), emphasizes that sustainable development is "that form of development that meets the needs of the present without compromising the ability of future generations to meet their own." In rural areas, this approach takes on special importance, as villages and communes are often highly dependent on local natural resources – soil, water, forests, biodiversity – as well as on traditional community values [9].

In Romania, the rural environment is characterized by a double polarization: on the one hand, by the considerable natural and human potential; on the other hand, by systemic problems such as poor infrastructure, an aging population, and limited access to quality public services. In this context, sustainable development provides an essential strategic framework for the revitalization of the Romanian village, without altering its specific identity. Sustainable solutions require multi-sectoral interventions: organic agriculture, biodiversity protection, responsible tourism promotion, waste management, and environmental education [12].

A fundamental principle of sustainable development is the integration of economic, social, and ecological dimensions into a coherent framework of action. In rural areas, this translates into investments that generate local jobs (without exceeding the carrying capacity of ecosystems), by conserving and valorizing natural resources responsibly, and through community involvement in decision-making processes. This fosters the emergence of "circular local economies", where economic benefits return to the community and natural capital is safeguarded for future generations [4].

Rural tourism and ecotourism can be clear examples of the application of sustainability principles. When developed with respect for the environment and with the active participation of local people, these forms of tourism contribute to the diversification of the rural economy, the preservation of traditions, and the education of visitors in the spirit of respect for nature and culture. Areas such as the Danube Delta, Maramureș, or Transylvania have demonstrated that a sustainable approach can transform seemingly marginal municipalities into examples of international success [6], [7].

On the other hand, sustainable development should not be confused with stagnation or the absolute conservation of the rural landscape. Change is inevitable, yet it must be managed through participatory strategic planning, in which local stakeholders – authorities, entrepreneurs, NGOs, and citizens – are equal partners in decision-making. In this regard, instruments such as local development strategies, LEADER programmes, and European structural funds can contribute decisively to the transition towards a green and inclusive rural economy [14]. Education and vocational training play a central role in this process. A sustainable rural community is one in which people are well-informed, capable of making sound decisions, and willing to actively participate in social and economic life. Promoting education for sustainable development in schools, alongside training programmes for farmers, entrepreneurs, or civil servants, can foster a local culture of responsibility for the environment and heritage [17], [11].

Sustainable development is not a "luxury" for Romanian villages, but a strategic necessity. Without a coherent approach that intelligently leverageslocal resources, protects the environment, and supports social inclusion, the rural environment risks turning into an area of depopulation and degradation. Therefore, Snagov commune and other localities with high tourism and ecological potential should explicitly adopt the principles of sustainable development, not merely as a public policy direction, but as a foundation for the community's future.

RESULTS AND DISCUSSIONS

Implementing sustainable development in rural areas in Romania is a complex challenge, influenced by economic, social, political, and cultural factors. Although the theoretical framework of sustainability is well-defined and supported by strategic documents at the national and European levels, its concrete implementation at the local level faces numerous obstacles, often undermining the outcomes of local initiatives.

One of the most common obstacles is institutional fragmentation and the lack of coherence between development policies at local, regional, and national levels. Many municipalities in Romania, especially small ones, lack the human and technical resources needed to design and implement integrated sustainable strategies. In the absence of teams of specialists in territorial planning, rural development, or project management, local administrations are often limited to momentary reactions driven byavailable funding, rather than a long-term vision [9], [14].

Another major impediment is the low level of education and awareness of the rural population regarding the principles of sustainable development. Although many communities are directly affected by environmental degradation, climate risks or the loss of local heritage, these issues are rarely perceived as urgent priorities. The culture of participation is weakly developed, and decision-making often remains centralized,

with little genuine public consultation. In addition, the phenomenon of migration – both abroad and to urban centers – has led to an accelerated depopulation of villages, which reduces the capacity of communities to initiate and support sustainable projects [17].

On the economic front, excessive dependence on subsistence agriculture and traditional income sources limits opportunities to sustainably diversify the rural economy. The lack of infrastructure (roads, sewage, digital access), combined with the low absorption of European funds, hindered by bureaucracy and a lack of administrative skills, perpetuates underdevelopment. Even in areas with high tourism potential, such as Snagov, initiatives for sustainable resource development are often fragmented, uncoordinated, and insufficiently embedded in regional strategic plans [4].

The absence of local models of good practice, adapted to the specifics of each region, is also a significant obstacle. Sustainable development strategies are often mechanically copied from other contexts, without adequately considering local identity, geographical particularities, or the real needs of the community. This results in short-term projects that fail to produce structural and lasting changes in either the economy or community life [7].

The impact of climate change, which disproportionately affects rural areas, cannot be ignored either. Prolonged droughts, extreme weather events, and biodiversity loss threaten the regeneration capacity of local resources, exacerbate economic instability, and generate new vulnerabilities. In the absence of monitoring and prevention systems, along with adapted public policies, the rural environment risks becoming even more exposed to these threats [12].

Snagov commune, located in northern Ilfov County, holds a privileged position from a natural, cultural, and geographical perspectives. The presence of Lake Snagov, the namesake forest, and historical sites of national importance provide a favorable framework for implementing a sustainable development strategy. Despite this potential, the development of the region has been uneven to date, with fragmented initiatives that often lack strategic coherence. Applying sustainable development principles in this commune could mark a turning point, yielding significant benefits for the community and the environment.

A first step towards sustainability would be to establish a local participatory planning framework, through which community stakeholders – local administration, residents, investors, NGOs, and educational institutions – would collaborate to define a common vision of development. Such a process would contribute to settingclear priorities, aligned with the real needs of local residents and environmental protection requirements. By actively involving citizens in decision-making, a sense of collective emerges, essential for the success of any sustainable project. In terms of natural resources, it is crucial to implement measures to protect Lake Snagov and its forest, through strict regulations on access and construction as well asgreening, reforestation, and environmental education initiatives. Tourism, an important economic resource for Snagov, should be developed through ecotourism and cultural tourism, which would promote responsible visiting of natural and historical sites. This involves the creation of thematic routes, tourist information centres, educational panels, and sustainable facilities, such as cycle paths or birdwatching points.

On the economic front, sustainable development can be advanced by encouraging small local enterprises, especially in areas such as organic farming, traditional crafts, local gastronomy, and rural tourism. Supporting local entrepreneurship through tax incentives, training programmes, and access to microfinance can contribute to diversifying the commune's economy and reducing dependence on external resources or speculative investments. At the same time, stable jobs can be created for local youth, thereby helping to curb migration.

The development of infrastructure must be carried out with respect for the natural specificities of the commune. It is necessary to modernize roads, water supply networks, sewage systems, and public lighting, as well as to digitalize public services, all in line with energy efficiency standards and environmental

protection requirements. At the same time, access to education and healthcare must be improved through investments in modern schools, extracurricular programs, and basic medical services in close proximity to households. Another essential aspect is the valorization of the local cultural heritage, through the restoration and integration into the tourist circuit the historical landmarks such as the Snagov Monastery or the Snagov Palace. Likewise, the promotion of local traditions, legends, stories about the Wallachian rulers, or traditional gastronomy can contribute to shaping an attractive local identity, with both educational and touristic potential [15].

The concrete implementation of sustainable development principles in Snagov commune must begin with and in-depth analysis of the local realities and be supported by an active partnership between administration and community. By coherently integrating ecological, economic, and social dimensions, Snagov can become a model of balanced development, where heritage preservation is harmoniously intertwoven with economic progress and quality of life.

Sustainable Development Strategy for the Municipality of Snagov -Vision

The municipality of Snagov aspires to become a model of balance between economic development, environmental protection, and social cohesion, by intelligently leveraging its natural and cultural heritage. This strategy proposes an integrated approach to development, in which local resources are used responsibly and the inhabitants are active actors of sustainable transformation.

→ Objective 1: Protect and sustainably utilize natural resources

Measure: Conservation of lake and forest ecosystems

Lake Snagov and its surrounding forest are essential elements of the local identity and represent a vital environmental resource for the entire region. Their conservation must become a strategic priority, given the increasing pressures exerted by urbanization, uncontrolled tourism, and pollution. The implementation of an Integrated Ecological Management Plan for these two natural areas would ensure continuous water quality monitoring, biodiversity conservation, control of invasive species, and the establishment of restricted access areas for strict protection. Urban planning regulations should also be revised to prohibit construction expansion along the lake shores.

Action: Development of ecotourism and educational trails

To utilize the area sustainably, thematic trails can be developed in the forest and along the lake, equipped with informational panels on flora, fauna, and the importance of ecosystem protection. Such trails can include bird observatories, rest areas constructed from natural materials, and lookout points. A practical example could be a "Snagov Biodiversity Trail", designed especially for students and visitors interested in ecotourism. These facilities should be built with minimal impact on the environment and maintained by local volunteers or staff, in collaboration with environmental NGOs.

→ Objective 2: Develop a sustainable and resilient local economy

Measure: Support local entrepreneurship in ecological sectors

Snagov commune has the potential to develop a local economy grounded in renewable resources, traditional crafts, and ecological agriculture. By establishing a Local Center for Green Economy, the town hall could provide consulting, professional training, and administrative support for entrepreneurial initiatives in fields such as beekeeping, ecological horticulture, wood processing, or local food production. A grant program for sustainable start-ups would stimulate youth initiatives whilecontributing to maintaining the active population in the commune.

Action: Organize local fairs and promotion platforms

To support these activities, it is essential to establish distribution and promotion channels. The regular organization of a local producers' fair in the center of the commune would allow small entrepreneurs to sell their products directly to consumers, while advancing the concept of a circular local economy. In parallel, an official digital platform of the commune could feature sections dedicated to tourism, local products, accommodation, and

cultural events. Thus, the visibility of the Snagov commune would be enhanced, attracting visitors and responsible investors.

→ Objective 3: Modernize infrastructure in accordance with the principles of sustainability

Measure: Ensure sustainable basic infrastructure

Access to quality public services is a fundamental condition for increasing the quality of life. The rehabilitation and expansion of water, sewage, and street lighting networks must be implemented using modern, energy-efficient technologies. For example, the use of LED street lighting powered by solar panels can significantly reduce public expenses and environmental impact. Similarly, modern treatment plants can prevent water pollution whiele protecting Lake Snagov.

Action: Sustainable mobility and ecological transport

Local transport should be restructured to reduce dependence on the personal car. The development of bicycle paths between the villages of the commune, as well as towards tourist areas, would encourage non-polluting forms of mobility. At the same time, charging stations for electric cars can be installed near tourist attractions and public institutions. The introduction of a community electric minibus, with daily routes between the village and the Snagov CFR train station or neighboring localities, would improve access to services and reduce emissions.

→ Objective 4: Valorization of local cultural and identity heritage

Measure: Conservation and promotion of built and intangible heritage

The cultural heritage of Snagov commune includes historical monuments, legends, crafts, and traditions that define the local identity. The restoration and valorization of Snagov Monastery, the alleged burial place of Vlad the Impaler, can attract an international audience interested in the medieval history of the Romanian Principalities. At the same time, Snagov Palace could be transformed into a cultural center or museum, contributing to cultural tourism and historical education of visitors.

Action: Cultural events and local museums

To revitalize cultural life, annual events such as the "Snagov Days" can be organized, featuring exhibitions, performances, and thematic workshops. These events can also include an educational component, addressed to young people, in collaboration with local. In addition, the establishment of a Museum of Local Identity is also proposed, which will exhibit documents, traditional objects, photographs, and testimonies about daily life in Snagov over the centuries. Such initiatives foster local pride and contribute to the transmission of cultural values to new generations.

→ Objective 5: Increase social cohesion and improve the quality of life

Measure: Equitable access to education and social services

A high level of quality of life requires universal access to education, health, and social services. It is necessary to modernize school buildings, equip them with digital tools and introduce programs on environmental education, heritage preservation, and active citizenship. A Multifunctional Community Center could also provide support to vulnerable groups, social assistance, activities for seniors, and integration programs for young people returning from the diaspora.

Action: Promote civic participation and volunteering

For development to be truly sustainable, it is essential that residents are involved in decision-making. Launching a local volunteer program, coordinated by the town hall, would allow citizens to engage in environmental protection activities, event organization, heritage restoration, or social assistance. Both digital and in-person public consultations can also be introduced prior the start of major projects. In this way, a culture of responsibility and solidarity is built within the community.

→ Objective 6: Promote innovation and digitalization in the community

Measure: Facilitate access to technology and develop digital skills

In the current context of the digital economy, access to technology is essential for the social inclusion and economic development of rural communities. For the commune of Snagov, implementing programs that ensure residents'

access to broadband internet and digital devices are a necessity. Organizing digital literacy courses for all age groups will also increase local skills and enable citizens to access online public services, develop digital businesses, and actively participate in community life.

Action: Creation of a Digital Community Center and organization of workshops

The town hall has established a Digital Community Center equipped with computers, Wi-Fi access, and educational materials. In this space, introductory workshops on the use of computers, the Internet, e-government platforms, and online commerce will be organized periodically. By collaborating with schools and specialized NGOs, mentoring programs can be organized for young people interested in IT and digital entrepreneurship, thereby stimulating a new generation of local innovators.

→ Objective 7: Responsible waste management and promotion of the circular economy

Measure: Implementation of an integrated waste collection and recycling system

Proper waste management is a major challenge in rural areas, where recycling infrastructure is frequently insufficient. In Snagov, it is necessary to establish an efficient selective waste collection system, in which citizens are informed and encouraged to properly separate household waste. The implementation of this system will contribute to reducing soil and water pollution, thus protecting the natural environment and community health.

Action: Educational campaigns and infrastructure for recycling

To ensure the success of the measure, information campaigns will be carried out in schools and across the entire community, explaining the benefits of recycling and proper collection methods. In parallel, containers for the separate collection of plastic, paper, glass, and organic waste will be placed at strategic locations throughout the commune. Collaboration with companies specialized in recycling will facilitate the transport and recovery of the collected waste. In addition, promoting circular economy practices in local households and businesses (composting organic waste, reusing materials) will reduce the total amount of waste generated.

→ Objective 8: Development of sports and recreational tourism

Measure: Development of infrastructure for outdoor sports and recreational activities

The rich natural area of Snagov offers excellent opportunities for the development of sports tourism. The development of water sports facilities (canoeing, kayaking, paddleboarding), hiking and cycling trails, along with sports fields (football, volleyball) will attract active tourists whilealso providing residents with healthy leisure opportunities.

Action: Development of a sports complex and promotion of sports events

The City Hall can invest in the construction of a multifunctional sports complex, equipped with landscaped fields and sports equipment rental facilities. Regular organization of local competitions and themed recreational events (marathons, cycling tours, lake regattas) will enhance Snagov's visibility as a destination for active tourism and contribute to the dynamization of the local economy through tourist and commercial services.

→ Objective 9: Strengthen regional and European partnerships

Measure: Develop collaborations with institutions and communities in the region and across the EU

In order to capitalize on external experience and resources, Snagov must develop partnerships with public administrations, NGOs, and universities in Ilfov County and the European Union. These partnerships can facilitate access to funded projects, exchanges of best practices and expertise in areas such as sustainable tourism, environmental protection and community development.

Action: Participation in European and regional projects and creation of a network of partners

The City Hall will designate a team dedicated to identifying and applying for European (e.g. ERDF funds, LIFE Program) and regional projects, collaborating with partner institutions. In addition, it will organize meetings and conferences with communities facing similar challenges and experiences to exchange know-how. A stable network of

partnerships will strengthen the administrative capacity of the commune and deliver long-term benefits.

→ Objective 10: Increase the resilience of the community to climate change

Measure: Implement adaptation measures to climate impact

Climate change generates heightened risks of floods, drought, and soil degradation, with direct effects on rural communities. For Snagov, it is vital to implement preventive and adaptation measures to protect agricultural land, ecosystems, and infrastructure. Planting protective forest curtains, increasing water retention capacity, and educating the population on the responsible use of natural resources are key components.

Action: Planting programs and ecological education on climate change

The City Hall will launch afforestation campaigns in areas affected by erosion and collaborate with farmers to introduce sustainable agricultural practices (crop rotation, use of natural fertilizers). At the same time, information sessions and workshops will be organized for citizens on the impacts of climate change and adaptation measures they can adopt in their households. In this way, the community becomes better prepared to face future challenges.

The operational plan for the implementation of the sustainable development strategy of Snagov commune involves a series of phased actions aimed at promoting digitalization, responsible waste management, developing sports tourism, strengthening partnerships, and enhancing the community's resilience to climate change. Regarding the digitalization of the community, the first step is to assess the existing IT infrastructure in schools and public spaces to identify actual needs and deficiencies in internet access and technical equipment. By organizing digital literacy courses, adapted to all age groups, the competent use of digital services will be stimulated, which will increase the degree of social and economic inclusion. Continuous monitoring of participation and feedback will enable program adjustments, ensuring their relevance and efficiency.

Regarding waste management, the plan begins with a detailed analysis of the waste flow and the needs of the community, to design an integrated selective collection system. Its implementation will involve the procurment and placement of dedicated containers in strategic locations throughout the commune to facilitate the separation of recyclable materials. Educational campaigns will play a central role, being carried out both in schools and at the level of the entire community, to inform and motivate citizens about the benefits of recycling and circular economy practices. Collaboration with specialized companies will ensure the proper collection and valorization of recycled materials, and periodic evaluations will allow progress to be measuredand adjusted.

For the development of sports and recreational tourism, the operational plan includes a feasibility study to identify the most suitable sports facilities and recreational routes in the Snagov area. Subsequently, bicycle paths, multifunctional fields, and sports equipment rental points will be developed, so that both tourists and locals can benefit from a favorable environment for outdoor physical activities. The organization of regular organization of sports and recreational events will contribute to promoting the commune as a destination for active tourism and boosting the local economy by increasing demand for accommodation, food, and leisure services.

Strengthening regional and European partnerships is another essential pillar of the strategy, aiming to increase administrative capacity and attract external funds. For this, potential partners and funding sources will be identified, and a dedicated team will manage the application to European and regional projects. In addition to accessing funds, the plan provides for the organization of annual conferences and meetings to exchange best practices, which will stimulate cooperation and the development of local knowledge.

In terms of increasing the community’s resilience to climate change, the plan begins with the assessment of vulnerable areas and specific risks, in order to adapt protection measures. Protective forest belt planting campaigns, and ecological education programs for farmers and residents will be implemented, promoting sustainable agricultural practices

and raising awareness of the effects of climate change. Continuous monitoring of these measures will enable the adjustment and consolidation of reinforcement efforts over time.

This operational plan is designed to be flexible, with clearly defined stages, responsibilities distributed between local authorities, schools, NGOs, and the community, and concrete performance indicators that allow progress to be tracked and the achievement of Snagov commune's strategic sustainable development objectives.

The implementation of Snagov commune's sustainable development strategy requires an integrated approach, ensuring the efficient coordination of all activities, the involvement of relevant actors, and the allocation of clear responsibilities. For this, it is essential to establish a multidisciplinary working group consisting of representatives of the local administration, public institutions, the local community, and the private sector. This group will have the role of supervising and coordinating the implementationof the operational plan stages, ensuring communication among the parties involved and facilitating access to the necessary resources. Also, the active involvement of citizens and non-governmental organizations will be encouraged through periodic consultations and participatory initiatives, aimed at strengthening the sense of belonging and responsibility towards the sustainable development of the community.

A key element in the implementation process is ensuring adequate and sustainable funding by leveraging both the local budget and external sources, including European, national, or private funds. Identifying and accessing these resources should be a priority for the working group, which will monitor funding opportunities and support drafting and submitting project applications. Monitoring and evaluating progress are fundamental components for ensuring the effectiveness of the strategy and for the continuous adjustment of the measures adopted. In this regard, clear performance indicators will be established for each objective and measure, allowing for the measurement of the impact of the activities carried out. Regular reports, prepared by the working group in collaboration with the partners involved, will provide updated information on the stage of implementation, the difficulties encountered, and the results obtained. These reports will be presented to the local council and made available to the community to ensure transparency and accountability.

It is also recommended to conduct external evaluations at regular intervals, which would provide an objective perspective on progress and recommend strategic adjustments if necessary. In addition, the use of digital technologies and dedicated online platforms can facilitate data collection and analysis, as well as rapid communication among the actors involved.

Through a rigorous implementation process and constant monitoring, the Snagov commune will be able to flexibly adapt the strategy to local conditions and external developments, thereby ensuring genuine sustainable development and long-term benefits for the entire community.

CONCLUSIONS

The implementation of the sustainable development strategy in Snagov commune represents a fundamental step towards creating a balanced community from an economic, social, and ecological point of view. This strategy is positioned as a major opportunity to harmonize economic growth with the protection of the natural environment, while respecting the cultural and traditional values of the area. Through rigorous planning, based on an in-depth analysis of local resources and community needs, combined with efficient coordination among the actors involved, Snagov can become an example of best practices for other rural communities in Romania and even in the European region. Thus, this initiative has the potential to transform the commune from a traditional area into a hub of sustainable development, adapted to both local and global challenges, such as climate change and accelerated digitalization.

One of the key benefits of the strategy is to expand the population's access to digital

technology and services, which is crucial in the current context of the information society. By facilitating broadband internet access and providing digital literacy programs, new opportunities for education, social inclusion, and economic development are opened up. This digitalization not only reduces social and geographical gaps but also stimulates innovation in local businesses, providing a platform for entrepreneurship and for the integration of Snagov into the regional and national economy.

In the field of the environment, the strategy advances an efficient and integrated waste management system, which will contribute to reducing pollution and preserving the biodiversity of the area. By implementing selective collection and through continuous educational campaigns, the community will be actively involved in the process of environmental protection. Thus, Snagov will be able to safeguard its valuable natural heritage, including the lake and forested areas, ensuring a higher quality of life for future generations. Also, responsible resource management will increase the tourist attractiveness of the area, making it more environmentally friendly and competitive in the eco-tourism market.

Another key element is the diversification of the tourism offer, especially by promoting sports and recreational tourism. This will not only generate new income sources for residents, but will also contribute to the creation of a strong local brand, attracting tourists interested in outdoor activities, health, and recreation. The development of bicycle paths, sports facilities, and the organization of thematic events will boost the local economy, while supporting local entrepreneurial initiatives and related services. The strategy also aims to increase the community's capacity to respond effectively to the challenges generated by climate change. By implementing concrete measures, such as afforestation, adapting agricultural practices, and educating the population, the commune will be able to reduce its vulnerability and increase its resilience to extreme phenomena. This adaptation is crucial for maintaining the functionality of local ecosystems, as well as ensuring the continuity of economic and social activities.

Strengthening partnerships at the regional and European levels is another major benefit of the strategy, as it brings financial resources and specialized expertise, thereby facilitating the implementation of complex projects. Cooperation with other communities, academic institutions and non-governmental organizations will stimulate the exchange of best practices and innovation, ensuring long-term sustainable development.

To ensure the success of this ambitious strategy, local authorities must adopt a series of concrete measures. First, it is necessary to establish a working group dedicated to implementatingthe strategy, consisting of representatives of the administration, civil society, the business environment, and educational institutions. This group should operate within a transparent and accountable framework, with the role of coordinating actions, mobilizing resources, and monitoring progress.

Citizen involvement is an essential component for the success of any sustainable development initiative. Thus, local authorities must develop information campaigns and periodic public consultations, which ensure two-way communication, in which the needs and suggestions of the community are taken into account in the decision-making process. This active participation will increase the degree of acceptance of the proposed measures and foster social accountability.

Strengthening administrative capacity is equally crucial. Authorities must invest in staff training and collaboration with experts, in order to improve project management, access to European funds, and resource management. A professional and well-prepared local administration can significantly increase the efficiency and impact of implemented interventions.

The continuous monitoring and evaluation of the implementation of the strategy must be a well-organized process, allowing for the rapid identification of potential problems and the adaptation of measures. For this, it is recommended to establish clear indicators and

periodic reports, made available to the public to ensure transparency and accountability.

Investments in education and awareness will support the formation of a culture of sustainable development among residents, especially among young people. This culture will contribute to the long-term sustainability of projects and the development of responsible attitudes towards the environment and society.

In conclusion, the sustainable development strategy for Snagov commune is an essential tool for capitalizing on local potential, protecting natural and cultural heritage, and promoting a healthy and prosperous way of life. Its successful implementation will contribute not only to the harmonious development of the community, but also to enhancing the role of Snagov within Ilfov County and the Bucharest-Ilfov region, thus laying the foundations for sustainable, inclusive, and competitive regional development.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE CONTRIBUTION OF TRAINEESHIPS IN ENHANCING THE EMPLOYMENT PROSPECTS OF YOUNG PEOPLE FROM RURAL ENVIRONMENTS

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Abstract

This study analyses the impact of traineeships in vocational and technical education on the labour market opportunities of young people in rural areas, with a special focus on Ilfov County. In the context of the economic and social challenges faced by young people in rural areas, traineeships are highlighted as fundamental tools for developing professional skills, facilitating the transition from theoretical education to effective integration into the labor market. Through them, students gain valuable practical experience, improving technical skills, developing professional networks, and becoming familiar with modern organizational cultures. Furthermore, the study highlights the importance of integrating complementary dimensions, such as the digitalization of the educational process, promoting social inclusion and ecological awareness, in order to increase employability and reduce disparities between rural and urban areas. The conclusions emphasize the role of traineeships as essential elements in increasing the competitiveness of young people and recommend their expansion, strengthening partnerships between schools and the economic environment, as well as continuous investments in the digitalization and modernization of educational processes.

Key words**:** *traineeships, vocational and technical education, insertion on the labor market, rural youth, school-work transition*

INTRODUCTION

In the current context of the Romanian economy, the integration of young people into the labor market is an essential priority for the economic and social development of the country, and this process becomes even more difficult in the case of young people from rural areas. This group of young people faces multiple challenges, from limited access to quality education to the poor infrastructure of the localities in which they live. In this sense, vocational and technical education, with an emphasis on traineeships, is becoming a crucial tool for increasing the employment opportunities of young people from rural areas. Traineeships, regulated by national legislation, allow students to gain direct experience in their field of study and to apply theoretical knowledge in a real work environment, which significantly contributes to enhancing their employability [7] [8].

In Romania, the pre-university vocational and technical education system has been regulated and supported through a series of reforms aimed at improving the vocational training of students and responding to the demands of the labor market. The pre-university Education Law emphasizes the importance of vocational education, explicitly mentioning traineeships as a fundamental element in the training of students. Moreover, through the National Strategy for Vocational and Technical Education (SNIPT), the Romanian authorities have recognized the need to connect schools more closely with the economic environment, especially in rural areas, in order to ensure that young people have real opportunities to integrate into the labor market. Traineeships carried out in partnership with economic operators play a vital role in this process,

providing students not only with technical skills but also with a thorough understanding of the requirements of the labor market. [7] [8] [10]

The contribution of traineeships in pre-university vocational and technical education in Romania is particularly relevant for young people in rural areas, who often face the absence of an adequate vocational training framework. According to a report by the European Commission (2018), young people in rural areas are often less prepared to meet the demands of the labor market due to limited access to vocational training and insufficient educational infrastructure. However, traineeships can reduce these disparities by offering rural students opportunities to learn directly from professionals, as well as to build connections with local or national employers. In addition, these traineeships significantly contribute to the development of transferable skills, such as communication, teamwork, and flexibility, essential skills for success in a dynamic and competitive work environment [1] [5].

Studies conducted by specialists in the field highlight the importance of traineeships as an effective method of integrating rural students into the labor market, with a direct impact on their employability. These traineeships contribute both to increasing the level of knowledge and skills specific to a given professional field and to facilitating integration into professional networks and the creation of employment opportunities. At the same time, they offer rural student's valuable exposure to labor market realities, thus contributing to improving working conditions and reducing economic and social inequalities [3] [9] [15].

Moreover, traineeships are a tool for preventing school dropout, especially in rural areas, where young people are often more likely to drop out of school due to a lack of economic prospects. According to research by Ioniță and Cojocaru (2020), involving students in practical activities within sustainable educational partnerships can significantly reduce the school dropout rate, as they begin to perceive education as a direct form of investment in their professional future. Thus, traineeships not only provide theoretical and practical training but also offer real employment opportunities, contributing to the development of an educational system adapted to the demands of the current economy [2] [3].

Traineeships in vocational and technical pre-university education play a fundamental role in increasing the employment opportunities of young people in rural areas. By integrating training methods adapted to the needs of the labor market and by establishing effective partnerships between educational institutions and economic agents, these traineeships can become an important driver for reducing economic and social inequalities, but also for stimulating the sustainable development of rural areas [4] [6].

In this context, the purpose of this research is to assess the impact of traineeships in vocational and technical education on the labour market opportunities of young people in rural areas, with a special focus on Ilfov County.

MATERIALS AND METHODS

In order to assess the perceptions of students in technological and vocational pre-university education in Ilfov County regarding the effectiveness of traineeships, a research methodology based on a sociological survey, implemented through an online questionnaire, was employed. The research was conducted over four school years (2021–2025), involving a significant sample of 2,510 students from seven pre-university technological and vocational education institutions in Ilfov County. This longitudinal approach allowed monitoring the evolution of students' perceptions over time, providing an overview of the impact of traineeships on their educational process and on employment opportunities, especially in rural areas [11] [13] [14].

The research adopted a descriptive approach, seeking to identify and analyze students' perceptions regarding the relevance of traineeships within pre-university vocational and technical education. The main objective was to evaluate the effectiveness of these traineeships in preparing students for integration into the labor market, with a special

focus on the rural environment. In addition, the research aimed to identify avenues for improving traineeships and to compare how students from different schools perceive their impact on their chances of employment and professional integration [12] [14].

The primary data collection tool was an online questionnaire, administered through the Google Forms platform. The questionnaire was structured in several sections, each addressing a specific dimension of the traineeships: the level of student satisfaction, the perception of their usefulness for developing professional skills, their impact on career choices, and the degree of integration of traineeships into the school curriculum. The questionnaire also included items on student's perceptions of working conditions during traineeships and their relationship with trainers from partner companies. The questionnaires were administered online, allowing for efficient data collection.

The sample consisted of 2,510 students from high schools with a technological and professional profile (including dual education programs) in Ilfov County, selected according to criteria of geographical and institutional representativeness. The participants were divided into four groups, corresponding to the four years of study: first year (658 students), second year (502 students), third year (679 students), and fourth year (671 students). This sample structure ensured a balanced coverage of the various stages of professional training, facilitating the analysis of the evolution of students' perceptions as they progressed in professional and technical education.

Each educational unit involved in the research was selected considering the diversity of educational profiles and geographical distribution, so as to obtain the most comprehensive picture of the educational context in Ilfov County. In addition, the research aimed to maintain a balance between students from urban and rural areas, given that the main purpose of the study was to evaluate the impact of traineeships on employment opportunities in rural areas.

The questionnaires were distributed online, and students were invited to participate in the research through invitations sent via email, social networks, or direct messages on the educational platforms used by the partner educational units. Participation was voluntary, and data confidentiality was ensured throughout the data collection process. To guarantee the completeness and validity of the data, the questionnaires were structured so that they were easy for students to understand and complete, and the questions were formulated in accessible language, adapted to their level of comprehension.

The collected data were analyzed quantitatively, and the results were processed through descriptive statistics, including frequencies, means, and percentages, to highlight relevant trends and correlations between students' perceptions of traineeships and their employment chances. In addition, longitudinal analyses were conducted, which made it possible to observe the evolution of students' perceptions over the four years of study. These analyses were essential to understand how traineeships influenced the students' educational process and their level of preparation for integration into the labor market, especially in rural areas.

Regarding the validity of the research, the selected sample was representative, and the geographical and institutional distribution met the diversity requirements of the study. However, the research was limited by the self-reported nature of the data, which may introduce a certain degree of subjectivity in the assessment of students' perceptions. Nevertheless, by applying a standardized and well-structured research instrument, rigorous data collection was achieved, which contributes to the validity and reliability of the results.

The methodology used was appropriate for the purpose of the research, and the data analysis enabled a detailed assessment of the impact of traineeships on vocational and technical education students in Ilfov County. Through a quantitative and longitudinal approach, the research provided relevant information for improving the educational process and traineeships, in order to increase the employment opportunities of young people in rural areas.

RESULTS AND DISCUSSIONS

The analysis of data obtained in Ilfov County from the 2021-2022 to the 2024-2025 school years, which reflects the opinion of over 2,500 vocational and technical education students, most of whom come from rural areas, highlights the importance of traineeships in their professional and personal development and in increasing their chances of integration into the labor market. Here are some key aspects that highlight their impact:

Familiarization with labor market requirements

For many young people from rural areas, traineeships represent the first opportunity to interact directly with an organized work environment. Participating in activities within companies, production units, or service organizations offers students the chance to understand the hierarchical structure of an organization, the norms of professional behavior, and the dynamics of workplace relations.

This exposure is essential to mitigate the discrepancies between students' expectations and the realities of the labor market. The lack of such experiences could result in major difficulties adapting to formal employment, and some young people might resort to migration in search of informal work or risk leaving their profession.

Developing a portfolio of professional and transferable skills

Students participating in the study consistently emphasized the importance of traineeships in developing key skills, including:

Technical skills specific to the training field: using equipment, applying technical procedures, and solving problems in real work contexts.

Transversal skills: communication skills, time management, teamwork, adaptability to change, and the ability to assume responsibilities.

Digital skills: familiarity with online platforms and the use of digital tools for planning, reporting, and monitoring. These skills are increasingly valuable, given the trend toward digitalization in both education and the professional sphere.

These skills not only increase students' self-confidence but also improve their employment prospects.

Clarifying career options and increasing motivation for employment

Many students emphasized that traineeship experiences provided them with a clear picture of the field in which they were specializing, helping them decide whether it aligns with their personal aspirations and abilities.

For young people in rural areas, who often do not have access to adequate career counseling, traineeships represent an important opportunity to observe the activity of a professional in the respective field and to gain a better understanding of labor market requirements.

Employment opportunities and professional integration

Although not all students received job offers immediately after completing traineeships, research shows that these experiences can represent a direct path to employment. Companies involved in traineeships often identify talented young people and can offer jobs as soon as they complete their studies.

For young people in rural areas, who face geographical limitations and a lack of professional networks, traineeships can provide a direct link to employers, sometimes even within their local communities.

Reducing migration and employment in the informal economy

A common problem in rural areas is the migration of young people to unskilled jobs, often abroad or in urban areas, in precarious conditions. Traineeships offer a successful alternative by developing certified skills recognized on the labor market, strengthening a sense of professional belonging, fostering the desire to remain in the chosen field, and opening communication channels with local employers.

Access to mentoring and professional role models

Another important benefit for students was the interaction with mentors or experienced professionals from the companies where they completed their traineeship. This experience involved not only technical training, but also of

counseling and mentorship, contributing to the professional development of young people.

Increasing professional and geographical mobility

Traineeships offered students the opportunity to adapt to economic environments different from the one they came from. This allowed them to broaden their horizons, both professionally and personally, more diverse opportunities to access jobs and educational programs at the local, national or international levels.

Reducing the urban-rural educational gap

By participating in traineeships in modern companies, students from rural areas gained access to cutting-edge technologies and professional practices. Thus, they managed to reduce the educational differences compared to students from urban areas, thereby becoming better prepared to meet the demands of the labor market.

Developing entrepreneurial skills

Some traineeships offered students the opportunity to become familiar with aspects such as resource management, customer interaction, and the initiation of micro-enterprises, essential skills for young people from rural areas who may pursue self-employment.

Building a network of professional contacts

Through traineeships, students had the opportunity to build a network of important professional contacts, which can facilitate their later access to jobs, professional recommendations, or even additional traineeship opportunities.

Improving discipline and professional ethics

Another significant impact of traineeships on students is the development of responsible professional behavior. Adhering to a work schedule, following rules of conduct, and meeting clear work objectives help students understand the requirements of the labor market and build a serious attitude towards the profession. This discipline, acquired in a real work setting, is essential for their professional development and for enhancing their employability in the labor market.

Building a professional identity and increasing self-esteem

The experience gained during traineeships contributes significantly to shaping a professional identity and enhancing students' self-esteem. Through feedback received from mentors and colleagues, they can validate their skills and gain a clearer understanding of the direction in which they wish to develop their careers. Especially for young people in rural areas, where professional role models are often lacking, traineeships can provide a framework in which they feel validated and encouraged to pursue a stable professional trajectory.

Stimulating lifelong learning

Traineeships promote an attitude of continuous learning, essential in a ever-changing professional environment. Through contact with specialists from various fields and the use of modern technological tools, students acquire not only technical skills but also openness to new fields and long-term learning opportunities. This mindset is particularly important in rural areas, where professional development opportunities are often limited.

Developing intercultural and social skills

Traineeships, which involve interacting with professionals from diverse organizational cultures and socio-economic contexts, are an opportunity for students to develop valuable intercultural and social skills. The ability to communicate effectively with people from diverse backgrounds, as well as the ability to adapt to diverse working and interaction conditions, are essential skills in any professional field. These skills contribute to the integration of young people into modern labor markets, favoring their inclusion into diverse and dynamic teams.

Promoting inclusion and reducing social exclusion

In rural areas, a significant proportion of students come from low-income families or vulnerable groups. Traineeships can be tailored to meet their needs, providing them with learning and professional integration opportunities that would otherwise be inaccessible to them. These experiences contribute to preventing social exclusion and increasing the employment chances of these young people, thus supporting their transition toward a stable and sustainable professional life.

Strengthening local and regional partnerships

Traineeships contribute not only to the personal and professional development of students but also to strengthening partnerships between educational institutions and local or regional companies. These collaborations are essential to ensure quality training, based on the real demands of the labor market, and to create a sustainable framework for the professional development of young people in Ilfov County.

Stimulating the use of green technologies and sustainable practices

In an era of climate change and the transition to a green economy, traineeships represent an essential opportunity for young people in Ilfov County to learn and apply green technologies. These traineeships can significantly contribute to their preparation for jobs in emerging sectors that are continuously evolving.

- Preparing students for jobs in emerging sectors: Organic agriculture, renewable energy, waste management, and other green industries are expanding fields that require specific technical skills. Young people who participate in traineeships in these fields become much better prepared for the demands of the green and sustainable labor market.
- Increasing environmental awareness: Traineeships are an opportunity for students to learn environmentally friendly practices and technologies through direct application. This not only provides them with technical skills but also contributes to the development of environmentally responsible behavior.
- Adapting skills to current labor market trends: With an increasing emphasis on sustainability, green innovation, and social responsibility, young people who acquire these practices during traineeships become significantly more attractive to employers. Their training not only increases their chances of employment but also gives them a competitive advantage in an ever-changing labor market.

Strengthening civic spirit and social responsibility

Another significant benefit of traineeships is the development of a strong civic awareness and a sense of social responsibility, essential for future community leaders.

- Taking responsibility: Active participation in traineeships helps students understand the importance of their work in the context of the community. Every task, even at a practical level, has an impact on those around them and on the environment in which they live.
- Community projects: Collaborating on projects that involve working with local communities allows young people to understand the active role of citizens in societal development and how they can contribute to solving social or economic problems in their area.
- Training active citizens: These experiences contribute to the formation of a mentality of involvement and social responsibility, representing an essential step in education for active citizenship. Young people will become more aware of the connection between education, work, and their contribution to the good of the community.

Integration into the formal education system and reducing school dropout

Traineeships can play a crucial role in preventing school dropout, especially in rural areas, where students may be more likely to drop out of school for various reasons.

- Linking theory to practical application: Practical experiences transform theoretical learning in school into a useful and relevant tool for everyday life. Students can see firsthand the applicability of knowledge and understand that education is the key to a stable job.
- Concrete learning purpose: Participation in traineeships gives a clear meaning to theoretical learning, reducing the feeling of abstractness of studies. Students recognize that what they learn can be directly applied in their future professional lives.
- Reducing the risk of school dropout: By actively integrating into the professional environment, traineeships help maintain students' motivation and increase their chances of completing their studies. This can lead to a significant reduction in school dropout rates in rural areas, where this phenomenon is often more pronounced.

Developing leadership skills and team responsibility

Traineeships are fertile ground for developing leadership skills and team-oriented responsibility, essential for success in any professional career.

- Taking initiative: Students are often encouraged to take on responsibilities within teams or projects, where they can demonstrate the ability to lead, make decisions, and propose innovative solutions.
- Managing teams and responsibilities: Another benefit of traineeships is that students learn to coordinate and collaborate effectively with their peers. This contributes not only to their professional development but also to the formation of a spirit of collaboration and solidarity.
- Communication and negotiation skills: In addition to technical skills, students also learn how to communicate effectively, how to negotiate, and how to reach constructive compromises. These skills are essential for any leader, but also for any employee in a collaborative work environment.

Improving perceptions of work and reducing stigma around technical professions

In many rural areas, technical professions are often perceived as inferior to theoretical ones. Traineeships can change this mindset by demonstrating the real value and complexity of technical professions.

- Demonstrating the value of practical work: Students are directly exposed to work in industry, realizing that technical professions are essential for the functioning of the economy. Through their experiences, they understand the complexity and importance of these professions.
- Positive experiences: By providing young people with a positive experience, traineeships help shift negative perceptions of technical jobs and increase respect for these professions. This can stimulate additional motivation to pursue a career in technical fields.
- Increasing motivation for technical careers: Young people who benefit from positive traineeship experiences are more likely to choose a technical career, thus responding to the growing labor market demands for qualified professionals in technical fields.

These dimensions reflect the significant impact of traineeships on young talents in Ilfov County, providing them with personal and professional development opportunities that offer advantages in the labor market and their communities.

The multidimensional analysis of the impact of traineeships on young people in rural areas of Ilfov County highlights their crucial role in facilitating the transition from education to the labor market. In a context marked by socio-economic disparities, low mobility, and limited access to professional opportunities, these traineeships prove to be an effective mechanism for mitigating these disadvantages and capitalizing on local human capital.

By developing technical and transversal skills, becoming familiar with organizational culture, expanding professional networks, and being exposed to modern work environments, young people from rural areas acquire practical training aligned with the current demands of the labor market. In Ilfov County, where both urban and rural areas meet, traineeships constitute effective platforms for experiential learning and career guidance, thanks to close collaboration with local economic agents. In addition, the complementary dimensions identified – such as the digitalization of traineeship processes, promoting inclusion, developing civic spirit, ecological education, and reducing the stigmatization of technical professions – strengthen the formative role of traineeships, integrating them into a broad framework of personal and professional development. They contribute to balancing the chances between students from rural and urban areas, supporting equitable socio-professional integration.

Traineeships, in their modernized form and adapted to local specifics, constitute a strategic catalyst for enhancing the employability of young people in Ilfov County. Continuing investments in this type of training, strengthening partnerships between schools and the economic environment, and digitalizing educational processes will have a significant impact in promoting sustainable professional integration and reducing territorial disparities in access to quality emplyment opportunities.

CONCLUSIONS

The analysis of data collected during the four school years analyzed highlights that traineeships have been an essential component of the educational process, facilitating the transition of students from theory to practice and supporting their integration into the labor market.

Traineeships in vocational and technical education have a significant impact on the chances of integration into the labor market of young people from rural areas, representing an essential tool in preparing them for the current demands of the labor market. The practical experience acquired within these traineeships facilitates the integration of young people into various economic sectors, encouraging the development of technical and transversal skills, as well as familiarization with organizational culture and the professional environment. In Ilfov County, where both urban and rural areas coexist, these traineeships have proven to be an important vehicle for creating close links between education and the labor market, thus responding to the need for qualification of the labor force in rural areas.

Impact on labor market insertion

1. Development of skills and abilities required by the labor market: Traineeships allow young people from rural areas to acquire not only theoretical knowledge, but also essential practical skills to meet the requirements of employers. Thus, they become more competitive in the labor market, benefiting from practical training directly applicable to their field of study.

2. Access to professional networks: Participation in traineeships offer young people from rural areas the opportunity to build professional networks that can facilitate future employment. This is an important opportunity, given the reduced mobility and limited access to information and resources in rural communities.

3. Improving motivation for education: The close connection between education and the labor market, provided by traineeships, increases the relevance of theoretical learning and stimulates students' motivation to continue school. This contributes to reducing school dropout, a phenomenon that particularly affects young people from rural areas.

4. Promoting social inclusion and reducing disparities: Traineeships, which integrate components of environmental education, digitalization, and social responsibility, contribute to reducing the stigmatization of technical professions and to promoting a fairer climate for professional development, supporting a more balanced socio-professional integration between rural and urban areas.

Recommendations

1. Expanding and diversifying partnerships between schools and the economic sector: It is essential for educational institutions to strengthen and diversify partnerships with local and regional economic agents. These collaborations will ensure traineeships that are better adapted to market requirements and will facilitate a better integration of young people in strategic economic sectors, such as organic farming, green technologies, or IT fields.

2. Digitalization of educational processes and traineeships: Investments in technology must be a priority, given that the digitalization of educational processes and traineeships will help continually update students' skills, improve access to educational resources, and facilitate distance learning. This will contribute to creating young people who are better prepared for the globalized labor market.

3. Incorporating education for sustainable development into traineeships: In the context of global concerns about climate change and sustainability, integrating green practices and education for sustainable development into traineeships is essential. Young people must be prepared not only for technical jobs, but also to understand the broader impact of their work on the environment and the community.

4. Continuous training and improvement of leadership skills: In addition to technical skills, it is important that traineeships include training sessions on leadership skills, communication, and team management. These skills are essential for the personal and professional development of young people and for developing local leader capable of contributing to the growth of the community.

5. Support measures for rural youth: To combat school dropout and the migration of young people from rural areas to cities, it is necessary to develop additional support measures, such as free transportation or traineeship scholarships. These initiatives would reduce the additional costs that may discourage the participation of rural youth in such programs.

Traineeships in vocational and technical education represent not only an opportunity for practical training among young people in rural areas, but also a determining factor in their integration into the labor market. In a context where disparities between rural and urban areas are significant, these traineeships become an effective tool for leveling opportunities, offering young people from disadvantaged areas access to real professional experience and networks of contacts that can open up new opportunities. They contribute to reducing economic and social barriers that can hinder professional mobility and support their integration into an increasingly diversified and technologically advanced economy. At the same time, by acquiring skills that are required on the labor market, these young people become more competitive, and the risk of exclusion from the economy is considerably reduced.

In addition, traineeships are an essential step in the shping a responsible workforce prepared to respond to current economic challenges, such as the transition to a green and digitalized economy. They not only improve technical and professional skills, but also contribute to the development of values such as social responsibility, civic spirit, and respect for labor. Moreover, these traineeships facilitate integration into emerging sectors, such as organic farming, renewable energies, and digital technologies, areas where specialization requirements are constantly increasing. Therefore, the continuation and expansion of this type of practical education will play a crucial role in reducing territorial disparities and ensuring a fair transition toward a sustainable and diversified professional future for young people in rural areas.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

EVALUATION OF TRAINEESHIPS CARRIED OUT AT THE LEVEL OF PRE-UNIVERSITY EDUCATIONAL INSTITUTIONS IN ILFOV COUNTY, ROMANIA

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Abstract

Traineeships are a fundamental element in the professional training of students, providing the opportunity to apply theoretical knowledge in a real work context. This paper focuses on the evaluation of traineeships conducted in pre-university education units in Ilfov County, Romania, in collaboration with local economic operators, from 2021 to 2025. The primary purpose is to assess the effectiveness and relevance of these traineeships, identify their strengths and areas for improvement, and formulate recommendations for their optimization. Data collected from a survey applied to students revealed a positive perception of the traineeship conditions, the quality of equipment and infrastructure, as well as the ongoing evaluation process. Effective collaboration between students, tutors, and coordinators was also observed, fostering the development of essential transferable skills, such as communication and teamwork. Despite the challenges posed by the COVID-19 pandemic, traineeships continued to run satisfactorily, supporting the integration of students into the labor market. However, the research highlights the need for adjustments regarding working conditions, the diversity of activities, and the more effective application of theoretical knowledge. These findings underscore the importance of a closer partnership between educational institutions and economic operators to enhance the employability and practical training of future generations of young professionals.

Key words**:** *practical training, vocational and technological education, traineeship*

INTRODUCTION

Pre-university vocational and technical education is an essential component of the Romanian education system, designed to prepare students for their integration into the labor market. Starting with the reforms of the 2000s and continuing with the implementation of the National Strategy for Vocational and Technical Education (SNIPT), pre-university education in Romania has undergone significant transformations, designed to respond to the demands of the labor market and to provide students with comprehensive training that includes both theoretical knowledge and essential practical skills. A central element of this form of education is the traineeships, carried out through partnerships between educational institutions and economic operators, and which are regulated by a detailed legislative framework [7].

Traineeships in pre-university education are primarily regulated by the Pre-university Education Law no. 198/2023, which stipulates the importance of vocational and technical education and professional training through education based on practical experience. According to the same laws, students in vocational and technical education must participate in traineeships organized within educational institutions, specialized workshops, or within economic entities that can directly contribute to the development of technical and professional skills. Additionally, Law No. 258/2007 on the organization and functioning of vocational and technical education stipulates the obligations of economic partners to contribute to the educational process by ensuring appropriate conditions for practical training [5] [9] [10].
In accordance with this legislative framework, traineeships offer students the opportunity to apply the theoretical knowledge they have

acquired in school in a real-world professional setting. Their role is not limited to training technical skills, but also extends to developing transversal skills, such as teamwork, communication, and flexibility, which are essential for success in future careers. Thus, traineeships constitute an integral component of the educational process, having a direct impact on increasing the employability of graduates and on meeting the demands of the labor market, which increasingly requires young professionals with practical experience [12].

Within the framework of vocational and technical education in Romania, traineeships are regulated through a system of collaboration between educational institutions and economic operators, the process being coordinated by coordinating teachers and traineeship tutors from economic agents. This collaboration is based on the principles of dual education, a model that involves alternating learning between school and the workplace. According to the legislation, traineeship activities are tailored to the professional profile of the students, and their evaluation is conducted both during the traineeship and at the end, to measure not only technical skills but also the development of social and personal competencies. Dual education has also been supported by the development of partnerships at regional and national levels, aimed at facilitating its implementation and supporting the integration of students into specific fields of activity [1].

The importance of traineeships in pre-university education extends beyond pedagogy to encompass economic and social benefits. According to recent studies, integrating work experience into a formal educational setting contributes to the better adaptability of graduates in the labor market and to the development of skills highly valued by employers, such as the ability to work under pressure, problem-solving skills, and team spirit. In this sense, traineeships are perceived as an essential learning environment, which provides a "bridge" between education and the labor market, supporting the development of a youth that is better prepared and able to respond to the demands of the economy [8].

At the same time, even if traineeships represent a valuable opportunity, there are still significant challenges in their implementation, such as the lack of adequate infrastructure in some educational institutions or insufficient collaboration between schools and economic agents. Additionally, despite the regulations and support provided by national legislation, there is a continuous need to adapt traineeship programs to the changing demands of the labor market and the specific needs of each professional sector [4].

This paper presents a study case concerning the evaluation of traineeships in pre-university education units in Ilfov County, Romania, pointing out the effectiveness and relevance of these traineeships, identifying their strengths and items for improvement, and finally for recommending solutions for their optimization.

MATERIALS AND METHODS

Data collection was conducted using a sociological survey with a questionnaire method over four school years. To ensure the validity of the research instrument, the questionnaire used in this study was developed through a rigorous process of operationalizing theoretical concepts. The items were developed based on specialized literature on traineeships conducted at the pre-university education level, including the structure of traineeships, their organizational methods, and the principles of evaluation in applied educational contexts. Content validity was ensured by aligning each item with the relevant theoretical dimensions: organization of the traineeship, conduct of practical activities, pedagogical coordination, and performance evaluation. The wording was adapted to the level of understanding of the participants (students) and reviewed for coherence, clarity, and ambiguity.

The questionnaire was also subject to a content validation process through consultation with experts in the field of educational sciences. They assessed the relevance, clarity, and wording of the items, offering suggestions that were integrated into the final version of the instrument. Additionally, before the actual

application, the questionnaire was tested in a pilot study with a small group of respondents to identify any difficulties in understanding or unclear wording.

These steps aimed to ensure the content and face validity of the instrument, so that it faithfully reflects the aspects relevant to the research objectives and allows the collection of pertinent and comparable data.

In this research, which aims to evaluate the characteristics of traineeships, their organization, and conduct, as well as the methods used to assess them, a quantitative approach was employed, based on the statistical analysis of data collected through a standardized questionnaire. The questionnaire consisted of 11 questions constructed from several Likert scale items, designed to capture the degree of agreement or disagreement of the respondents with statements regarding the school environment in the context of traineeships. The choice of this scale was based on its methodological advantages, recognized in the specialized literature for research in the social and educational sciences [6] [11].

The Likert scale enables the expression of the degree of agreement or disagreement with statements formulated in clear, simple, and concrete terms, thereby facilitating the collection of quantitative data from subjective perceptions. By using a 5-point scale (ranging from "totally disagree" to "totally agree"), respondents had the opportunity to nuance their attitudes without being forced to choose between extremes. This favors obtaining answers that are more faithful to the reality experienced by the participants, especially in the context of evaluating educational experiences [11] [13].

The Likert scale also enables the subsequent application of descriptive and inferential statistical analyses, such as calculating the mean, standard deviation, or comparing groups. This is essential for the research objectives, as it seeks not only a general description of perceptions but also the identification of possible differences between years of study or between aspects of traineeships (organization, implementation, evaluation). The use of the Likert scale provided a flexible, valid, and efficient framework for measuring respondents' attitudes and perceptions in relation to the study's central variables.

The data were collected from a sample of participants, distributed by year of study, and analyzed separately for each year to identify possible differences in perception depending on the level of practical experience. In the quantitative analysis of the data obtained by applying the questionnaire, the arithmetic mean was used for each item at the level of each year of study. The arithmetic mean represents one of the most widely used descriptive statistical indicators, providing a single numerical value that summarizes the average level of agreement expressed by respondents with each statement proposed within the Likert scale [6] [11] [13].

The nature of the data collected justifies the choice of this function: the questionnaire items were formulated on a 5-point Likert scale, allowing the transformation of responses into numerical values (for example: 1 = completely disagree, 5 = agree entirely). Thus, the average of the responses for each item provides a relevant indicator of the general trend in perceptions related to the organization, conduct, and evaluation of traineeships. This approach enabled the comparison of results between the participant groups, as well as the identification of aspects that were appreciated positively or, conversely, perceived as deficient. For example, an average score close to the value 5 may indicate a strong positive perception of an aspect of the specialized practice (such as the clarity of the indications provided by the traineeship tutor). In contrast, an average score close to 2 or 3 may signal ambiguities, deficiencies, or inconsistencies in the organization or evaluation method [6] [11] [13].

Therefore, the statistical analysis of the data significantly contributed to achieving the research objectives, facilitating the synthesis and comparison of the participants' perceptions in relation to the analyzed dimensions of the practical training courses.

Research methodology

Research type: descriptive

Tools used: Questionnaire applied to students

Sample: 2,510 students from vocational and technical education (year I - 658 students, year II - 502 students, year III - 679 students, year IV - 671 students)

Research period: school years 2021-2022, 2022-2023, 2023-2024, 2024-2025.

The research conducted over four school years (2021–2025) aimed to investigate the perceptions of students in vocational and technological education in Ilfov County on the quality of traineeships, with a focus on their relevance for increasing employment opportunities, especially in rural areas. The overall objective was to evaluate the efficiency and impact of these traineeships from the perspective of the direct beneficiaries—the students—and to identify areas for improvement, in line with European best practices regarding vocational training.

The data obtained through the sociological survey, conducted via a questionnaire, enabled a significant quantitative analysis involving 2,510 respondents from seven pre-university education units with a technological or professional profile in Ilfov County. This extensive coverage ensures a high degree of validity of the data, especially given that the research aimed to maintain a balance between educational profiles, years of study, and the geographical distribution of the respondents.

In the national context, students' access to traineeships in companies remains low, according to recent studies, which emphasizes the importance of empirical approaches such as the present one, through which both the real needs of the beneficiaries and local good practices can be highlighted. At the European level, quality standards for traineeships include clear pedagogical objectives, integration into the real work environment, competent trainers, and transparent evaluation—elements that can serve as a model for analyzing the results of the present research.

Organization of experimental groups

a. School year 2021–2022

In the first year of the research, 658 students participated, coming from the following educational institutions:

- "Mihail Kogălniceanu" Theoretical High School, Snagov – 76 students;
- "Vintilă Brătianu" Technological High School Dragomirești-Vale – 54 students;
- "Nicolae Bălcescu" Technological High School, Voluntari – 36 students;
- "Barbu Știrbey" Technological High School Buftea – 152 students;
- "Pamfil Șeicaru" Technological High School, Ciorogârla – 150 students;
- "Doamna Chiajna" Technological High School Roșu (Chiajna) – 66 students;
- "Cezar Nicolau" Technological High School, Brănești – 124 students.

In the first year of the research, participation was remarkable, with a total of 658 student respondents, coming from the seven selected pre-university education units. The distribution by high schools was relatively balanced, but a high presence was noted from the Technological High School "Barbu Știrbey" Buftea (152 students) and the Technological High School "Pamfil Șeicaru" Ciorogârla (150 students), which may reflect either an efficient internal mobilization or an organizational culture favorable to the involvement of students in extracurricular activities and research.

This stage represented a solid starting point for the present study, providing an overview of students' perceptions of traineeships and subsequently facilitating longitudinal comparisons.

b. School year 2022–2023

In the second year of implementation, the total number of respondents was 502 students, distributed as follows:

- "Mihail Kogălniceanu" Theoretical High School, Snagov – 91 students;
- "Vintilă Brătianu" Technological High School Dragomirești-Vale – 43 students;
- "Nicolae Bălcescu" Technological High School, Voluntari – 24 students;
- "Barbu Știrbey" Technological High School Buftea – 116 students;
- "Pamfil Șeicaru" Technological High School Ciorogârla – 54 students;
- "Doamna Chiajna" Technological High School Roșu – 71 students;
- "Cezar Nicolau" Technological High School, Brănești – 103 students.

In the second year of the research, the total number of respondents was 502 students, a

decrease from the previous year. However, the quality of participation and the distribution of the sample were maintained within balanced parameters, with good geographical and institutional coverage. High schools such as "Barbu Știrbey" Buftea (116 students), "Mihail Kogălniceanu" Snagov (91 students), and "Cezar Nicolau" Brănești (103 students) continued to actively support the research actively, thus ensuring the consistency of the investigative approach.

This stage was characterized by a more meticulous monitoring of the diversity of profiles and years of study, aimed at achieving a balance between students in the final grades and those in the early years of training. The numerical decrease compared to the previous year did not affect the relevance of the data, but contributed to a more careful selection, which allowed the consolidation of the evaluation tools and the refinement of the applied methodology [3].

c. School year 2023–2024

In the third year of research, the sample increased to 679 students, of which:

- "Mihail Kogălniceanu" Theoretical High School, Snagov – 178 students;
- "Vintilă Brătianu" Technological High School Dragomirești-Vale – 49 students;
- "Nicolae Bălcescu" Technological High School, Voluntari – 33 students;
- "Barbu Știrbey" Technological High School Buftea – 160 students;
- "Pamfil Șeicaru" Technological High School Ciorogârla – 66 students;
- "Doamna Chiajna" Technological High School Roșu – 73 students;
- "Cezar Nicolau" Technological High School, Brănești – 120 students.

The third year of research implementation recorded the highest number of respondents: 679 students. This significant increase reflects a maturation of the implementation process and an increased involvement of the partner educational units. A considerable increase in participation from the "Mihail Kogălniceanu" Theoretical High School in Snagov (178 students) is noted, which indicates a greater openness on the part of the school management and better information among the students regarding the purpose and benefits of the research.

This stage was characterized by methodological and logistical consolidation, including the better adaptation of questionnaires to students' levels of understanding and facilitating the completion process. The representativeness of the sample was enhanced, allowing for a deeper understanding of the evolution of perceptions on traineeships, as well as their relationship with the prospects of professional integration in rural environments [2].

d. School year 2024–2025

In the last year of research, 671 completed questionnaires were recorded, with the following distribution:

- "Mihail Kogălniceanu" Theoretical High School, Snagov – 103 students;
- "Vintilă Brătianu" Technological High School Dragomirești-Vale – 54 students;
- "Nicolae Bălcescu" Technological High School, Voluntari – 33 students;
- "Barbu Știrbey" Technological High School Buftea – 157 students;
- "Pamfil Șeicaru" Technological High School Ciorogârla – 147 students;
- "Doamna Chiajna" Technological High School Roșu – 61 students;
- "Cezar Nicolau" Technological High School, Brănești – 116 students.

In the final year of the research, the number of respondents was 671 students, very close to the number registered in the previous year. The numerical stability of the sample confirms that the investigative approach was well integrated into the routine of school activities and became familiar among students and teachers. The sustained participation of high schools such as "Barbu Știrbey" Buftea (157 students) and "Pamfil Șeicaru" Ciorogârla (147 students) reconfirms the constant interest of these institutions in the research topic.

This final stage also allowed the validation of the preliminary conclusions formulated in previous years, offering the possibility of establishing correlations between the quantitative data and the longitudinally observed trends. The coherence in the selection of participants, the uniform application of the methodology, and the maintenance of balance

between the educational profiles contributed to the consolidation of the research's scientific rigor. Thus, the 2024–2025 school year marked the conclusion of a research cycle carried out in a coherent, phased manner, with representative coverage of technological and vocational education in Ilfov County.

RESULTS AND DISCUSSIONS

The evaluation of students' perceptions of traineeships conducted in educational institutions in Ilfov County during the 2021–2025 school years highlights several relevant aspects related to the quality of the practical experience, particularly regarding the equipment provided by economic operators (Fig. 1).

Trends in students' perceptions of the equipment provided

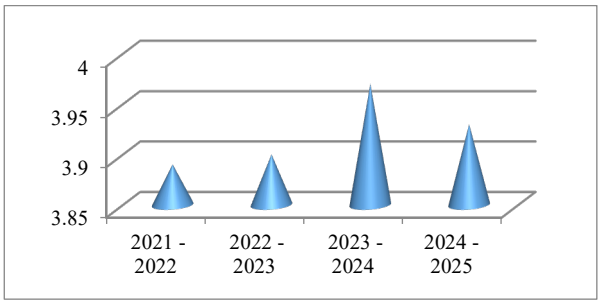


Fig. 1. Evolution of perception regarding equipment
Source: Own determination.

The item "the equipment provided by the economic operator was appropriate for carrying out the activities within the practical training" obtained relatively constant and high scores in the four years analyzed, indicating a generally satisfactory level of technical equipment available during the practical training.

A slight upward trend is observed until the 2023–2024 school year, followed by a slight decrease in the 2024–2025 school year. However, the variations are minor and do not indicate significant fluctuations, suggesting a high degree of stability in the quality of the equipment provided.

In relation to this item, the other factors analyzed — working conditions (space, atmosphere, etc.), the level of guidance provided by the tutor assigned by the host company, and the level of intercollegiate collaboration during practical activities — recorded lower satisfaction values. This indicates that, although the material endowment is perceived positively, there are gaps in the human and organizational dimensions of the traineeships.

The results suggest that economic operators have invested adequately in the equipment made available to students, but the success of traineeships does not depend exclusively on the infrastructure. Elements of pedagogical support and social environment, such as tutor involvement and the dynamics of peer collaboration, require specific interventions for improvement.

Thus, it is recommended:

- training traineeship tutors to improve mentoring and communication skills;
- periodic assessment of the organizational climate in partner companies;
- creating contexts that encourage teamwork and the exchange of experiences between students;
- Establishing continuous feedback between students, companies, and educational institutions to monitor the quality of traineeships.

The analysis of data related to the four school years reveals that students' perception of the equipment provided remains consistently positive, suggesting a solid basis for carrying out practical activities. However, relational and organizational aspects require increased attention, as they can significantly influence the efficiency and quality of the learning experience in the real work environment. For a favorable overall evaluation of traineeships, it is essential to balance the material component with the human and educational components.

Evolution of satisfaction regarding the smooth running of the program

The qualitative evaluation of the traineeships in Ilfov County, conducted in educational institutions over four school years (2021–2025), reveals a positive dynamic in terms of students' perceptions of collaboration with economic operators. One of the central aspects of the overall satisfaction analysis concerns how the economic operator's activity impacted the operation of the traineeship program (Fig.

2). A significant increase is observed between 2021–2022 and 2022–2023, followed by a stabilization in the interval 2023–2025, with a slight, insignificant decrease in the last year. These data indicate a continuous improvement in the collaboration between educational institutions and economic operators, with a direct impact on the fluidity and coherence of the traineeship program.

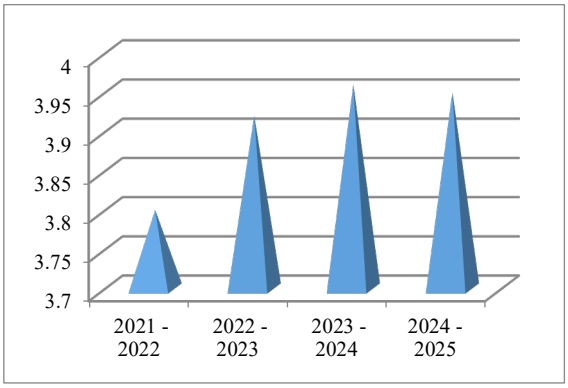


Fig. 2. Perception of program organization
Source: Own determination.

This evolution can be attributed to the optimization of school-economic partnerships, as well as to a progressive adaptation of operators to the formative needs of students and the organizational structure of traineeships.

In contrast, other evaluated items – "the traineeship period and daily schedule" and "the activity of the economic operator corresponded to the expectations of students" – obtained lower satisfaction values, which signals persistent tensions between the needs of students and the concrete way of organizing the traineeship.

These results suggest that, although economic operators did not significantly disrupt the traineeship activity, discrepancies exist between the educational expectations of students and the content of the actual activities carried out, as well as problems in adapting the daily schedule to their rhythms and availability.

Possible causes may include: a Rigid or inconsistent schedule that does not take into account the specifics of age and educational path; a Lack of clear communication regarding the traineeship objectives; and differences between the actual offer of the economic operator and the expectations previously formed by students.

The analysis of data from the four school years reveals that the activity of economic operators has become increasingly integrated into the practical training process, without generating any dysfunctions in the program's implementation. This trend is a positive indicator of the consolidation of educational partnerships in Ilfov County.

However, issues related to the relevance and effective organization of the practice for students require specific interventions. Among the recommendations for improvement are:

- Reviewing the structure of the daily program to ensure a balance between practical activity and the assimilation capacity of students;
- Increasing transparency in the communication of objectives and expectations between schools, operators, and students;
- Actively involving students in the feedback process for the dynamic adjustment of the practice content;
- Continuous monitoring of participant satisfaction to identify potential dysfunctions early.

The global evaluation of traineeships in Ilfov County highlights constant progress toward an efficient integration of the economic environment into the educational process, while also emphasizing the need for a finer adaptation to the direct needs and expectations of students.

Evolution of students' perception of the development of teamwork skills

In the context of vocational and technical education, traineeships play a crucial role in developing students' transversal skills, with teamwork skills occupying a central place. They are indispensable in preparing future graduates for the demands of the labor market, where collaboration, effective communication, and integration into a professional team are highly valued skills.

The data collected for the item "contribution of traineeships to the development of teamwork skills" indicate a high and constant level of satisfaction, with a positive trend throughout the four school years analyzed.

A sustained increase is observed in the first three years, followed by a slight stabilization from 2024 to 2025. This positive dynamic reflects the fact that traineeships contribute significantly to the development of students' collaborative skills, providing them with real-world contexts in which they are encouraged to cooperate, assume team roles, and solve everyday tasks (Fig. 3).

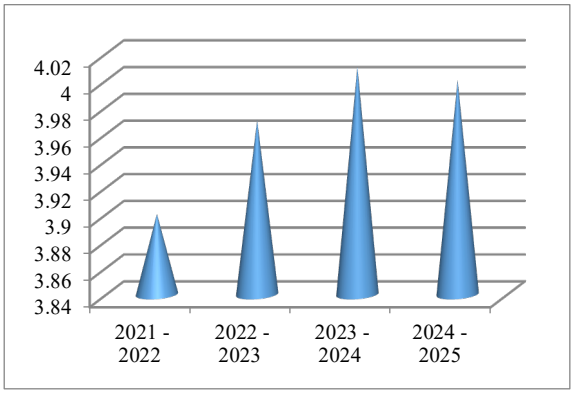


Fig. 3. The evolution of the perception of teamwork
Source: Own determination.

This favorable perception can be linked to several active factors in the context of professional practice: The structure of the activities carried out, which frequently involves tasks carried out in groups, under the supervision of a tutor; Constant interaction with classmates or from other specializations, which encourages the exchange of ideas and mutual support; The involvement of economic operators in creating a working environment that simulates the real professional context; The role of practice coordinators, who can facilitate collaboration and collective learning processes.

Teamwork skills are recognized as an integral part of the key competences of the 21st century. They are not only part of the European vocational training standards but are also explicitly required by employers in all fields of activity. In this regard, the data demonstrate a tangible impact of practical training on students' preparation for integration into the labor market.

Even if the scores are high, maintaining and consolidating these results requires: Deliberate inclusion of collaborative activities in the traineeship program (joint projects, group problem solving); Training tutors and coordinators in facilitating collaborative learning; Creating post-activity reflection contexts, where students can discuss the roles assumed, the difficulties encountered and the way to solve them; Systematic assessment of collaboration skills, not only at the perceptual level, but also by observing concrete behaviors.

The results obtained indicate a consistently positive contribution of traineeships to the development of teamwork skills, an essential aspect in the professional training of students in Ilfov County. This competence, being highly valued in the labor market, confirms that professional practice not only has an applicative role, but is also a framework for comprehensive socio-professional training. Continuing these good practices and expanding them through modern pedagogical methods can help consolidate this positive trend in the years to come.

Evolution of the perception of student responsibility

In the context of professional training for students in vocational and technical education, responsibility for the tasks assigned is one of the key competencies pursued during traineeships. The evaluations conducted over four school years in Ilfov County clearly demonstrate how these traineeships contribute to the development of students' professional attitudes. For the item "increasing the degree of responsibility for the assigned tasks", the collected data highlight a constant and significant progress.

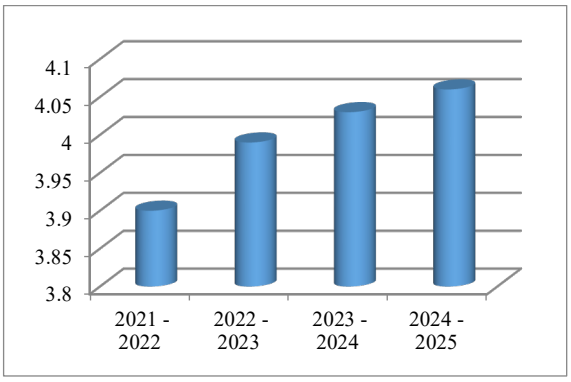


Fig. 4. Evolution of the perception of student responsibility
Source: Own determination.

This upward trend reflects the fact that students are progressively developing their capacity to assume responsibilities within practical activities.

This evolution can be interpreted as the result of direct exposure to real work situations, where the results of tasks are visible and evaluable, as well as the provision of careful supervision and guidance by tutors, and the behavioral maturation of students in structured professional contexts (Fig. 4).

These data support the idea that traineeships not only transmit applied knowledge but also shape behaviors and attitudes relevant to employability.

In contrast, other evaluated items, considered essential for complete professional training, obtained lower average values: the development of practical skills, the practical application of acquired theoretical knowledge, and securing a placement in the labor market upon graduation.

These results suggest a distinction between the development of attitudes and the acquisition of concrete technical and professional skills. In other words, although students become more responsible and aware of their role in professional activity, not all of them manage to consolidate their technical skills sufficiently or to apply the theoretical knowledge acquired in school effectively.

Furthermore, the item on employment highlights an uncertainty among students regarding the traineeship's capacity to prepare them concretely for employment, thus signaling a need for a closer correlation between the traineeship content and the real requirements of employers.

This discrepancy between attitudes (e.g. responsibility) and practical or applicative skills can be interpreted in several ways: The conditions offered within the traineeship are more favorable to personal development than to technical-professional development (e.g. repetitive or poorly specialized tasks); Pedagogical support in applying theory in practice is insufficient, leaving students to improvise or limit themselves to execution activities; The lack of structured and individualized feedback can affect students' ability to recognize progress in practical skills.

In order to fully capitalize on the contribution of traineeships, it is crucial that the actors involved (schools, economic operators, tutors) act in a coordinated manner to:

- Enhance the quality of practical activities by diversifying tasks and aligning them with relevant qualification standards.
- More efficient integration of theory with practice, by assigning applied projects that require the knowledge learned;
- Organizing career guidance sessions, in which students better understand the requirements of employers and the real prospects for professional insertion;
- Continuous training of traineeship tutors, to support students in all dimensions of professional development - not only behavioral, but also technical and applicative.

The analyzed data show that traineeships in Ilfov County significantly contribute to the development of students' professional responsibility, providing a solid foundation for success in their future careers. However, to ensure complete training, it is essential that the development of practical skills, the application of knowledge, and orientation towards the labour market are strengthened systematically and coherently.

The need to train students on the organizational and decision-making structure of economic agents before practice

In preparing students for integration into the professional environment, knowledge of the organizational and decision-making structure of the company or institution in which they are to carry out their traineeship is an essential component. This knowledge facilitates the understanding of hierarchies, communication channels, and functional responsibilities, thus contributing to a faster and more efficient adaptation within the organization.

The item analyzed records an upward trend throughout the study period. This evolution reveals a tendency of constant growth and stabilization at a high level of positive perception. Students clearly appreciate the usefulness of this information and consider that familiarization with the internal structure of the company or institution is an absolute necessity before starting practical activities (Fig. 5).

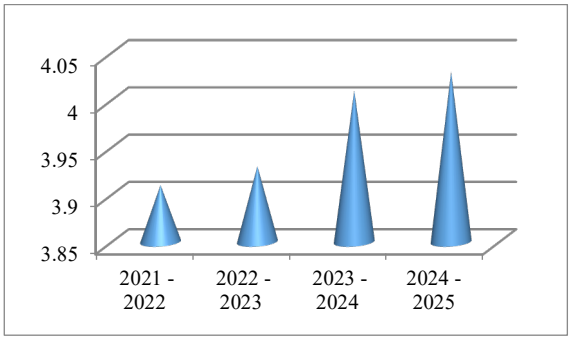


Fig. 5. Evolution of the need to train students on the organizational and decision-making structure of economic agents before practice
Source: Own determination.

Knowledge of the organizational and decision-making structure reduces the risk of confusion and inappropriate approaches during the traineeship, helps students better understand the chain of responsibilities, place their own role within the team and respect internal rules, contributes to the formation of a mature professional attitude, based on understanding the real functioning of the organizational environment and prepares students for effective communication and behaviors consistent with the employer's expectations.

In contrast, other items with complementary relevance recorded lower average scores, suggesting additional training needs in career counseling and guidance, as well as in basic elements of organizational communication and teamwork, concepts related to organizational culture, and corporate social responsibility.

This hierarchy of perceptions suggests that students place greater emphasis on "technical" knowledge of internal organization than on soft, cultural, and personal development dimensions. However, the latter are equally crucial for harmonious integration into a work team and for developing a conscious and sustainable professional path.

To increase the relevance of pre-practical training, it is recommended: Systematically including an introductory module on the organizational structure and functional roles of partner companies, in an accessible format (presentations, diagrams, case studies); Completing the training through an integrated approach, which should also include: notions of effective communication within organizations; introducing the concepts of organizational culture and corporate social responsibility; professional counseling and career planning sessions; Active partnerships with economic operators, which should directly contribute to the presentation of these aspects, either in school or at the company headquarters, during information visits.

The perceptions of the students clearly highlight that pre-practical training should include information on the organizational and decision-making structure of the company/institution, this component being considered necessary in a high proportion and stable throughout the four years analyzed. At the same time, there are gaps in relational and cultural training, which necessitate an expansion of the training content and a holistic approach to preparing students for real professional life.

The evolution of students' perceptions of traineeship evaluation

The evaluation of traineeships is a fundamental pillar in ensuring the quality of students' professional training. A coherent, complex, and well-structured assessment not only allows for measuring individual progress but also creates constructive feedback, essential for the development of professional skills. In this context, combined evaluation – carried out both along the way and at the end, by characterizing the tutor and grading projects or other documentation – is considered an optimal model for assessing students' performance in traineeships.

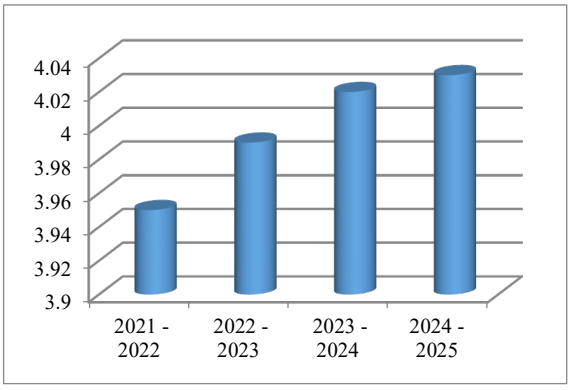


Fig. 6. Evolution of students' perception of the evaluation of traineeships
Source: Own determination.

The analyzed data indicate a trend of constant growth and stabilization at a high level of

satisfaction. Students perceive the combined assessment as more relevant, fair, and effective in reflecting their performance and involvement during the traineeship (Fig. 6).

Several aspects can explain students' preference for this type of assessment:

- it provides a more balanced overview, taking into account both the evolution over time and the final result;
- it involves a diversity of assessment methods (observation, characterization, project/documentation analysis), which more faithfully reflects the complexity of the practical activity;
- it encourages the constant involvement of the student, knowing that both the process and the final product matter significantly;
- it allows for a contextualized assessment, carried out by people directly involved in the student's training (the traineeship tutor).

In contrast, other items referring to specific forms of evaluation obtained lower scores: on-the-job evaluation carried out exclusively by the traineeship tutor, final evaluation based solely on the tutor's characterization, and conducting assessments through an online platform.

These results suggest that students do not perceive positively unilateral or simplified forms of assessment, in which:

- the emphasis is only on one stage (either along the way or at the end);
- the evaluation is based on a single source (tutors), without a demonstrable practical component (e.g., a project);
- digital tools are not sufficiently developed or personalized for professional practice.

A practical blended assessment involves:

- ✓ Training practice tutors to wholly and objectively assess students' progress;
- ✓ Creating clear assessment grids and criteria, known to students from the beginning of the traineeship;
- ✓ Integrating the products made by students (projects, journals, documentation) in the final assessment portfolio;
- ✓ Using digital platforms only as support tools, not as an exclusive means of assessment.

To consolidate blended assessment as standard practice in Ilfov County, it is necessary:

- ✓ avoiding evaluation based solely on the tutor's subjective characterization;
- ✓ encourage the creation of concrete evaluation products (projects, reports, practice diaries) that can be objectively analyzed;
- ✓ develop digital platforms adapted to traineeships, allowing progress to be tracked and work products to be uploaded, but without completely replacing human evaluation.

The analyzed data confirm that students appreciate combined evaluation – along the way and at the end – as the most relevant and fair form of assessing their activity during traineeships. This approach reflects not only the result of the work but also the continuous involvement and individual progress. At the same time, unilateral or exclusively digital forms of evaluation are not perceived as being as effective, which underlines the need for a balanced review, centered on the student and the concrete activity carried out in the traineeship.

The efficiency of forms of communication between the traineeship supervisor and students

Effective communication between trainees and their designated supervisor, as defined by the company or institution, is crucial for the smooth operation of activities, the prompt resolution of emerging issues, and supporting the experiential learning process. In this context, students from Ilfov County were surveyed on their perceived effectiveness of different forms of communication over a four-year period (Fig. 7).

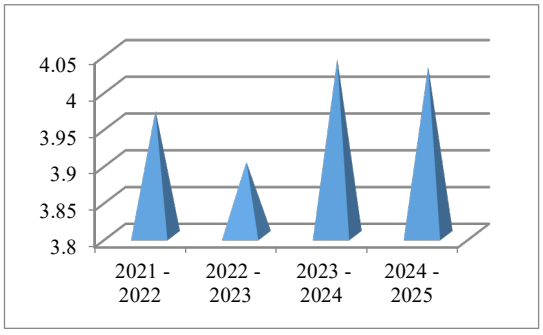


Fig. 7. The efficiency of forms of communication between the traineeship supervisor and students
Source: Own determination.

Daily attendance at meetings at the company's headquarters is the most effective form. The

data indicate a trend of stabilization around a score of 4, suggesting a high level of satisfaction and a generally positive assessment of the effectiveness of this form of communication. Although a slight decrease is observed in 2022–2023, the overall average remains consistently high, reinforcing the idea that direct, face-to-face interaction is perceived as the most effective and valuable form of communication between students and the traineeship tutor.

The perceived benefits of this form:

- ✓ provides immediate clarity in the transmission of instructions and expectations;
- ✓ allows for rapid and contextualized feedback;
- ✓ contributes to the development of interpersonal relationships and mutual trust;
- ✓ creates a formal framework for daily coordination, which structures the students' activity.

Items that recorded lower scores reflect a generally more reserved perception of indirect or mediated forms of communication, including daily communication through a student group coordinator, telephone communication with all students at their initiative, and constant communication through an online platform.

From the students' perspective, these forms present limitations in terms of clarity, accessibility, and absolute efficiency. In more detail:

a) Through a student coordinator: May generate filtering or distortion of information; Does not offer the possibility of individual expression or direct clarification; May be perceived as uninvolved on the part of the company manager.

b) By telephone, at the student's initiative. Communication is not systematic, but somewhat fragmented and dependent on the student's initiative, which leads to a lack of continuity, delayed responses, and a feeling of insecurity or a lack of organized support.

c) Through an online platform. Although it has technological potential, it is possible that the tools used are not suitable for the specific needs of the practice, interactions are impersonal and sporadic, or there are technical or usability issues affecting some students or tutors.

To optimize communication during traineeships, the results suggest:

- ✓ Maintaining daily direct interaction at the company headquarters as the primary form of coordination and support;
- ✓ Avoiding outsourcing communication through student coordinators, rather than as a complementary and well-structured form;
- ✓ Establishing clear routines for phone calls or messages, with a pre-established schedule, to avoid communication chaos;
- ✓ Developing specialized, interactive, and field-specific online platforms that facilitate asynchronous but efficient communication (e.g., uploading tasks, written feedback, question forums).

The data highlights the fact that, for students in Ilfov County, daily participation in meetings organized at the company headquarters is considered the most efficient form of communication with the traineeship manager. Indirect forms, whether through intermediaries or digital or telephone channels, are perceived as less efficient, primarily due to the lack of personalization and a decrease in interaction quality. These perceptions highlight the significance of direct human contact in formative processes, particularly in applied settings, such as professional practice.

Clarity of objectives and tracking of task accomplishment during traineeships

Establishing clear objectives and precisely defining tasks is a fundamental condition for traineeships to contribute effectively to the professional training of students. At the same time, close monitoring of the achievement of these objectives is essential to ensure coherence between the activity in the company and the educational goals of the traineeship.

The scores are consistently close, indicating a high and stable level of satisfaction. The slight increase over the four years suggests a gradual improvement in the way tasks are planned and tracked, which is positively perceived by the students.

These data show presented in Fig. 8 reflect that most students consider that the tasks received were clear, well-formulated, and adapted to their level of training, the objectives were

explicit, allowing understanding of the purpose of each activity, and the completion of the tasks was monitored by the tutor or traineeship coordinator, which stimulated involvement and assumption of responsibility.

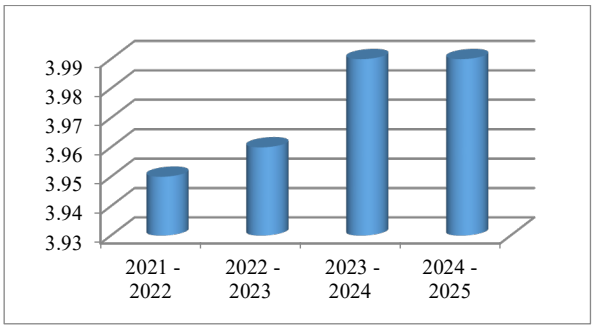


Fig. 8. Evolution of clarity of objectives and achievement of work tasks during traineeships
Source: Own determination.

These aspects contribute to an efficient applied learning process and support the development of the student's professional autonomy.
The constant and high scores can be correlated with several possible good practices:

- ➢ the use of objective and task sheets at the beginning of the traineeship;
- ➢ establishing a weekly activity plan, clearly communicated and understood by all participants;
- ➢ the active involvement of tutors in monitoring and adjusting the tasks, depending on the pace and interest of each student;
- ➢ continuous feedback on how students complete their tasks.

Even if the scores are positive, the fact that the 4.00 threshold is not consistently exceeded may indicate the existence of minor dysfunctions or areas with potential for improvement, such as:

- ✓ lack of personalization of tasks according to the profile and level of the students;
- ✓ vague or too technical formulation of the objectives in some cases;
- ✓ formal monitoring, without active involvement in the feedback given to the student;
- ✓ differences in the way of organization between the partner companies/institutions.

To consolidate a transparent and efficient practice in establishing and following up on objectives:

- ➢ Standardizing the way of drawing up objectives and tasks through standard documents (activity plans, task sheets);
- ➢ Training for tutors on the formulation of learning objectives, in accessible and concrete terms;
- ➢ Introducing student self-assessment at the end of each week, to assess the extent to which they have understood and accomplished the tasks;
- ➢ Using short review/feedback sessions at the end of each day or week of practice.

Students in Ilfov County consistently rated the clarity of objectives and the tracking of their achievement as necessary and efficiently managed components of traineeships during the period from 2021 to 2025. These results indicate good collaboration between schools and economic operators in establishing the framework for traineeships. However, there is room for optimization through clearer tools, more frequent feedback, and greater adaptation to the individual needs of students.

Student satisfaction with practical skills acquired during traineeships

Vocational training through traineeships is a crucial element in preparing students for integration into the labor market, and the development of practical skills is a primary objective of these activities. In this context, the assessment of student satisfaction with the level of practical skills acquired serves as a relevant indicator of the effectiveness of the traineeship program carried out in educational institutions in Ilfov County during the period 2021–2025.
The scores are consistently close to the 4.00 level, indicating a high degree of satisfaction with the formative results of the traineeship. The slight fluctuation over the four years is statistically insignificant, indicating stability in the quality of practical training perceived by students. The upward trend in the last school year suggests a slight improvement in the traineeship program's efficiency, possibly due to enhanced collaboration with economic operators or curricular adjustments (Fig. 9).
The results reveal a significant reality: traineeships, in their current form, offer valuable practical experience but are not always curricularly integrated or sufficiently

grounded in the theoretical foundations acquired in the classroom.

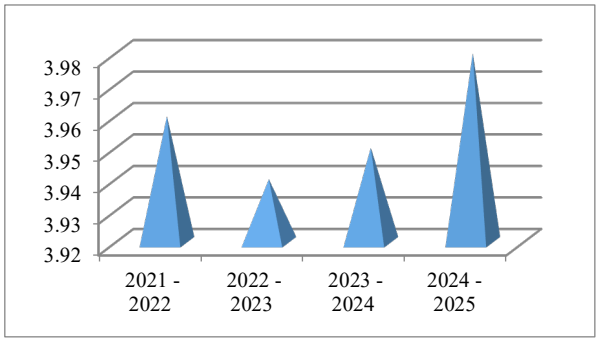


Fig. 9. Evolution of students' satisfaction with the practical skills acquired during traineeships
Source: Own determination.

This disjunction can be explained by Differences between the curricular content and the actual activities of companies/institutions, a possible lack of communication between the school and economic operators regarding the student's training profile, and insufficient prior preparation of students to apply the knowledge acquired in school.

To further strengthen the efficiency of training through practice, it is recommended:

- Aligning the practice topic with the curricular profile, through detailed educational contracts between the educational unit and the partner company;
- Adapting the theoretical contents in the classroom according to the requirements of the labor market and the collaborating companies;
- Introducing practical theory review sessions before the start of the traineeship;
- Creating connection sheets between theoretical skills and practical activities, so that students are aware of what they are applying and how they are applying it.

Between 2021 and 2025, students from Ilfov County consistently demonstrated a high degree of satisfaction with the practical skills they acquired during their traineeships. These results confirm the formative nature of these activities and their relevance in building authentic professional skills. At the same time, the differences compared to other items highlight the need for a better correlation between the theoretical component, the theme of the traineeship, and the concrete activities carried out in practice.

Digitalization and involvement in the organization of traineeships

The digitalization of educational processes has become an essential component of modernizing the education system, particularly in the context of applied learning, such as traineeships for students. Easy access to digital tools dedicated to planning, monitoring, and communication between the actors involved (students, teachers, tutors from companies/institutions) is a relevant indicator of the efficiency and quality of these traineeships.

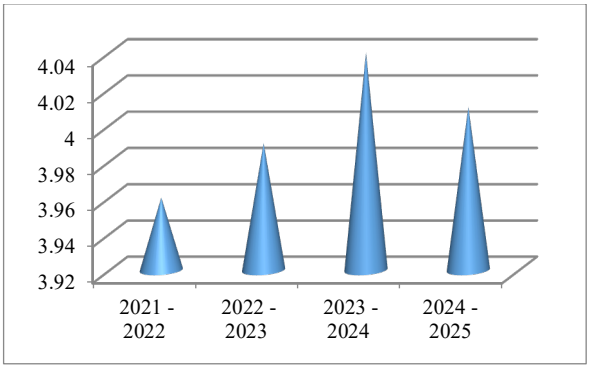


Fig. 10. The evolution of digitalization and involvement in the organization of traineeships
Source: Own determination.

The scores recorded are high and constant, with a general upward trend, reaching a peak in the 2023–2024 school year (Fig. 10).

Values above the 4.00 threshold indicate a positive perception of the use and usefulness of digital tools in the context of traineeships;

Students report an increase in organizational quality and communication, aspects that directly contribute to the efficiency of the formative act in the practical environment.

The use of digital tools in traineeships has several direct benefits:

- ✓ Efficient planning of activities (including synchronization of student, teacher, and company agendas);
- ✓ Objective monitoring of progress, through digital activity sheets and traineeship diaries;
- ✓ Fast and documented communication, both between the student and the tutor, and between the traineeship coordinator and the educational unit;

✓ Improving coordination capacity at the institutional level, through automatic reporting and centralized evaluations.

At the same time, student involvement in the organizational process is supported by these tools, which create a participatory framework where information is accessible and responsibilities can be distributed transparently.

To fully capitalize on the potential of this area, it is recommended:

➢ Developing platforms dedicated to traineeships, which include integrated functionalities: planning, feedback, evaluation, communication, and activity records;

➢ Training teachers and tutors in the use of these platforms, so that they are used efficiently and not just formally;

➢ Stimulating the active involvement of students through direct access to the traineeship plan, proposed objectives, daily tasks, and the possibility of self-assessment;

➢ Constantly monitoring the impact of digitalization through annual feedback from students and economic partners.

The perception of students in Ilfov County regarding the use of digital tools and their involvement in organizing traineeships is positive and has been increasing slightly over the period from 2021 to 2025. These results validate the modernizing direction of the technological and vocational education system and confirm that digitalization, when implemented correctly, increases the transparency, efficiency, and quality of practical experience.

Familiarization with a work environment through traineeships

One of the essential functions of traineeships is to facilitate the transition of students from the educational to the professional environment, providing them with the opportunity to familiarize themselves with the requirements, dynamics, and culture of a real workplace. Familiarization with such an environment plays a significant role in developing appropriate professional attitudes and behaviors, shaping a realistic image of the field of activity, and informing future career orientation (Fig. 11).

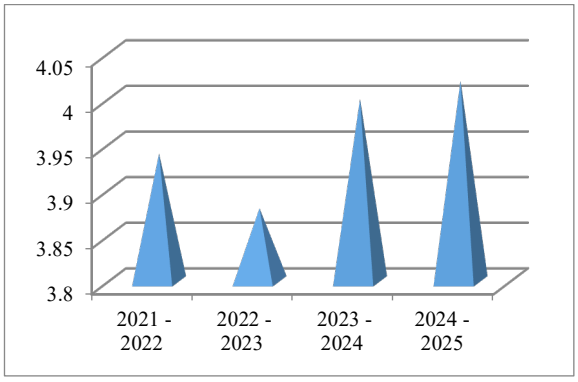


Fig. 11. The evolution of familiarization with a work environment through traineeships
Source: Own determination.

The scores are consistently high and relatively stable, all approaching the 4.00 threshold. The evolution over the last two years indicates a slight upward trend, suggesting an improvement in the quality of the traineeship contexts offered. Minor fluctuations (of the order of hundredths) do not indicate structural problems but reflect possible differences in the direct experience provided by various traineeship partners.

A constant score signals that students perceive the traineeship as: a relevant opportunity to interact with real structures, rules and work relationships; An appropriate setting for observing the functioning of a company/institution and for experiencing the routine of a working day; An informal learning space, where they can assimilate norms of professional behavior, specific terms, the pace of work and ways of collaboration particular to the field in question.

However, the fact that no year consistently reaches a score of 4.00 could signal some limits of the familiarization experience, such as: Repetitive activities or poorly integrated into the real processes of the company; Reduced involvement of tutors in explaining the organizational context; and Lack of prior preparation that would help the student to capitalize on contact with the work environment.

This component is fundamental for: forming the students' professional identity, developing adaptive behaviors, such as punctuality, compliance with tasks, and professional communication, clarifying future career choices, through confrontation with the

realities of the field, and reducing the shock of the transition from school to work, in the case of immediate employment after completing studies.

To increase the formative impact of familiarization with the work environment, it is recommended:

- Organizing orientation sessions at the beginning of the traineeship, in which students are informed about the structure and culture of the company;
- Ensuring active involvement of tutors, which facilitates the integration of students into the current activities of the company;
- Using observation sheets, through which students reflect on the organizational elements, processes, and behaviors observed;
- A close correlation with theoretical training allows students to interpret what they see within the context of the knowledge they have acquired.

During the four years analyzed, students from Ilfov County expressed a consistently high level of satisfaction with the opportunity to familiarize themselves with a real work environment through traineeships. These results highlight the effectiveness of educational partnerships established between academic units and companies/institutions, as well as the practical potential of these traineeships in authentic professional training for students. However, achieving even higher scores could be possible by optimizing tutor involvement, diversifying activities, and anchoring traineeships more deeply in organizational reality.

Acquiring knowledge specific to the training field through traineeships

Traineeships in vocational and technical education play a central role in strengthening specialized training, offering students the opportunity to apply, in authentic contexts, theoretically learned concepts and to acquire knowledge specific to their field of training. This dimension is crucial in relation to curricular objectives and relevance in the labor market.

The scores are high and slightly increasing, with a peak reached in the 2023–2024 school year (3.98). The fluctuations are statistically insignificant but signal a positive trend in students' perception of the practical usefulness of traineeships for deepening specialized knowledge. All values are close to the 4.00 threshold, which suggests a solid and coherent formative experience in relation to the students' training profile (Fig. 12).

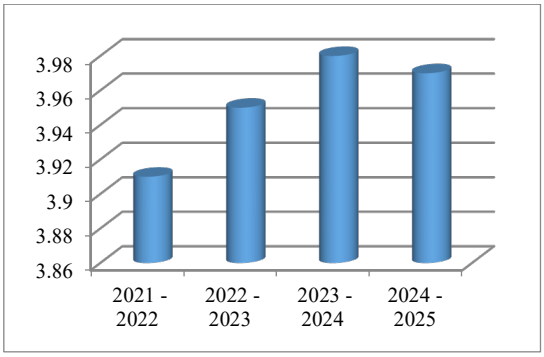


Fig. 12. The evolution of knowledge specific to the training field through traineeships
Source: Own determination.

This trend supports the fact that:

- the activities carried out during the traineeships were, for the most part, relevant to the students' field of training;
- the partner companies/institutions managed to provide real and meaningful contexts for the application and expansion of specialized knowledge;
- the students recognized and valued the educational component of the traineeship, not just the experiential or organizational one.

However, maintaining scores slightly below 4.00 may signal certain aspects that require improvement, such as:

- ✓ The need for closer coordination between the school and the traineeship partners, to ensure a perfect correspondence between the activities carried out and the specialization curriculum;
- ✓ The need to adapt the activities to the student's level of preparation, to avoid overloading or, conversely, too simple tasks;
- ✓ The lack of structured feedback on progress in the acquisition of specialized knowledge.

The acquisition of specific knowledge in practice directly contributes to:

- ✓ developing fundamental professional skills required by employers;

✓ increasing students' self-confidence, by understanding the applicability of theoretical learning;

✓ facilitating the post-graduation professional integration process, through direct contact with techniques, procedures, and equipment relevant to the field.

To increase the formative efficiency of traineeships in relation to the acquisition of specialized knowledge, it is recommended:

✓ careful alignment of the practice plan with the curricular objectives of each qualification;

✓ methodological support of practice tutors is needed to structure activities that explicitly contribute to specialized learning;

✓ encouraging students to document and reflect on the knowledge acquired, through practice diaries or mini-projects;

✓ implementing digital tools for tracking progress could facilitate the identification of areas in which practical learning needs to be adjusted.

During the 2021–2025 school years, the perception of students in Ilfov County on the acquisition of knowledge specific to the training field during traineeships was consistently positive, with a slight upward trend. These data reflect a good integration of practical experience into the student's educational path but also indicate the need to strengthen the link between the school curriculum and activities carried out in partnership with economic operators.

The opportunity offered by traineeships to meet potential future employers

One of the primary objectives of traineeships is to establish a direct connection between students and the economic environment, enabling them to interact with potential employers. This aspect represents an essential dimension in the transition process from school to the labor market, influencing the subsequent professional integration of young people.

There are no significant fluctuations, suggesting stability and consistency in offering this opportunity to students. Values close to 4.00 indicate a positive perception, with students considering that traineeships provide them a genuine chance to connect with potential employers (Fig. 13).

This consistency reflects:

✓ a good collaboration between educational institutions and economic partners, facilitating students' access to diverse professional environments;

✓ the role of traineeships as platforms for creating professional and social networks, essential in students' career development;

✓ the possibility for students to evaluate their own skills and interests in the context of real employer requirements.

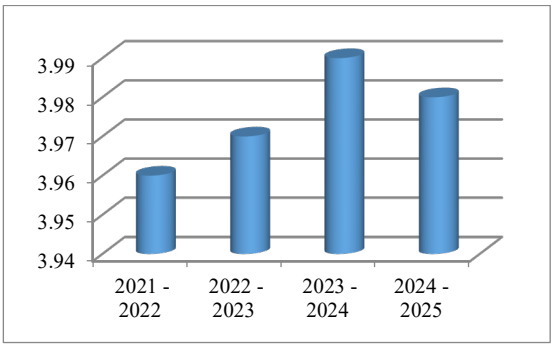


Fig. 13. The opportunity offered by traineeships to meet potential future employers
Source: Own determination.

Getting to know potential employers through traineeships contributes to:

✓ active professional guidance, by clearly identifying professional profiles and expectations from the work environment;

✓ increasing the motivation and involvement of students, who see a direct connection between the effort made and employment opportunities;

✓ facilitating integration into the labor market, as students can come into contact with companies that can subsequently offer employment opportunities;

✓ Strengthening local educational and economic partnerships.

Recommendations for maintaining and increasing this opportunity:

➢ Expanding and diversifying the network of economic partners involved in traineeships, so that students have access to a broader range of employers;

➢ Organizing networking sessions, traineeship, and career fairs in collaboration with partner companies;

➢ Active involvement of traineeship coordinators in facilitating direct contact

between students and company representatives;

➢ Continuous monitoring of student satisfaction regarding this aspect, to adapt the traineeship program to the needs of the labor market.

The data collected for the period 2021–2025 highlights that traineeships in Ilfov County have provided students with a consistent and valued opportunity to meet potential future employers. This aspect contributes significantly to the success of the school-to-labor market transition process, and maintaining and expanding these opportunities should be a priority for all parties involved in organizing traineeships.

Developing communication skills, teamwork, and flexibility within traineeships

The development of transversal skills, such as effective communication, teamwork, and flexibility, is essential for the adaptability and success of students in the modern labor market. These skills support professional integration, contributing to the development of appropriate professional behaviors and improving performance in various organizational environments. All values are consistently above the 4.00 threshold, indicating a high and stable perception among students of the benefits of traineeships in developing these skills. A slight increase is noted in 2023–2024, suggesting a possible improvement in the organization or quality of practical interactions. The stability of the scores emphasizes the fact that these skills have been a constant focus in the programming and implementation of traineeships (Fig. 14).

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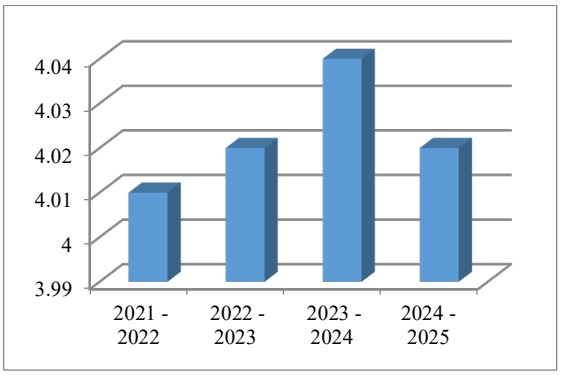


Fig. 14. Training of communication skills, teamwork, and flexibility during traineeships
Source: Own determination.

The transversal skills mentioned are fundamental for the social and professional integration of students, facilitating effective communication and collaboration in multidisciplinary teams, for adaptation to various work contexts and to the dynamic demands of the labor market, and for the development of soft skills, complementary to technical ones, which increase the value of students as future employees.

The consistently high value reflects the fact that traineeships provide appropriate environments for practicing and consolidating these skills through direct interaction with colleagues, tutors, and employees of host companies. The importance of these skills in the current context is:

✓ the labor market increasingly requires employees who can communicate clearly, work in a team, and adapt quickly to changes;

✓ transversal skills are recognized as key elements of employability and long-term professional success;

✓ their development during traineeships contributes to a holistic preparation of students, which goes beyond technical knowledge and skills.

Recommendations for supporting and optimizing the training of these skills:

➢ Integrating structured communication and teamwork activities into traineeship programs,

such as workshops, joint projects, or role-playing games;

- Training and actively involving traineeship tutors to encourage and assess these skills throughout the traineeship;
- Using continuous feedback and self-assessment to be aware of progress in the field of transversal skills.

The perception of students in Ilfov County regarding the development of communication, teamwork, and flexibility skills during traineeships remains positive and stable from 2021 to 2025. These skills, essential for professional integration and adaptability in the labor market, are effectively supported through organized traineeship programs, thus confirming the value of practical education in the current context.

CONCLUSIONS

The traineeships conducted in Ilfov County over the four school years studied served as a crucial pillar in the educational process, facilitating the transition of students from theory to practice and, implicitly, their subsequent integration into the labor market. The data collected reflect a positive and stable perception by students regarding the multiple dimensions of these traineeships, highlighting both strengths and areas with potential for improvement. It is essential to note that the first part of the 2021-2022 school year was still marked by the ongoing impact of the COVID-19 pandemic, which influenced the organization and conduct of traineeships, necessitating additional adaptations and restrictions. Despite these difficulties, the traineeship programs were able to take place under satisfactory conditions, reflecting a sustained effort on the part of educational institutions and economic operators to maintain the continuity of the educational process and provide students with practical training.

One of the most appreciated aspects of traineeships is the quality of the equipment and working environment provided by economic operators, with average scores that have increased slightly, remaining in the range of 3.89 to 3.97 on a satisfaction scale of 1 to 5. This indicates that the infrastructure and material conditions were generally adequate, not creating major obstacles in carrying out practical activities. Additionally, collaboration and communication among students, tutors, and coordinators were at high levels, reflecting a climate conducive to the development of both professional and social skills. The training of transversal skills, such as communication, teamwork, and flexibility, consistently yielded scores above 4.00, highlighting the importance of traineeships as formative environments for developing essential skills in the current labor market context.

Regarding the content of the training, students appreciated the need for specialized training before the traineeship, in the specific field of activity of the host companies, as well as knowledge of their organizational and decision-making structure. These elements were considered fundamental for an efficient integration and a better understanding of the professional environment. In addition, the combined evaluation process, carried out both during the traineeship and at the end, by scoring the practical activities and characterizing the tutor, was perceived positively. Another strong point of the traineeships was the opportunity offered to students to come into direct contact with potential future employers, an aspect with a stable and high average score. This constitutes a significant benefit of the traineeships, supporting professional orientation and facilitating the transition to the labor market by building relevant professional connections. At the same time, sustained attention was noted to the permanent monitoring and coordination of the traineeships, as well as constant communication between all parties involved – students, tutors, and traineeship coordinators – elements that ensure a coherent and efficient process.

However, there are areas where opportunities for improvement can be identified. These include working conditions related to space and atmosphere, the degree of theoretical knowledge applied in practical activities, and the development of more advanced practical skills. Additionally, greater flexibility and diversity in daily programs are necessary, as

well as increased involvement in stimulating students' active participation. These aspects indicate the need for adjustments that better respond to the real needs of students and the specifics of the local economic environment. In conclusion, the traineeships in Ilfov County, carried out during the four school years analyzed, constituted a valuable educational experience, strengthening both the technical and transversal skills of students. The quality of collaboration with the economic environment, access to adequate resources and opportunities for assessment and professional guidance contributed to the success of this endeavor. The development of these traineeships, with a focus on optimizing the aspects identified as deficient, will enhance the employability and practical training of future generations of students, thereby strengthening the connection between the educational system and the labor market's demands.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DECONSTRUCTING HACCP PERFORMANCE: A NINE-DIMENSIONAL ASSESSMENT FRAMEWORK FOR ROMANIAN FOOD SERVICE OPERATIONS

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Abstract

In this paper we used a dimensional scoring methodology on a 127-item questionnaire (with nine critical dimensions) to assess the HACCP system's implementation in 392 public food establishments in Romania. The findings show serious flaws in the infrastructure for food safety: 95.4% of the units had insufficient provisions for supplementary facilities, and 87.5% of the units received quality control scores lower than 5/10. Sixty-one percent of the staff has inadequate training, and there are serious issues with service coordination and technological flow management. However, protective equipment is better managed (77.6% moderate scores). Statistical analyses indicate significant associations between FIFO application and labelling ($\chi^2 = 12.6$; $p = 0.013$), as well as between supplier certification and documentation control ($\chi^2 = 17.5$; $p = 0.002$). Geographical differences and educational level influence overall performance. The study highlights the discrepancies between the requirements specified in legislation and the need to implement systemic interventions focused on traceability and continuous monitoring.

Key words**:** *HACCP performance metrics, food safety infrastructure assessment, operational compliance framework; dimensional scoring methodology in food safety analysis*

INTRODUCTION

Food safety in the public catering sector is a continuous concern for health authorities and economic operators, especially in the context of the exponential growth of consumption outside individual households and the diversification of business models in the HoReCa field. The implementation of the HACCP system, although mandatory under Regulation (EC) No. 852/2004 on the hygiene of foodstuffs [10], remains an operational challenge for public catering establishments in Romania, where financial, organisational, and professional competence barriers create discrepancies between the regulatory framework and daily practice [3].
We observe a decrease in interest in HACCP research in international scientific literature over the last decade. Predominantly, the regions where the HACCP system has received sustained academic attention recently are African and Middle Eastern countries (e.g., [1], [6], [7]).

Based on a bibliometric analysis spanning 4 decades, the study by Radu et al. [8] notes that there was limited scientific activity in the field until the early 1990s, and only then, as concerns about food safety grew, did the first significant efforts emerge. Until 2012, the United States conducted the most research on topics related to the HACCP system, when Italy, the United Kingdom, China, and Greece took numerous initiatives in this regard. The authors also highlighted the barriers to the wide spread implementation of the HACCP system (in terms of costs, complexity, lack of training and resources in enterprises), as well as its obvious opportunities (increasing consumer demand, strict rregulations etc.), offering future research directions focused on sustainability, regenerative requirements, adaptability to emerging risks, and regulatory compliance [8].
One of the few articles in recent literature on the HACCP system in Romania is the research conducted by Borda et al. [2], which analyses the level of knowledge of Romanian consumers about food risks, their attitude

towards certified products, and reliable sources of information. The study results show that approximately half of the respondents were unable to identify relevant biological hazards (mycotoxins, Listeria, Campylobacter, Yersinia, Clostridium), although they perceived substances like food additives or genetically modified organisms – which, in reality, do not pose direct risks if regulated – as dangerous. The authors' research also shows that, worryingly, certified products tend to generate trust, but consumers do not distinguish between different certification schemes. At the same time, although consumers consider scientific sources (books and specialised texts) credible, they prefer to seek information from their immediate environment (family, friends) and the mass media, and only a small percentage of scientific information influences their decisions.

Given the limited number of studies currently available on the compliance of public food establishments with HACCP principles [4][5][9] and the priority of this topic for public health, we believe it is necessary to continuously map how commercial entities in the HoReCa sector meet HACCP standards. In this regard, the present research aims to map the actual level of HACCP principle implementation in Romanian restaurants and identify the socio-demographic and organisational factors that influence the quality of this system's implementation.

MATERIALS AND METHODS

The present research was conducted based on a 127-item questionnaire covering all HACCP areas to analyse compliance with hygiene and sanitation standards in restaurants and other dining establishments. The theoretical basis came from European legislation 852/2004 regarding food hygiene, supplemented by the regulations of the veterinary sanitary authorities in Romania. Data collection was conducted using digital forms distributed through Survey Monkey and promoted on Linked Into restaurant professionals. 392 people from most regions of the country participated. Statistical processing was done in SPSS version 20, at a 95% confidence interval. The questionnaire items were distributed across nine themes that covered the entire operational chain: quality management, work wear, raw material supply, product storage, cooking processes, dining room layout, service team organisation, auxiliary equipment, and activity monitoring. The purpose of the questions was to verify two essential aspects: whether there are written protocols and the extent to which they are put into practice daily, the gap between theory and application being a recurring issue in the field of consumer protection.

The data was transformed numerically and aggregated across the 9 domains investigated. Frequency distributions were calculated for broad characterisation in order to create composite indicators for each assessed area. Association analysis and comparison tests were used to identify correlations between variables.

RESULTS AND DISCUSSIONS

Staff Organisation and Training

The percentage of responses classified between 1 and 4 reaches 61.0%, indicating a significant presence of unclear or incorrectly applied procedures. The average range (5–7) accounts for 38.8%, and higher scores are very rare, only 0.3% (Figure 1). In Bucharest, the percentage of low evaluations reaches 13.0%, while 7.1% fall into the average range. In Cluj-Napoca, the percentages are 7.4% for both categories. Those with vocational training have a significantly greater percentage of scores between 1 and 4, at 30.1%, whilst those with university degrees have the lowest percentage (4.8%). The absence of skills matrices, job descriptions, and consistent professional training programs is reflected in these distributions. Without these tools, the unit cannot clearly demonstrate employee competence. Insufficient documentation of training makes it difficult to identify those responsible in case of an incident, and staff turnover hinders the effective transfer of experience within the team. In the absence of a structured training system, clearly assigning

responsibilities in the event of incidents becomes difficult, and excessive reliance on informal training methods compromises the effectiveness of any subsequent HACCP strategy implemented.

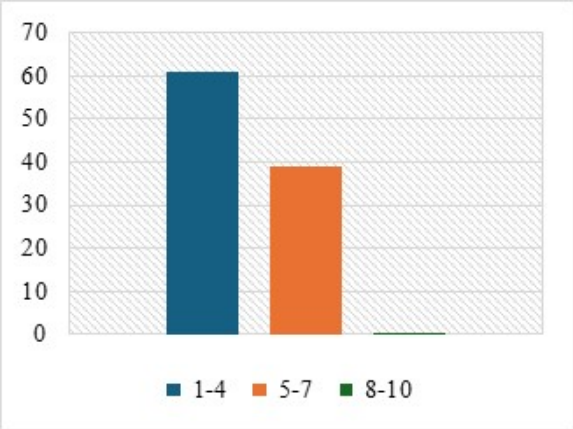


Fig. 1. Distribution of scores on the staff organisation and training dimension.
Source: Own item analysis performed in SPSS.

Responsibility and Quality Control

87.5% of the evaluations are below the threshold of 5, and the remaining 12.5% (instead of 11.5) fall within the 5-7 range – with no scores above that (Figure 2). Essentially, self-control procedures are either absent or merely declarative. Without effective checks for potential deviations and without records of corrective measures taken, the preventive function of the HACCP system disappears, and quality control becomes an occasional endeavour, triggered only when a problem arises.

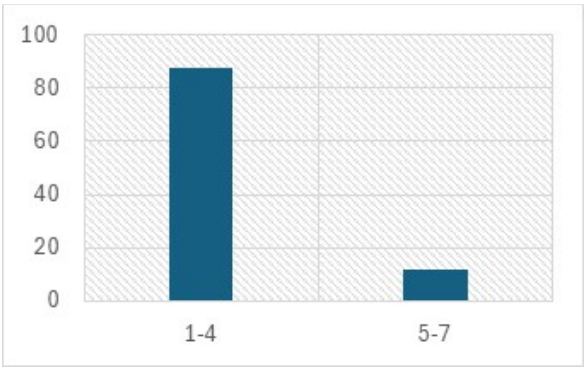


Fig.2. Distribution of scores on the responsibility and quality control dimension
Source: own item analysis conducted in SPSS.

Without clarification of responsibilities for each critical point, accountability in the event of a microbiological incident becomes difficult, and delays in remediation increase the risk of product recalls and sanctions.

Protective Equipment and Uniforms

Regarding the provision of specific equipment and work clothing to personnel, empirical data show that the majority of units (77.6%) received a minimum score (2 out of 5), indicating that the protection provided is insufficient. Only 20 (5.1%) reached level 3, and 68 (17.3%, Figure 3) fall below the adequate threshold (below 5 points). The use of minimal protective equipment, such as masks, caps, and non-slip footwear, is consistent, but other protective gear, like cut-resistant gloves, is almost non-existent. Thus, although there is a minimum form of individual protection, the real commitment to worker safety is reduced, with lower costs being prioritised over adequate and up-to-date protection.

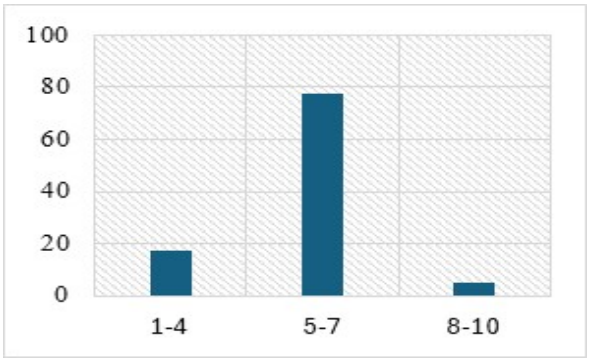


Fig. 3. Distribution of evaluations regarding protective equipment and uniforms.
Source: Own item analysis performed in SPSS.

Purchasing and Receiving Raw Materials

First-In, First-Out (FIFO) practices are applied in 63.3% of cases, reflecting scores between 5 and 7 (Figure 4). Labelling is relatively common: the date of receipt appears in 80.1% of cases, and the expiration date is mentioned in 70.4% of cases.

The temperatures of refrigeration equipment are monitored daily in 51.3% of restaurants, while 6.6% do not perform any checks at all. The storage regime between 0 and 4°C is maintained in 87.8% of establishments, a favourable result in terms of microbiological control.

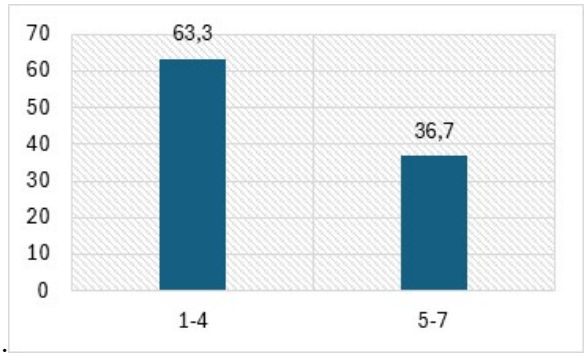


Fig..4. Distribution of assessments regarding raw material procurement and reception
Source: Own item analysis conducted in SPSS.

Freezing spaces are lacking in 16.3% of units, and 29.8% have large rooms (> 10 m²), which, if not managed efficiently, can lead to unnecessary energy consumption. Statistical analysis reveals a significant link between using the FIFO system and proper labelling ($\chi^2 \approx 12.6$; $p = 0.013$), highlighting that operators who correctly mark products also manage stock rotation adequately.

Regarding procurement, 35.5% of respondents select suppliers based on formal contracts, 26.3% rely on informal recommendations, and 16.6% admit to occasional purchases without supporting documentation. Regarding certifications, only 23.7% verify the documentation with each delivery, while 10.0% never consult these records. The reception of products by specialised personnel – a sign of a mature logistics system – occurs in 41.6% of cases, with the remaining units using informal methods: chefs take delivery of the goods without formal procedures, or the supplier leaves them unattended.

Storage and Food Safety

Most units (84.7%) fall within the average evaluation range (5–7), only 9.4% achieve high scores (8–10), and 5.9% are below the minimum acceptable level (below 5). Although separating raw foods from those intended for consumption and adhering to the FIFO principle are common practices, the documentation of corrective actions remains superficial, usually limited to informal mentions. The weighted average is around 6.1, but maximum values are rare, indicating the need for much more documented real-time monitoring.

Preparation and Technological Flow

Over 61% of the units score very poorly (1-4), while the remaining 38.8% are between 5 and 7, with no unit reaching the highest level. The differences between cities are small: Cluj-Napoca has 7.4% in the medium range, while Craiova has only 3.1%. 35% of those without higher education are in the low-income zone, compared to 6.1% among those with university degrees. Restaurants with 50-100 seats show a peak of 12.4% average scores. The context reveals problematic work areas, violations of the cold-hot path, and unsafe measuring equipment, providing logical explanations for the absence of maximum evaluations. These shortcomings increase the risk of contamination, and a positive correlation ($r = 0.102$) between the technological flow and auxiliary facilities shows us that investments in related spaces indirectly influence the quality of the operation.

Service Areas and Facilities

Almost half of the restaurants (43.9%) score low (1-4), compared to 55.9% that are in the average range (5-7). Lighting is considered adequate by 46.2%, but 27.8% report dark areas, and 15.8% identify it too intense. Separate sanitary facilities for men and women, as well as for people with disabilities, are present in 55.6%, and full ventilation is only functioning in 36.2% of cases. Disinfection of cutlery before serving occurs in 57.1%; however, 14.5% of it is simply placed on the table without cleaning. Waste management is problematic: only 54.1% empty the bins regularly, and only 42.6% practise recycling. Overall, the service areas are poorly rated, with significant deficiencies in ventilation, spacing, and universal accessibility.

Service and Coordination

Only 31.1% of units offer regular training to their team in serving techniques; another 41.1% hold occasional sessions, and 5.6% do not train at all. Dedicated management is present in half of the restaurants; in 17.6%, waiters act autonomously, leading to inconsistency. Shift scheduling is rigid for 37.2%, and 22.7% of employees work over time. Regarding hygiene, only 21.9% used is posable gloves; the rest handle the cutlery unsterilised. Overall, the service performs

below average: less than a third apply standard preparation procedures, and many rely solely on experience.

Complementary Facilities and Comfort

This dimension is the most deficient: 95.4% score very low (1-4) and only 4.6% average (5-7), with no high evaluations. Average values occasionally appear in restaurants with 50-100 seats (5.1%) and more frequently among women (4.6%). The complete absence of top scores (8-10) highlights the neglect of investments in comfort – even though these would positively influence visitor satisfaction and the duration of visits.

CONCLUSIONS

The HACCP system's implementation in Romanian public dining establishments shows a notable inconsistency between existing practices and regulatory mandates. The evaluation of the nine facets of food safety identifies significant shortcomings that affect eateries' ability to offer patrons standards that are acceptable.

The results obtained on the quality control dimension show the absence of functional monitoring and verification mechanisms in most of the evaluated units. Self-control procedures are either nonexistent or remain on a declarative level without being translated into measurable daily practices. Thus, the preventive nature of the HACCP system is lost, transforming it into a reactive tool that intervenes after an event.

The absence of skill matrices, clear job descriptions, and systematic training programs creates ambiguity in the allocation of responsibilities and makes it difficult to trace decisions in the event of an incident. The positive correlation between educational levels and the quality of implementation reflects the fact that specialised training is a determining factor in the effective adoption of HACCP principles.

The technological flow and preparation processes demonstrate serious vulnerabilities, with frequent violations of work area separation and compromise of the cold chain. The statistical association between the quality of the technological flow and the provision of auxiliary facilities indicates the nature of the identified problems, highlighting the need for integrated interventions.

The support infrastructure, assessed in terms of complementary facilities, shows the lowest level of compliance among all the dimensions analysed. A lack of investment in ventilation systems, adequate sanitation facilities, and waste management creates favourable conditions for cross-contamination, which compromises the sustainability of any control measures implemented at the operational level. Furthermore, the procurement and receiving practices are entirely unique, with a relatively consistent application of the FIFO principle, contrasting with the sporadic verification of supplier documentation. The statistically significant association between FIFO applications and labelling practices indicates the existence of excellent practices that work when implemented simultaneously.

The uniform geographical distribution of the identified deficiencies indicates that these problems are prevalent across a significant portion of our country. The food sector as a whole, not just certain regions, faces barriers to the implementation of HACCP.

The results confirm the persistence of organisational, financial, and competency barriers identified in specialised literature, but their intensity in the Romanian context seems amplified by specific contextual factors. Transposing the European legislative framework without developing implementation capacities creates a false compliance that does not lead to effective practices for ensuring food safety.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

HACCP BETWEEN THEORY AND PRACTICE: MAPPING THE COMPLIANCE OF PUBLIC CATERING ESTABLISHMENTS IN ROMANIA

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Abstract

The present paper examines the current stage of HACCP compliance in the public catering sector in Romania, based on data collected from 392 HoReCa establishments located in the country's main historical regions. The research employed a structured questionnaire developed in accordance with Regulation (EC) 852/2004. Responses from both employees and managers provided insights into organizational characteristics, staff training, equipment, procurement, storage, food preparation, service, sanitation, and event management. Descriptive statistical methods, including frequency distributions, were applied to analyze the data. Findings reveal that while most respondents are aware of HACCP guidelines, their application remains inconsistent across establishments. Differences in educational background, insufficient training, and unclear responsibilities hinder the effective implementation of food safety regulations. Technical barriers, such as inadequate equipment and substandard storage facilities, further undermine compliance. Hygiene standards are acknowledged but often practiced irregularly, suggesting that HACCP is followed formally rather than functionally. The conclusions emphasize the need for targeted interventions to improve infrastructure, strengthen training, clarify responsibilities, and promote a preventive, safety-oriented culture within the Romanian HoReCa sector.

Key words**:** *HACCP Compliance; public food infrastructure; HoReCa issues; regional food safety mappings, refrigeration capacity-compliance*

INTRODUCTION

Directive 93/43/EEC introduced the first horizontal hygiene requirements, granting Member States the freedom to adopt sectoral guidelines for implementation.

Dima, Radu, and Dobrin [2] evaluated the barriers to HACCP implementation and identified the cost of external auditing and lack of managerial support as determining factors. Initial costs still pose a serious obstacle for micro-enterprises: financial modelling conducted in a pasteurized milk plant indicates an increase of approximately 24% in investment when HACCP is implemented without prior preparation of GMP/SSOP programmes [13]. In the retail sector, over 60% of the annual HACCP maintenance budget is absorbed by the salaries of monitoring personnel [14]. But significantly higher HACCP scores and reduced technological deviations were observed in ISO 22000 certified companies than in non-certified companies [9].

The ISO 22000:2018 edition included organisational context analysis requirements and how to differentiate between strategic and operational risk [8], while the GFSI recognition of FSSC 22000 Version 6 in August 2024 provides added food chain scheme convergence [5]. The ISO 22000:2018 revision allowed for easy alignment with ISO 9001 and ISO 14001, a point highlighted in the official ISO document [8].

The direct technological effects are illustrated through a case study of the food supplement industry, where Enterobacteriaceae load was reduced below 1.0 log CFU/g after the implementation of ISO 22000 [4]. In public health, the efficiency of HACCP to suppress US chicken slaughterhouses from producing some estimated 190,000 cases of salmonellosis annually is estimated following a decline of 56% in contaminated carcasses [16]. The

digitalisation of prerequisite programmes (PRPs) and the integration of management standards have demonstrated operational, commercial, and regulatory benefits for organisations in the food chain.

In Romania, the first technical standards were concretised through Emergency Ordinance 97/2001 regarding the production, processing, and marketing of food, which was subsequently harmonised by Government Decision 924/2005. The ANSVSA 2023 National Integrated Control Plan document testifies to HACCP procedure verification as a central objective but registers regional differences in regard to infrastructure and technical skills of operators [1].

The National Sanitary Veterinary and Food Safety Authority applies the same evaluation criteria to any kind of food business operator, whether by scale or detail [15]. But, the rules for demarcating raw and processed product flow, providing changing facilities for staff, and setting up disinfection systems are applied in industrial buildings and cannot be easily applied in older rural structures. Pașțiu and collaborators [11] highlight that over half of the sample of Romanian rural households included in their study consider the constant availability of perishable products to be a decisive factor in food insecurity. The lack of specialised storage facilities and unpaved secondary roads lengthen the route from the farm to the market and the possibilities for sales. Also, meeting quality standards depends on the punctual application of HACCP principles, which is a problem for many units in rural areas.

Agrotourism operators are facing the challenge of maintaining the traditional characteristics of local food products within the context of implementing food safety regulations. The small scale of agritourism operations leads to a different organisation compared to the large-scale food industry. The same people cultivate the raw materials, process them, and serve them to visitors, concentrating responsibilities at successive stages of the food chain. Industrial operators employ automated sensors for temperature, pH, and other critical parameter monitoring, while rural guesthouse operators apply eye inspection and experience to determine food safety. This methodological difference creates spaces in process documentation and product traceability.

Existing literature in Europe on agritourism sustains that ongoing internal controls and disclosure to the public about hygiene practices lead to a more favourable consumer mindset toward food safety, although the effect size depends on the visitors' overall level of trust [7][10].Qualitative interviews conducted in mountain guesthouses in Romania indicated that publishing the results of drinking water analyses and organising demonstration tours in the processing area increase guests' sense of transparency without imposing high costs on operators [12].

Examining the bibliographic sources confirms the gap between the requirements of international protocols and the practical possibilities of farms and guesthouses in rural Romania [3] [6]. The identified limitations (tight budgets, unskilled workforce, poor technical equipment, and distance from centers of expertise) constitute major obstacles to achieving compliance.

MATERIALS AND METHODS

The research included an approach that combines quantitative and qualitative methods. The main data collection instrument is a structured questionnaire comprising 127 items organized into 9 distinct sections, each corresponding to a HACCP dimension. For each dimension, the questions were formulated to assess both the existence of formal procedures and the actual degree of their application in daily practice.

-*Section 1* - Staff Organization and Professional Training (14 questions) aimed to identify the degree of formalization of responsibilities and investments in professional skills development.

-*Section 2* - Responsibility and Quality Control (12 questions) aimed to determine the level of systematization of quality control.

-*Section 3* - Protective Equipment and Uniform (15 questions) aimed to evaluate compliance with personal hygiene rules.

-*Section 4* - Procurement and Receipt of Raw Materials (16 questions) aimed to evaluate control over the supply chain.
-*Section 5* - Food Storage and Safety (18 questions) aimed to identify contamination prevention practices during the storage phase.
-*Section 6* - Preparation and Technological Flow (14 questions) aimed to evaluate control over the production process.
-*Section 7* - Service Areas and Facilities (12 questions) aimed to evaluate the conditions offered to customers.
-*Section 8* - Service and Coordination (13 questions) aimed to evaluate operational organization.
-*Section 9* - Complementary Facilities and Comfort (13 questions) aimed to identify investments in auxiliary facilities.

The questionnaire was published on the Survey Monkey platform and promoted on LinkedIn, requesting restaurant employes to complete it. Out of the 1,535 views, 392 resulted in the questionnaires being completed.

Among the 392 respondents, 15.6% indicated a secondary education level, 9.7% mentioned high school, 19.4% post-secondary education, 7.7% university education, and almost half, 47.7%, specified that they had specialised education. The gender distribution was approximately equal: 49.7% men, 50.3% women. Almost a quarter of respondents (20.4%) are located in Bucharest, and the next highest-ranking cities are Cluj-Napoca (14.8%), Timișoara (9.7%) and Iași (9.5%, N = 392). Brașov contributes 8.2% of the total, Constanța 7.1%, Sibiu 5.3%, Oradea and Craiova together amount to 5% and 4.1%, respectively, and Ploiești is represented at 4.1%. The rest of the respondents come from smaller or rural areas, such as Râmnicu Vâlcea, Buzău, Bacău or areas in Suceava, Vâlcea and Neamț counties, all of which amount to 12.1% of the responses.

The data obtained from the questionnaire were analysed using descriptive statistics, specifically frequency analysis, in order to highlight the distribution of responses for each item

RESULTS AND DISCUSSIONS

The profile of the respondents as a public catering unit

Regarding the types of services offered by the establishments analyzed, almost three quarters of them (72.7%) offer à la carte dining, 31.1% offer buffets, and 37.8% offer a fixed menu "table d'hôte". The prix fixe menu is available in 29.6% of the restaurants, the tasting menu appears in 13.8% of the cases, and the flexible menu is present in 22.7% of the establishments. Over half of the restaurants (54.1%) provide catering for events, 24.7% practice fast-food service, and 40.3% have takeaway services. Home delivery is found in 34.2% of the cases, room service in 10.7%, bar and cocktail services in 50.3%, and wine and specialty drink tastings are offered in 11.5% of the establishments. Personalized packages for groups and events appear in 25.0% of the situations, and other services were reported by 7.1% of those surveyed.

The total number of employees differs significantly between establishments, with an average of 18–22 people, and on average there are 4.3 waiters and 3.1 chefs who have specialized studies in the food industry. Pastry chefs, confectioners or sommeliers represent an average of 2.2 specialists per establishment. In the kitchen, the average is 3.1 chefs and 2.8 assistant chefs, and in the lounge, 4.2 waiters and 1.5 piccolos for the current activity. For events, the average increases to 5.3 waiters and 2.1 piccolos.

Regarding the restaurant's partitioning, compared to the serving room, 8.2% of the restaurants have less than 20 seats, 21.7% have 20–50 seats, and 35.5% fall within the range of 50–100 seats. The percentage of establishments with a capacity between 100 and 200 seats is 24.0%, and those with over 200 seats represent 10.7% of the total. Outdoor terraces have less than 20 seats in 13.8% of cases, between 20 and 50 seats in 25.0%, and over 50 seats in 12.0%, while 49.2% of respondents did not provide an answer in this regard. Regarding the VIP or lounge area, 10.5% have spaces under 10 seats, 19.9% have between 10 and 30 seats, 6.9% exceed 30 seats, and 62.8% did not report the existence of a VIP area.

The children's playground is small (less than 10 seats) in 4.6% of cases, medium (10–30 seats) in 6.4%, large (over 30 seats) in 3.1%, and 85.9% of the units do not have a playground.

The separate bar appears in 6.9% for a capacity of less than 10 seats, 21.2% for 10–30 seats, 9.2% for over 30 seats, and 62.8% did not provide answers in this regard. 39.0% of establishments have clearly demarcated and well-ventilated outdoor smoking areas, 20.9% have smoking areas but without effective separation from the non-smoking area, 24.7% have a total ban, and 15.3% have no clear rules.

For the live music or DJ area, 13.8% have a dedicated space for the stage and sound equipment, 9.7% have a dance area, 8.2% have a separate DJ booth, 28.8% have ambient music without a dedicated area, and 39.5% did not verify the answers regarding the spaces for live music or DJ.

Regarding open kitchens, 20.2% of restaurants opted for open kitchens, and 79.8% responded that they do not have an open kitchen. The buffet serving area is present in 35.0% of the units, while 65.0% stated that they do not have such space.

Employee changing rooms exist in 89.0% of restaurants, separate ones for men and women in 44.9%, a common changing room in 26.0%, and 11.0% of establishments do not have a dedicated changing room.

Administrative offices are present in 50.5% of cases for management, space for accounting exists in 36.5%, and 21.9% of establishments do not have separate administrative spaces.

Regarding the sanitary facilities for customers, 55.6% have separate toilets for men, women, and people with disabilities, while 44.4% have a single common sanitary facility.

Private parking for less than 10 spaces is available in 32.1% of restaurants, 40.3% have 10–30 spaces and 27.6% have more than 30 spaces. Other spaces were mentioned by 9.7% of respondents.

The question related to ventilation and air conditioning systems shows that 36.2% of restaurants have air conditioning and efficient ventilation in all spaces, 32.7% have systems used occasionally, and 31.1% do not have a functional air conditioning system.

The existence of formal procedures and the actual degree of their application in daily practice

Staff organization

Regarding staff organization, 50.5% of respondents confirmed the existence of a clear job description, 28.3% said that there is one but with overlapping roles, and 21.2% reported that responsibilities are divided informally. Written procedures for each position are followed exactly in 36.2% of cases; in 25.0% their existence is mentioned, but with sporadic application; and 38.8% indicated that there are no written procedures.

Regarding knowledge of hygiene and food safety rules, 41.3% responded that employees are trained upon hiring and through regular courses, 26.3% noted periodic training, 20.9% stated that training is partial, 7.4% said that only a few were trained and 4.1% reported that there is no clear training programme.

Regarding the person responsible for quality control, only 18.9% confirmed the presence of an exclusively designated person, 37.5% stated that the person responsible also has other responsibilities, and 43.6% indicated that there is no clear person responsible.

When asked about the distribution of responsibilities for quality control, 25.0% of respondents said that there is a person in charge for each shift, 34.2% mentioned that the manager deals exclusively with this aspect, and 40.8% answered that there is no clear system of responsibilities. Regarding staff rotation for maintaining quality, 28.3% confirmed the existence of a shift plan, 37.2% said that they try to maintain team stability without a clear plan, and 34.4% reported that rotation is not systematically organized.

The ways of communicating quality issues between employees and management are based in 21.2% of cases on regular reports and meetings, in 50.3% on informal communication, and in 28.6% there is no clear system. When asked if there is a system of bonuses or sanctions for maintaining quality standards, 24.0% confirmed the granting of incentives, 47.7% said there are only sanctions, and 28.3% answered that there is no reward or penalty system.

The employee performance evaluation system exists in 26.0% of restaurants with periodic evaluations and training sessions, 35.2% have evaluations without concrete measures, and 38.8% indicated that there is no formal evaluation method.

Correction of staff mistakes affecting service quality was handled through training sessions and regular feedback in 25.0% of cases, through warnings without additional training in 44.9%, and in 30.1% there is no clear correction system.

Medical tests of personnel are performed every 3 months in 21.4%, every 6 months in 30.1%, once a year in 40.6%, and only upon hiring in 6.6%, and 1.3% do not perform tests at all.

Protective equipment

Regarding protective equipment in the kitchen, 67.3% of chefs wear a hat, cap, or hairnet; 72.0% have a white tunic or special uniform; 39.3% wear long pants; 58.9% wear a waterproof apron; 79.3% wear non-slip footwear; 45.4% wear disposable gloves; 24.5% wear heat-resistant gloves; 14.8% wear cut-resistant gloves; and 5.9% wear other types of equipment. Among waiters, 21.9% use disposable gloves, 13.3% protective masks, 44.6% protective aprons, 76.8% non-slip footwear, and 26.0% mentioned that there is no mandatory protective equipment. The waiters' uniform consists, in 54.1% of cases, of a white shirt, black pants or a black skirt, dark socks, and a vest; 18.6% wear a black t-shirt with the unit's emblem; 11.7% have a dark jacket with a white shirt and dark pants; 7.9% have a different uniform; and 7.7% do not have a mandatory uniform.

Procurement Organization

Regarding procurement organization, 35.5% of respondents select suppliers based on contracts with authorized suppliers, 12.2% rely on the lowest price, 26.3% choose based on recommendations and business relationships, 16.6% make occasional purchases without clear contracts, and 9.4% do not have a clear selection system.

Supplier conformity documents are checked for each delivery in 23.7% of units, occasionally only for new products or when changing suppliers in 39.8%, only for the first collaboration in 26.5%, and 10.0% do not have a clear verification protocol.

The reception and acceptance of goods is carried out by specialized personnel according to a clear protocol in 41.6% of restaurants; in 37.5%, the reception is done by chefs or kitchen staff without formalization; 21.4% responded that suppliers leave the goods without strict verification; 28.6% record the reception in specific documents; and 25.0% do not have a clear procedure. The qualitative and quantitative reception of raw materials involves visual inspection in 59.4% of units, weighing products in 50.3%, measuring temperature upon reception in 41.6%, checking the expiration date in 70.7%, and taking samples for testing in 20.9%, while 27.8% do not perform detailed checks.

Temperature checks of perishable products upon receipt are carried out in 36.2% of establishments, occasionally without clear documentation in 41.1%, and are not checked at all in 22.7%.

Product handling upon receipt to prevent cross-contamination is ensured by separate storage of raw products in 64.8% of cases, by storage on lower shelves in 54.3%, by airtight containers in 50.3%, by separating dairy products from meat and vegetables in 37.8%, by checking the temperature and expiry date of dairy products periodically in 30.9%, and by using different utensils for ready-to-eat foods than for raw meat in 44.4%, and 16.3% use the same utensils and surfaces for all foods. The raw material receiving log exists in 28.8% of units, only the main products are recorded in 43.1%, and 28.1% do not have a log.

Managing non-conforming raw materials involves returning them to the supplier and documentation in 19.6% of restaurants, recording the issue without immediate action in 39.3%, and accepting them if they show no visible defects in 41.1%. The transport conditions of perishable products are checked by monitoring the temperature in transport vehicles in 51.3% of cases, controlling the cleanliness of the vehicles in 44.9%, and requesting appropriate transport documents in 36.2%; 27.0% do not have a clear protocol, and 22.4% accept the products without checking the transport.

Storage and food safety

77.0% of respondents store raw materials separately by category, 64.0% follow the FIFO principle, 54.6% use properly labeled containers, 68.6% separate raw food from ready-to-eat food, 50.5% store vegetables and fruits separately from meat and fish, 40.1% store frozen products at appropriate temperatures, and 21.2% do not have a clear storage system.

Validity dates are checked daily by designated personnel in 41.1% of cases, weekly in 34.4%, occasionally in 17.3%, and 7.1% do not have a clear process. Storage labels contain the product name in 88.0% of units, the date of receipt/preparation in 80.1%, the expiration date in 70.4%, the optimal storage temperature in 56.4%, the supplier's name in 50.5%, the person who received/packaged the product in 41.3%, the product category in 36.2%, special instructions for use in 25.0%, and 6.9% do not use labels.

Temperature checks for refrigerators and cooking equipment are carried out daily with records in control sheets in 51.3% of establishments, weekly without clear documentation in 28.6%, only when there are technical difficulties in 13.5%, and 6.6% do not conduct regular checks.

The temperature for storing refrigerated products is between 0 and 4°C in 87.8% of restaurants, 6.4% place it between 4 and 10°C, 2.0% between 10 and 25°C, and 3.8% do not monitor it. 89.5% of frozen products are stored at -18 and 0°C, 5.1% are kept between 0 and 4°C, and 5.4% are not monitored. Fruits and vegetables are stored between 0 and 4°C in 64.0% of cases, 19.4% place them between 4 and 10°C, 7.6% between -18 and 0°C, 2.3% between 10 and 25°C, and 6.6% do not monitor.

Dry goods are stored between 10 and 25°C in 85.2% of restaurants, 4.6% between 4 and 10°C, and 10.2% do not monitor. Cooked preparations are stored at room temperature (10–25°C) in 46.7% of establishments, 31.9% between 4 and 10°C, 12.8% between 0 and 4°C, and 8.7% above 63°C.

Regarding the management of non-conforming or expired products, 51.3% label and isolate them separately, 45.2% document their disposal in control sheets, 32.1% return them to the supplier when possible, 31.9% separate them without a clear disposal system, 11.0% keep the products until the stock is depleted regardless of the expiration date, 8.7 % use expired products if they show no visible signs of deterioration, and 24.5% dispose of them without clear documentation.

Food preparation organization

Regarding food preparation organization, 59.2% of restaurants have separate areas for meat, vegetables, dairy products, fish, and ready-to-eat foods; 26.3% have partially separate areas with overlapping stages; and 14.5% do not have a clear separation between food types. Food preparation takes place in dedicated areas for each type of dish in 44.4% of cases, 32.7% cook as needed without clear separation, and 23.0% handle raw and ready-to-eat products in the same areas.

Equipment used for food processing includes stoves, ovens, and fryers in 76.8% of restaurants; kitchen thermometers in 54.6%; temperature-monitored refrigerators and freezers in 71.2%; stainless steel tables and countertops in 60.2%; mixers, blenders, and food processors in 34.7%; sous-vide equipment in 12.5%; and ventilation systems and hoods in 41.6%, and 14.8% responded that they do not have dedicated equipment. Monitoring cooking temperatures for meat products is done through strict records for each batch in 36.5%, occasionally without a clear system in 40.1%, and without any monitoring at all in 23.5%.

In 41.3% of units, the technological flow of raw materials is logically organized to prevent raw products from intersecting with ready-to-eat ones; 30.1% have a clear circuit from reception to service; 20.2% have partially managed overlaps; and 8.4% do not have a clear flow.

Cleaning and disinfecting surfaces and utensils after each stage is done according to a strict protocol in 25.8% of restaurants; 37.5% have approved disinfectant solutions and dedicated clothes; 29.6% use color codes for utensils and cloths; 20.2% clean only at the end of the shift; and 12.5% do not have a clear protocol.

Service Area

The service area is kept airy with appropriate distances between tables in 37.8% of

restaurants, 25.8% have a densely crowded space, 22.7% lack a clear circulation area, 14.3% have VIP or lounge areas, and 18.4% have facilities for people with disabilities, while 28.6% have outdoor seating areas.

The tables are positioned at an optimal distance for circulation (41.6%); 29.8% are close together to maximize seating; 50.3% have stable, clean chairs; 33.7% sanitize the chairs and tables after each customer; 22.7% arrange the tables modularly for events; and 17.6% do not have a clear organizational plan.

Access to service areas is managed through a clear reservation and flow management system in 36.2% of cases, while 40.6% seat customers on a first-come, first-served basis without any clear system; 31.1% adhere to evacuation routes and safety regulations, and 22.7% lack a clear organizational system. The lighting is adequate and creates a pleasant atmosphere in 46.2% of restaurants; 27.8% have areas with insufficient lighting, 15.8% consider the light too strong, 8.7% do not have a uniform lighting system, and 18.4% can turn the lights on and off in sections.

Ensuring hygiene

Compliance with food hygiene and safety procedures is checked daily by 28.3% of establishments, weekly by 19.4%, occasionally from external sources by 21.4%, and 30.9% responded that there is no systematic examination.

In the field of quality management, 28.8% of units conduct daily staff hygiene checks by a designated person, 21.4% perform periodic checks through internal controls, 37.5% rely on self-monitoring, 9.7% only verify during external inspections, and 2.6% do not have a clear system in place. Staff hygiene is ensured by wearing gloves when necessary (19.4%), frequent handwashing (49.2%), avoiding direct contact with cutlery (28.6%), using the same gloves for multiple tasks (6.9%), and not following clear rules (12.0%). Hygiene materials are checked and replenished periodically in 37.0% of units, while 21.2% have a designated person responsible for checking them, and 32.9% do not have a clear protocol.

Restrooms are cleaned and sanitized regularly, with disinfectant materials available in 44.9 % of cases; they are cleaned at regular intervals (1–2 hours) in 33.7%, several times a day without a set schedule in 15.1%, only at the beginning and end of the day in 4.3%, and when visibly dirty in 2.0%.In 53.3% of establishments, tables are cleaned and sanitized after each customer; 25.8% clean them at regular intervals regardless of use, 13.3% only clean them at the end of the day, 7.7% clean them when they get dirty, and 25.0% of waiters use dedicated cloths and solutions for each.

Cutlery and plates are disinfected and checked before each service in 57.1% of cases, 14.5% place them directly on tables without protection, 36.5% use special holders and boxes, 33.7% bring cutlery individually for each customer, 44.6% store glasses upside down on special racks, and 17.6% do not have a clear protocol.

Cleaning Organization

Cleaning in the kitchen and preparation areas is scheduled daily in 41.3% of restaurants, with deep cleaning weekly in 33.4%, occasionally in 20.2%, and 5.1% do not have a clear plan. Cleaning products and disinfectants are stored separately, away from food, in 42.6% of establishments, in a dedicated cabinet within the same spaces as food in 41.6%, and 15.8% do not have a defined area.

Maintaining cooking equipment and refrigerators involves daily cleaning and disinfection in 33.4% of locations, daily refrigerator checks in 37.5%, periodic technical maintenance in 25.0%, the existence of a maintenance log in 19.4%, occasional cleaning in 27.3%, and 13.3% have no maintenance protocol. The coordination of the serving service is handled by the manager or head waiter in 50.3% of cases, a designated waiter in 29.6%, each waiter individually in 17.6%, and 2.6% report that no one is in charge until the event begins.

Serving services

In the food service sector, 31.1% of servers receive regular training in serving techniques, 41.1% receive occasional training, 22.2% say training is only provided upon hiring, and 5.6% have no formal training. The working hours of the serving staff consist of fixed shifts in 37.2% of establishments, variable shifts in 33.7%,

frequent overtime without a fixed schedule in 22.7%, and spontaneous shifts in 6.4%.

Communication and food transfer between the kitchen and service occur in the following ways: digital in 25.0% of cases, verbal in 48.2%, with a designated person responsible for checking orders in 19.4%, the designated waiter picking up food directly from the kitchen in 51.8%, the busser assisting under supervision in 33.7%, the bartender handling drinks and food service in 22.2%, and 23.5% of establishments lacking a clear system.

Tasks during service are distributed as follows: 37.5% have a clear number of tables per waiter, 27.0% rotate between waiters to balance the workload, 50.3% divide order taking and serving between waiters and busboys, and 23.5% have no clear system.

Service staff breaks are scheduled in the following ways: 30.9% are planned to avoid affecting service, 37.0% are spontaneous, 21.2% are allowed only during quiet times, and 11.0% have no clear system.

In 18.6% of restaurants, handling and serving cutlery is done with gloves or special utensils; in 41.6%, waiters serve cutlery with bare hands; in 22.7%, cutlery is placed in an individual envelope or napkin; in 15.6%, it is placed directly on the table without protection; in 11.5%, customers take cutlery from a common holder; 18.6% use disposable cutlery, and 6.9% have no clear protocol.

Wine and alcoholic beverages are served at the optimal temperature in 37.5% of cases, the waiter presents the bottle before opening in 28.6%, the customer tastes before serving in 19.4%, and the drinks are served directly without presentation In 14.5% of restaurants, plates for hot dishes are preheated in 28.3%, served at room temperature in 50.3%, and served cold without considering the dish's temperature in 21.4%. in 21.4%. In situations where a customer returns a dish, 52.8% of restaurants discard it without reusing it, 34.2 % replace it with a new one, 24.5% determine the reason for the return and document the issue, 5.4% reuse the dish, and 17.6% do not have a clear procedure.

Event Organization

When it comes to organizing events, 37.2% of restaurants have a clear reservation system with confirmed contracts and details, 32.4% plan events on an ad hoc basis, 24.7% allow customers to customize menus or decorations, and 5.6% do not have a clear reservation management system. In 28.6% of establishments, special event areas are available as private rooms with a defined capacity; in 31.6%, events occur in the main area without clear separation; 22.7% feature a terrace or garden dedicated to events and 17.1 % lack a dedicated space.

Service at larger events involves one waiter for every 10–12 people in 48.0% of situations, 2 waiters for the same table with a menu in 24.7 % of cases, 1-2 waiters and busboys per table in 26.3%, and 14.3% do not have a defined number of waiters. Staff coordination during events is the responsibility of the manager or head waiter in 34.7% of cases, a designated coordinator in 25.8%, or each waiter individually in 29.8%. 9.7% have no designated person in charge. The free space between tables during events is over 1.5 meters in 23.5% of establishments, between 1 and 1.5 meters in 30.1%, between 0.5 and 1 meter in 32.7%, and less than 0.5 meters in 13.8%. Linen for events is installed and cleaned by changing and sanitizing after each event in 32.1% of cases, checking before each event in 24.7%, changing only when visible stains are identified in 36.5%, outsourcing washing and ironing in 17.3%, in-house cleaning in 21.4%, and 12.5% do not have a clear protocol. Food scraps and waste are managed through strategically placed and regularly emptied trash bins in 54.1% of restaurants; 42.6% use separate containers for recycling, 25.0% collect waste according to a waste reduction plan, 36.5% train staff to clean frequently, 13.5% dispose of waste without a clear sorting system, and 9.7% have no clear protocol.

Collecting feedback on service quality

Feedback on service quality is collected from sources such as customers in 40.1% of restaurants, employees in 36.2%, internal checks in 29.6%, external inspections in 25.0%, while 10.0% have no collection system. Problems reported through feedback are analyzed and quickly resolved in 21.2% of units, discussed occasionally in 44.6%,

corrected only in critical cases in 26.3%, and 7.9% do not have a clear remediation process.

Menu management

Planning and reviewing menus to ensure a quality offering is done periodically based on seasonality and preferences in 40.3%, through the intervention of nutritionists or specialized chefs in 25.8%, by using fresh products and carefully selecting suppliers in 51.8%, by taking into account allergies and special diets in 35.0%, and through internal tastings in 25.0%, while 7.7% do not periodically review menus and 5.6% do not have a clear verification process. Managing food allergies and special requests involves allergen information being present on the menu in 25.8% of restaurants, staff being trained to ask customers in 36.5%, separate preparation of dishes for customers with allergies in 19.4%, the existence of a clear protocol in 17.6%, the lack of a clear system in 25.0%, and recommending consumption at one's own risk without a guarantee of allergen elimination in 6.1%.

Risk Management

Regarding crisis management that can affect service quality, 20.9% of restaurants have a clear emergency and task redistribution plan; 30.1% train staff for unforeseen circumstances; 24.7% have alternative suppliers or solutions for procurement; 16.1% collaborate with temporary staff; 33.7% manage issues as they arise; and 8.9% do not have a specific plan for such situations.

In 31.4% of restaurants, unforeseen situations during events are managed through a technical backup plan; 25.8% have clear instructions for service delays, 35.2% mobilize additional resources in case of staff shortages, and 33.2% do not have a clear plan. an. Customer complaints during events are handled and resolved according to a clear protocol in 25.8% of situations, the manager discusses directly with the customer in 31.4%, waiters report to management in 35.0%, an internal report is completed in 20.2%, occasional complaint handling occurs in 19.1%, and 15.1% do not have a complaint management process.

CONCLUSIONS

The findings of the study present us with the enduring gap between theoretical HACCP system requirements and actual practice in Romanian institutions of public catering. Though the majority of employees and managers are aware that HACCP regulations do exist, their implementation into daily practice is non-conformant and usually absent. Profile analysis of respondents indicated that while almost half of the staff possess some form of specialised training in the hospitality or food industry, the other half are founded on general education, which can reduce their potential to ensure food safety procedures all the time. This educational imbalance is illustrated in the variable quality of hygiene procedures and in the insufficient standardisation of routine operations.

The level of menu complexity and number of distribution formats enhance the risk and necessitate more stringent compliance procedures, founded on an examination of the foods available through catering establishments.

The study does, however, confirm that there remains little conformity of HACCP practices to these models of service and that many establishments are placing emphasis on formal compliance rather than upon preventing foodborne hazards. The same gap existed in the human resource organisation as well. Although all the majority units have individuals assigned specifically to food safety, they are not necessarily at distinct tasks, and the amount of continuous training is not sufficient enough to maintain continuous HACCP compliance.

As far as the technical aspect is concerned, equipment availability and storage and preparation facilities are still major areas of concern. There is a significant percentage of units that have faced difficulties in having proper temperature control, maintaining proper separation of raw and cooked products, and constantly monitoring critical control points. These deficiencies mean that the implementation of HACCP is often plagued by cost constraints, poor infrastructure, and lack of managerial commitment. The research also shows that long-standing strengths in hygiene and sanitation practices continue to exist.

Despite the predominance of facilities' declarations on the existence of cleaning procedures, their operational execution is non-standard and not formalised into control systems.

In general, the findings indicate that the implementation of HACCP in Romanian public catering is more motivated by legislative requirements than a proactive food safety culture. This may question the long-term appropriateness of compliance and the establishment's resistance to possible attacks on public health. Priorities such as expenditure on state-of-the-art equipment, reinforcing staff training, defining roles, and a prevention rather than reaction mentality are included. Therefore, all involved, including policymakers, inspectors, and catering managers, have much to benefit from the research's findings to make up for theory-practice gaps.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SUSTAINABLE DEVELOPMENT AND THE BERRY SECTOR IN ROMANIA: LINKING TRADITIONAL PRACTICES TO FOOD SECURITY AND MARKET DYNAMICS

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Abstract

The berry sector in Romania represents a strategic resource for healthy nutrition, food security, and sustainable rural development, contributing to Goal 2 – "Zero Hunger" of the 2030 Agenda. This study aims to evaluate the dynamics of berry production, exports, and imports in Romania, analyzing the economic, social, and ecological impacts, as well as the role of traditional occupations in mountainous areas. Data were collected from official sources, primarily the National Institute of Statistics, including regional production, imports, and exports both within the EU and outside the EU. Statistical indicators such as standard deviation, mean, coefficient of variation, annual growth rate, and CAGR were used for interpretation. A SWOT analysis was applied to identify the strengths and weaknesses, opportunities, and threats of the sector. The results show significant regional variations, with a general national downward trend, but notable increases in the North-East and North-West regions. Romanian exports are concentrated in the EU market, while rising imports reflect domestic demand and limitations in local production. The study highlights the economic potential of the sector, the need for modernizing plantations, and the integration of traditional practices with modern technologies for sustainable development.

Key words: *berries, sustainable development, food security, Goal 2 – Zero Hunger, agricultural production, export, import, traditional occupations*

INTRODUCTION

The concept of sustainable development was internationally established throughthe Brundtland Report [21], where it is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definitione mphasizes the balance between the economic, social, and environmental dimensions of development.

Sustainable Development Goal 2 of the 2030 Agenda – "Zero Hunger" – aims to eradicate hunger, ensure food security, improve nutrition, and promote sustainable agriculture [11]. This goal involves not only increasing agricultural production through modern methods but also leveraging local resources, traditional occupations, and biodiversity as tools for resilience and sustainability [5].

In the mountainous areas of Romania, the collection and utilization of medicinal plants and wild berries are traditional occupations practiced for centuries. These activities:

-contribute to food security by providing natural products rich in vitamins and antioxidants (blueberries, raspberries, rosehips, mint, St. John'swort, etc.);

-provide supplementary income for mountain households, where intensive agriculture is limited by natural conditions;

-support biodiversity and the cultural landscape through sustainable harvesting methods and the perpetuation of local knowledge [3].

The "Zero Hunger" objective is not limited to expanding industrial agricultural production but is directly linked to the protection of natural and cultural heritage and the integration of traditional products into a responsible global market [5].

Berries are a valuable resource for Romania's agricultural economy, generating income for rural households and contributing to exports. Romania produces and exports mainly

blueberries, raspberries, and currants, with a significant expansion of blueberry plantations in recent years, resulting in an increase of over 800% between 2014 and 2022 [7]. Exports are primarily directed to the EU market, but alsoto extra-EU markets, indicating economic development potential [1, 18].

Berry harvesting is a traditional occupation in mountainous and rural areas, providing supplementary income and maintaining local traditions. Harvesting and processing practices (jams, syrups, preserves) are part of the cultural heritage and ensure the continuity of traditional knowledge [10].

Berries grow mainly in mountainous and forested areas, contributing to biodiversity maintenance and soil protection. Sustainable collection and cultivation help prevent ecosystem degradation and support ecological farming practices [16].

Berries play a strategic role in ensuring access to healthy food, being key components of SDG 2 – Zero Hunger. They enable dietary diversification and offer economic opportunities for rural communities, helping to reduce vulnerability to poverty and hunger [5,11].

Globally, Mexico holds the leading position in fresh blackberry production, serving as the main supplier to the United States and European Union markets. In terms of raspberry production, the Russian Federation holds the leading position, with an annual yield exceeding 100,000 tonnes, while Serbia and Poland follow, each surpassing 80,000 tonnes [2]. In northern countries such as Norway, berry cultivation is limited by low temperatures. Nevertheless, in the past decades, Poland, the Netherlands, the United Kingdom, and Belgium have developed raspberry and blackberry production under protected systems (tunnels and plastic greenhouses) to prolong the harvesting season and better satisfy market demand [13, 19]. Furthermore, recent studies indicate that cultivating blackberries within shaded systems associated with productive forestry could generate commercially viable outcomes [6]. In Romania, the blueberry harvest season begins in early June and lasts until September, opening earlier than in several Central and Northern European countries. This provides a seasonal advantage in the regional market, further reinforced by comparatively lower labor costs than in Western Europe [7]. In countries such as Poland, the Netherlands, the United Kingdom, and Belgium, protected cultivation systems (e.g., high tunnels and plastic greenhouses) are widely implemented to extend the production period and enhance yield stability, Romanian production is still largely concentrated in open-field systems, with gradual adoption of modern technologies such as drip irrigation, frost protection, and anti-hail nets. These differences in technological strategies reflect both climatic conditions and the structural characteristics of each national berry sector [14].

This study aims to evaluate and interpret the dynamics of the berry sector in Romania from economic, social, and ecological perspectives of sustainable development. The main objective is to identify the factors influencing the production, export, and import of berries, as well as their role in ensuring food security and promoting traditional occupations in mountainous areas. The analysis is based on official statistical data, specialized literature, and recent studies on market evolution and valorization strategies, providing a framework for reflection on sustainable agricultural policies and local economic development.

MATERIALSAND METHODS

The data used in this study were obtained from official sources, primarily from the National Institute of Statistics of Romania, including databases on the production, imports, and exports of berries. The analysis focused on berry production in Romania and its regions, as well as on the international trade of berries, both within the European Union (intra-EU) and with countries outside the EU (extra-EU).

To interpret the collected data, the following statistical methods were applied:

Time series analysis was used to examine the evolution of berry production, imports, and exports over the analyzed period, calculating annual growth rates and variation ratios.

Calculation of *the growth index* (%) was performed using the formula:

$$I_t = \frac{X_t}{X_{t-1}} \times 100 \quad \text{.....(1)}$$

where:
I_t= growth index for year t,
X_t = indicator value in year t,
X_{t-1} = indicator value in the previous year.
The coefficient of variation (CV) was used to assess the fluctuations in production, imports, and exports, according to the formula:

$$CV=\sigma/\mu \quad \text{.....(2)}$$

where:
σ = standard deviation,
μ= arithmetic mean of the data series.
A CV below 0.2 indicates low variability, and a CV above 0.5 indicates high variability.
The Compound Annual Growth Rate (CAGR) was calculated to analyze the long-term trends in the production, imports, and exports of berries. CAGR is a valuable tool in long-term analysis because it allows for the comparison of growth or decline over different periods, taking into account market or data fluctuations. It is useful for:
-Evaluating investment performance – it provides a clear picture of how an investment or economic sector has developed, such as berry production or trade.
-Estimating long-term growth – based on historical data, it can help forecast the future development of a sector or market.
-Comparing sectors or regions – it allows for the comparison of growth rates across different agricultural sectors or geographic regions.

$$CAGR = \left(\frac{V_f}{V_i}\right)^{\frac{1}{n}} - 1 \quad \text{.....(3)}$$

where:
V_f= the final value of the indicator,
V_i = theinitialvalue of the indicator,
n = thenumber of yearsunderreview.
The *SWOT analysis* was applied to provide a clear overview of Romania's berry sector, highlighting its strengths and weaknesses, as well as existing opportunities and threats. This approach enables a comprehensive assessment of the internal and external factors influencing production and market dynamics, offering a valuable tool for strategic planning and decision-making.

RESULTS AND DISCUSSIONS

Berries play a strategic role in Romania, contributing both to healthy nutrition and food security. Cultivated or wild-harvested species – such as blueberries, raspberries, and currants – provide vitamins and antioxidants, being essential foods for preventing malnutrition and diversifying the diet, in line with Sustainable Development Goal 2 – "Zero Hunger" of the 2030 Agenda. The analysis of berry production in Romania for the period 2014–2023 reveals contrasting trends between the national level and the development regions. Table 1, which present sstatistical indicators such as standard deviation, mean, coefficient of variation, and compound annual growth rate (CAGR), highlights both notable fluctuations and an overall declining trend.
At the national level, average annual production reached 2,495 tons, accompanied by a standard deviation of 876 tonsand a coefficient of variation of 0.35, suggesting moderate variability between years. Nevertheless, the compound annual growth rate of –9.67% confirms a pronounced downward trajectory. This decline can be associated with factors such as aging plantations, low yields, lack of modern infrastructure (storage facilities, irrigation), and the impact of climate change on crops [20].
Regional disparities are notable:
-The North-East has the highest average production (822 t/year), with an almost negligible decline (–0.63%), suggesting a relatively stable core of the sector.
-The North-West remains significant (547 t/year), with a moderate decrease (–4.04%).
-The Center, South-East, South-Muntenia, and Oltenia show dramatic declines (between –17% and –21% annually), accompanied by high variability, reflecting unstable and vulnerable production.
-Bucharest–Ilfov and the West have almost disappeared from statistics (CAGR –100%), suggesting abandonment or insignificance of cultivated areas.

Table1. Berry production in Romania, total and by region

Specification	Standard deviation	Mean	Coefficient of variation (%)	Annual growth rate (%)
TOTAL	876.22	2495.13	0.35	-9.67
NORTH-WEST	184.85	546.99	0.34	-4.04
CENTER	149.37	249.04	0.60	-18.76
NORTH-EAST	245.48	821.99	0.30	-0.63
SOUTH-EAST	153.36	251	0.61	-21.17
SOUTH-MUNTENIA	184.07	353.89	0.52	-20.11
BUCHAREST-ILFOV	24.29	18.88	1.29	-100.00
SOUTH-WEST OLTENIA	149.39	241.99	0.62	-17.19
WEST	16.19	11.33	1.43	-100.00

Source: own calculations based on data collected from www.insse.ro [9].

Table 2. Exports of berries from Romania

Category	Standard deviation	Mean	Coefficient of variation (%)	Annual growth rate (%)
Total	11.24	20.9	0.54	11.6
Intra-UE	8.41	18.2	0.46	10.7
Extra-UE	2.77	2.3	1.20	17.3

Source: Own calculations based on data collected from www.insse.ro [9].

Table 2 provides a synthetic overview of Romanian berry exports, based on four indicators: standard deviation, mean, coefficient of variation, and annual growth rate. These indicators allow for the evaluation of stability, volatility, and growth trends in exports.

The average exports (20.88) indicate a significant share of berries in Romanian agri-food trade, while the standard deviation of 11.24 highlights large annual variations, driven by seasonality and climatic conditions [15]. The coefficient of variation of 0.54 shows moderate-to-high variability, signaling structural instability. However, the annual growth rate of 11.64% confirms an upward trend in exports, aligned with the increasing demand for berries within the EU and international markets [4].

The average level of intra-EU exports (18.2) shows that the majority of Romanian berries are directed toward the European market, which ensures a relatively stable outlet [18]. The comparatively low standard deviation (8.41) and coefficient of variation (0.46) indicate greater predictability within the European market than in total exports. The annual growth rate of 10.74% indicates sustainable, though more moderate, growth compared to extra-EU markets, where there is still room for expansion. The average extra-EU exports (2.3) are muchlower, indicating a marginal role of these markets for Romanian producers.

The high coefficient of variation (1.20) highlights significant volatility and an opportunistic character of exports to non-EU markets. Nevertheless, the annual growth rate of 17.25% shows high potential for market diversification, especially toward the Middle East and Asia, where there is demand for premium berries [15].

Concentration of exports in the EU market provides short-term stability but limits diversification and exposes Romania to regional competition [4]. Rapid expansion into extra-EU markets could be an effective strategy for growth and risk reduction but requires investment in infrastructure, international certifications, and branding [8]. Overall export volatility indicates the sector's vulnerability to exogenous factors, such as climatic conditions and price fluctuations [17].

Table 3. Imports of Berries in Romania

Category	Standard deviation	Mean	Coefficient of variation	Annual growth rate (%)
Total	34.3	39.9	0.86	36.49
Intra-UE	29.6	33.2	0.89	36.62
Extra-UE	4.9	6.8	0.71	35.82

Source: Own calculations based on data collected from www.insse.ro [9]

The data presented in Table 3 highlight several important characteristics regarding the dynamics of berry imports in Romania. The overall mean of 39.96, accompanied by a high standard deviation (34.32) and a coefficient of variation of 0.86, suggests that the market is characterized by pronounced volatility and a lack of medium-termstability. The same trend is observed for intra-EU imports, where a mean of 33.15 and a coefficient of variation of 0.89 indicate significant dependence on European trade partners, as well as increased vulnerability to fluctuations in production and prices within the common market.

In contrast, imports from extra-EU countries, although much smaller in volume (mean of 6.85), exhibit a lower standard deviation (4.89) and a coefficient of variation of 0.71, reflecting a more stable trend and serving as a diversification of supply sources. This relative stability is important in the context of risks associated with seasonality and variability in European production.

Another remarkable aspect is the high annual growth rate, both for intra-EU imports (36.62%) and extra-EU imports (35.82%), confirming an accelerated trend in Romania's dependence on external sources of berries. This dynamic can be explained by rising domestic demand, driven by changing consumer preferences toward healthy products [15], the development of the HoReCa industry and the processing sector, as well as the insufficiency of domestic production, affected by farm fragmentation and technological limitations [8].

In conclusion, the analysis highlights Romania's increasing dependence on berry imports, especially from the European area, while also exhibiting high volatility that implies economic and commercial risks. Additionally, the diversification of extra-EU sources contributes to relative stability but does not offset the general upward trend in imports. This situation underscores the need for agricultural and trade policies aimed at stimulating domestic production and reducing vulnerabilities in the external market.

SWOT Analysis

Strengths

Favorable climate andbiodiversity

Romania benefits from favorable climatic and pedoclimatic conditions for berry cultivation, especially in mountainous and forested regions. This ecological diversity allows for both commercial production and the maintenance of wild-harvested berries, contributing to biodiversity conservation and supporting local ecosystems [16].

Seasonal window

Romania's harvest window, from early June through September for blueberries, is earlier than that of some Central and Northern European countries, providing a competitive seasonal advantage. Labour costs are also generally lower compared to Western EU countries [7].

Significant increase in cultivated areas

Between 2014 and 2022, the area planted with berry crops grew from approximately 470 hectares to over 1,700 hectares, an expansion of more than 250%. This reflects growing interest among producers and the economic potential of the sector [18].

Traditionand local knowledge

Berry harvesting and processing are traditional occupations passed down through generations in mountainous and rural areas. These practices preserve local traditions and support sustainable rural development through ecological harvesting methods and utilization of local natural resources [3].

European financial support

Berry producers have access to EU funds that facilitate plantation modernization, development of processing and storage infrastructure, and implementation of modern technologies. This support enhances competitiveness and integration of Romanian production into European and international markets [8].

Weaknesses

Unstable and low production

The average annual production of berries is approximately 2,495 tonnes, with a negative average annual growth rate of –9.67%, indicating structural decline and medium-term instability.

Lack of modern infrastructure

Many plantations face deficiencies in cold storage, irrigation, and mechanized harvesting

equipment, limiting yields and product quality [20].

Fragmentation of farms

The sector is dominated by small and semi-subsistence farms, reducing efficiency and competitiveness [12].

Variable product quality

Products may exhibit significant quality differences between seasons and regions, affecting uniformity and appeal on external markets.

Opportunities

Growing demand on external markets

Romanian berry exports have an annual growth rate of 11.64%, with opportunities to expand to extra-EU markets, including the Middle East and Asia, where demand for premium products is high [18].

Product diversification and added value

There is potential for developing processed products such as jams, juices, frozen berries, or organic products, increasing added value and profitability.

Agrotourism and ecological tourism

Promoting eco-tourism and berry-picking experiences can generate additional income and support environmental conservation.

Implementation of modern technologies

Optical sorting, packaging, and mechanized harvesting technologies can increase productivity and quality while reducing post-harvest losses.

Threats

Climate change and extreme events

Droughts, late frosts, or excessive rainfall negatively affect production and may cause significant losses.

International competition

Countries such as Poland, Serbia, and Hungary produce berries at large scale and lower costs, potentially affecting Romania's competitiveness on external markets.

Price and demand fluctuations

Market volatility, driven by seasonality and international demand, may impact local producers' revenues.

Lack of qualified personnel

Shortages of seasonal workers and lack of specialized training can limit harvesting and processing efficiency [17].

CONCLUSIONS

Berries play a strategic role in Romania, contributing to healthy nutrition, food security, and the economic development of rural communities, in alignment with Sustainable Development Goal 2 – "Zero Hunger" of the 2030 Agenda.

The analysis of production (2014–2023) shows a structural decline at the national level (CAGR –9.67%), with significant regional variations. The North-East and North-West regions remain relatively stable, while the southern regions and Bucharest–Ilfov experience dramatic decreases.

Berry exports have recorded sustained growth (11.64% annually), primarily concentrated on the EU market, with potential for expansion to extra-EU markets, where high volatility is observed alongside opportunities for market diversification.

Imports are increasing rapidly (over 36% annually), indicating a growing dependence on external sources, driven by rising domestic demand and insufficient internal production, affected by farm fragmentation and technological limitations.

The SWOT analysis highlights strengths such as favorable climate, biodiversity, local tradition, and access to European funds; weaknesses include unstable production, insufficient infrastructure, and fragmented farms; opportunities include increasing external demand, product diversification, agrotourism, and modern technologies; threats comprise climate change, international competition, price fluctuations, and shortages of qualified personnel.

To strengthen the sector and reduce import dependence, public policies are needed to support plantation modernization, increase domestic production, promote traditional products, and integrate modern technologies.

Overall, Romania's berry sector presents significant economic potential, but long-term success depends on balancing domestic production with international demand and adapting to climatic and technological challenges.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF EMOTIONAL INTELLIGENCE DIMENSIONS IN LEADERSHIP - CASE STUDY

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Abstract

Developing emotional intelligence (EQ) brings numerous benefits in different aspects of a person life, including interpersonal relationships, career, school and mental health. Thinking before acting is an essential element. Emotionally intelligent people know that they must act, they know that emotions are strong and intense, but also that the need to control impulses is fierce. It is not only social constraints that dictate this direction, it is about the conscious tempering of impulses that comes from the complexity of understanding and correct reasoning. A greater awareness of one's own emotions, feelings and needs then extends to the others too. People with developed and fully aware emotional intelligence also show an associated empathy, which comes from understanding how we would react if we were in the same situation. Based on these considerations, the present study aimed to capture how different people, in terms of age, gender and occupation, act in different contexts and which dimensions of emotional intelligence are predominant, depending on the mentioned characteristics. For this purpose, it was used a standardized questionnaire, elaborated by Daniel Goleman, with 10 multiple-choice questions, to which we added 3 filter questions for a better in-depth study, applied to a sample of 320 respondents, from the student category, institutional sector and private sector. The correlations between the items were analyzed using the theoretical $\chi 2$ test. Following the study, we cannot conclude that age has a significant importance in the components of emotional intelligence, but the results from the socio-professional groups gave us some important clues. The fact that students obtained the highest score is probably the result of the introduction into the study program of disciplines that directly or indirectly develop this type of intelligence, and the field that had a close score was the private economic sector, where most people are administrators and, in the competitive context of our economy, they had to develop leadership skills in order for their business to work.

Key words**:** *emotions, emotional intelligence, leadership***,** *questionnaire, perspectives*

INTRODUCTION

Charles Darwin was the first to highlight the importance of emotional intelligence for survival [8].

In the 20th century, researchers began to realize the importance of non-cognitive aspects for intelligence. Immanuel Kant (1724-1804) distinguished "three types of action": (i) technical action (the way of handling objects), (ii) pragmatic action (the way of dealing with people), and (iii) ethical action (the way of approaching moral values), which Müller-Merbach transferred to the level of intelligence [8,11]. The distinction between technical, pragmatic, and ethical action helps to realize the total responsibility of agents. According to Kant, these actions correspond to the hypothetical imperative subordinate to the categorical imperatives. There is a hierarchy between the three types of action and the corresponding imperatives. The problematic and the affirmative imperative are hypothetical in that they are subordinate to the categorical imperative. According to Russell, the hypothetical imperative states how one should act according to a purpose, unlike categorical imperatives which declare the necessity of actions without regard to any purpose; thus, the categorical imperative "acts as if the maxim of your action would by your will become a general law of nature" [8].

In 1920, E. L. Thorndike used the term social intelligence in human relations, proposing several types of intelligence. In 1940, David Wechsler highlighted the importance of affective, personal, and social factors in predicting one's ability to succeed in life as

cited [2 and 12]. The term "emotional intelligence" first appeared in a 1964 paper by Michael Beldoch and in a 1966 paper by B. Leuner entitled "Emotional Intelligence and Emancipation" in the Journal of Psychotherapy: "The Practice of Child Psychology and Child Psychiatry" [11]. In 1983, in *Frames of Mind: The Theory of Multiple Intelligences*, Howard Gardner introduced the idea of multiple intelligences, interpersonal and intrapersonal [9]. The term reappeared in Wayne Payne's doctoral thesis, *A Study of Emotion: Developing Emotional Intelligence* in 1985 [9].

The first use of the term "EQ" (Emotional Quotient) was in an article in 1987 by Keith Beasley in the British magazine Mensa [12]. In 1989, Stanley Greenspan presented a model describing EI, followed by another by Peter Salovey and John Mayer published the following year [6,11]. Psychologists John Mayer and Peter Salovey introduced the concept of emotional intelligence as "The ability to perceive emotions, to access and generate emotions in a way that aids thinking, to understand emotions and emotional knowledge, and to regulate emotions reflectively in a way that promotes emotional and intellectual growth." The term became popular with the publication of Daniel Goleman's book: *Emotional Intelligence – Why it can matter more than* IQ [4]. In 1996, Reuven Bar-On developed the first scientifically validated measurement of emotional intelligence, through a test covering five domains: intrapersonal, interpersonal, adaptability, stress management, and general mood [1].

The distinction between features and skills emotional intelligence was introduced in 2000 [3, 5]. Emotional intelligence (EQ) consists of a person's ability to recognize and manage both their own emotions and those of the people they interact with, using emotional intelligence information in an efficient and empathetic manner [6,11].

That is why we call on self-control, self-knowledge, empathy, motivation, social skills, all of which are components of emotional intelligence [4,13].

As advantages of emotional intelligence, we can list improving relationships with people, communication, developing empathy skills, increasing confidence, reducing stress levels, managing change more confidently, and career prospects [3,12].

It has been found, without scientific proof, that people with high emotional intelligence (EI) have better mental health, better job performance, and better leadership skills. (A) Daniel Goleman indicated that EI accounted for 67% of the skills needed for leadership performance and counted twice as much as technical knowledge or IQ [4].

There are several models that aim to measure EI levels [5, 9]. Daniel Goleman's original model is a mixed model that combines skills with features [4]. A feature model was developed by Konstantinos V. Petrides in 2001 [10] with an emphasis on self-awareness, and a skill model was developed by Mayer et al. (2000) focusing on social relationships [6].

What led us to approach this topic was the fact that we observed in different circumstances people who, although intelligent, in the general sense of the term, did not achieve the expected success in life. It was a signal that made us study this aspect, to analyze personal development not only through the lens of cognitive processes but also of psychic and emotional ones. We thus found that most people consider academic intelligence more important than emotional intelligence in achieving performance, although psychologists demonstrated that these abilities are not generated by a high level of theoretical/academic knowledge, but they constitute a kind of specific sensitivity towards practice and interpersonal relationships [10,12,13].

This study has the goal to identify how different people, in terms of age, gender and occupation, act in various contexts and which dimensions of emotional intelligence are predominant, depending on the mentioned characteristics.

MATERIALS AND METHODS

The purpose of this paper is to analyze and interpret how different people, by age, gender

and occupation, act in different contexts and which dimensions of emotional intelligence are predominant, depending on the listed characteristics. To this end, we applied a standardized questionnaire, elaborated by Daniel Goleman, with 10 multiple-choice questions, to which we added 3 filter questions for a better in-depth study, applied to a sample of 320 respondents, from the student category, the institutional sector and the private sector, as shown in Table 2. Completing the test took into account, on the one hand, the transposition of the respondent into the respective situation, and on the other hand, the choice of one of the four possible answer options, which represent some concrete ways of reacting in the predetermined situations indicated by the questions. The answers were scored with points from zero to 20 up to 100p – below average score; 100p-125p – average score; 125p-175p – above average score; 200p – exceptional. The scoring and interpretation of the answers to the emotional intelligence test consisted of adding the points corresponding to the four answer options from the ten items, after which the score obtained was reported to the standard. The questions were structured on two levels, respectively, 3 filter questions and 10 grid-type questions, with 4 predetermined answers.

The questionnaire was applied both physically and online, through Google Forms, on a sample of 320 people from different public and private institutions. The test questions consisted of the subject being transposed into a certain situation and the way he/she would react. The filter questions aimed at classifying the respondent into an age category, his/her gender and place of work. The age groups were structured in five steps, starting with the 18-25 year-old group, up to the over 60 year-old group, as mentioned in Table 1.

In forming the research sample, the condition was established that the respondent be a student or active in the labor market because in a world of collaboration, multicultural teams and digital communication, observing the competencies in the five dimensions of emotional intelligence in a team or community is important to identify strengths and vulnerabilities (Table 2). It is necessary to know the people around us and fundamental to know ourselves to be successful leaders. Measured variables: Emotional awareness, expression of emotions, regulation of emotions, use of emotions.

Potential limitations: Like other self-report-based tests, it can be affected by the subjectivity and self-reporting tendencies of the respondent.

Table 1. The structure and share of respondents according to age

Age group	No of respondents	%
18- 25 years old	72	*22.5*
26-35 years old	87	*27.2.*
36-45 years old	65	*20.3*
46-60 years old	59	*18.4*
>60 years old	37	*11.6*
Total	**320**	***100***

Source: Questionnaire on measuring emotional intelligence [4].

Table 2. The structure of the respondents according to the profession

Socio-professional categories	Total	
	No.	%
Teaching staff	49	*15.3*
Medical staff	23	*7.2*
Civil servants	31	*9.7*
Bank employees	10	*3.1*
Private economic sector	44	*13.7*
Private technical sector	48	*15.0*
Private agricultural sector	27	*8.4*
Students	82	*25.6*
Other categories	6	*1.9*
Total	**320**	***100.0***

Source: Questionnaire on measuring emotional intelligence [4].

In establishing the correlations of the information collected on the basis of the questionnaire, the theoretical Chi, Hi or $\chi 2$ test was used, theoretically, a concordance test applied to statistical distributions for which we can calculate the cumulative distribution function [7].

RESULTS AND DISCUSSIONS

A positive and sustainable organizational climate is a very important condition in today society, characterized by permanent evolution and rapid changes.

People have emotional needs and seek not only financial well-being but also psychic and emotional well-being in any kind of interpersonal relationships, and here emotional and social skills play a more important role than cognitive intelligence [1, 4].

In this context, emotional intelligence became an almost fundamental element in the practice of effective leadership.

In this study, we aimed to identify the predominant dimensions of emotional intelligence by respondent categories and by sectors of activity, respectively, private and institutional. The responses regarding the identification of specific characteristics of emotional intelligence were scored, with a maximum of 200 points, and were subsequently organized in graphs and tables to obtain an overview of the level of emotional intelligence, correlated with the age group in which the respondent falls and with his occupation. As shown in Table 3, we assigned the questions in the test to the five components of emotional intelligence, as grouped by Daniel Goleman [4].

In Table 4, we averaged the respondents' scores by age group, where we could observe a total of 90/200 points, a low to average score, with higher emotional intelligence being in the first age group. Although we cannot say that it is a conclusive factor, due to the unequal number of respondents, we note that the average score decreases as the age category advances, in the over 60 category we had the lowest score, which may be the result of the relatively recent training of leadership skills in Romania.

To investigate whether the participants' occupation has an influence on their emotional intelligence, we grouped them into socio-professional categories and averaged the score obtained by each in the test, as presented in Table 5.

The highest score was obtained by students, with an average of 107 points out of 200, closely followed by teaching staff and civil servants.

Regarding the private sector, those working in the agricultural sector rank first, with 93/200 points, while employees in the private economic sector and bank employees have the same score, 76/200 points.

In Table 6, it was correlated the respondents age with the sector in which they work. The value of the Chi calculated test, of 31.87, indicates a significant correlation between the two variables, meaning that people in the age categories 26-45 years, as well as the age category over 60 years, work mostly in the private sector, while the age category 46-60 years works mostly in the public sector.

In Table 7, in order to observe the predominant characteristics of the respondents to the test, we distributed the points obtained on the questions according to each dimension. We thus observed that self-regulation and social skills hold the share, while our respondents have a fairly low level of empathy, one of the important characteristics of social awareness: sensitivity to the needs of others, awareness of emotions, willingness to provide help where needed.

It is worth mentioning the high level of social skills, which includes skills such as managing the anger of others, influencing, identifying and communicating optimal solutions for a climate favorable to collective development.

In the self-regulation chapter, it is worth mentioning that the first question was about a single emotion, namely: fear for one's own life and how we react in a stressful situation. Here, out of the ten questions, we have the highest score obtained: 90% of the test respondents chose an appropriate answer.

Unlike the first, the second question, however, concerned a tense situation, where aggression and pride were present in the relationship with a loved one.

Only 16.25% of the people surveyed chose the option marked in the test.

We can deduce that such feelings affect interpersonal relationships, very few have the ability to stop when things degenerate, taking into account their own righteousness and ego more than the relationship and its importance.

Table 3. Correlation of questions in the test with the element of emotional intelligence

Elements of emotional intelligence	Question in the test
Self-knowledge	3. You got a bad grade at school/faculty, which could make you lose your scholarship. What do you do? 10. How do you proceed if you decide you want to use your time effectively and resume training in a sport you practiced as a child?
Self-regulation	1. You are flying on a plane and there is turbulence that shakes the aircraft; what do you do? 7. When an argument in your couple degenerates into verbal violence and personal attacks from both parties, what should be done?
Social awareness	2. A little child is crying because the others do not want to play with him; what do you do? 9. If you have a shy, sensitive child who is afraid of strange people and places. What do you do?
Social skills	5. You are the leader of an organization for ethnic and racial equality. Someone tells a racist joke; what do you do? 6. What do you do if, while in a friend's car, another car is about to hit you and your friend gets angry? 8. As a team leader, you need to find a creative and urgent solution to an unforeseen problem. What do you do first?
Self-motivation	4. You are a telephone sales agent; today all the customers hung up on you, you are discouraged; what do you do? 10. How do you proceed if you decide you want to use your time effectively and resume training in a sport you practiced as a child?

Source: Elaborated by authors.

Table 4. Average score obtained by age categories

Age category	Number of respondents	Average score obtained
18-25 years old	72	113/200
26-35 years old	87	97/200
36-45 years old	65	96/200
46-60 years old	59	82/200
Over 60 years old	37	60/200
Total	**320**	**90/200**

Source: Questionnaire on mesuring emotional intelligence [4].

Table 5. Average score obtained by socio-professional categories

Socio-professional category	Number of respondents	Average score obtained
Teaching staff	49	106/200
Medical staff	24	99/200
Civil servants	31	101/200
Bank employees	10	76/200
Private economic sector	44	76/200
Private technical sector	48	62/200
Agricultural sector	27	93/200
Students	82	107/200
Other categories	6	90/200
Total	**320**	**90/200**

Source: Questionnaire on measuring emotional intelligence [4].

Table 6. Analysis of the correlation between the age of the respondents and sector where the respondent works

Age	MU	Sector of work			Total	
		Students	public	Private	no	%
18- 25 years old	No	67	1	4	72	22.5
26-35 years old	No	15	27	45	87	27.5
36-45 years old	No	0	23	42	65	20.3
46-60 years old	No	0	40	19	59	18.4
>60 years old	No	0	12	25	37	11.6
Total	No	82	103	135	320	100
	%	25.62	32.19	42.19	100	X
Indicators	Test $\chi 2$	Significance threshold				
	≤	0.1	0.05	0.01	0.001	
Chi theoretical	≥	16.37	24.23	29.57	34.23	**
Chi calculated	31.87					

Source: Questionnaire on measuring emotional intelligence [4].

Table 7. Respondents skills depending on the components of emotional intelligence

Components of emotional intelligence	Answers 20 points	Answers 5 points	Average of skills %
Self-knowledge	124/320 56/320	N/A	56.25%
Self-regulation	188/320 52/320	N/A	75.0%
Social awareness (empathy)	114/320 103/320	35/320	47.5%
Social skills	112/320 27/320 37/320	53/320	71.56%
Self-motivation	82/320 94/320	N/A	55.0%

Source: Questionnaire on measuring emotional intelligence [4].

Table 8. Analysis of the correlation between the respondents age and components of emotional intelligence

Age	MU	Components of emotional intelligence					Total	
		Self-knowledge	Self-regulation	Empathy	Social skills	Self-motivation	No.	%
18- 25 years old	No.	13	18	14	7	20	72	22.5
26-35 years old	No.	15	22	13	27	10	87	27.5
36-45 years old	No.	11	21	5	23	5	65	20.3
46-60 years old	No.	10	12	9	17	11	59	18.4
>60 years old	No.	10	12	4	7	4	37	11.6
Total	No.	59	85	45	81	50	320	100
	%	18.44	26.56	14.06	25.31	15.63	100	X
Indicators	Test $\chi 2$	Significance threshold						
	≤	0.2	0.1	0.05	0.01	0.001		
Chi theoretical	≥	22.04	23.15	26.2.3	32.27	38.11	N	
Chi calculated	21.74							

Source: Questionnaire on measuring emotional intelligence [4].

In Table 8, the respondents age was correlated with the components of emotional intelligence. The calculated Chi test value of 21.74 indicates an insignificant correlation between the two variables, with self-regulation and social skills being predominant in all age categories, except for the 18-25 age category, where self-motivation ranks first.

CONCLUSIONS

Emotional intelligence (EQ) is a crucial component of professional success and fulfillment in the workplace. Research in the field has shown that people with high EQ can be effective leaders, who have the ability to inspire and motivate the team, manage conflicts effectively, and organize a positive work climate. Effective communication is an important component of EQ in the workplace, as it contributes to a clear expression of emotions and thoughts, active listening, correct understanding of the perspectives and needs of team members, and the avoidance of conflicts.
In addition, a developed EQ facilitates the establishment and maintenance of healthy interpersonal relationships in the workplace.
From the study carried out, we cannot deduce whether age has a significant importance in emotional intelligence skills, but the results from socio-professional groupings gave us some important clues. The highest score was obtained by students, with an average of 107 points out of 200, closely followed by teaching staff and civil servants. As for the private sector, those working in the agricultural sector are in first place, with 93/200 points, while employees in the private economic sector and bank employees have the same score, 76/200 points.
We observed that self-regulation and social skills hold the share, while our respondents have a fairly low level of empathy, one of the important characteristics of social awareness.
In order to achieve outstanding leadership performance, we need skills dispersed in all five areas of emotional intelligence, and the good thing is that it can be developed through different leadership techniques. Following the research carried out, we can deduce that most of the people surveyed have a high level of social skills and self-regulation in stressful situations, but there is an urgent need to introduce training courses to develop self-knowledge, self-motivation, empathy, conflict management skills in almost all socio-professional areas analyzed.
In order to make real steps towards progress, we need leaders who combine logical thinking with human sensitivity, capable of creating a healthy work area, based on respect, cooperation and mutual trust.
Healthy and harmonious relationships contribute to a sense of belonging, emotional satisfaction and greater resilience in front of stress and life difficulties. Developing emotional intelligence is essential for creating and maintaining harmonious interpersonal relationships. Emotional intelligence helps us understand and manage our own and others' emotions in a healthy and constructive way. It gives us the skills needed to communicate effectively, be empathetic, and resolve conflicts in a way that promotes understanding and cooperation.
In conclusion, developing emotional intelligence brings significant benefits in multiple aspects of life, contributing to healthier relationships, career success, improved academic performance, and overall mental health and well-being.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF THE BEEKEEPING PERFORMANCE OF EUROPEAN UNION COUNTRIES USING THE SAW METHOD

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Abstract

The current study was conducted to analyse the beekeeping performance of some European Union countries. The data for the study were obtained from the records of the European Commission. The SAW method was used in the study and the criteria of the number of beehives, honey production, producer prices and honey export volume were used to determine the beekeeping performance of the countries. The study determined that Spain, Germany and Poland have the best beekeeping performance among the European Union countries. It is concluded that it is important to take measures to improve the production of beekeeping products in European Union countries and to ensure the long-term sustainability of beekeeping.

Key words**:** *beekeeping, European Union, SAW (Simple Additive Weighting) method*

INTRODUCTION

Beekeeping is an important supportive enterprise in small family agriculture to utilise family labour and provide additional income. In addition, beekeeping is an important activity in terms of economic, environmental and social sustainability that can be transferred from generation to generation. [12, 19]. Pollinators, including honeybees, bumblebees and wild bees, are estimated to contribute at least 22 billion Euros annually to the European agricultural industry. They pollinate more than 80% of agricultural and wild plants in Europe. Honeybees also provide honey and other beekeeping products such as pollen, beeswax used in food processing, propolis used in food technology and royal jelly, which is used as a dietary supplement and food ingredient [1].
Beekeeping activities carried out in almost all countries of the European Union provide an annual added value of approximately one billion euros in European agriculture [5]. Among the European Union countries, Germany, Romania, Italy and Greece are the countries where beekeeping is intensively practised. In 2022, the total number of beehives in the European Union was approximately 20.3 million, 285.7 thousand tonnes of honey was produced and the yield per beehive was 14.09 kilograms [2].
The EU is the second-largest honey producer in the world. Beekeeping is one of the sectors supported within the EU. In the European Union, beekeeping will be supported with a total of 610 million Euros from both national funds and EU funds between 2023 and 2027. These supports will cover investments in combating beehive diseases, adapting to climate change, restocking beehives and increasing their numbers. Promotional activities, consultancy services and training will also be financially supported [3].
For the European Union, beekeeping is an essential branch of agriculture that has recently gained special attention due to the effects of climate change and the use of pesticides in crop production. The European Union provides support through National Beekeeping Programs to improve production and support the marketing of beekeeping products [9].
There is a high level of heterogeneity within the beekeeping industry in the European Union [4]. Factors such as the climate, flora, biodiversity and colony numbers in each

country are some of the reasons for these differences.

In this regard, the purpose of the current study is to evaluate the beekeeping performance of European Union countries.

MATERIALS AND METHODS

Data collection

The data for the study were obtained from the records of the European Commission and FAO. In addition, previously published studies conducted using the SAW method on the subject were utilized.

The variables used in the study are from the year 2022. The European Union countries to be included in the study were determined by the availability of data.

The European Union countries (Spain, Romania, Greece, Poland, Italy, Hungary, Germany, Bulgaria, Czech Republic, Portugal, Austria, Croatia, Lithuania, Slovenia, Denmark, Latvia, the Netherlands, Belgium, Finland, Estonia and Ireland) that met the established criteria related to beekeeping were included in the study.

Methods used

In the study, the SAW method was used to evaluate the beekeeping performance of European Union countries. Four criteria were considered while evaluating the performances. These criteria are the number of beehives, honey production, producer prices and honey export volume. SAW (Simple Additive Weighting), which is stated to be the most widely used method in many studies, was first used by Churchman and Ackoff in a portfolio selection problem. The fundamental concept of the SAW method is to find a weighted sum of each alternative's performance across all attributes. The SAW method requires the process of normalizing the decision matrix (X) to a scale that allows comparison of all ratings of the alternatives [8].

In the SAW method, the decision-maker assigns a relative weight value to each attribute. The total value is obtained by multiplying each category's weight value by the alternative value. Calculations using the SAW method are performed solely through the input of alternative values and the normalization of the matrix containing these alternative values [6].

The stages of the SAW model can be summarized as follows:

Formation of the decision matrix (x_{ij})

The first step in the SAW method involves creating a pairwise comparison matrix for each criterion in each alternative:

$$Xij = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad \text{Eq 1}$$

Here, x_{ij} represents the response of the pairwise comparison matrix given by alternative j for criterion i, where n represents the criteria and m represents the alternatives.

Determination of the criteria weights (w_i)

These weights can be considered as numbers ranging from 0 to 1 and can be represented as follows.

$$\sum_{i=1}^{n} w_i = 1 \quad \text{Eq 2}$$

Here, w_i is the criterion weight, and it must be equal to 1.

Normalization of the criterion value i for alternative j (r_{ij})

r is the term used to represent the normalized value of criterion i for alternative j.

The calculation of this value depends on whether the problem is of a cost or benefit type. In cost problems, the goal is to minimize the value while in benefit problems, the goal is to maximize the value.

These differences are reflected in the calculation of r as follows:

$$r_{ij} = \frac{\min_j x_{ij}}{x_{ij}} \quad \text{if j is of a cost type} \quad \text{Eq 3}$$

$$r_{ij} = \frac{x_{ij}}{\max_j ij} \quad \text{if j is of a benefit type} \quad \text{Eq 4}$$

Determination of the alternative ranking

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \quad \text{Eq 5}$$

Here, *V* is the preference value of the alternative. A larger value of *V* indicates that the alternative is more preferred.

RESULTS AND DISCUSSIONS

Preparation of the decision matrix

In the study, firstly the decision matrix was created. This matrix contains alternatives and criteria. In the created model, there are alternatives in the rows and criteria in the columns (Table 1).

Table 1. Decision matrix

Countries	X_1	X_2	X_3	X_4
Spain	2,923	27.4	5.89	28,370.4
Romania	2,355	29.80	2.22	12,182.8
Greece	2,249	21.5	9	6,741.2
Poland	2,181	24	7.66	15,036.2
Italy	1,834	24.5	5.3	5,770.9
Hungary	1,192	25	6.39	14,483.0
Germany	996	34.1	6.22	26,943.6
Bulgaria	823	11.9	4.49	12,738.1
Czech Republic	715	6.1	8.35	972.8
Portugal	710	11.5	6.57	10,999.3
Austria	480	4.5	11	1,465.2
Croatia	461	8.3	8.21	681.4
Lithuania	230	6	6.66	2,258.8
Slovenia	213	2.4	12.05	1,169.0
Denmark	126	2.4	7	2,756.9
Latvia	105	2.3	5	560.3
Netherlands	90	0.7	12.27	4,997.0
Belgium	75	2.7	14	32,116.5
Finland	78	3.3	16.79	12.1
Estonia	55	1.6	8	17.3
Ireland	27	0.3	20	352.6

Note: X_1= number of hives (1,000 units), X_2= honey production (1,000 tons), X_3= producer price (€/kg), X_4= honey export quantity (tons)
Source: [2, 10].

Determination of criteria weights

In the study, it was assumed that the weights of the four criteria included in the model were equal to each other. Thus, the weight of each criterion was accepted as 1/4 = 0.25.

Normalization of the decision matrix and weighted decision matrix

In the first stage, since the variables represent a benefit condition, the decision matrix is normalised using the formula in Equation 4. (Table 2). Then, each variable in the normalised decision matrix was multiplied by the criteria weights to obtain a weighted decision matrix (Table 3).

The process of ranking the alternatives

In the final stage of the SAW method, the V_i values are obtained using the formula in Equation 5. The highest obtained V_i value is considered the best alternative. When Table 4 is examined, it is seen that Spain, Germany and Poland have the best beekeeping performances among the EU countries. Similarly, in the study conducted by [7], Spain is stated to be the largest honey-producing country in the EU.

Spain ranks first among European Union countries in terms of hive population, with a 15% share [5].In the study conducted by [18], it was stated that 280,000 tons of honey were produced in the EU in 2019, with 76.44% of this amount produced by the largest producer countries: Spain, Romania, Hungary, Germany, Greece, Poland, France, Italy and Bulgaria. After Spain, Romania has a good position as a honey producer in the EU and its honey is of a high quality, this being the reason why it is exported in higher and higher amounts [11, 17].

Table 2. Normalized decision matrix

Countries	X_1	X_2	X_3	X_4
Spain	1.000	0.804	0.295	0.883
Romania	0.806	0.874	0.111	0.379
Greece	0.769	0.630	0.450	0.210
Poland	0.746	0.704	0.383	0.468
Italy	0.627	0.718	0.265	0.180
Hungary	0.408	0.733	0.320	0.451
Germany	0.341	1.000	0.311	0.839
Bulgaria	0.282	0.349	0.225	0.397
Czech Republic	0.245	0.179	0.418	0.030
Portugal	0.243	0.337	0.329	0.342
Austria	0.164	0.132	0.550	0.046
Croatia	0.158	0.243	0.411	0.021
Lithuania	0.079	0.176	0.333	0.070
Slovenia	0.073	0.070	0.603	0.036
Denmark	0.043	0.070	0.350	0.086
Latvia	0.036	0.067	0.250	0.017
Netherlands	0.031	0.021	0.614	0.156
Belgium	0.026	0.079	0.700	1.000
Finland	0.027	0.097	0.840	0.000
Estonia	0.019	0.047	0.400	0.001
Ireland	0.009	0.009	1.000	0.011

Note: X_1= number of hives (1,000 units), X_2= honey production (1,000 tons), X_3= producer price (€/kg), X_4= honey export quantity (tons)
Source: Calculated by the authors.

Table 3. Weighted normalized decision matrix

Countries	X_1	X_2	X_3	X_4
Spain	0.250	0.201	0.074	0.221
Romania	0.201	0.218	0.028	0.095
Greece	0.192	0.158	0.113	0.052
Poland	0.187	0.176	0.096	0.117
Italy	0.157	0.180	0.066	0.045
Hungary	0.102	0.183	0.080	0.113
Germany	0.085	0.250	0.078	0.210
Bulgaria	0.070	0.087	0.056	0.099
Czech Republic	0.061	0.045	0.104	0.008
Portugal	0.061	0.084	0.082	0.086
Austria	0.041	0.033	0.138	0.011
Croatia	0.039	0.061	0.103	0.005
Lithuania	0.020	0.044	0.083	0.018
Slovenia	0.018	0.018	0.151	0.009
Denmark	0.011	0.018	0.088	0.021
Latvia	0.009	0.017	0.063	0.004
Netherlands	0.008	0.005	0.153	0.039
Belgium	0.006	0.020	0.175	0.250
Finland	0.007	0.024	0.210	0.000
Estonia	0.005	0.012	0.100	0.000
Ireland	0.002	0.002	0.250	0.003

Note: X_1= number of hives (1,000 units), X_2= honey production (1,000 tons), X_3= producer price (€/kg), X_4= honey export quantity (tons)
Source: Calculated by the authors.

In the study conducted by Nikolova et al [15], it is stated that the EU is the world's second largest producer of bee products and is recognised as an important role in the world beekeeping market. In the study conducted by Jarka and Trajer [14], it is stated that the beekeeping sector is supported within the framework of the Common Agricultural Policy. In this respect, it is emphasised that Spain, France, Greece, Romania, Italy and

Poland receive the most support from the EU budget.

Table 4. Ranking of V_i values

Countries	V_i	Rank
Spain	0.10554	1
Romania	0.07682	4
Greece	0.07292	5
Poland	0.08146	3
Italy	0.06339	8
Hungary	0.06767	6
Germany	0.08817	2
Bulgaria	0.04431	9
Czech Republic	0.03084	14
Portugal	0.04429	10
Austria	0.03157	13
Croatia	0.02948	15
Lithuania	0.02329	18
Slovenia	0.02769	17
Denmark	0.01945	19
Latvia	0.01313	21
Netherlands	0.02904	16
Belgium	0.06389	7
Finland	0.03410	12
Estonia	0.01651	20
Ireland	0.03643	11

Source: Calculated by the authors.

In the study conducted by Perichon et al [16], it is stated that beekeepers in Southern Europe face economic difficulties due to threats such as climate change and pests, while these same threats have not yet affected the northern countries to the same extent.

CONCLUSIONS

Beekeeping is an important enterprise in the agricultural sector, contributing to economic and ecological sustainability. It also makes important contributions to the development of rural areas. In addition, honeybee species also makes important contributions to human health and nutrition. Honeybee products such as honey, beeswax, royal jelly, pollen, propolis and bee venom are important food products used by humans. Bee products are also used as raw materials in many industries from food to cosmetics. Honeybee colonies play a crucial role in agricultural production through pollination and contribute to biodiversity [13]. The study examined the beekeeping indicators of some European Union countries. The SAW method, one of the multi-criteria decision-making methods, was used in the study. According to the results of the SAW analysis based on the number of hives, honey production, producer price and honey export amount criteria, Spain ranked first in the performance ranking, followed by Germany and Poland.

In European Union countries, beekeeping is an increasingly important production activity in agricultural economy. In addition to providing bee products, bees contribute to the pollination of plants. Therefore, beekeeping should continue to be supported in EU countries. As climate change and global warming affect every area of agriculture, they also impact beekeeping. Therefore, necessary precautions should be taken to prevent bees from being affected by climate change and global warming. Maximum care should be taken to prevent bees from being affected by pesticides.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC ANALYSIS OF GREENHOUSE TOMATO PRODUCTION UNDER AGROECOLOGICAL AND CONVENTIONAL CONDITIONS: THE CASE OF ANTALYA PROVINCE, TÜRKIYE

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Abstract

This study aimed to compare the economic aspects of greenhouse tomato production under agroecological and conventional conditions in Antalya province, which ranks first in tomato production in Türkiye. The main material of this study was collected from questionnaires compiled by face-to-face interviews with 80 producers following either agroecological or conventional management for tomato production under greenhouse conditions. According to the results of the research, the average farm size was 3.97 ha, with 2.68 ha devoted to tomato production area on 5.8 parcels in agroecological farms and 1.55 ha, 1.11 ha and 4.49 parcels in conventional farms, respectively. Total production costs per hectare resulted 68,840.80€ in agroecological farms and 59,744.67€ in conventional ones. Gross production value per hectare was 139,625.34€ in agroecological production and 87,707.84€ in conventional one. Net profit was 70,784.55 €/ha and 27,963.17 €/ha for agroecological and conventional production, respectively. Profit margin resulted 0.34 and 0.18 €/kg in agroecological and conventional production, respectively. The ratio of profit margin to sales price was 50% in agroecological production and 31.83% in conventional one. In terms of profitability indicators, agroecological production was found to be more advantageous than conventional one due to a higher production value resulting from higher yield and tomato selling price.

Key words: *tomato, agroecological practices, factors that motivate for agroecological production, production cost, profit margin*

INTRODUCTION

Tomatoes are among the most important vegetables at the world level being cultivated on 4.98 million ha and registering a production of 182 million tons, representing 16.28% of the global production of vegetables in the period 2016-2021 [10].
Türkiye has a good potential for producing tomatoes looking for more efficient growing systems like in geothermal houses [14].
During the last decade there has been a growing sensibility in the consumers about the undesired effects that the conventional management of agricultural production has on the environment and on human health. This is partly due to the increasing quantities of synthetic inputs (fertilizers, pesticides) required to achieve satisfactory levels of yield to cope with the depletion of the soil and with invasive and native pests, the latter made more aggressive by climatic change. Hence, in economically important crops, including tomato, there has been a demand for alternative management approaches more respectful for the environment and human health. In this context, the agroecological approach seemed to be a valid alternative to conventional one being based on the exploitation of functional biodiversity (above and belowground) regulating the ecosystem services (plant nutrition, protection and pollination).
The exploitation of plant diversity and biocontrol agents aboveground together with soil symbionts belowground leads to a progressive reduction of synthetic inputs needed to feed and protect the agricultural production. However, before proposing this

approach to conventional farmers, a scrupolous analysis of costs and benefits of the agroecological management must be carried out. Due to the increase of population in Türkiye and in the world and the division of agricultural land, it is advisable to exploit all available small agricultural areas. Protected agriculture is one of the leading methods to obtain higher yields from unit area. It also guarantees a constant availability of vegetables, which are a basic element of human health and nutrition [19]. According to 2022 data, world tomato production is approximately 186 million tons and Türkiye ranks third after China and India with a production of 13 million tons [6]. In Türkiye, according to 2023 data, a total of 70,000 hectares are cultivated in greenhouses of which 57.95% is represented by plastic greenhouses, 18.89% by low tunnels, 13.45% by high tunnels and 9.71% by glass greenhouses. Tomato ranks first among the vegetable species produced under greenhouses and 4.71 million tons of tomatoes were produced under greenhouses in 2023 of which 62% come from Antalya province [17].

The aim of this study was to compare the economic aspects of greenhouse tomato production following an agroecological or conventional management in Antalya province, which ranks first in tomato production in Türkiye. The agroecological and conventional production systems were compared in terms of general characteristics of farmers (age, education, experience, cooperative membership, record keeping and credit utilization), land assets of the farms, crops grown, tomato varieties grown, planting periods, production costs and profitability indicators including gross profit, net profit and relative return. In addition, we recorded which agroecological practices were adopted by the farmers, the reasons to follow the agroecological management, the institutions and organizations encouraging agroecological practice and the possible problems experienced. We expect that the results of this study will provide useful information to researchers and investors who are considering to move to an agroecological approach for tomato production and to other relevant institutions and organizations.

MATERIALS AND METHODS

Data were collected by face-to-face interviews to tomato farmers following either agroecological or conventional production in greenhouses in Antalya province to fill in a questionnaire elaborated after a preliminary survey/test. We also used data collected by previous study in the same province. The survey data referred to the production of 2022. The list of producers following an agroecological approach for tomato cultivation was obtained by contacting the officials of Antalya Provincial Directorate of Agriculture and Forestry. According to this list, Aksu, Kumluca, Serik, Demre, Kas and Manavgat districts were selected for the study. A total of 80 producers, 35 producers agroecological and 45 conventional, were interviewed. The data collected from the producers by questionnaire method were elaborated by Microsoft Excel and SPSS programs. General Linear Model (GLM) approach was used to determine the significance levels of variables between agroecological and conventional production systems. Significance levels of $p<0.01$ and $p<0.05$ were selected.

The questionnaire included questions on general information such as age, education, experience, population, cooperative membership, credit use, general information about the farm such as total land assets, crops grown, agroecological and conventional greenhouses and tools and machinery, inputs used in agroecological and conventional tomato production (seedlings, labor, fertilizer, pesticides, electricity, water, bumblebees, etc.), tomato yield, and economic activities such as sales price. The questionnaire also included questions on which agroecological practices the producers who adopted the agroecological production system adopted, the factors motivating agroecological practice, institutions and organizations encouraging agroecological practice, and the problems encountered in cultivation.

In order to calculate the total production costs, we considered both variable and fixed costs.

Variable costs change depending on the scale of production and occur as production is carried out. Fixed costs, on the other hand, are costs that do not depend on the scale of production and always occur regardless of production [9, 16]. Variable costs include: seedlings, fertilizers, chemical pesticides, bumblebees (if used), heating, water, electricity, temporary labor, rope, cocopeat, shade dust, insects, insurance, certificates, packaging, oil and fuel, repair and maintenance of tools and machinery, and interest on revolving funds. Fixed costs include: general administrative expenses, permanent labor, land rent, greenhouse repair and maintenance, greenhouse capital depreciation, greenhouse capital interest, greenhouse capital interest, tool-machine depreciation, and tool-machine capital interest.

Of the total variable costs 3% are considered general administrative expenses. Interest on revolving capital is a variable cost and constitutes the opportunity cost of capital invested in the production activity. Interest on revolving capital was calculated by applying half of the interest rate (1.70% for agroecological production and 2.125% for conventional production) applied by the Turkish Republic Agricultural Bank to the changing costs.

Land rent was calculated by taking 5% of the bare land value.

Interest on greenhouse and tool-machine capital was calculated by applying 5% real interest to the total greenhouse and tool-machine half-value [11]. For the depreciation share of greenhouse and machinery capital, the depreciation rate was 5% [15].

Gross production value, gross profit, net profit and relative return indicators were calculated to find the profitability levels of agroecological and conventional tomato production. Gross production value was calculated by including subsidies in the tomato sales income resulting from multiplying tomato yield by sales price. Gross profit was calculated by subtracting variable costs from the gross production value, net profit by subtracting total production costs, and relative return by the ratio of gross production value to total production costs [16].

RESULTS AND DISCUSSIONS

The information about agroecological and conventional farmers is given in Table 1. All agroecological producers were male, their average age was 46 years, education level was 11 years, experience was about 9 years and family composition was 3.31 people. It was determined that 5.71% of the agroecological producers were members of an agricultural cooperative, 60% of them received training on tomato cultivation, 97.14% of them were included in the farmer registration system and 71.43% of them kept records. It resulted that 17.14% of agroecological producers used agricultural credit and 22.86% of them were engaged in a non-agricultural business. The proportions of producers who watched agricultural programs, read agricultural magazines, newspapers and brochures and used the internet were 22.86%, 17.14% and 91.43%, respectively. When the conventional producers were analyzed, it was determined that their gender, age, education level and population were similar to the producers engaged in agroecological production. However, the duration of experience in tomato cultivation resulted higher in conventional production. This was expected because agroecological approach is a relatively recent management system compared to conventional production. The proportion of producers who received training on tomato cultivation and kept records was found to be higher in agroecological production. This shows that producers engaged in agroecological production are more conscious and professional. The rate of agricultural credit utilization was found to be higher in conventional producers than in agroecological producers due to their smaller farm sizes that render them economically weaker. The rate of following agricultural programs was found to be higher in conventional producers. The rate of producers who read agricultural magazines, newspapers and brochures was low in both production systems. Conversely, the rate of internet use was found to be high regardless the type of management.

Table 1. General characteristics of producers.

Characteristics	Production system	
	Agroecological	Conventional
Male (%)	100.00	100.00
Age (year)	46.00	44.87
Education (year)	11.09	9.80
Experience in tomato production (year)	8.66	18.33
Population (person / family)	3.31	3.67
Membership of cooperative (%)	5.71	33.33
Tomato cultivation training (%)	60.00	26.67
Involvement in farmer registration system (%)	97.14	97.78
Proportion of producers keeping records (%)	71.43	51.11
Proportion of producers using agricultural credit (%)	17.14	48.89
Proportion of producers engaged in a non-agricultural business (%)	22.86	15.56
Proportion of producers following agricultural programs (%)	22.86	42.22
Proportion of producers reading agricultural magazines, newspapers and brochures (%)	17.14	11.11
Proportion of producers using the Internet (%)	91.43	86.67

Source: Own calculation.

Table 2. Land presence of farms.

	Production system		P value
	Agroecological	Conventional	
Total land size (ha/farm)	3.97	1.55	0.011*
Tomato land size (ha/farm)	2.68	1.11	0.024**
Property land (ha/farm)	3.88	1.51	0.019**
Rent land (ha/farm))	0.09	0.04	0.152
Irrigated land (ha/farm))	3.97	1.55	0.011*
Number of parcel (parcel/farm)	5.8	4.49	0.918

Source: Own calculation. *: $p<0.01$, **: $p<0.05$

Table 3. Plants grown in farms.

Plants	Production system			
	Agroecological		Conventional	
	ha/farm	%*	ha/farm	%*
Tomato	2.68	67.48	1.11	71.57
Pepper	0.78	19.72	0.07	4.58
Aubergine	0.05	1.15	0.01	0.43
Cucumber	0.10	2.58	-	0.00
Citrus	0.07	1.87	0.20	12.89
Olive	-	-	0.02	1.43
Other	0.29	7.19	0.14	9.09
Total	3.97	100.00	1.55	100.00

Source: Own calculation. *percentages are higher than 100 because of multiple choice

The land features of the farms are given in Table 2. It was calculated that the total amount of land per farm, tomato production area and number of parcels were higher in agroecological farms than in conventional ones.

In detail, the total extension of farm was 3.97 ha, of which tomato production area was 2.68 ha over 5.8 parcel units in agroecological farms, and 1.55 ha, 1.11 ha and 4.49 parcel units in conventional farms, respectively. In both production systems, tomato was irrigated and most farmers were also owners of the land. The production features in the farms are given in Table 3. Vegetables constitute the majority of plants in the farms with tomato ranking first among vegetables. The share of tomato cultivation land in total cultivated land was 67.48% in agroecological farms and 71.57% in conventional ones. The other vegetables grown in the farms were aubergine, pepper and cucumber.

Table 4. Varieties of tomato grown in farms

Tomato varieties	Production system			
	Agroecological		Conventional	
	(n)	%*	(n)	%*
Truss tomato	14	40.00	11	24.44
Big red tomato	14	40.00	30	66.67
Big pink tomato	6	17.14	6	13.33
Cherry tomato	3	8.57	10	22.22
Cocktail tomato	3	8.57	-	-
Single tomato	3	8.57	5	11.11
Elips	1	2.86	-	-

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 5. Tomato planting periods in farms

	Production system			
	Agroecological		Conventional	
Production periods	(n)	%	(n)	%
Single planting per year	24	68.57	32	71.11
Two plantings per year	11	31.43	13	28.89
Total	35	100.00	45	100.00
Single planting periods				
September -June	22	91.67	32	100.00
April-November	2	8.33	-	-
Two planting periods				
Autumn period				
August-January	11	100.00	13	100.00
Spring period				
February-June	11	100.00	13	100.00

Source: Own calculation.

The tomato varieties grown in the farms are reported in Table 4. The most common tomato varieties grown in agroecological farms were Truss (40%) and Big Red (40%), while Big Red (66.67%), Truss (24.44%) and Cherry (22.22%) were grown in conventional farms.

Tomato planting periods are given in Table 5. It was determined that the majority of the agroecological and conventional farms planted run only one tomato crop per year. The proportion of the farms practicing single planting in a year was found to be 68.57% in agroecological production and 71.11% in conventional production. It was determined that the single planting period mainly occurs during September-June period.

The proportion of farms planting tomato twice/year was found to be 31.43% in agroecological production and 28.89% in conventional one. The two planting periods were August-January (autumn cycle) and February-June (spring cycle).

The production costs elements are given in Table 6. The average production costs were higher in agroecological farms than in conventional farms ($p<0.01$). Total production costs per hectare were 68 840.80€ in agroecological farms and 59 744.67€ in conventional ones. In agroecological and conventional farms, fixed costs constituted a large portion of total production costs. The share of fixed costs in total production costs was 64.92% in agroecological production and 63.85% in conventional one. The share of variable costs was 35.08% and 36.15% in agroecological and conventional production, respectively. The most important fixed cost items were permanent labor, land rent and depreciation. Seedling, fertilizer, pesticide and heating costs constituted the highest share among the variable cost items.

Profitability indicators in the analyzed farms are given in Table 7. The gross production value per hectare was higher in agroecological farms than in conventional farms ($p<0.01$). The gross production value per hectare was found to be 139,625.34€ in agroecological production and 87,707.84€ in conventional one. The higher gross production value in agroecological production was due to the

higher yield per hectare and the higher sale price of tomatoes. Gross profit is an important criterion that measures the success of the production branches in the farm and is used in the short-term planning of agricultural farms. It was determined that gross profit was higher in agroecological production (115,478.41 €/ha) than in conventional one (66,112.85 €/ha) ($p<0.01$). However, net profit represents a more precise value. While fixed costs are included in gross profit, both variable and fixed costs are subtracted from net profit. In terms of net profit, agroecological farms resulted more advantageous than conventional farms with values of 70,784.55 €/ha and 27,963.17 €/ha respectively ($p<0.01$).

Table 6. Production costs in farms

Cost items	Production system				P value
	Agroecological		Conventional		
	(€/ha)	%	(€/ha)	%	
Seedling	4,634.73	6.73	4,435.05	7.42	0.341
Fertilizer	7,627.00	11.08	6,188.38	10.36	0.124
Pesticide	3,156.64	4.59	3,301.05	5.53	0.043**
Bumble bee	235.72	0.34	228.53	0.38	0.573
Heating	3,715.14	5.40	1,665.05	2.79	0.000*
Water	8.86	0.01	109.31	0.18	0.046**
Electricity	857.06	1.24	547.33	0.92	0.139
Temporary labour	113.63	0.17	2,413.05	4.04	0.000*
Rope	403.09	0.59	167.99	0.28	0.388
Cocopeat	42.36	0.06	0.00	0.00	0.002*
Shadow powder	184.85	0.27	105.59	0.18	0.184
Beneficial insects (natural enemies)	49.26	0.07	-	-	0.250
Insurance	774.12	1.12	540.87	0.91	0.546
Certification	162.10	0.24	-	-	-
Packaging	933.32	1.36	-	-	-
Fuel	654.72	0.95	1,078.56	1.81	0.001*
Machinery repair and maintenance	190.70	0.28	364.90	0.61	0.010*
Revolving fund interest	403.64	0.59	449.35	0.75	0.004*
Total variable costs (A)	24,146.93	35.08	21,594.99	36.15	0.950
Administrative costs (A*0.03)	724.41	1.05	647.85	1.08	0.950
Permanent labour	13,603.20	19.76	7,003.12	11.72	0.001*
Land rent	11,592.78	16.84	14,335.89	24.00	0.013*
Greenhouse repair maintenance	1,257.31	1.83	1,779.87	2.98	0.010*
Greenhouse depreciation	8,891.63	12.92	5,162.84	8.64	0.139
Greenhouse interest	4,445.81	6.46	2,868.77	4.80	0.895
Machinery depreciation	3,561.26	5.17	4,697.78	7.86	0.049**
Machinery interest	617.47	0.90	1 653.56	2.77	0.000*
Total fixed costs (B)	44,693.86	64.92	38,149.68	63.85	0.048**
Total production costs (A+B)	68,840.80	100.00	59,744.67	100.00	0.009*

Source: Own calculation. *: $p<0.01$, **: $p<0.05$

Relative return shows the income obtained for one unit of cost. It helps producers to choose the production branches in which they will utilize their resources in the best way. When the interviewed farms were compared in terms of relative return, it resulted that agroecological farms were more profitable. Relative return was calculated as 2.03 in agroecological production and 1.47 in conventional one due to higher gross production value obtained with higher yield and tomato sales price.

The profit margin of 1 kg of tomato produced and the ratio of profit margin to sales price in farms are given in Table 8. The profit margin per kilogram was found by subtracting the production costs of 1 kg tomato from the price of 1 kg tomato. The ratio of the profit margin to the selling price was used to determine how much of 1 kg of tomato did cost and how much produced as profit. By comparing the profit margin referred to 1 kg tomato, the value resulted significantly higher in agroecological

production (0.34 €/kg) than in conventional one (0.18 €/kg) ($p<0.01$).

The ratio of profit margin to sales price was higher in agroecological production (50%) that in conventional one (31.83%).

Table 7. Gross profit, net profit and relative return in farms

	Production system		P value
	Agroecological	Conventional	
Yield (ton/ha)	203.86	154.56	0.000*
Sale price (€/ton)	683.91	567.05	0.021**
Tomato sales revenue (€/ha)	139,419.54	87,640.70	0.000*
Agricultural supports (€/ha)	205.80	67.14	0.000*
Gross product value (€/ha)	139,625.34	87,707.84	0.000*
Variable costs (€/ha)	24,146.93	21,594.99	0.950
Production costs (€/ha)	68,840.80	59,744.67	0.009*
Gross profit (€/ha)	115,478.41	66,112.85	0.000*
Net profit (€/ha)	70,784.55	27,963.17	0.009*
Relative return	2.03	1.47	0.182

Source: Own calculation. *: $p<0.01$, **: $p<0.05$

Table 8. Profit margin for 1 kg tomato in farms

	Production system		P value
	Agroecological	Conventional	
Production costs (€/ha)	68 840.80	59 744.67	0.009*
Yield (kg/ha)	203 857.14	154 555.56	0.000*
Production costs (€/kg)	0.34	0.39	0.746
Sale price (€/kg)	0.68	0.57	0.021**
Profit margin (€/kg)	0.34	0.18	0.018**
Share of profit margin in sales price (%)	50.00	31.83	0.168

Source: Own calculation. *: $p<0.01$, **: $p<0.05$

There have been many studies on the socio-economic impact of agroecology. Altieri suggested that natural resource management strategies should target poor farmers not only to increase production and conserve natural resources, but also to create employment and provide access to local inputs and output markets. Their study emphasized that researchers and rural development practitioners should apply general ecological principles and natural resource management strategies to the conditions and needs of smallholder farmers and they noted that governments and public international organizations should encourage and support effective collaboration between civil society organizations, local universities and farmers' organizations to empower and help poor farmers achieve food security, income generation and conservation of natural resources [1].

Research showed that agroecology enhances financial, human and social capital that contribute to sustainable livelihoods at the farmer level and adopting agroecological practices increased yield and profitability compared to traditional practices [2, 3, 4].

Our results are in accordance with what reported by Muhammed et al., who conducted a study on Mediterranean organic greenhouse production and reported that rational combination of agroecological practices (short-cycle agroecological service products, farmyard manure or compost-based fertilization regimes, crop residue recycling) within a crop rotation program resulted in agronomic benefits while maintaining profitability [12].

Agroecology could be the basis for the future transformation of European agricultural policies, as it not only enables healthier food to be produced in a more sustainable way, but also significantly increases farmers' incomes.

Likewise, agroecology holds the promise of re-expanding productive agricultural employment and increasing the total income generated by the agricultural sector at both regional and national levels [18].

The report published by Grémillet and Fosse, reviewed the scientific literature and analyzed the framework of twenty-three references on agroecology. In particular, the study emphasized that organic agriculture is the best economically and environmentally option for today [8].

Agroecological approaches can be also a suitable solution for resource-poor farmers, especially on marginal lands that are less profitable for agricultural activities. The farmers who adopt this system have better social relations at the community level, which can expand farmers' influence on institutions and contribute to better solutions to complex problems such as poverty and food security [5].

When considering the effect of agro-ecology, environmental impact of it should also be considered. Fiore et al. reviewed studies on the socio-economic impacts of agroecology. They highlighted a significant gap in addressing climate change issues, methodologically, the prevalence of qualitative approaches and the need for a shift towards bottom-up, participatory research methods. Studies on food security and food sovereignty reveal the potential of agroecology, but more research is needed in socio-economic contexts [7].

In agreement with our results, a recent research showed that the socio-economic impacts of agroecological practices are mostly positive (51% positive, 30% negative, 10% neutral and 9% uncertain outcomes) [13].

Tomato sales places of the farms are given in Table 9. It was determined that the majority of agroecological and conventional production farms sell to wholesales market. In addition to the wholesale markets, agroecological farms also sell to exporters and organic markets.

Table 9. Tomato sale places of farms

Sale Places	Production system			
	Agroecological		Conventional	
	(n)	%*	(n)	%*
Merchant	-	-	2	4.44
Wholesales market	24	68.57	45	100.00
Exporter	10	28.57	-	-
Organic market	4	11.43	-	-

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 10. Agricultural supports for tomato production

Agricultural supports	Support amount
Organic agriculture support (€/ha)	57.47
Diesel support (€/ha)	9.77
Chemical fertilizer support (€/ha)	0.56
Soil analysis support (€/ha)	3.33
Good agricultural practices support (€/ha)	2.78
Agricultural products insurance support (%)	50.00
Bumble bee (€/colony)	0.16
Biological control support (€/ha)	7.41
Biotechnical control support (€/ha)	2.22
Small family farm support (€/ha)	3.71

Source: Own calculation.

In Türkiye, some supports are provided by the Ministry of Agriculture and Forestry to tomato production. These supports are for organic farming, diesel oil, chemical fertilizer, soil

analysis, good agricultural practices, agricultural insurance pool (TARSİM), bumblebee, biological control, biotechnical control and small family farm supports (Table 10). It was determined that agroecological production farms benefited more from the supports (Table 11), and that producers engaged in agroecological production follow the supports better and meet the criteria for receiving support better.

Table 11. Agricultural supports received by producers for tomato production

	Production system			
	Agroecological		Conventional	
Agricultural supports	(n)	%*	(n)	%*
Organic agriculture support	4	11.43	-	-
Diesel support	28	80.00	13	28.89
Chemical fertilizer support	26	74.29	8	17.78
Soil analysis support	3	8.57	-	-
Good agricultural practices support	27	77.14	-	-
Agricultural products insurance support	35	100.00	26	57.78
Bumble bee	35	100.00	40	88.89
Biological control support	4	11.43	-	-
Biotechnical control support	3	8.57	-	-
Small family farm support	1	2.86	-	-

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 12. Agroecological practices of farms

Agroecological practices	(n)	%*
Reducing pesticide use	18	51.43
Biological and biotechnical control	5	14.29
Bumble bee use	35	100.00
Good agricultural practices	27	77.14
Organic agriculture	4	11.43
Organic and green fertilizers use	3	8.57
Remote monitoring and management system	1	2.86
Drip irrigation application	35	100.00

Source: Own calculation. *percentages are higher than 100 because of multiple choice

The different agroecological practices followed in the agroecological management by farms are given in Table 12. The most common were the use of bumblebees (100%), the drip irrigation (100%), the good agricultural practices (44.14%) and the reduction of pesticide use (51.43%). On the other hand, it was found that the proportion of farms implementing agroecological practices such as biological and biotechnological control, organic farming, organic and green fertilizer use, and remote monitoring and management system was lower.

The factors motivating the agroecological production in farms are given in Table 13. The main factor motivating the choice is the easier marketing (77.14%) followed by agroecological products being healthier (40%), sensitivity to the environment (40%), higher profitable plants (40%), higher demand for agroecological products (37.14%), support received (5.71%) and being an effective method in combating pests (2.86%).

The institutions, organizations or individuals who were helpful in the producers' initiation of tomato cultivation are given in Table 14. In starting tomato cultivation, agroecological farmers stated they were effectively helped by the Provincial Directorate of Agriculture and Forestry (31.43%), their own family (28.57%), agricultural fertilizer, pesticide and seed dealers (20%), and other producers (20%). As for conventional farming the family played a key role (66.67%) followed by other producers (48.89%).

The main problems encountered by the producers in tomato cultivation are given in Table 15. For Agoecological producers they were: insufficient support (42.86%), diseases and pests (40%) and high costs (25.71%). Conversely, diseases and pests (82.22%), high costs (37.78%), instability in prices (31.11%) and insufficient support (20%) were the most important problems encountered by conventional producers.

The institutions, organizations or individuals to whom the producers applied for the solution of the problems encountered in tomato cultivation are given in Table 16. Producers engaged in agroecological production mostly applied to pesticide, fertilizer and seed dealers and Provincial Directorate of Agriculture and Forestry for the solution of the problems encountered in cultivation.

Table 13. Factors that motivate producers for agroecological production

Motivation factors	(n)	%*
Having healthy products	14	40.00
Environmental awareness	14	40.00
High demand for products	13	37.14
Having profitable products	14	40.00
Marketing is easy	27	77.14
To get support	2	5.71
Being the most effective method in control pests	1	2.86

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 14. Institutions/organizations or individuals that are helpful to start tomato cultivation

	Production system			
	Agroecological		Conventional	
	(n)	%*	(n)	%*
Provincial Directorate of Agriculture and Forestry	11	31.43	1	2.22
Agricultural pesticide, fertilizer and seed dealer	7	20.00	2	4.44
Other farmer	7	20.00	22	48.89
Internet	1	2.86	1	2.22
Agricultural fairs	3	8.57	-	-
Family	10	28.57	30	66.67
Itself	1	2.86	3	6.67

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 15. Problems of producers regarding tomato cultivation

	Production system			
	Agroecological		Conventional	
	(n)	%*	(n)	%*
Diseases and pests	14	40.00	37	82.22
High costs	9	25.71	17	37.78
Low yield	-	-	2	4.44
Difficulties in labour supply	1	2.86	3	6.67
Price instability	5	14.29	14	31.11
Marketing difficulties	3	8.57	2	4.44
Low demand	1	2.86	-	-
Embargoes on exports	2	5.71	-	-
Insufficiency of supports	15	42.86	9	20.00
No problem	5	14.29	1	2.22

Source: Own calculation. *percentages are higher than 100 because of multiple choice

Table 16. People or institutions that producers turn to solve problems

	Production system			
	Agroecological		Conventional	
		%*	(n)	%*
Provincial Directorate of Agriculture and Forestry	14	40.00	12	26.67
Agricultural pesticide, fertilizer and seed dealer	23	65.71	43	95.56
Other farmer	3	8.57	10	22.22
Agricultural cooperatives or producer associations	-	-	1	2.22
Certification firm	1	2.86	-	-

Source: Own calculation. *percentages are higher than 100 because of multiple choice

The shares of pesticide, fertilizer and seed dealers and Provincial Directorate of Agriculture and Forestry were found to be 65.71% and 40 7%. In conventional production, the institutions, organizations or individuals that producers applied for the solution of problems related to cultivation were determined as pesticide, fertilizer and seed dealers (95.56%), Provincial Directorate of Agriculture and Forestry (26.67%) and other producers (22.22%), respectively.

CONCLUSIONS

Our results, which are in line with previous ones, demonstrated the profitability of the agroecological approach in respect to the conventional one for the management of tomato crop under greenhouse conditions. The economic parameters were analyzed are all in favour of the agroecological production due to higher yield and higher selling price. To this, add the benefits for the environment and the human health. The reduced application of synthetic inputs characterizing the agroecological approach results in a fruitful protection of biodiversity above and belowground whose exploitation leads to better plant protection, nutrition and pollination. Nonetheless, if not supported by economic benefits, the agroecological approach would be rarely followed by farmers. In this context, we believe that our study contributed to demonstrate the feasibility of this modern concept of agriculture, more respectful of the environment and less dependent by synthetic inputs.

ACKNOWLEDGEMENTS

This research was funded by financial support of the project “Agroecology-inspired strategies and tools to enhance resilience and ecosystem services in tomato crop, ASTER”, Prima Section 2 2021-Multi-Topic, by grant 122N050 from The Scientific and Technological Research Council of Turkey (TUBITAK). This study was derived from the part of the project.
The authors thank to the Scientific and Technological Research Council of Turkey (TUBITAK) for financial support, Managers and Technical staff of Antalya Directorate of Provincial Agriculture and Forestry for providing communication with tomato producers and producers who participated in the survey.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ASSESSING THE ECONOMIC AND SOCIAL EVOLUTION OF TOURISM IN ROMANIA: NAVIGATING POST-COVID CHALLENGES

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Abstract

This study intends to evaluate the evolution and current state of Romania's tourism sector, with a particular focus on the effects generated by the COVID-19 pandemic and the strategic directions pursued in the post-pandemic context. The analysis highlights the main structural transformations within the tourism market, shifts in tourist behaviour, and the necessary adaptations of the sector to both the challenges of the pandemic period and the requirements of the recovery phase. The analysis relied on both quantitative and qualitative data. Statistical indicators on tourism dynamics, structure, and trends were drawn from the National Institute of Statistics' database and the White Card of Tourism in Romania, 2024 edition. Key metrics such as bed capacity, tourist arrivals, overnight stays, and occupancy rates were compared for 2019 and 2023 across regions and types of accommodation. Additionally, data from a survey of 705 tourism operators captured perspectives on income evolution, risk factors, financing, human resources, and digital sales channels. This mixed-method approach enabled a comprehensive assessment of how Romania's tourism sector has evolved and adapted in the post-COVID context. Among the main results of the study, we note the following: domestic tourism has developed due to Romanians' growing preference for local destinations amid the uncertainties associated with international travel; an increased preference for online booking platforms; and a greater demand for personalized travel, with tourists prioritizing safety and health measures. The results highlight the strength of the Romanian tourism sector, which, despite challenges, has a substantial potential for growth, particularly through innovative digital technologies and sustainable practices. Furthermore, the study suggests that ongoing adaptation to evolving consumer preferences and the development of local tourism infrastructure will be essential for sustaining this growth.

Key words**:** *tourism, COVID-19 pandemic, market response*

INTRODUCTION

The outbreak of the COVID-19 pandemic in 2020 severely disrupted the tourism sector, causing widespread temporary closures of tourist destinations, the suspension of travel plans, and a notable decline in student mobility and arrivals.

The COVID-19 pandemic had, in Romania, a multifaceted impact, but its primary consequence was a dramatic decline in the influx of tourists, particularly those from abroad [8]. Underlying this inclination, they have undergone a sequence of structural modifications, complemented by other elements that influence the current tourism landscape. These include a notable decline in the demand for "coach" tourism, favouring individual or small group tours; an increase in the proportion of last-minute bookings; a rise in black tourism, where a green certificate is no longer necessary due to vaccination requirements; and changes in the countries of origin of foreign tourists. Both the county-level and tourist destination-level analyses demonstrate distinct impacts on the tourism market. Also, the types of tourism that were generally based on indoor activities, such as business or spa tourism, were directly affected. Additionally, we observed significant alterations in the tourist offerings in certain mountainous regions, as a result of a shift in tourist demographics from foreigners to Romanians.

The National Institute of Statistics (INS) indicates that the COVID-19 epidemic has had

a substantial effect on the service industry, encompassing tourism, hospitality, transportation, and entertainment [7, 10]. Because of the closure of hotels, restaurants, events, and travel restrictions, demand has decreased, resulting in job losses. Border closures, travel restrictions, and health concerns have had a profound impact on the tourism sector, resulting in a substantial decline in travellers and cancellations. The hotel, airline, restaurant, and tourism agency sectors have all incurred substantial financial losses.

Romania, as noted by Ștefanovici and Mazilu (2021) [17], promptly confronted the COVID-19 situation, demonstrating a keen awareness of the hazards and accompanying social and economic consequences. The country prioritized prompt interventions to preserve lives and reduce fatalities, implementing guidelines devised by experts in infectious illnesses and epidemiological studies. The government and central bank enacted procedures to ascertain the fundamental characteristics of the shock. The epidemic has compelled Romanian tourism to transform, as an increasing number of restaurants have made investments in terraces, travel agencies have transitioned to online platforms, and hotels have adopted online booking technologies. Improved or newly developed digital applications have also started to appear, highlighting the importance of prompt and effective responses to the challenges posed by the COVID-19 crisis. In order to reduce the adverse effects generated by the pandemic, efforts have been made to support the sector tourists. In this sense, the Government's Emergency Ordinance no. 224/2020 introduced the sup-port financial for tourism businesses [6]. To these were added state aid/minimis schemes, grants, support for investments etc. [13].

A study conducted by Gabor et al. (2020) [5] examined the conduct of Romanian tourists during the Covid-19 pandemic. One undeniable reality is that the outbreak of the new virus has significantly influenced the focus of Romanian tourists on the local market. With the increasing closure of borders and implementation of restrictions, there was a redistribution of travel towards local locations, resulting in a decrease in tourism to foreign places. Romanians have maintained their enthusiasm for travel and have instead chosen to spend their holidays within the country, in familiar locations such as family guesthouses, small hotels, or remote areas, flats, and vacation villas. The orientation of tourists towards the domestic market was also stimulated by the holiday vouchers provided by the government [16].

Concerning the influence of the epidemic on the development of tourism, numerous research have demonstrated that: tourism in the mountain regions was mostly un-affected by the epidemic due to their remote location [4]; in the more isolated mountain localities, tourist offers managed efficiently by the locals have also led to an in-crease in tourist traffic, especially after the second half of 2020 [1]; although some of the units were closed or worked at reduced capacity, the orientation of the Romanians towards domestic tourism within the limits of the restrictions allowed many accommodation units to be saved [15]; The offer's diversification, personalized packages, bonuses, price flexibility, personal safety assurance, and intensified virtual promotion attracted customers in 2021 and 2022 [14]; there is an orientation of tourists towards micro-vacations, on short distances, throughout the year, as well as a higher orientation towards rural tourism [11]; during 2020-2022 period tourism facilitated the expansion of rural areas due to their tranquil landscapes, customized packages, incentives, and adaptable pricing [12].

Studies related to the consequences of the pandemic on the tourism sector have focused, either on analyses at the country level, at the regional level, or the level of case studies. At the national level, studies have examined the pandemic's impact on tourism demand, stakeholders' perceptions, tourism flows, and conducted comparative analyses between domestic and international tourism. Regionally, the research focused on NUTS 2 territorial units, major geographical areas, and specific tourist destinations such as mountain resorts, spa towns, or deltaic zones. Cehan and Iaţu (2024) emphasize the existence of

significant regional disparities in both the pandemic and post-pandemic periods, shaped by the distinct characteristics of each area (regions, counties and destinations) and reorder the expansion of research to highlight the factors that contribute to the resilience of economic agents in tourism [2].

In this context, the present paper wants to underline, starting from quantitative and qualitative data, which are the elements that contribute to the development of post-pandemic tourism.

The purpose of this research is to advance the existing literature by examining how the tourism industry has been affected by the COVID-19 pandemic, with a focus on structural and behavioural transformations. It will analyse various geographical levels and focus on the territory of Romania in 2019 and 2023. Furthermore, we will provide the perspectives of stakeholders on crucial metrics in a comparative analysis, both before and after the epidemic.

MATERIALS AND METHODS

The study approach of this paper was grounded on data analysis of dynamics, structure, and trends. This study involved thoroughly examining current literature and analysing indicators sourced from the Tempo database of the National Institute of Statistics (INS) [9] and the White Card of Tourism in Romania, 2024 edition [3]. Both sources present statistical data for the designated years 2019 and 2023.

In the first part, we used indicators provided by Tempo Online. The National Tourism Statistics (INS) offers comprehensive information on key performance indicators of the tourism industry. The evolution is categorized according to geographic regions and the specific form of lodging. Our study allows us to evaluate tourism growth in the years preceding and following the pandemic (2019 and 2023) by presenting the market's structure and dynamics. To precisely assess the true magnitude of the tourism market, we performed an analysis utilizing statistical indicators provided by INS like bed capacity, tourist volume, overnight accommodation, and occupancy rate.

In the second phase of the study, we employed the tourist barometer created in 2024 by the „Government of Romania's National Council of Small and Medium Private Enterprises" and "Groupama Insurance" in partnership with the "Ministry of Economy, Entrepreneurship and Tourism". This report functions as the sole collection of data acquired from industry participants. The report presents research findings from an extensive sample of 705 individuals (210 travel companies and 495 accommodation businesses) and analyses both large and small enterprises engaged in Romania's tourism sector. This study's sample includes all Romanian growth zones and a range of experience levels. We gathered the following indicators for the report: the factors that positively influence tourism; income from tourism; average overnight stays; the number of tourists; the support received from public institutions; financing methods; promotion channels; The main digital sales channel; the average salary in tourism; human resources (evolution, benefits); risk classification and risk management.

RESULTS AND DISCUSSIONS

Quantitative assessment of the tourism sector's dynamics: 2023 versus 2019

As a result of nearly two decades of steady growth, Romania exceeded the threshold of 13.3 million tourists in 2019, representing a significant milestone in the development of the tourism sector (Table 1).

Within the initial year of the epidemic, there was a significant decline of 52.2% in the overall visitor count, with a particularly substantial drop of 83.1% in the number of international tourists.

Although a moderate recovery was recorded in 2023, with total tourist numbers surpassing pre-pandemic levels by 4%, the volume of international visitors remained approximately 20% below the figures reported in 2019. Furthermore, the number of overnight hotels stays and the occupancy rate are lower compared to the figures from 2019.

Due to its improved offer, which includes over 50% more facilities and 21% more beds, the Romanian market shows potential.

Table 1. The evolution of touristic key indicators at the country level

	2019	2020	2023	Change 2019-2020	Change 2020-2023	Change 2023 compared to 2019
Number of establishments	8,402	8,610	12,697	2.5 %	47.5 %	+51.1 %
Number of beds	356,562	358,119	433,487	0.4 %	21.0 %	+21.6 %
Number of beds - days	88,789,656	64,040,595	98,293,110	-27.9 %	53.5 %	+10.7 %
Number of tourists	13,374,943	6,398,642	13,910,956	-52.2 %	117.4 %	+4.0 %
Number of foreigners	2,683,748	453,867	2,120,068	-83.1 %	367.1 %	-21.0 %
Number of overnight stays	30,086,091	14,579,140	29,691,592	-51.5 %	103.7 %	-1.3 %
Net use indices of the tourist accommodation capacity in use	33.9%	22.8%	30.2%	-11.1 pp	7.4 pp	-3.7 pp

Source: INS, Tempo online [9].

An analysis reveals an increase in tourist amenities at the Danube Delta, Seaside, and Mountain Resorts compared to 2019. Moreover, as previously said, there was an increase in the number of Romanian tourists in all tourist destinations, except the Danube Delta. Although the occupancy rate decreased in all tourist destinations, it remains at over 40% in the coastal and spa are-as, and around 25% in the mountain and delta areas.

Table 2. The change of key indicators during the 2019-2023 period, on tourist destinations

	Total	Seaside	Spas	Mountain resorts	The Danube Delta	County capitals	Other
				%			
Number of establishments	51.1	62.7	56.6	57.6	94.1	33.7	46.7
Number of beds	21.6	25.7	13.0	28.0	51.9	8.3	29.2
Number of beds - days	10.7	21.3	5.5	20.5	-5.7	1.6	14.5
Number of tourists	4.0	20.9	3.3	16.7	-17.7	-2.3	2.1
Number of Romanian tourists	10.3	22.3	3.5	20.2	-12.3	6.8	6.0
Number of foreigners	-21.0	-25.3	-4.2	-20.9	-56.2	-20.8	-21.2
Number of overnight stays	-1.3	2.9	-13.2	10.0	-24.7	-21	-1.3
Net use indices of the tourist accommodation capacity in use in 2023	30.2%	43.3%	39.3%	24.1%	26.2%	34.7%	19.4%
Net use indices of the tourist accommodation capacity in use	-3.7 pp	-7.7 pp	-8.4 pp	-2.3 pp	-6.6 pp	-1.3 pp	-3.1 pp

Source: INS, Tempo online [9].

As can be seen, Romanian tourism recovered after the pandemic but it did not reach the same level of development as in 2019. Nevertheless, the pandemic period saw investments that contributed to the establishment of new accommodation facilities and the diversification of the tourism offer, highlighting the sector's capacity for further development.

Qualitative approach to sectoral developments from the perspective of tourism operators

As reported by key players in the tourism sector, the relaunch of local activities (festivals, concerts, etc.) to support tourist circulation has become more important after the pandemic (Table 3). Also, improving the tourist infrastructure is much more necessary to convince Romanian tourists to visit their own country.

However, it is considered that the most important factors for tourist activity are the customers returning to the Romanian tourist circuit, the attraction of new tourists, and the price level.

The decrease of over 10 percentual points of rate of return and the slow increase of the stays over 3 nights may explain the market contraction. The survey indicates that 53% of respondents had smaller incomes in 2023 compared with 2019 due to the decrease in overnight stays and the increase in expenses. For example, 57% of respondents declare an increase in wages. However, the salary increase was lower than in 2019, opting for meal vouchers that are exempt from tax or for a percentage of sales, particularly in the restaurant sector.

The report also identifies the source of financing as an issue. In 2019, nearly all

respondents had their funds, which they partially supplemented with other sources. However, by 2023, their share has dropped below 70%, and suppliers' financing has increased, indicating a greater preference for their funds and a greater reliance on leasing and loans.

Table 3. The opinion of operators in the tourism sector (restaurants, accommodation facilities, and tourist agencies)

Category	2019	2023	Trend
What are the factors that positively influence tourism activity:			
- Tourists who revisit	70%	67%	↘
- New tourists	59%	55%	↘
- Prices	46%	43%	↘
- Local events	19%	27%	↗
- Infrastructure	5%	12%	↗
Average rate of return			
- Total	45%	33%	↘
- Accommodation units	43%	30%	↘
- Travel agencies	50%	40%	↘
Dynamics of the average number of accommodation nights (2019-2023)			
- 1-2 nights		24%	
- 2-3 nights		54%	
- 3-4 nights		17%	
- Over 4 nights		5%	
How the income evolved compared with 2019:			
- Increased		35%	
- The same		12%	
- Decreased		53%	
The level of average wage compared with 2019:			
- Increased		57%	
- The same		21%	
- Decreased		22%	
Methods of financing used in tourism:			
- Self-financing	92%	67%	↘
- Bank loans	23%	30%	↗
- Supplier credit	21%	23%	↗
- Non-refundable funds	18%	30%	↗
- Leasing	13%	35%	↗
- Other answer options	Under 10%	Under 10%	-
Pre- and post-pandemic strategic options:			
- Profit growth	66%	60%	↘
- Investment growth	58%	51%	↘
- Increase in the number of employees	42%	39%	↘
- Increasing the capacity to provide services	27%	26%	↘
- Maintaining the business at current dimensions	24%	39%	↗
Benefits offered to tourism employees			
- Annual salary increases	42%	36%	↘
- Meal vouchers	32%	37%	↗
- Specialized training	30%	20%	↘
- Health insurance	26%	26%	--
- Holiday vouchers	24%	9%	↘
- Percentage of sales value	9%	21%	↗
- Other answer options	12%	5%	↘
The first 10 risks	Rank	Rank	
- The cost of raw materials and energy	5	1	
- Road/transport infrastructure	3	2	

Category	2019	2023	Trend
- Inadequate legislation in the field	7	3	
- Tourist budgets	9	4	
- The impact of meteorological phenomena	-	5	
- Staff retention costs	2	6	
- Lack of investment funds	-	7	
- Lack of public transport infrastructure	6	8	
- Difficult relations with the authorities	8	9	
- Poor income	-	10	
- Lack of qualified personnel	1	-	
- Lack of legislative stability	4	-	
- Seasonal variation	10	-	
Risk management through:			
- Marketing campaign	61%	26%	
- Assurance	54%	11%	
- Training programs for employees	30%	31%	
- Accessing European funds	11%	41%	
- Other options	3%	5%	
Tourism promotion:			
- Website and social media (Facebook, etc.)	85%	62%	↘
- Tourists' recommendations	83%	75%	↘
- Catalogues, tourist guides, leaflets	29%	34%	↗
- Participation in tourism fairs	26%	20%	↘
- Promotion through Tourist Information Centers	18%	14%	↘
- Advertisements in newspapers, magazines, radio, TV	16%	24%	↗
Digital sales channel			
- Own site/channel	44%	48%	↗
- Specialized reservation site	30%	25%	↘
- Social media	24%	29%	↗

Source: CNIPMMR, 2024 [3].

Also, although in business management the growth of profit, in-vestments, and production capacities is still pursued, there is an increase in economic agents who prefer to remain at the current level of development (almost 40% in 2023).

Another change that occurred after the pandemic period was a shift in risk perception. In 2019, the tourism sector primarily faced risks associated with the recruitment and retention of staff and infrastructure. In 2023, we will identify issues related to energy and materials costs, infrastructure, and legislation. In 2019, we approached these risks through marketing campaigns and assurance packages, but in 2023, the respondents indicated that they prefer to access European funds or invest in staff training to resolve these issues.

The ways to promote the business didn't change much compared with 2019. Social media, tourists, and printed materials remain the primary channels for gaining clients. We observe, however, more investments in advertising (printed, online, or media channels). Additionally, there has been a surge in the utilization of websites and social media platforms for sales, particularly in the hospitality and restaurant industries.

CONCLUSIONS

The Romanian tourism sector did not return to its pre-pandemic levels in 2023. Although new facilities were constructed and tourist-offering were expanded, the number of international tourists decreased, and the rise in Romanian tourists was in-sufficient to offset the reduction in occupancy rate.

The study presented in this paper demonstrates that the tourist industry in Romania is consistently encountering a multitude of obstacles. On the other hand, there has been a

marked decline in the number of international arrivals, overnight stays, and the average duration of trips, all of which have negatively affected the sector's revenue streams. At the same time, operational costs have risen significantly, particularly in relation to energy consumption, raw materials, and wages.

Compounding these challenges is the reduced circulation rate of financial resources within tourist destinations, along with the obvious need to supplement one's income with money from European funds, loans, or leasing. Also, in 2019, the economic agents complained about the lack of personnel qualifications and transport infrastructure, but currently, the main problem is the increase in costs, inadequate legislation, and the reduced purchasing power of tourists. The promotion and sales channels remained approximately the same, yet there is a clear tendency among operators to rely increasingly on their own websites and social media channels for promotion and customer interaction.

Although the Romanian tourism sector was significantly affected by the pandemic, it demonstrated a degree of adaptability in the face of crisis it failed to return to the previous level of COVID-19. This paper presents a critical approach to the sector and emphasizes the need to adapt to consumer behaviour and the current challenges of the tourism market. While Romanians' shift towards domestic consumption has compensated for the decline in foreign tourists, it becomes increasingly clear that the tourism industry requires continuous innovation and well-targeted strategic investments in order to capitalize on emerging opportunities and address the challenge of escalating operational costs. There is a pressing need to improve the offering of tourist ser-vices, make greater use of digital platforms, and, last but not least, identify measures to increase the degree of occupancy and attract foreign tourists.

In short, this paper emphasizes that sustainable practices and digital advances are essential to ensure the development of the Romanian tourism industry in a post-pandemic world. Investing in new tourist facilities is not sufficient; we also need legislative support, cost reduction, and a response to the constantly changing preferences of tourists.

In conclusion, this paper highlights the dual challenges and opportunities facing the tourism sector in Romania after the pandemic. Increased reliance on domestic tourism and the growth of online booking platforms are promising trends; however, the sector's long-term recovery depends on addressing rising operational costs, legislative inadequacies, and the need for improved infrastructure. A comprehensive strategy that includes upgrading infrastructure, attracting foreign tourists, targeted marketing, and policy reform will be essential to ensuring the long-term viability and competitiveness of the sector.

Further research is required on the long-term impacts of post-pandemic adaptations in Romania's tourism sector, particularly regarding consumer behaviour shifts, the effectiveness of digital transformation initiatives, and the sustainability of increased domestic tourism. Additionally, studies focusing on comparative analyses with other European countries could provide valuable insights into best practices and strategies for fostering international tourism recovery.

ACKNOWLEDGEMENTS

The publication of this article was possible thanks to project no. 844/30 June 2023, "Evaluation of authenticity in rural guesthouses in Romania", financed by USAMV Bucharest.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DYNAMICS OF THE DEVELOPMENT OF THE POULTRY SECTOR IN THE NORTH-WEST REGION OF ROMANIA BETWEEN 2019 AND 2023

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Abstract

The poultry sector matters as it is one of the most consumed types of meat in Romania. It is a sector that has greatly benefited from both public and European funds and it also registered an increase in animal welfare through a series of dedicated measures. Ultimately, the investments have generated a series of improvements to the poultry farms and to the production capacities. The enormous importance of the sector for Romania's national economy and for the country's food security is presented, and the need for a continuous flow of financing to guarantee its stability is emphasized. It is a strategic sector that requires constant attention, yet if properly cared for, it may provide high outputs and become a key element of agricultural economics at regional, national, and European levels. This article examines the dynamics of the poultry sector in Romania from 2019 to 2023, with a particular focus on the North-West Region and Bihor County. It presents the challenges and opportunities that the pandemic presented to the sector and how it developed with the help of subsidies. Both quantitative and qualitative research methodologies were employed in the study's creation, enabling the identification of key advancements as well as possibilities and challenges. Statistical data taken from the National Institute of Statistics were used. Also, the Annual Activity Reports of the Agency for Payments and Interventions in Agriculture, as well as the Selection Reports of the Agency for Financing Rural Investments, for the Intervention DR-20: poultry component, were analysed. The article highlights the fact that Bihor County was a beneficiary of European and national funds, which favoured the development of the sector, chicken meat being a star of the national market.

Key words**:** *subsidies, poultry sector, livestock, North-West region, CAP Strategic Plan 2023 – 2027*

INTRODUCTION

Romania has a strong tradition of poultry farming and significant potential for producing poultry meat. Despite past challenges, the sector remains a key dynamic force in the economy [23, 25]. Several studies highlight that a significant proportion of the population consumes poultry meat on a regular basis, with more than two-thirds of respondents purchasing it at least once a week [10, 15]. The preference for this type of meat is mainly driven by its affordability and nutritional benefits [14]. In the livestock production a key role is played by aviculture as it provides valuable food products and shows mobility as its compatible with diverse farming scales and uses efficiently the various feed resources [16]. Poultry meat and eggs are essential sources of high-quality, accessible protein. The economic efficiency of the poultry industry is attributed to several key factors, including the short growth period of broiler chickens, relatively low production costs, and consistently high consumer demand for poultry meat [24]. We need a sustainable local production in order to reduce the imports and have the products available for the population.

Romania became the direct beneficiary of a series of EU programs dedicated to rural development after 2007 that were supplemented by the National Rural Development Program (PNDR) and, the current CAP National Strategic Plan.

Due to EU funding the poultry sector went through a thorough modernization, with

European funds under Pillar II of the CAP (Rural Development) and Pillar I (Direct Payments). Romania undertook the transformation of its institutional structures in order to meet the requirements of animal welfare [20]. The poultry welfare is contingent on the prevailing environmental conditions, in all forms of agricultural production [11]. Variables, such as genetics, rearing practices, diet, and poultry handling, determine the quality of chicken meat, and influence its processing and sensory attributes [19].

2024 research highlights that in Romania, from 2007 to 2022, we saw an increase of the average annual consumption of poultry, due to its relatively low price [17].

Due to the EU funding the Romanian poultry sector reached the Western European technological standards in the sector [12]. EU subsidies have increased the output growth in the meat industry [21, 28].

Given the fact that poultry meat consumption levels are very high, the poultry sector in Romania warrants our attention and this paper aims to analyse its dynamics in the 2019-2023-time span, with a particular focus on the North West Region and Bihor Country while also looking at the results of the CAP Strategic Plan 2023 – 2027.

MATERIALS AND METHODS

The literature review places particular emphasis on the influence of agricultural policies and subsidy schemes in shaping the development of the poultry industry. It also addresses the sector's main growth determinants, analyses market trends and consumer behaviour, and highlights the key challenges and strategic opportunities relevant to the sustainable advancement of this agricultural branch.

The TEMPO Online database of the National Institute of Statistics (INS) provided statistical data, such as: growth or decline trends in poultry populations and evolution of poultry flocks, at the level of the North-West Region and Bihor County, for the period 2019-2023. Simultaneously, an assessment was carried out regarding the support instruments targeting the poultry sector in Romania, based on the reports issued by the Agency for Payments and Intervention in Agriculture (APIA) for the period 2019–2024. Furthermore, the analysis of the Common Agricultural Policy (CAP) Strategic Plan 2023–2027 focused on identifying specific support measures relevant to the poultry sector and evaluating their potential impact, also to identify the opportunities and challenges related to the implementation of these measures.

RESULTS AND DISCUSSIONS

The quantitative analysis examined the development of the poultry sector between 2019 and 2023, both at the national level and within the North-West Region, emphasizing the region's significant role in the growth of poultry farming. Over this period, the poultry sector in Romania exhibited a moderate upward trend at the national level, with an increase of approximately 3% in the total number of poultry (from 75.36 million heads in 2019 to 77.75 million in 2023) (Table 1). The 3% increase shows a relative stability of poultry production. The maximum was reached in 2021 compared to 2020, by 8%.

The poultry meat consumption ranged between 27 and 30 kg/capita during 2019–2023, remaining above the European Union average in certain periods [9, 18, 26]. This shows the population's preferences for poultry meat. It generated a stable domestic demand and contributed to maintaining poultry stocks in a functional economic balance. Poultry meat remains the cheapest animal protein in Romania, even if prices are constantly moving and it is difficult to anticipate what will happen to their level [29].

At the regional level, it is observed that during the analysed period, increases in 2023 compared to 2019 are highlighted in the West region (with an increase of 11%), followed by the North West region with an increase of 9% (Table 2).

The North-West region ranked 2nd at the national level. It increased from 6.75 million in 2019 to 7.33 million heads in 2023. We have a trend of consolidation of the poultry sector, reflecting both the agricultural potential and the adaptability of farmers to economic and

technological conditions. A constant annual increase is observed in the North-West region, compared to the situation at the national level, where 2020 was marked by a decrease in poultry flocks compared to 2019.

The 2020 SARS-COV-2 pandemic had a huge impact on the economy and agriculture was no exception. In the livestock sector, farmers had to face problems such as supply chain disruption and production, processing and distribution difficulties.

Yet the poultry sector managed to remain stable and it quickly adapted to the new context. It's also important to note that the pandemic also affected investment dynamics, production capacity expansion and this has had an impact on the livestock dynamics in the post-pandemic period. The poultry sector was supported during the SARS COV 2 Pandemic at the national level.

A Government Ordinance was issued in August 2020 in a total amount of 109,800 thousand lei. The beneficiaries of this measure were represented by farmers in the poultry sector, namely individual enterprises, family enterprises, authorized individuals, as well as legal entities that carry out activities of reproduction, incubation and/or raising birds for the purpose of obtaining meat or eggs [27].

The poultry flocks between 2019 and 2023 in the North-West region highlights a general growth trend in three of the six component counties: Bihor, Maramureș and Satu Mare. These counties recorded higher flock values in 2023 compared to the reference year 2019, indicating a development of the poultry sector.

Table 1. Poultry populations at National level and at Regional level 2019-2023

Specification	2019	2020	2021	2022	2023	Δ 2023-2019 (Number)	2023/2019 %
	Number						
TOTAL	75,364,575	71,183,431	77,148,372	78,220,737	77,749,597	2,385,022	103
NORTHWEST Region	6,750,551	6,813,085	7,081,358	7,161,199	7,337,525	586,974	109
CENTER Region	8,778,306	9,554,517	9,476,299	9,335,580	9,207,186	428,880	105
NORTHEAST Region	13,182,686	13,192,575	14,735,616	13,402,499	13,839,813	657,127	105
SOUTH-EASTERN Region	13,754,726	12,805,267	14,239,519	14,914,072	14,353,494	598,768	104
SOUTH-MUNTENA Region	19,981,486	15,897,501	17,315,970	19,248,605	19,414,810	-566,676	97
BUCHAREST - ILFOV Region	466,793	475,492	140,662	143,262	131,708	-335,085	28
SOUTHWEST OLTENIA Region	7,850,142	8,357,340	8,295,661	8,218,190	8,360,683	510,541	107
WEST Region	4,599,885	4,087,654	5,863,287	5,797,330	5,104,378	504,493	111

Source: Own calculation on based on data from INS Tempo on line database 2019-2023 [22].

Table 2. Poultry populations at national level and at the North West region level, 2019-2023

Specification	2019	2020	2021	2022	2023	Δ 2023-2019 (Number)	2023/2019 %
	UM: Number						
Romania	75,364,575	71,183,431	77,148,372	78,220,737	77,749,597	2,385,022	103
NORTH-WEST Region	6,750,551	6,813,085	7,081,358	7,161,199	7,337,525	586,974	109
Bihor County	1,724,373	2,271,747	2,346,828	2,257,603	1,967,931	243,558	114
Bistrița County	781,925	590,671	587,155	592,444	666,331	-115,594	85
Cluj County	1,489,802	1,378,243	1,399,522	1,318,392	1,243,577	-246.225	83
Maramures County	698,923	590,444	767,938	1,147,181	1,242,522	543,599	178
Satu Mare County	1,329,209	1,378,869	1,316,168	1,238,290	1,669,704	340,495	126
Salaj County	726,319	603,111	663,747	607,289	547,460	-178,859	75

Source: Own calculation based on data from INS Tempo online database 2019-2023 [22].

Bihor County stands out for its constant positive evolution during the period 2020–2022, being the only county of the three previously mentioned that in 2023, recorded a decrease in poultry numbers by 12.8% compared to the previous year, marking a reversal of the upward trend.

It is observed that the poultry populations in Bihor County are the largest in the North West region (Table 3), this was also true in reference year 1, namely 2019, as well as in reference year 5, namely 2023.

Thus, in 2023, Bihor County had 27% of the total poultry populations in the region.

An important measure to support poultry farmers at the national level was the support for Animal Welfare, which was and is managed by APIA.

Table 3. Poultry numbers 2023, NW Region

Poultry populations in 2023 NW Region & counties		% of total
NORTHWEST Region	7,337,525	100
Bihor County	1,967,931	27
Bistrița County	666,331	9
Cluj County	1,243,577	17
Maramures County	1,242,522	17
Satu Mare County	1,669,704	23
Salaj County	547,460	7

Source: Own calculation on the basis of data from Tempo online database 2023 [22].

The significance of animal welfare is underscored by the inclusion of a dedicated intervention Measure 14 within PNDR 2014–2020, specifically aimed at supporting and enhancing welfare standards in livestock farming [20]. Thus, during the analysed period, the transition was made from Measure 215 to Measure 14 and then to DR-06 within the CAP Strategic Plan 2023-2027.

Measure 215 (PNDR 2007-2013) Animal welfare payments – applied to a limited extent in 2019, marking the end of the previous financial year. Measure 215 aimed to support animal welfare on livestock farms by compensating for additional costs and income losses resulting from voluntary commitments that went beyond the minimum legal requirements. It was organised into five sub-packages (1b–5b) for bird welfare, targeting lighting, density, transport, access to water and reduction of nuisances.

Measure 14 - M14 (PNDR 2014-2020) general objective was the improvement of the environment and the rural space by promoting higher standards of animal welfare. Its specific objective consists of supporting the livestock farms that adopt voluntary commitments. These measures exceeded the basic mandatory requirements, and financial assistance was provided in the form of compensation aimed at offsetting the additional expenses and income reductions resulting from their implementation. Animal welfare payments were available under M14 for two sectors: pigs and poultry.

Package B under M14 included five sub-packages aimed at improving the conditions of raising and transporting poultry, that are:

1b) providing artificial lighting of 30 lux minimum in order to help birds maintain their natural behaviour;

2b) improving comfort and reducing stress by reducing by 10% the housing density in relation to the minimal requirements that refer to the area allocated for each bird;

3b) improving transportation conditions by reducing bird density by at least 30%;

4b) ensuring drinking water safety and quality by lowering nitrite and nitrate levels

5b) Reducing noxious emissions by 30% compared to standard levels, by maintaining microclimate parameters (temperature, humidity, ammonia) within optimal ranges.

In the context of the new programming period 2023–2027, the CAP was transposed into the CAP Strategic Plan, and support for animal welfare was maintained as an important component. The animal welfare measure, previously applicable through M14, was taken over and continued in the new financial year through intervention DR-06. This further includes the package for the poultry sector, reaffirming the commitment to improving the conditions for raising birds and to promoting a responsible and sustainable production system. For the period 2023-2027, support through DR-06 targets the bird sector through Package B payments in favour of bird welfare:

1 b) – reduction of bird density by 15% compared to the density resulting from the application of the mandatory minimum requirements regarding the minimum area allocated for each category of birds,

2 b) – reducing pollution by 30% compared to the minimum mandatory level by maintaining microclimate parameters within optimal limits [8].

For sub-package 1b, the commitment consists of decreasing the density of birds by extracting (eliminating) a sufficient number of animals, so that the space allocated to each remaining animal increase by at least 15%, compared to the density resulting from the application of the minimum mandatory requirements, as follows:

- For broiler chickens, the density must be reduced based on the level used, meaning reduced density from the customary values of 28.69 kg/m^2, 33.91 kg/m^2 or 36.52 kg/m^2;
- For laying hens, the values differ as such: a minimum of 1,278 cm^2/head if the alternative system is used or a minimum of 862 cm^2/head if the improved cage system is used;
- For heavy breed breeding hens, the stock density must be adjusted to the standard value of 21.74 kg/m^2;
- For turkeys, the maximum density will be of 47.83 kg/m^2 for males and 43.48 kg/m^2 for females [13].

In 2020, the smallest number of applications was submitted, namely 273 whereas 2023 was the year with the most applications submitted, at 279. We can observe that there is a minuscule difference between the number of applications submitted and the number of applications authorized for payment. The year with the biggest difference was 2021, when 30 applications were rejected so only 93% of the submitted payment applications were authorized.

The authorization for payment of intervention DR-06, Animal Welfare, for the commitment year 2024 is carried out in 2025, by 30.06.2025 – Table 4 [8].

Table 4. Numerical and value evolution of requests and payments (2019–2024) - Poultry Animal Welfare Package B

Year	Applications submitted (number)	Requested value (Euro)	Authorized requests (number)	Authorized value (Euro)	% Authorized Applications from Applications submitted
2019 (M215 and M14)	275 (51/M215+224 /M14)	76,796,819	273	70,036,285	99
2020 (M14)	273	73,105,059	262	66,540,764	96
2021 (M14)	278	77,184,481	258	69,504,443	93
2022 (M14)	278	79,655,725	268	72,485,308	96
2023 (DR-06)	279	83,202,979	265	76,232,915	95
2024 (DR-06)	279	87,593,493			

Source: Own processing based on APIA Reports 2019-2024 [2, 3, 4, 5, 6, 7, 8].

Table 5. DR-20 - Session 01/23 - 30.04.2024 Component poultry and other farm animals, including bees North West Region

Specification	Euro eligible currency	Euro support value
Bihor County	11,629,601	7,559,238
Total NW Region	11,629,601	7,559,238
Total allocated per session	22,461,072.80	22,461,072.80
% NW Region of total allocated		34

Source: Own processing based on AFIR Selection Reports related to DR-20 [1].

The financial support granted through the European Agricultural Fund for Rural Development (EAFRD) has contributed to a notable increase in the share of commercial poultry farms applying enhanced animal welfare standards, which reached 84% at the national level [13].

Within CAP Strategic Plan 2023-2027, through the intervention of DR-20 Investments in the livestock sector, the poultry sector is also supported. The maximum value of public support for a project that can be financed under DR-20 is 2,000,000 Euros/project, and in the case of projects that only propose the acquisition of agricultural machinery and equipment. The maximum value of public support will be 300,000 Euros/project. Intensity of public support non-refundable refers strictly to the eligible costs related to the project and can be a maximum of 65% of the eligible value of a project. This supports the proper functioning of high-performance poultry farms at all levels. Thus, within DR-20 - the poultry and other farm animals' component, including bees, had allocated for the DR-20 project submission session 01/23 -

30.04.2024 a value of 22,461,072.8 Euros, a value requested in full by potential beneficiaries – Table 5.
During the DR-20 session 01/23 - 30.04.2024 for the poultry and other farm animals' component, including bees, a number of 39 projects were submitted, of which 8 were in the North West region [1].
Of these, 4 projects were selected for funding, considering the allocated value and the score achieved by each investment. The approved projects concerned investments in broiler farms, all located in Bihor County. Their eligible value represented 34% of the total support allocated during the project submission session.

CONCLUSIONS

The analysis of Romania's poultry sector from 2019 to 2023 underscores its resilience and growth, particularly in the North-West Region and Bihor County. Despite challenges like the SARS-COV-2 pandemic, the sector showed adaptability, with a 3% increase in poultry populations nationally and notable regional growth.
Romanian consumers have a "love affair" with the poultry meat who is an important source of protein and is consumed more that in the other member states.
This generated a stable public support through strategic investments that were supplemented by EU funds.
Despite numerous challenges, the greatest of which was the pandemic, the poultry sector managed to increase its population by 3% nationally and demonstrated notable regional growth. Romanians prefer poultry meat and consume it on a regular basis for protein intake, making Romania the biggest poultry meat market in the EU. This has led to constants public support and strategic investments using EU funds.
As a novelty we also had strong investments in the poultry welfare that also generated a more efficient and sustainable sector,
Bihor County is one of the net beneficiaries of this favourable climate. Moreover, the sector is of critical importance for the national economy and more EU funds are need to consolidate it.
In further developments need to take into consideration the emerging challenges, leveraging technological advancements, and promoting sustainable practices to maintain the sector's competitive edge.

ACKNOWLEDGEMENTS

This work was supported by a grant of the University of Oradea, funded by SC AGRODI VITALIS SRL, Project number 14/23.06.2025, „Study on the Improvement of Economic Performance of SC AGRODI VITALIS SRL from Bihor County".

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

RESEARCH ON THE INFLUENCE OF ARTIFICIAL INTELLIGENCE AND ITS SUBDOMAINS IN THE MEAT PROCESSING INDUSTRY

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Abstract

This study conducts a bibliometric analysis and narrative review of the impact of artificial intelligence (AI) on the meat industry from 2000 to 2023, using data from the Scopus and Web of Science databases. The results indicate a significant increase in AI research within the meat industry, with a particular emphasis on computer vision, machine learning, and deep learning. China and the USA are the leading contributors to this research, and keywords such as "meat," "quality," and "prediction" frequently appear in discussions. AI has been effectively applied in areas such as image processing, quality assurance, supply chain optimization, and predictive improvement. Emerging technologies like blockchain and computer vision have enhanced traceability and food safety. The analysis also highlights a growing interest in using machine learning and deep learning for meat deficiency detection, unauthorized activity monitoring. Although it offers numerous advantages, the integration of AI in the meat industry faces challenges, including data complexity, stringent regulations, high initial implementation costs, and the absence of standardized protocols, which limit interoperability. Successful integration of AI requires a balanced approach that combines human expertise with machine capabilities.

Key words**:** *meat, artificial intelligence, computer vision, machine learning, deep learning*

INTRODUCTION

Artificial Intelligence (AI) is an advanced technology that equips humans with software and tools to enhance learning, crisis handling, judgment, and innovation across various fields. The sustainability of a healthy economy requires among other things to assure food safety of the population. Based on the consumption dynamics, Machine Learning (ML) methods could provide useful tools in improving management along the food chain from agricultural farms to processing industry and final food in the consumers' plate.

In a word AI is an instrument which could help to predict statistics and making the right decisions at the national level [42, 43].

In the food industry in general, and in the meat processing industry in particular, automation entered relatively late compared to other industrial branches due to the raw materials that exhibit significant variations in terms of shape, texture, elasticity, etc. Additionally, there are hygienic requirements and physical factors such as high environmental humidity.

Currently, artificial intelligence has a significant impact on the meat industry, positively influencing the productivity of technological lines, process and inventory optimization, quality control of food products, and social aspects [20, 30]. The increased efficiency through AI implementation can be explained by replacing repetitive human activities, which in many situations occur at excessively high or low temperatures and very high air humidity [24]. In the supply chain, optimizing it with the help of AI can be achieved by improving stocks, waste reduction, and optimized distribution [20, 34]. On the other hand, cost reduction can be achieved by optimizing production and distribution processes, as well as improving resource efficiency, and this can be done based on market demand forecasting.[40].

In addition, especially in the meat industry, AI can be used to meet hygiene requirements in the field and ensure the quality of meat and meat products. Furthermore, it allows for efficient decision making, management of food waste, and the application of intelligent sorting

and packaging solutions [26]. Additionally, AI can contribute to the development of new foods that strengthen immunity, evaluate diets, and predict the toxicity of food ingredients [27].

Alongside these advantages, there are social barriers that can be overcome through the financial and digital literacy development of farmers and the dissemination of best practices among participants in the food supply chain [6].

The goals pursued in this article are to examine and emphasize the progression of research in the application of AI within the meat industry over time, using two databases: the Web of Science (Clarivate) and Scopus (Elsevier) databases. The originality of this work consists in its comprehensive analysis of AI research in the meat industry. Both AI and its subfields, namely computer vision (CV), machine learning (ML), and deep learning (DL) represent the independent variables considered in the analysis, while the dependent variables include the dynamics of scientific research publications, the ranking of the top five most prolific countries, and the dynamics of keywords.

State-of-the-Art Review

In the pursuit of increased productivity in the meat industry, the adoption of new technologies has become a priority. Automation was first introduced in poultry and pork slaughterhouses [8]. However, the implementation of robotics presented challenges, as the items to be processed often lacked uniform shapes, sizes, and consistency [46]. After automating smaller and relatively uniform items, such as poultry carcasses or processing poultry meat for nuggets, the industry advanced to AI-based automation [7]. In this case, information about the entity is initially acquired using sensors, cameras, or other components; then, decisions are made using artificial intelligence, and finally, actions are taken [47].

The European Commission defines AI as systems exhibiting intelligent behaviour through the analysis of the environment and the execution of actions at various degrees of autonomy to achieve defined objectives. AI systems can exist either as software applications or as integrated components within hardware devices. For software, these systems function solely in the digital domain, such as in image processing (e.g., classifying beef or poultry carcasses). As for hardware integration, it involves advanced robotic systems [17].

Currently, AI encompasses the subsystem known as ML, which, in turn, includes DL [38]. CV plays a particularly important role in the meat industry by processing photos, videos, or 3D images, using DL models to identify or classify objects. [2].

At present, AI is utilized in the meat industry for:

• Robotics - AI-driven robots are employed in meat processing plants for tasks such as cutting, sorting, and packaging. They can work independently or alongside human operators to improve efficiency and reduce manual work [46].

• Monitoring – AI - equipped smart sensors can continuously monitor factors such as temperature, humidity, and other environmental conditions during meat processing. This helps maintain the freshness and quality of the meat [38].

• Quality control and inspection - CV technology can inspect meat products for defects, contamination, and ensure compliance with quality standards. This helps maintain consistency and enhance the overall quality of products [28].

• Traceability and Blockchain - Blockchain, integrated with AI, is utilized to ensure transparency and traceability within the meat supply chain. This allows for the provision of information regarding the origin, processing, and transportation of meat/animals. [10].

• Supply chain optimization - AI is employed to enhance and streamline the meat supply chain by anticipating demand, optimizing inventory management, and improving logistics. This helps reduce waste, cut costs, and ensure a more efficient distribution process [3].

• Predictive maintenance - AI algorithms are used for predictive maintenance of meat processing machines. By analysing data from sensors and equipment, artificial intelligence can predict when machines are likely to

malfunction, enabling proactive maintenance and reducing downtime [23].

MATERIALS AND METHODS

Within this work, a semi-structured method is used, combining bibliometric analysis with narrative review.

Data Collection

To begin with, in the multidisciplinary databases Web of Science and SCOPUS, original articles, reviews, and books resulting from the search terms "meat" and "industry" or "processing" and "artificial intelligence" were identified. The chosen period ranged from 2000 to 2023. Since the number of articles resulting from the Web of Science database was lower when using the words "industry" or "processing" than in their absence, these were excluded from subsequent searches. On the other hand, since AI encompasses the subsystems mentioned earlier, namely CV, ML, and DL, it was considered necessary to collect literature separately in the two databases through the following three query variants: "meat" and "computer vision," then "meat" and "machine learning," and finally "meat" and "deep learning." This resulted in 8 datasets, 4 for each database. This allowed for a comparison of results obtained for the 4 research directions: AI, CV, ML, and DL, as well as a comparison of results between the two databases.

Data Analysis

For the analysis of the collected data, two AI-based chatbots were used. The data obtained from the Web of Science database were bibliometric analysed using the Biblioshiny tools from Bibliometrix package 3.1 in RStudio (version 4.1.2) [4,12]. Normally, this application allows the combination of data obtained from multiple databases.

Since the literature resulting from the Scopus database could not be exported completely due to recurring errors, these results were analysed using the analysis system provided by Scopus. The dependent variables analysed were those common to both bibliometric analysis packages, and the merging of analysis results was done manually. These common dependent variables included the temporal evolution of articles addressing the 4 subjects: AI, CV, ML, and DL, the countries from which the authors of these articles originated, and the temporal dynamics of keywords only for Web of Science. A narrative review was then conducted for these keywords.

RESULTS AND DISCUSSIONS

Establishment of Independent Variables

Table 1. Results obtained from querying the Web of Science and Scopus databases using three search variants

Search terms	Web of Science		SCOPUS	
	Total	Article type	Total	Article type
meat AND industry AND artificial AND intelligence	62	40 article 13 reviews 9 proceedings paper	3,712	1879 article 797 reviews 391 proceedings paper 325 books 286 books chapters other
meat AND processing AND artificial AND intelligence	86	51 article 14 reviews 21 proceedings paper	4,739	2593 article 920 reviews 599 proceedings paper 301 books 296 books chapters other
meat AND artificial AND intelligence	214	140 article 31 reviews 42 proceedings paper 1 capitol de carte	8,026	4630 article 1248 reviews 1119 proceedings paper 483 books 474 books chapters Other

Source: Biblioshiny, based on the WOS and Scopus dataset [48].

When using the search terms "meat and industry and artificial intelligence" in the Web of Science database, only 62 articles were obtained, while the combination "meat and processing and artificial intelligence" returned 86 articles. Much better results were obtained

when using only "meat and artificial intelligence." Out of the 214 results, the majority were published in the journals: Food Science Technology, Computer Science Artificial Intelligence, and Agriculture Dairy Animal Science

As seen in Table 1 especially in the case of the Scopus database, the highest number of articles was obtained for the combination "meat and artificial intelligence." The main sources are Lecture Notes In Computer Science (including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics), Foods, Computers And Electronics In Agriculture.

Dynamics of Scientific Research Publications

By excluding the terms "industry" or "processing" in the query, more results were obtained because there are numerous articles that focus, for example, only on meat quality, and these would not have been included in the results. For this reason, the search in the two databases continued using only the word "meat," to which the subdomains of artificial intelligence were added: CV, ML, DL. The temporal evolution of the four sets of queries in the two databases is presented in Fig. 1.

The temporal distribution of publications is presented in Fig. 1 and showing a significant increase starting from 2017. The maximum number is reached in 2022, with a slight decrease in 2023. Consequently, it can be stated that the topic is currently of significant interest.

As expected, more results were obtained by accessing the SCOPUS database.

In the first 2/3 of the studied interval, CV has the most articles due to concerns related to animal welfare and carcass classification.

Concurrently, with the increasing interest in ML and DL, the number of articles begins to rise, especially

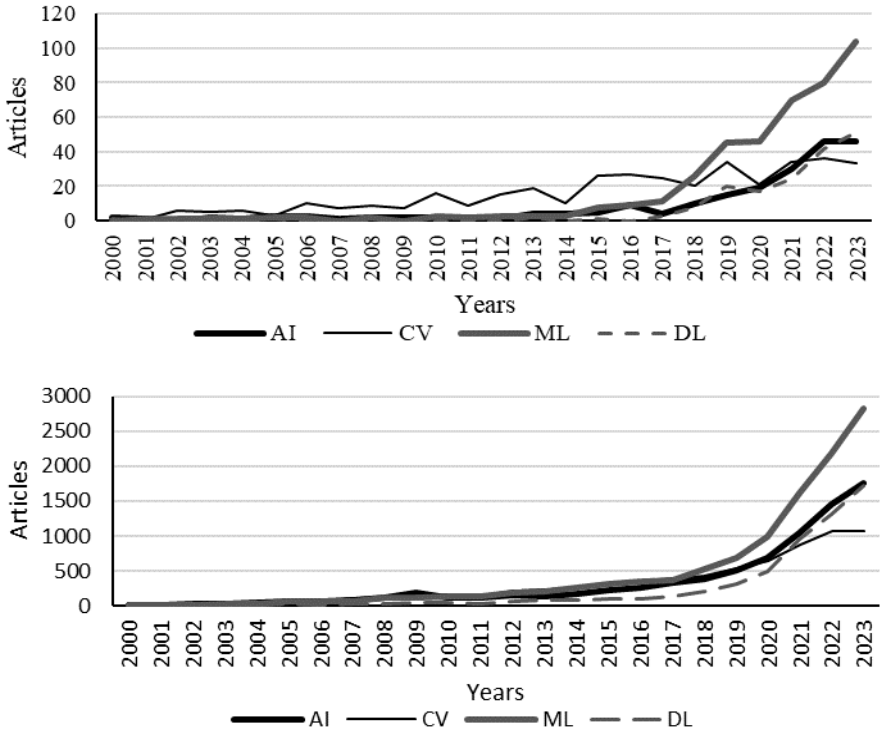


Fig.1. The dynamics of scientific research publications in the field of meat related to AI and its subsystems, as found in the Web of Science and Scopus databases

Source: Biblioshiny, based on the WOS and Scopus dataset [48].

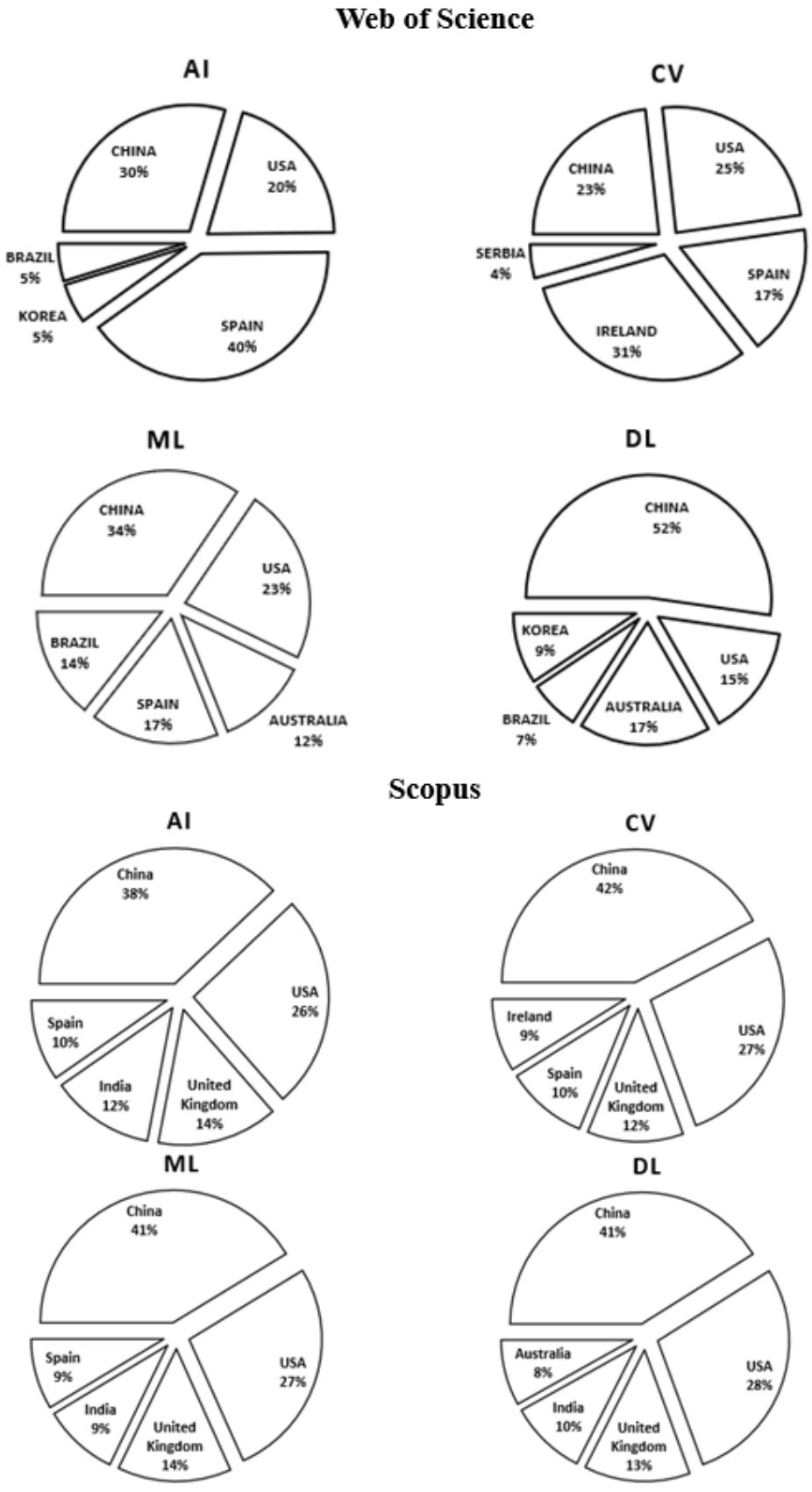


Fig.2. Proportion of the top five countries contributing to scientific research in the field of meat industry related to AI and its subdomains, present in both databases
Source: Biblioshiny, based on the WOS and Scopus dataset.

	AI									
Year	MEAT	QUALITY	PREDICTION	CLASSIFICATION	SYSTEM	COMPUTER VISION	SPECTROSCOPY	SYSTEMS	BEEF	GROWTH
2001	0	0	0	0	1	0	0	0	0	0
2002	0	0	0	0	1	0	0	0	0	0
2003	0	0	0	0	2	0	0	0	0	0
2004	0	0	0	0	2	0	0	0	0	0
2005	0	0	0	0	2	0	0	0	0	0
2006	0	0	0	1	2	0	0	0	0	0
2007	0	0	0	1	2	0	0	0	0	0
2008	0	0	1	1	3	0	0	0	0	0
2009	1	1	1	1	3	0	0	0	0	0
2010	1	1	1	1	3	0	0	0	0	0
2011	1	1	1	1	3	0	0	0	0	0
2012	1	1	2	2	3	0	0	0	0	0
2013	2	1	2	2	3	0	0	0	0	0
2014	2	2	2	2	3	0	0	0	1	1
2015	2	2	2	2	4	0	0	0	2	2
2016	3	2	2	2	4	0	1	0	2	2
2017	3	2	2	2	4	0	1	0	2	2
2018	4	3	3	4	4	0	2	0	3	2
2019	5	4	4	7	4	0	3	1	4	2
2020	6	5	5	8	4	0	3	1	4	5
2021	11	5	7	9	6	1	5	2	4	6
2022	17	10	11	10	8	3	7	5	5	7
2023	25	17	14	12	9	8	8	8	6	7

	CV									
Year	COMPUTER VISION	PREDICTION	QUALITY	MEAT	CLASSIFICATION	COLOR	QUALITY EVALUATION	BEEF	MEAT QUALITY	SYSTEM
2001	0	0	0	0	0	0	0	0	0	0
2002	0	1	1	0	1	1	0	0	0	0
2003	0	1	1	0	2	1	0	0	0	1
2004	0	1	1	1	4	1	0	1	0	2
2005	0	1	2	3	5	2	0	1	0	3
2006	4	3	5	5	11	2	1	6	5	4
2007	7	5	6	7	12	2	1	7	6	6
2008	13	6	7	8	14	5	1	9	9	8
2009	15	9	8	10	15	8	1	9	12	8
2010	19	13	11	15	17	11	2	12	14	10
2011	21	15	12	15	17	12	3	12	15	11
2012	25	19	16	16	20	15	5	13	16	11
2013	34	23	19	22	22	18	12	17	17	13
2014	35	26	23	23	23	21	12	18	19	13
2015	48	33	31	28	27	24	20	25	20	14
2016	63	42	34	30	33	30	27	28	24	15
2017	78	43	39	35	35	34	32	28	26	15
2018	85	47	40	41	42	38	35	29	31	19
2019	92	56	50	44	46	41	38	32	32	20
2020	99	60	52	49	51	43	38	34	33	21
2021	106	63	58	52	57	51	41	34	37	26
2022	114	69	66	58	59	51	42	39	37	32
2023	125	73	72	63	61	53	42	41	38	37

	ML									
Year	MEAT	QUALITY	CLASSIFICATION	PREDICTION	IDENTIFICATION	SPECTROSCOPY	BEEF	SYSTEM	REGRESSION	PORK
2001	0	0	0	0	0	0	0	1	0	0
2002	0	0	0	0	1	0	0	1	1	0
2003	0	0	0	0	1	0	0	2	1	0
2004	1	0	0	0	2	0	0	2	1	0
2005	2	0	0	0	2	0	0	2	1	1
2006	2	0	1	0	2	0	0	2	1	1
2007	2	0	1	0	2	0	0	2	1	1
2008	2	1	1	0	2	0	0	2	1	1
2009	2	1	1	0	2	0	0	2	1	1
2010	3	2	1	0	3	1	0	2	1	1
2011	3	2	1	1	3	2	0	2	1	1
2012	3	2	2	2	3	2	0	2	1	1
2013	3	3	2	2	3	3	1	2	1	1
2014	3	3	2	2	4	3	1	2	1	1
2015	4	4	3	2	4	3	2	3	2	1
2016	7	8	5	3	5	4	3	3	3	2
2017	7	10	5	6	5	4	6	4	3	4
2018	10	15	9	11	8	10	10	5	3	8
2019	14	22	17	14	12	13	12	7	6	11
2020	23	27	27	19	17	18	15	9	10	12
2021	36	35	39	28	21	22	17	12	12	14
2022	58	45	45	35	31	24	22	15	15	15
2023	81	64	56	43	35	29	25	23	23	18

	DL									
Year	MEAT	QUALITY	CLASSIFICATION	PREDICTION	BEEF	MODEL	SYSTEM	BEHAVIOR	COMPUTER VISION	MEAT QUALITY
2001	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0
2013	0	1	0	0	0	0	0	0	0	0
2014	0	1	0	0	0	0	0	0	0	0
2015	0	1	0	0	0	0	0	0	0	0
2016	0	1	0	0	0	0	0	0	0	0
2017	0	1	0	1	0	0	0	0	0	0
2018	2	3	2	2	1	0	0	0	0	0
2019	6	6	5	4	4	1	0	1	2	0
2020	7	7	9	5	6	2	0	1	3	2
2021	13	11	12	7	6	4	3	2	5	3
2022	19	15	15	10	8	8	6	6	5	3
2023	28	23	19	14	10	10	9	8	8	8

Fig.3. Dynamics of the top 10 keywords in the Web of Science database
Source: Biblioshiny, based on the WOS and Scopus dataset [48].

Ranking of the Top Five Most Prolific Countries

The top five countries presenting the results of their research in the field of AI and its subsystems are shown in Fig. 2. In all datasets, China is followed by the USA, except in Web of Science research related to CV, where their positions are reversed. Generally, China holds the first place, but in the case of AI and CV within Web of Science, it ranks 2nd and 3rd,

with Spain and Ireland, respectively, and the USA taking the lead. On the other hand, Spain appears in these rankings except for DL in both databases.

Fig. 2 also reveals that the United Kingdom and India are only present in the Scopus database, while Brazil and Korea appear in Web of Science.

Dynamics of Keywords

The trend in keyword usage in Web of Science-indexed research is presented in Fig. 3. As expected, in all four sets, the most frequently appearing word is "meat," followed by the word "quality," except for the CV-related set. Among the cattle species, beef and bovine meat were the most studied. There were numerous attempts, especially for cattle, to classify carcasses using artificial intelligence, particularly since the price is determined based on the quality class [15]. Classification is also used in assessing meat quality [33].

Another frequently appearing word is "prediction" regardless of the chosen independent variable. Using AI algorithms, historical data can be analysed to predict future demands, reduce unplanned downtime, optimize resources, etc. [32].

Narrative Analysis of Keywords

AI along with its subsystems has been introduced into the meat industry to achieve one of its major objectives, namely the quality of products [24].

For example, image processing and ML models provide non-invasive opportunities for food safety and inspection in meat industry units with large production capacities [14]. In this regard, the detection of pork chop quality based on its colour and marbling can be mentioned [39]. Using statistics and AI, the freshness of salmon can be determined based on eye colour [22], or the freshness of beef, and the required equipment being portable can be positioned where desired [5]. Another issue that can be addressed in this way is the detection of meat exhibiting abnormal states, especially PSE, which poses significant technological challenges [13].

DL has been used to highlight frauds such as the substitution of minced beef [36].

ML models are employed to train the CV system to recognize and classify various types of defects in meat products. These models learn from a large set of labelled image data to accurately identify and classify defects, such as discoloration, bruises, and foreign objects [21].

In various cases where CV is coupled with AI, data acquisition is practically done using video images, ultrasound, nuclear magnetic resonance, computed tomography, dual-energy X-ray absorption, near-infrared spectroscopy, and hyperspectral imaging. Essentially, image recognition algorithms in AI-based computer vision technology operate through: 1-image pre-processing using spatial domain and transformation domain methods; 2-image segmentation by selecting illumination, image filtering, and thresholding; 3-extraction of features such as size, shape, colour, and texture for subsequent analysis and classification; 4-defect classification based on the extracted features, generally using artificial neural networks, decision trees, fuzzy logic, and support vector machines [16].

Therefore, a key benefit of AI lies in maintaining food safety and quality by ensuring compliance with safety standards and preventing cross-contamination with foodborne pathogens [3]. The use of computer vision in meat processing can lead to waste reduction by providing rapid, accurate, and non-destructive detection methods for meat quality assessment [37].

Another important aspect is optimizing the recipes of meat products in terms of taste and nutritional value. In this case, the challenge lies in the creativity and practical nature of recipes generated by AI. These can be quickly generated, allowing for the discovery of new flavour combinations and personalized recommendations [44].

Traceability involved in food safety can be enhanced with the help of AI by finding solutions such as Boxed Meat Label Verification (BLV) systems, which verify the type of meat compared to the label data [21]. Additionally, artificial intelligence can be used in conjunction with other technologies such as cloud computing and the Internet of Things to create personalized traceability systems [11].

Predictive artificial intelligence is used in the meat industry to enhance various aspects of

production, processing, and supply chain management.

Wang *et al.* (2021) developed a framework for weight estimation and prediction to support intelligent production decisions, thereby increasing poultry slaughter yield and, consequently, revenue [45]. Technologically, artificial intelligence predictive modelling has been employed for pork colour and marbling degree, processing line speed, with prediction result accuracies of 92.5% and 75.0%, respectively [37]. From these examples, it can be stated that predictive AI allows the automation and optimization of meat processing, leading to increased productivity and unit efficiency [9]. On the other hand, predictive AI can enhance the meat industry's supply chain by optimizing logistics, food delivery, and predicting maintenance in food processing machinery. It can also help reduce food waste and contribute to sustainable consumption by decreasing the carbon footprint of food [34, 3].

However, there are challenges in using AI algorithms, such as predicting future demand for certain meat products. In this case, a challenge is the variability of internal and external factors that can affect demand, such as promotional offers, seasons, and holidays [29]. Another challenge is the complexity and diversity of data in the food industry, requiring the development of machine learning models specifically tailored to the industry [32]. Additionally, accurate demand estimation is crucial for perishable food products, as excess stocks can lead to food waste and monetary losses [19].

Furthermore, in some cases, obtaining accurate and sufficient data for training AI models can be a challenge. If the data is incomplete, biased, or not representative, it can affect the performance and reliability of the AI system. Also, data transfer through various networks makes them susceptible to cybersecurity threats [18].

On the other hand, as previously mentioned, meat processing involves a complex set of tasks, and the variability of raw materials can be significant [41].

The meat industry is subject to strict regulations and standards for food safety and quality, meaning the implementation of AI technologies may require compliance with additional regulations compared to other domains. This is compounded by the absence of protocols and standards for AI applications in meat processing, which can hinder interoperability and collaboration between different systems [31].

Due to significant initial costs, including hardware acquisition, software, and staff training, implementing AI systems in medium or small-capacity processing units is challenging. This is coupled with expenses for monitoring, continuous updating, and maintenance [1].

Integrating AI systems into existing meat processing workflows requires careful consideration of human-machine collaboration. Ensuring that AI technologies complement human abilities and work seamlessly with human operators is essential for successful implementation [35].

Some AI algorithms, especially deep learning models, may be perceived as "black boxes" because their decision-making processes are not easily explainable. In industries with strict regulatory requirements, such as meat processing, the lack of transparency in AI decision-making can pose challenges [25].

CONCLUSIONS

This study aims to analyse research published between 2000 and 2023, using the Web of Science and Scopus databases, regarding the impact of AI and its subdomains: CV, ML, and DL in the meat industry. Through bibliometric analysis, an increasing interest has been observed, especially in the last six years, regarding the progress brought about by the implementation of AI, CV, ML, and DL. The main countries contributing to the specialized literature in this field are China and the USA, along with European countries such as Spain, Ireland, and the United Kingdom.

The keyword analysis revealed that research concerns are primarily focused on "quality," "bovine" meat, and "prediction," indicating a major focus on ensuring product quality and process optimization. In the narrative analysis of these topics, the benefits of AI and its

subdomains were highlighted, along with the challenges and respective limitations. Thus, it was shown that the use of AI algorithms faces difficulties such as variability in factors affecting demand, data complexity in the industry, and strict regulations for food safety. Possible errors and, not least, significant initial costs were also identified.

On the other hand, while AI can replace repetitive work in unfavourable environmental conditions, the integration of AI systems requires careful human-machine collaboration.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DIGITALIZATION PROCESSES IN THE MANAGEMENT OF THE FUNCTIONING OF AGRICULTURAL ENTERPRISES: A CASE STUDY OF UKRAINE

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Abstract

The article explores the peculiarities of digitalization in the management of agribusiness enterprises as a key factor in enhancing their efficiency under modern economic conditions. Data from the Statistical Institute and other sources have been processed using abstract-logical method, analysis and synthesis, induction, systematization and generalization, monographic and grouping methods. The distribution of countries around the world by the level of digitalization of the economy was studied. The evolution of business models in the agricultural sector amid economic digitalization is examined. The study analyzes contemporary information technologies widely used in the Ukrainian agrarian business. The dynamics of enterprises engaged in e-commerce operations in Ukraine are assessed. A regional classification of Ukraine is conducted based on the share of agribusiness processing enterprises involved in e-commerce. The research also investigates the dynamics of agricultural product volumes sold through electronic commerce in Ukraine. Conceptual foundations for the implementation of strategic directions for digital transformation in the agribusiness sector of Ukraine are proposed.

Key words**:** *digitalization, agribusiness, management, e-commerce, information technologies, business models*

INTRODUCTION

The digitalization of the agribusiness sector serves as a fundamental vector in the evolution of economic systems, driving radical transformations in managerial processes and the strategic positioning of enterprises within the industry. Amid increasing global market volatility and escalating regulatory pressures, digital technologies have emerged as key drivers of operational efficiency and the sustainable development of agribusiness in Ukraine. Institutional and technological changes accompanying digitalization processes are shaping a new paradigm of agribusiness management, where information-analytical tools and automated control systems play a central role.

It is noteworthy that the application of digital platforms and algorithmic forecasting models facilitates a synergistic effect by integrating production, logistics, and financial processes. Consequently, adaptive digital management models in the agricultural sector are transforming decision-making methodologies, emphasizing the minimization of transaction costs and the overall optimization of resource allocation. At the same time, the differentiation

of digital strategies is contingent upon the level of technological maturity, scale of operations, and specific market conditions of enterprises, resulting in a heterogeneous impact of digitalization on the industry's overall competitiveness.

Many scientists and practitioners have studied this issue, among which it is worth highlighting the research of such authors as N. Antoniuk [1], I. Arakelova [2], M. Bezpartochnyi [3], I. Britchenko [4-8], A. Dibrova [10], S. Ionitescu [12], N. Khomiuk [13], V. Kostiuk [14], M. Kryshtanovych [15], N. Kunitsyna [16], M. Kuzheliev[17], I. Mazniev [19], T. Mirzoieva [22], A. Popescu [23-32], M. Rudenko [33], V. Sarioglo [34], T. Shmatkovska [35-41], R. Sodoma [42-43], A. Verzun [45], Zastrozhnikova [47], A. Zielińska [47] and others.

In the context of Ukraine, the digitalization of the agricultural sector is an integral component of its adaptation to integration challenges associated with European integration and broader geoeconomic shifts. Thus, an in-depth examination of these processes is critically important for the formulation of effective strategies for digital development in the agricultural sector, the mitigation of associated risks, and the maximization of economic benefits.

MATERIALS AND METHODS

The study of digitalization processes in the management of agribusiness enterprises in Ukraine utilized a range of specialized scientific analysis methods, ensuring a comprehensive assessment of digital transformation and its impact on the efficiency of business activities in the sector.

The abstract-logical method was employed for the theoretical generalization of key trends in the digitalization of agribusiness enterprises, the formulation of conceptual principles, and the determination of the logical sequence of transformation processes. This method contributed to the systematization of scientific approaches to analyzing digital tools used in enterprise management.

Based on the use of analysis and synthesis methods, the specifics of digitalization of business processes at agribusiness enterprises were assessed, the level of integration of modern digital technologies in them was determined, and the impact of digitalization on the growth of productivity of their production activities was investigated. In addition, the results obtained were summarized using the synthesis method, on the basis of which approaches were formed to intensify the pace of digitalization in the agricultural sector of Ukraine on the basis of increasing the operational efficiency of business processes.

The induction method clarified the features of digitalization in agribusiness processes and regional distinctions, while deduction was applied to define the role of digitalization in managing economic activities and its influence on managerial functions.

The monographic method facilitated an in-depth analysis of contemporary approaches to the digitalization of management processes in Ukrainian agribusiness enterprises. Both scientific and practical aspects of using information technologies were examined, focusing on the automation of operational processes, monitoring of production indicators, and market situation forecasting.

The method of systematization and generalization enabled the structuring and interpretation of collected information on digital tools and technological solutions used in Ukraine's agricultural sector.

To construct and visualize the cartogram of digital transformation in agricultural enterprises, a grouping method was applied, allowing the identification of digitalization levels across Ukraine's regions. Based on this, key factors causing the unevenness of the process were clarified, and prospects for transforming the infrastructure of agricultural enterprises in specific regions were outlined.

These methods enabled a comprehensive assessment of digital transformation specifics in Ukraine's agricultural sector and highlighted the main directions for the further development of the digital agricultural ecosystem.

RESULTS AND DISCUSSIONS

In the context of transformational processes of the modern economy, digital modernization of business entities in the agricultural sector appears as a determinant vector of increasing their operational efficiency and strategic

adaptability to fluctuations in the market environment. At the same time, the institutionalization of digital tools and algorithmic solutions ensures not only the total automation of agricultural production cycles, but also the implementation of digital systems in the context of management synergy, which creates the prerequisites for increasing system manageability and optimizing the functional and organizational architecture of enterprises of the agro-industrial complex. At the same time, disparities in access to technology, institutional barriers, and financial constraints create imbalances in the pace of digital transformation both within individual economies and on a global scale. In particular, current trends in the global differentiation of digital transformation levels among national economies, in our view, are determined by the uneven development of information and communication technologies and the level of investment in the digital economy. Based on this, distinct groups of countries can be identified according to the level of digitalization of their economic systems (Fig. 1).

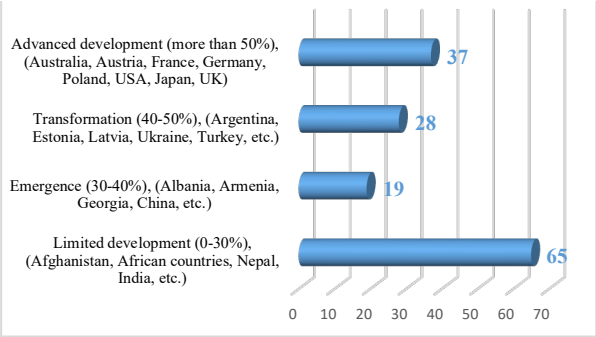


Fig. 1. Distribution of countries by level of economic digitalization in 2024
Source: systematized based on [11].

As seen in Fig. 1, the leading countries in digitalization (those with a high level of digital technology implementation) demonstrate strong integration of automated business management systems, as well as well-developed digital financial and logistics services. In our opinion, this contributes to increased productivity and the formation of new business models within these economic systems.

It is also important to note that countries in the transformation phase, including Ukraine, exhibit a moderate level of digital adaptation, characterized by the active implementation of electronic document management, the development of online trade, and the automation of production processes. However, key challenges remain, such as the digital divide between economic sectors and the need for large-scale investments in digital infrastructure. Conversely, countries with a limited level of digitalization face insufficient funding for technological development and low levels of digital literacy among the population, which slows their integration into the global digital economy. Overall, the growing role of digital competitiveness can be identified as a key factor in economic development and driving the modernization of market relations, including in the agricultural sector.

It is essential to highlight that the integration of digital technologies into the agricultural sector has its specific characteristics, dictated by the industry's unique features. Consequently, the evolution of business models in agricultural enterprises under economic digitalization has followed a slightly different trajectory compared to traditional industrial production (Fig. 2).

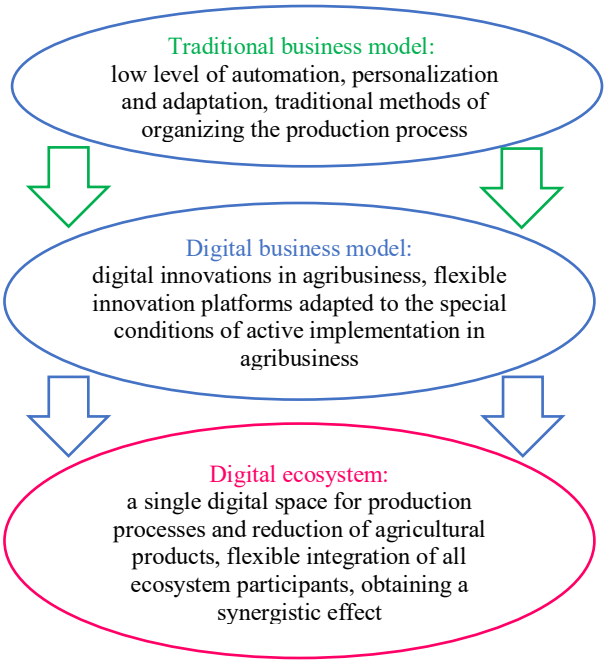


Fig. 2. Evolution of business models in agricultural enterprises under economic digitalization
Source: developed by the author.

In this context, a gradual paradigm shift in agribusiness management can be observed, influenced by digital technologies that have

enabled the optimization of production processes and increased productivity.

It should be noted that the absence of digital solutions in traditional business models has limited the scalability and flexibility of agricultural enterprises, maintaining high transaction costs and dependence on physical resources. Therefore, the transition to digital business models among agricultural producers has been driven by several key factors, including the automation of production processes, the development of e-commerce, and the integration of analytical systems for yield forecasting and cost optimization.

As a result of this transition, agricultural enterprises have achieved cost reductions in logistics and improved overall control over production processes. At present, the formation of digital ecosystems in the agribusiness sector is reshaping the nature of competition. Enterprises that implement automated management algorithms and gain competitive advantages are capable of enhancing their operational efficiency by mitigating the impact of seasonal risks and adopting a personalized approach to agribusiness management.

Under such conditions, the implementation of digital solutions creates the prerequisites for market concentration, as enterprises with access to innovative digital technologies become more resilient to market fluctuations, whereas less technologically advanced businesses risk losing their market share due to relatively lower efficiency and limited sales channels.

Table 1. Modern information technologies widely used in the Ukrainian agribusiness

Field of Application	Information Technologies
Mechanized soil cultivation, crop growing processes, and harvesting systems	Modern electronic cartographic solutions and tools based on satellite image analysis; visualization of real-time soil express analysis dynamics; development of yield maps for agricultural crops; monitoring of crop development dynamics and changes; identification of the most productive and fertile land plots; environmental condition monitoring of fields; crop yield forecasting.
Information solutions for the logistics and distribution of agribusiness products	Optimization of financial and time expenditures for planning routes for the collection and transportation of harvested agricultural products from the field to storage facilities or processing enterprises.
Monitoring the condition and utilization time of agricultural machinery	Optimization of scheduling and costs for routine and capital maintenance of agricultural machinery; prevention of premature wear of specific parts or mechanisms through a notification system and record-keeping.

Source: summarized based on [20; 46].

At the same time, the efficiency of enterprises largely depends on the functional purpose and scope of modern information technologies applied in agribusiness in Ukraine (Table 1).

Analyzing the parameters of the economic effectiveness of the implementation of digital technologies in the domestic agricultural sector, it is advisable to divide them structurally and functionally into priority vectors of digitalization. Among them, aerial photogrammetric complexes based on unmanned aircraft systems, agrochemical spectroscopy and geochemical analysis of soil cover, satellite remote agricultural monitoring analytics, as well as integrated meteorological forecasting systems are distinguished. These technological domains act as strategic drivers of the transformation of agricultural production in the digital economy. (Table 2).

Table 2. The multiplier effect of integrating digital technologies in the agricultural sector

Digital Technology	Economic Impact
Parallel guidance	Fuel, seed, fertilizer, and crop protection cost savings of up to 15%.
Variable rate application	Resource savings of up to 10%, increased profitability due to higher crop yields.
Soil analysis	Reduction in production costs, optimized fertilizer application, yield increase, and efficiency improvements by 10-30%.
Drones	Fuel savings, minimized use of seed materials, fertilizers, and irrigation water; preservation and enhancement of yields through timely sowing and harvesting; optimization of production costs and improved planning quality in agricultural enterprises.
Satellite monitoring	Reduction in fuel, seed, fertilizer, and crop protection costs; increased production efficiency; capability to assess land suitability, develop land reclamation plans, and estimate potential yield levels.
Meteorological monitoring	Increased efficiency of production operations, improved yield performance with reduced dependency on climatic conditions, resource savings, and enhanced financial results.

Source: systematized based on [9].

Assessing the dynamics of the number of Ukrainian enterprises engaged in e-commerce operations, as well as the total number of agribusiness enterprises involved in e-commerce, allows us to conclude a steady increase in market participants amid the digital transformation of the economy. In recent years, the overall number of enterprises engaged in e-commerce has demonstrated a growing trend, which is a result of the active implementation

of digital technologies and the increasing accessibility of internet infrastructure in Ukraine (Table 3).

Analyzing structural changes, attention should be paid to the dynamics of processing enterprises in Ukraine, whose share in the total number of e-commerce entities has gradually increased from 27.1% in 2020 to 28.3% in 2023. This dynamic reflects the institutional and technological adaptation of the processing sector to the paradigm of digital distribution channels and the evolution of electronic commercial interfaces within the B2B and B2C segments. At the same time, the specific index of the presence of processing industry enterprises in the total mass of Ukrainian economic entities involved in e-commerce activity has undergone a regressive trend (from 5.7% in 2020 to 5.3% in 2023), which is interpreted as evidence of a higher intensity of digital transformation in related sectoral domains of the national economy.

Table 3. Dynamics of enterprises engaged in e-commerce operations in Ukraine (2020–2023)

Indicator	Value by year			
	2020	2021	2022	2023
Number of enterprises that implement the full range of business operations within the electronic business environment, units	2,476	2,441	2,495	2,522
Total number of processing sector involved in digital transaction processes, units	676	663	685	723
- specific value in the structure of the total number of e-commerce entities, %	27.2	27.3	27.6	28.4
- specific weight in the total array of Ukrainian enterprises operating in the e-commerce format, %	5.7	5.4	5.5	5.3
The total number of agro-industrial formations integrated into electronic sales and procurement channels, units	157	148	156	172
- share in the total number of all processing enterprises in Ukraine engaged in e-commerce, %	23.3	22.2	22.3	22.6
- share in the total number of all enterprises engaged in e-commerce, %	6.9	6.5	6.7	7.0

Source: compiled based on [18, 44].

The agricultural sector deserves special attention, as its share among enterprises operating in e-commerce fluctuates between 6.5% and 7.0%. This indicates a stable interest of Ukrainian agribusiness in digital sales of finished products, although the growth rate here is noticeably lower than in related industries.

One of the key determinants of this phenomenon, in our analytical assessment, is the inertial dominance of classic sales trajectories combined with the complication of logistics configurations associated with the digital distribution of agricultural products within the national economic space of Ukraine. At the same time, the absolute number of Ukrainian agricultural enterprises using e-commerce has increased (from 157 units in 2020 to 172 units in 2023), pointing to the gradual formation of new market interaction models, particularly through electronic exchanges and marketplaces.

In Ukraine, the practical formation of new models of interaction of agricultural companies with the market through electronic exchanges and marketplaces occurs mainly through the integration of digital platforms into the processes of buying and selling agricultural products. Electronic exchanges, such as GrainTrade, AgroMarket and Agroxy, provide transparency of transactions, access to analytical data and expansion of sales markets. In turn, marketplaces, in particular Prom.ua, OLX Agro and specialized agricultural platforms, allow small and medium-sized producers to directly interact with end consumers and traders, which helps to minimize intermediary costs and increase price competition.

In our view, the key factors influencing these changes include economic incentives,

macroeconomic instability (the search for alternative sales channels amid logistical constraints), and targeted state support for business digitalization in Ukraine. The consequences of these processes may include further market concentration around major players, increased competition, and growing investments in technological solutions that optimize the operational activities of enterprises in the e-commerce sector in Ukraine.

Assessing the trends in the digitalization of Ukrainian agricultural enterprises at the regional level, we have developed a cartogram of Ukraine's regions based on the share of agribusiness processing enterprises engaged in e-commerce in 2022 (Fig. 3).

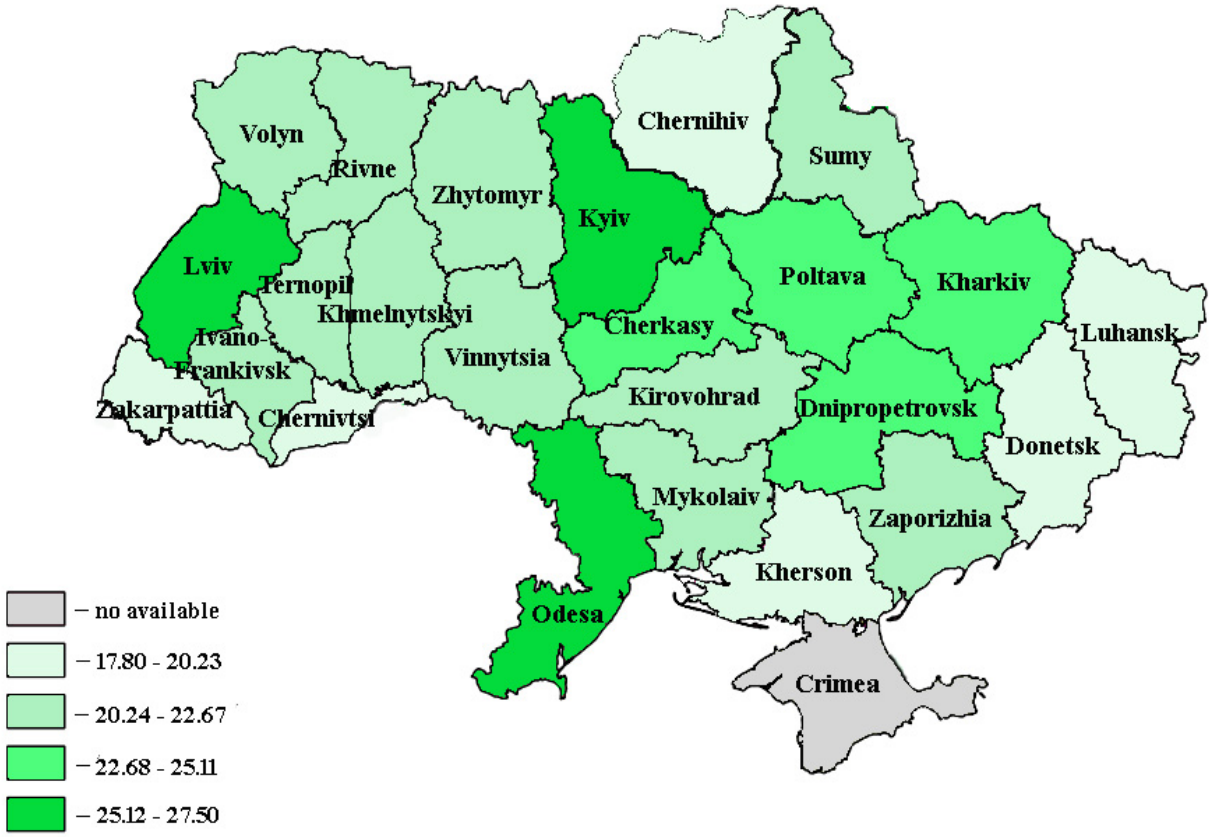


Fig. 3. Cartogram of the classification distribution of regions of Ukraine by the specific weight of entities of the processing segment of the agro-industrial system involved in e-commerce activities in 2022.
Source: constructed by the author based on [21].

In parallel, an analytical interpretation of the temporal dynamics of product sales volumes within the e-commerce sector in Ukraine indicates intensive scaling of virtualized product sales channels. The total volume of products sold via e-commerce in Ukraine increased from UAH 228.1 billion in 2020 to UAH 395.4 billion in 2023, indicating a large-scale transition of businesses to digital models for selling finished products (Table 4).

As Table 4 shows, the processing sector demonstrates a significant contribution to the macrostructure of the e-commerce segment of Ukraine - its share in the total volume of products sold increased from 27.1% in 2020 to 28.3% in 2023. Such dynamics serve as an indicator of the evolution of the commercial paradigm and its functional adaptation to the transformed requirements of the digitalized consumer market.

However, in the structure of sales volume sold via e-commerce in Ukraine, the share of agribusiness products decreased from 14.9% in 2020 to 11.2% in 2023. This may be due to the relatively low flexibility of Ukraine's agricultural sector in terms of digitalization and its predominant reliance on traditional distribution channels.

Table 4. Dynamics of product volumes sold via e-commerce in Ukraine (2020–2023)

Indicator	Value by year			
	2020	2021	2022	2023
Total volume of products from all types of production and commercial activities in e-business, billion UAH	228.1	292.9	364.7	395.4
Total volume of processed industry products sold via e-commerce, billion UAH	52.7	56.4	61.0	64.7
- share in the consolidated volume of goods sold through e-commerce channels, %	27.1	27.3	27.6	28.4
- relative indicator in the total volume of product sales through digital sales mechanisms, %	2.8	3.2	3.2	3.9
Integral volume of agricultural products sold through electronic trading platforms, billion UAH	33.8	36.6	38.5	40.3
- share in the total volume of products sold by the processing industry through e-commerce, %	14.9	12.6	10.8	11.2
- structural indicator in the total volume of products sold within digital commerce, %	5.3	5.9	5.3	5.4

Source: compiled based on [18, 44].

At the same time, the absolute growth in sales of agricultural products in Ukraine (from UAH 33.8 billion in 2020 to UAH 40.3 billion in 2023) confirms the gradual adoption of digital technologies, particularly in high-tech segments of agribusiness. Accordingly, structural changes in e-commerce in Ukraine indicate a redistribution of market share in favor of sectors that adapt more quickly to digital tools. The long-term consequences of these changes in Ukraine may include market consolidation, increased competition among producers, and further growth in investment in automation and digital logistics. Figure 4 presents a multi-level approach to the digitalization of Ukraine's agribusiness sector, identifying key factors influencing this process and strategic directions for development. Methodological platform of the study is formalized through the prism of mutual determination of endogenous and exogenous market determinants in combination with the target guidelines of digital renovation of the agricultural sector.

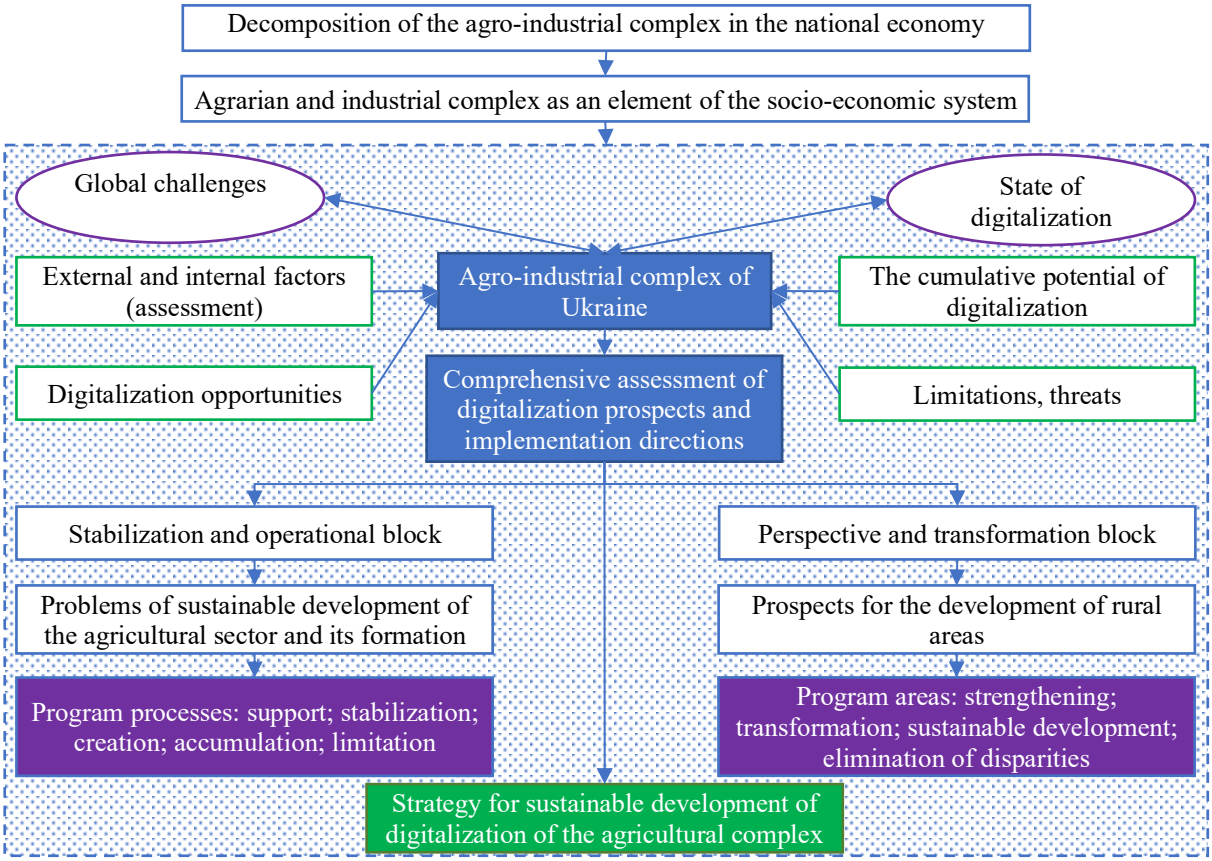


Fig. 4. Theoretical and methodological imperatives of implementing strategically oriented vectors of digital transformation of the agro-industrial sector of Ukraine
Source: own generalizations.

In our opinion, in the paradigm of progressive development of the agricultural sector of Ukraine, it is advisable to focus on a comprehensive audit of digitalization potential, which includes the identification of structural and resource support and the level of innovative susceptibility of the subjects of the agro-industrial complex to digital integration. The conceptual structure we have formulated integrates the stabilization and operational module (assessment of the current demand for digital solutions) and the strategic and evolutionary cluster (long-term digital transformation of agricultural production with an emphasis on the implementation of high-tech tools). A specific focus in shaping the conceptual foundations for implementing strategic directions of digitalization in Ukraine's agribusiness sector has been placed on software processes and digital transformation pathways. This means that the concept not only outlines the necessary changes but also proposes implementation mechanisms, including support for innovative solutions, a strategy for sustainable digitalization development, and bridging the digital divide between large agribusiness enterprises and small-scale producers in Ukraine.

CONCLUSIONS

Thus, we conclude that the digitalization of agribusiness management determines a shift in the economic behavior of enterprises, transforming their strategic orientations, efficiency assessment methodologies, and competitive positions in the market. Therefore, the use of analytical approaches to the systematization and forecasting of managerial decisions contributes to the development of adaptive business models based on resource flow integration and the enhancement of operational efficiency. The results of the analytical testing showed the asymmetric pace of digital transformation in the agro-industrial complex of Ukraine, which is determined by the degree of technological adaptability of business structures and the level of their resource and material support. It was found that the productivity of digital transformations demonstrates a high degree of correlation with the institutional ability of business entities to implement intelligent analytical platforms and automated systems of management contour control. At the same time, for small and medium-sized agricultural production units, significant barrier restrictions remain, which inhibit the process of scaling digital solutions and provoke risks of deepening intra-sectoral structural fragmentation. The summarized research findings indicate the necessity of a comprehensive approach to regulating digital transformation, which would combine strategic support for innovation with mechanisms to minimize technological inequality within the agribusiness sector.

Thus, the implementation of the presented Conceptual Model for the formation of strategic vectors of digital transformation of the agro-industrial complex of Ukraine involves the institutionalization of an integrated digital space within the agro-industrial complex, which will function as a multifunctional catalyst for increasing the productive and efficient parameters of agricultural production and accelerating the processes of digitalization of the national agricultural sector. We believe that this could result in enhanced competitiveness of the Ukrainian agribusiness sector in international markets and a general increase in agricultural production productivity.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE IMPACT OF DIGITAL TECHNOLOGIES ON THE EFFICIENCY OF THE ACTIVITIES OF AGRICULTURAL SECTOR ENTERPRISES: A CASE STUDY OF UKRAINE

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Abstract

The article examines the role of digital technologies in enhancing the efficiency of Ukraine's agricultural sector under current economic conditions. It is established that the digitalization of agricultural production serves as a critical factor in maintaining the sector's competitiveness. The dynamics of investments in digitalization and the level of digital skills among the rural population are analyzed, and their relationship with agricultural output is identified. Based on correlation-regression analysis, it is demonstrated that investments in the digitalization of business processes exert a significant positive effect on enterprise efficiency, while the development of digital competencies among the population produces a delayed impact. It is concluded that the combination of digital innovations with the development of human capital ensures the long-term growth of value added in the agricultural sector. The findings prove that the strategy of digital transformation in agriculture must be based on a balance between stimulating investment in advanced technologies and fostering digital skills among workers, since these factors generate conditions for innovative growth only through their interaction.

Key words**:** *agricultural sector digitalization, technology investments, digital skills of population, production efficiency, human capital*

INTRODUCTION

Currently, the situation in the agricultural sector of Ukraine can be characterized by two main trends - firstly, it is one of the most important components of the national economy, and secondly, the sector faces a technological gap associated with the slower pace of digital adoption in agricultural enterprises compared to industry and finance. Enterprises that have successfully integrated modern digital and information solutions demonstrate relatively higher operational efficiency. Overall, this indicates that the digital transformation of agriculture today is not an optional modernization, but a strategic factor for sustaining the competitiveness of the entire sector in global markets. This is explained by the fact that the profitability of agribusiness is largely determined by the efficiency of resource use, which increases significantly with the application of advanced digital technologies. Modern automated management systems and platforms for monitoring and controlling production processes impact not only enterprise productivity and operating costs but also financial resilience.

Practical evidence shows that the integration of digital technologies into business processes substantially increases the transparency of managerial decisions and ultimately leads to higher profitability and investment attractiveness. This underlines the relevance of assessing the efficiency of digital technology implementation in Ukraine's agricultural sector, which requires additional incentives to compete successfully in today's challenging global environment.

Contemporary research increasingly focuses on the role of digital technologies in transforming agricultural enterprises by

optimizing production processes. Significant contributions to this field have been made by scholars such as O. Agres [1], N. Antoniuk [2], I. Arakelova [3], M. Bezpartochnyi [4], I. Britchenko [5-9], A. Dibrova [10], S. Ionitescu [11], N. Khomiuk [12], V. Kostiuk [13], M. Kryshtanovych [14], N. Kunitsyna [15], M. Kuzheliev [16], I. Mazniev [17], T. Mirzoieva [19], A. Popescu [20-29], M. Rudenko [30], V. Sarioglo [31], T. Shmatkovska [32-38], R. Sodoma [39-40], D. Tanhua [42], A. Verzun [43], A. Zielińska [45] among others. Nevertheless, there remains a need to explore the specific factors influencing the efficiency of agricultural digitalization and enterprise management.

MATERIALS AND METHODS

The study is based on a comprehensive approach that combines both specialized and general scientific methods. In particular, the method of logical generalization was applied to interpret the obtained results and formulate conclusions. This allowed us to highlight the key role that digital technologies and human capital play in stimulating the economic growth of Ukraine's agricultural sector.

In addition, to determine the impact of selected factors on the production volume of agricultural enterprises, the study used correlation-regression analysis. To statistically verify the significance of the developed correlation-regression model, the coefficient of determination (R^2), Fisher's F-test, and Student's t-statistics for each variable were employed. The data were processed using the functionality of MS Excel software, which ensured calculation accuracy and enabled the visualization of the obtained results.

RESULTS AND DISCUSSIONS

Agriculture holds an essential position in the structure of Ukraine's national economy. Specifically, its share in total production accounts for approximately 10% of all output. It should be noted that the agricultural sector accounts for 55–59% of Ukraine's total export volume. As a result, agriculture is a fairly important component of the country's economic security [41]. At the same time, the importance of the agricultural sector is determined not only by its high share in the production structure, but also by its key role in shaping Ukraine's national food security. Ukraine is among the world's leading exporters of grains, oilseeds, and processed products, which makes agriculture a system-forming sector of external economic activity. The gross value added generated by agricultural enterprises has shown a steady upward trend despite market fluctuations (Fig. 1).

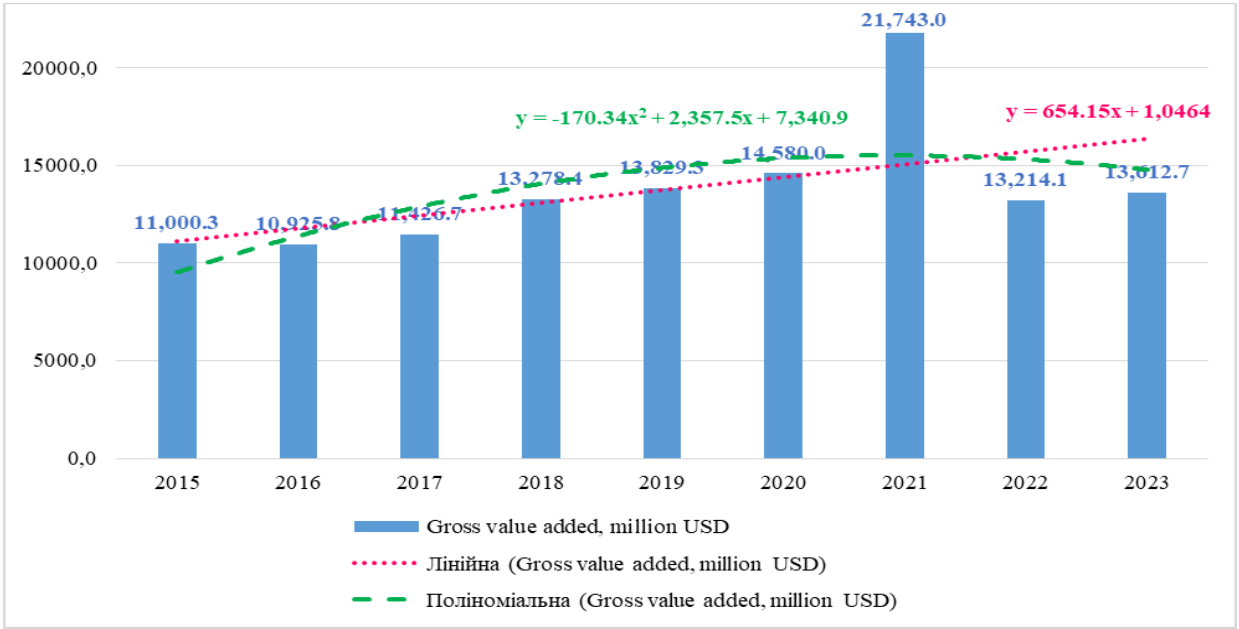


Fig. 1. Trend estimation of the gross value added of Ukraine's agricultural sector in 2015–2023
Source: compiled by the author based on [41].

As we can see, the linear trend shows that the GVA indicator of the agricultural sector of Ukraine in the analyzed period was characterized by growth. The absolute increase in this indicator amounted to 654.15 million USD. On the other hand, the analysis of the polynomial trend results shows that the actual annual change in gross value added reached 2,357.5 million USD, with an initial decline of 170.34 million USD.

It should also be emphasized that under conditions of economic destabilization, the agricultural sector acquires critical importance as an economic stabilizer, ensuring the inflow of foreign currency resources. Therefore, it can be argued that at present the agricultural sector serves as the foundation of Ukraine's economic resilience and long-term competitiveness.

Therefore, the key task for the national economy of Ukraine in the current conditions is to achieve high efficiency of agricultural producers. Digital and information technologies are of particular importance for this. Whereas 10–15 years ago their role was mainly limited to improving management systems and cost analysis, today digitalization encompasses precision farming systems, specialized ERP systems for agricultural producers, robotic technologies, and automation of agricultural machinery. However, it is worth noting that in practice, the implementation of these technologies requires agricultural producers to make significant additional investment costs. But, while the acquisition of advanced new machinery built on digitalization principles and equipped with network connectivity is classified as investment in fixed assets, expenditures on specialized information and digital technologies tailored to the needs of a particular producer require enterprises to mobilize additional financial resources. Therefore, enhancing the efficiency of digital solutions in the operations of agricultural companies necessitates corresponding investments (Fig. 2).

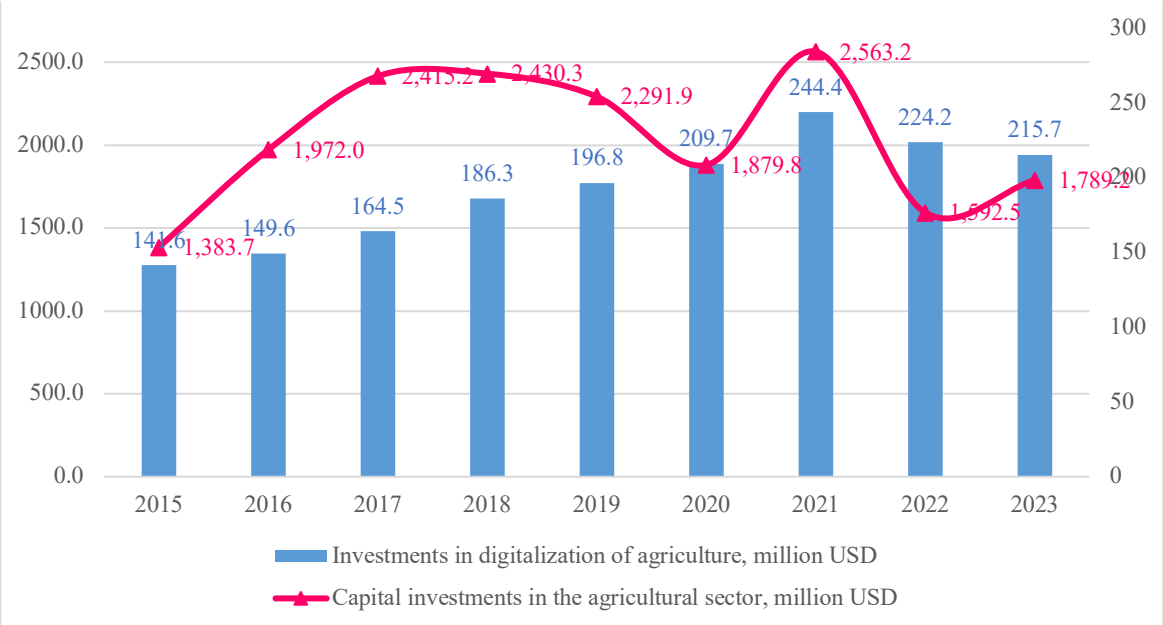


Fig. 2. Change in capital investments and investments in the digitalization of the agricultural sector of Ukraine in 2015–2023

Source: built by the author based on [41; 44].

From the diagram we see that the volume of capital investments in agriculture in Ukraine exhibited an upward trend until 2021, reaching a peak of more than USD 2.5 billion. However, in 2022–2023, a significant decline was observed, directly caused by overall economic destabilization and elevated risks for investors. At the same time, investments in digitalization, although relatively low in absolute terms, displayed a more stable dynamic. Their gradual growth indicates that even under crisis conditions enterprises sought to optimize costs

and improve production efficiency through the use of digital solutions. This trend can be explained by the comparatively lower costs of implementing digital technologies relative to large-scale infrastructure investments. In particular, while in 2015–2021 investments in digitalization averaged 9–10% of total agricultural sector investment, in 2022 this figure rose to 14.1%, and in 2023 it stood at 12.1%. As a result, these tendencies point to a gradual reconfiguration of agribusiness models towards more intensive adoption of technological innovations, which serves as a prerequisite for strengthening the sector's overall competitiveness.

Moreover, it should be emphasized that a fundamental condition for the successful implementation of digital technologies in agricultural enterprises is the availability of digital skills among the workforce to be employed in this sector. A shortage of workers capable of applying digital tools or interpreting data generated by relevant software applications may significantly reduce the overall efficiency of technological adoption. Considering the specific features of agriculture such as: soil management, crop cultivation, and logistics, workers' competencies play a decisive role in ensuring the effectiveness of innovations. As practice shows, in countries with a high level of digital literacy, investments in technology achieve faster returns and enterprises can reduce production costs. For Ukraine, this factor is particularly important, since a deficit of digital skills in rural areas may hinder the modernization of the agricultural sector. Thus, human capital with advanced digital competencies becomes a critical asset capable of transforming technologies into a competitive advantage for enterprises. Accordingly, it is essential to assess the level of basic and advanced digital skills among Ukraine's rural population to determine whether the labor force meets the needs of agricultural enterprises (Fig. 3).

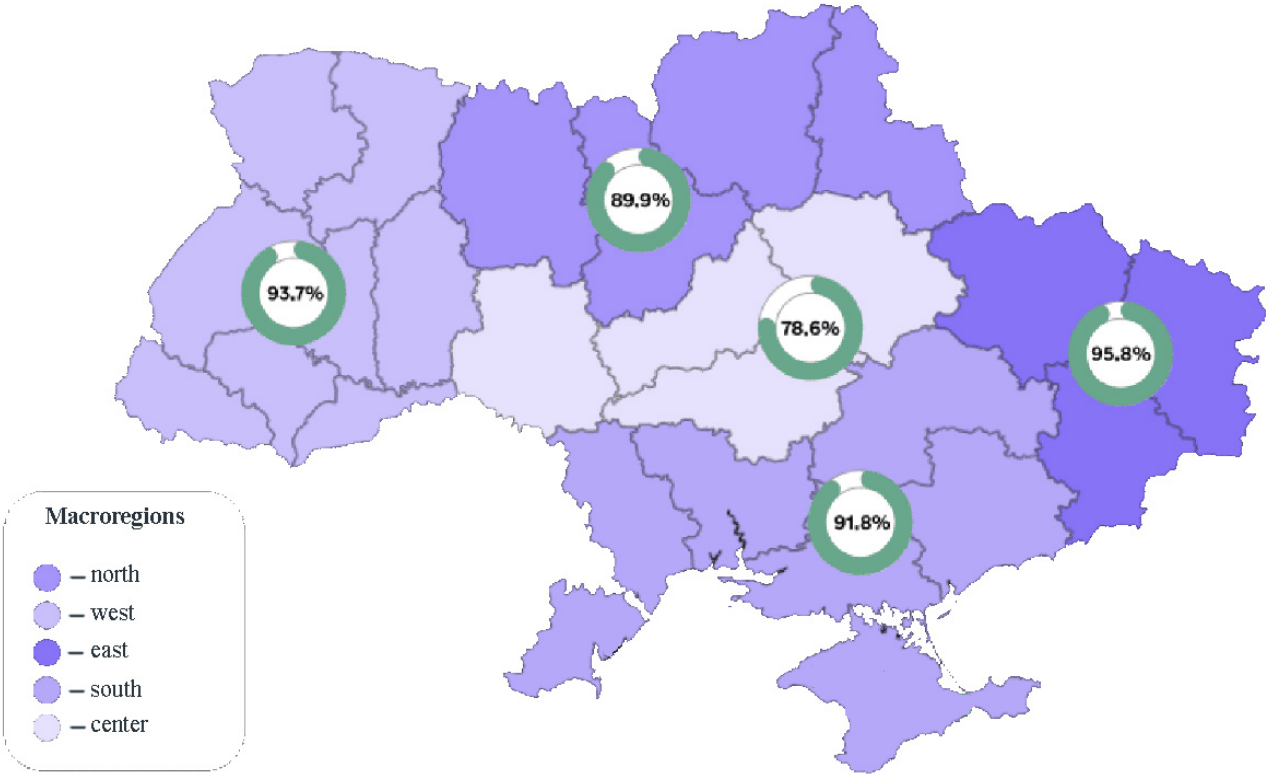


Fig. 3. Levels of basic and advanced digital skills among the rural population of Ukraine in 2024 by macro-regions
Source: [18].

Figure 3 shows that the highest levels of digital skills are recorded in the eastern regions of Ukraine – 95.8%, which indicates an active integration of digital technologies even in rural areas. High values are also characteristic of the western (93.7%) and southern (91.8%) regions, where a significant number of agricultural enterprises are concentrated. In contrast, the

northern macro-region demonstrates a somewhat lower level of digital literacy – 89.9%. Nevertheless, this level is still sufficiently high to ensure workers' readiness to adopt digital solutions. The lowest level of digital skills is observed in the central region – 78.6%, although even this figure is adequate for providing enterprises with personnel capable of using innovative products. Overall, these results indicate a substantial level of progress in the development of digital skills among Ukraine's rural population, which constitutes the foundation for the successful digitalization of the entire agricultural sector.

Since investments in production digitalization and the digital literacy of the population are, in our view, the key factors influencing the efficiency of agricultural enterprises in the context of digital technology adoption, it is appropriate to analyze their impact on overall productivity. It must be emphasized that enterprise performance will be affected not only by workers with basic but especially by those with advanced digital skills. To determine such influence, correlation analysis was applied, which makes it possible to identify the most significant relationships between agricultural output and the two selected factors. For empirical verification of this hypothesis, we developed and constructed a correlation-regression model. Annual statistical data for 2010–2023 were used regarding two independent variables relevant to the digitalization of agricultural enterprises in Ukraine and influencing production growth (Table 1).

Table 1. Dynamics of the indicators used for building the correlation-regression model, 2010–2023

Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Production volume, million USD	23,854.5	31,815.4	32,324.2	24,578.9	24,130.0	19,076.0	18,586.5	19,703.8	22,650.5	24,629.1	25,196.9	37,754.2	22,724.5	21,742.8
Investments in digitalization of agriculture, million USD	126.2	145.4	154.5	154.6	150.6	141.6	149.6	164.5	186.3	196.8	219.7	274.4	224.2	215.7
Share of rural population with advanced digital skills, %	4.1*	5.7*	7.2*	11.8*	19.4*	29.1*	32.8*	38.7*	42.3*	47	49.6	52.2	56.7	59.6

*the indicator of the level of digital skills for the period 2010–2018 was determined based on expert assessments of the Ministry of Digital Information of Ukraine.
Source: [18; 41; 44].

Table 2 presents the key parameters of the regression model that describes the influence of selected factors on the volume of agricultural production.

Table 2. Parameters of the developed correlation-regression model for determining the impact of selected factors on the volume of agricultural production (y)

Factor	Coefficient (B)	Standard error	t-statistic
Production volume, million USD (y)	293.231	2870.087	0.102
Investments in digitalization of agriculture, million USD (x1)	214.458	22.032	9.734
Share of rural population with advanced digital skills, % (x2)	-421.664	46.596	-9.049

Source: own research.

The correlation-regression model equation obtained as a result of the analysis describes the dependence of the production volume of agricultural enterprises on two key factors of digitalization:

$$y = 293.23 + 214.46x_1 - 421.66x_2$$

The obtained correlation-regression model indicates that the most significant factor in the growth of agricultural production is investment in digitalization. In particular, an increase of this indicator by 1 million USD leads, on average, to a rise in production volume of 214.5 million USD. Accordingly, this confirms the substantial effect of implementing digital technologies, the result of which is an increase in production efficiency.

By contrast, the coefficient for the share of the rural population with digital skills has a negative value (–421.7), which may reflect the ambiguous role of this factor. Most likely, the growth of digital literacy among the population alone cannot ensure a rapid increase in production volumes and requires enterprises to

make prior investments in the digitalization of their business processes.

The developed model confirms the hypothesis of the key importance of investments in digitalization for agriculture. However, there is also an objective need to ensure the proper balance between the level of human capital development and technological modernization of the industry. At the same time, it is absolutely clear that without synchronization of these factors, achieving the proper level of digitalization efficiency will be problematic.

To visualize the calculations, a comparison of actual and predicted production volumes was made using the constructed model (Fig. 4).

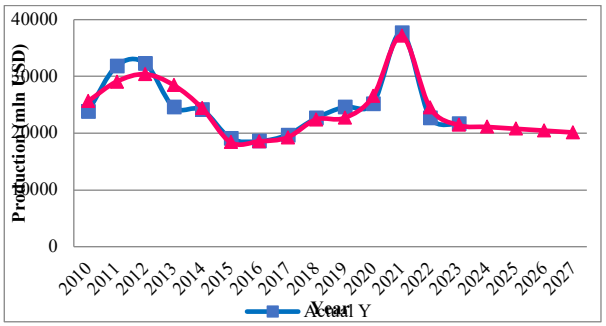


Fig. 4. Actual and predicted values of agricultural production in Ukraine according to the developed regression model

Source: own research.

The figure shows that the model adequately reflects the dynamics of Ukraine's agricultural production during 2015–2023. The lines of actual and predicted values are nearly parallel, which indicates a high level of consistency between the empirical data and the calculated results of the model. The convergence of these curves is particularly evident in periods of production growth after 2016 and in the decline phase of 2022–2023. Thus, the constructed regression model approximates the real dynamics well and accounts for the key influencing factors. The high coefficient of determination (R^2 = 0.899) confirms its reliability.

We also present the summary results of the correlation-regression analysis of the relationship between production volume and the selected factors. Specifically, the main coefficients of the developed correlation-regression model indicate the following:

Coefficient of determination (R^2 = 0.899) – the model explains about 90% of the variation in agricultural production, which demonstrates its high adequacy.

Adjusted R^2 (0.881) confirms the high accuracy of the model even when accounting for the number of included factors.

F-statistic: 49.04 ($p < 0.00001$) – the model as a whole is statistically significant.

Student's t-statistics:

- for x_1 (investments in digitalization): $t = 9.73$, $p < 0.001$ – the variable is statistically significant and has a substantial positive impact;
- for x_2 (digital skills of the population): $t = -9.05$, $p < 0.001$ – this variable is also statistically significant but exerts a negative effect in the short term.

Therefore, it can be argued that the developed model is reliable and demonstrates that both factors have a significant impact on the volume of agricultural production, although their effects differ in direction.

In addition, we proceed with the assessment of the correlation matrix (Table 3).

Table 3. Matrix of mutual correlation of factor and outcome variables

Indicators	Production volume (y)	Investments in digitalization (x_1)	Rural population with advanced digital skills (x_2)
Production volume (y)	1	X	X
Investments in digitalization (x_1)	0,385201	1	X
Rural population with advanced digital skills (x_2)	-0,174572	0.823365	1

Source: own research.

As shown by the calculations, the strongest correlation with the volume of agricultural production is demonstrated by investments in digitalization (0.385), whereas the correlation with the share of the rural population possessing digital skills is weak and negative (–0.175). This indicates that the short-term effect of digital competencies has not yet translated into an increase in production volumes. At the same time, investments in digital technological solutions directly enhance the performance of agricultural enterprises. Furthermore, the high level of interdependence

between the two factors (0.823) points to a structural relationship: investments in digitalization stimulate the spread of digital skills, but a certain period is required before the corresponding effect materializes.

Overall, the conducted correlation-regression analysis empirically confirmed the hypothesis regarding the significant impact of investments in digital technologies on the development of Ukraine's agricultural sector. The most statistically significant factor proved to be investment ($t = 9.73$, $p < 0.001$). In contrast, the negative regression coefficient for digital skills of the population ($t = –9.05$, $p < 0.001$) suggests that the growth of competencies does not immediately translate into positive economic outcomes. The reliability of the model is confirmed by the high coefficient of determination ($R^2 = 0.899$) and the statistical significance according to Fisher's criterion ($F = 49.04$, $p < 0.00001$). This indicates the suitability of the model for forecasting the dynamics of agricultural production.

The results obtained show that to ensure a high level of efficiency in Ukrainian agriculture, it is necessary to encourage agricultural enterprises to constantly increase investments in digital technologies. In addition, such investments should be combined with parallel human capital development to ensure their maximum effectiveness in the long term.

CONCLUSIONS

Therefore, it can be argued that stimulating investments in the digitalization of Ukrainian agriculture is currently a key indicator of its competitiveness. The results of the correlation-regression analysis confirm the key role of investments in digital technologies. Their growth has a statistically significant positive impact on agricultural production volumes, reflecting the tangible benefits of implementing technological innovations. At the same time, it should be noted that the impact of the population's digital skills on production volumes proved to be more complex – In the short term, their increase is accompanied by a negative effect. In our view, this is explained by the necessity of upfront expenditures for improving business processes and adjusting production systems according to new technological principles. However, as practice demonstrates, the development of digital competencies creates the foundation for the long-term return on investments in digitalization and for enhancing the efficiency of resource utilization in enterprises.

The developed model proves that the effective advancement of technical innovations and human capital is a necessary prerequisite for the successful digital transformation of Ukraine's entire agricultural sector. The digital development strategy must therefore focus on systematic investments not only in technologies but also in the upskilling of the rural population to implement these solutions directly in production. Only the combination of these factors generates the desired effect, ensuring cost reduction and the formation of long-term investment attractiveness for Ukrainian agricultural enterprises. Accordingly, these principles can serve as the basis for the strategic planning of the digital transformation of Ukraine's agricultural sector, provided that both economic and social dimensions of this strategy are taken into account.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

TECHNICAL EFFICIENCY ANALYSIS OF GRAIN MAIZE PRODUCTION: A CASE STUDY IN TÜRKİYE

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Abstract

The purpose of this study is to examine the input usage levels of grain maize farmers in Izmir province, Türkiye and to determine the efficiency of input utilization. The study was conducted in four districts of Izmir province, where maize farming is most prevalent. Data were collected through face-to-face surveys with 141 farmers, selected using a stratified random sampling method. The study employs Data Envelopment Analysis (DEA) to assess input usage efficiency. 33.33% of farms were fully efficient under CRS, and 43.26% were fully efficient under VRS. The average efficiency scores ranged between 0.86 and 0.99. The average technical efficiency (CRS) was determined as 0.90. Results indicate that the technical efficiency scores vary across farm sizes, with small farms being relatively more efficient in input use. The results highlight inefficiencies in seed, fertilizer, and irrigation usage, suggesting opportunities for optimization. Policy recommendations include promoting soil testing, increasing awareness of input management, and improving extension services. Enhancing efficiency in maize production could reduce costs, increase profitability, and improve sustainability in Turkish agriculture.

Key words**:** *grain maize, input usage, efficiency analysis, technical efficiency, data envelopment analysis*

INTRODUCTION

Grain maize is cultivated in many countries today due to its importance in human nutrition, its use as animal feed, and its role as a crucial raw material for industry, contributing significantly to economic growth. Globally, approximately 65-70% of produced grain maize is used as animal feed, 20% is directly consumed by humans, and the remaining 10-15% is utilized in industries. In the industry, many products are obtained from grain maize, including flour, oil, starch and sweeteners [4]. According to FAO's 2023 data, global grain maize production increased to 1.24 billion tons due to both the expansion of cultivation areas and the increase in yield. Grain maize ranks second in terms of cultivation area among cereal crops worldwide (208 million hectares), following wheat, but it is the leading crop in terms of production. Approximately 31% of global grain maize production occurs in the USA, 23% in China, and 14% in South America [22]. According to TURKSTAT data, Türkiye produced 9 million tons of grain maize on 958,017 hectares in 2023. These figures indicate that Türkiye accounts for 0.46% of the global grain maize cultivation area and 0.72% of global grain maize production. The examination of grain maize cultivation areas in Türkiye between 2012 and 2023 shows a decline in 2017, followed by an increase until 2023. In the same period, grain maize production increased by 65% [42]. It is thought that the policies of the Ministry of Agriculture and Forestry and Turkish Grain Board, the use of certified seeds and the developments in the use of technology in production have a significant impact on these increases. In 2023, 29% of Türkiye's grain maize production was obtained from the Western Anatolia region, 24% from the South-Eastern Anatolia region,

21% from Mediterranean region, 10% from Eastern Marmara region, and 7% from the Aegean region. Grain maize yield varies regionally within Türkiye. In 2023, the national average grain maize yield was 9,390 kg per hectare, exceeding the global average of 5,962 kg [42].

According to TURKSTAT data, Türkiye's self-sufficiency rate in grain maize was 96% in 2023. However, due to the development of the manufacturing industry, the demand for raw materials, and the increase in exports of finished goods, Türkiye imports grain maize in addition to domestic production. In 2023, Türkiye exported 3.35 million tons of grain maize and imported 3.27 million tons. Türkiye primarily imports grain maize from the Russian Federation, Ukraine, Romania, and Serbia [42].

In Türkiye, grain maize can be used as feed as well as in the production of starch, oil, glucose and bioethanol. Grain maize can be rotated with crops such as cotton, wheat, and oilseeds. Farmers decide between growing grain maize or alternative crops based on product prices and government support. Therefore, fluctuations in grain maize production can occur [35, 40]. Farmers may change the crops they cultivate on irrigable lands based on economic conditions, drought, or labour shortages. In recent years, declines in cotton, processing tomato, and wheat revenues have led farmers in Izmir province to shift towards grain maize production. In 2023, 89,677 tons of grain maize were produced on 12,088 hectares in Izmir province. The examination of grain maize production in Izmir province between 2012 and 2023 reveals an increase until 2017, followed by a decline in subsequent years. In 2023, grain maize production in Izmir province accounted for 15% of the Aegean Region's total production and approximately 1% of Türkiye's total grain maize production. The grain maize yield in Izmir province in 2023 was 8,960 kg per hectare, below the national average (9,390 kg/ha) [42].

Several studies have been conducted on the economic aspects of grain maize in Türkiye. Some of these studies have analyzed grain maize's cost and profitability [1, 28, 41, 20, 25, 21, 15, 3, 17, 14, 47], while others have focused on input usage [8, 32, 6, 27], the impact of government support [2, 33, 16, 18, 29, 23], efficiency analyses [11, 26, 43, 30, 31, 5, 19, 45], and marketing structures [39, 38].

Türkiye meets part of its grain maize demand through imports. Additionally, issues such as genetically modified (GMO) grain maize, ethanol production from grain maize, climate change impacts on agriculture, and fluctuations in national and international prices necessitate identifying sustainability issues in grain maize production and conducting scientific research to develop solutions. Natural and economic conditions can significantly impact the income of grain maize farmers.

Therefore, it is essential to determine farmer practices, input selection, and usage levels over time and at a regional level through research. The results of this research can serve as a guide for farmers in determining crop patterns and contribute to the preparation of production plans, the formulation of appropriate agricultural policies, and their implementation. The purpose of this study is to examine the input usage levels of grain maize farmers in Izmir province, Türkiye and to determine the efficiency of input utilization.

MATERIALS AND METHODS

The primary data for this study were collected through face-to-face surveys with grain maize farmers in Izmir province, Türkiye. In addition, previous study results and statistical data published by institutions such as FAO and TURKSTAT were also used.

The study focused on the districts of Torbali, Menderes, Tire, and Bergama in Izmir province, where grain maize production is supported under the Agricultural Basins Support Model. According to TURKSTAT's data, these four districts accounted for 75% of Izmir province's grain maize cultivation areas and 77% of its grain maize production. The study planned to include four neighbourhoods from each district where grain maize production is most concentrated. The main population in 16 selected neighbourhoods consisted of 1,455 grain maize farmers registered in the Farmer Registration System in these neighbourhoods.

A stratified random sampling method was used to select a representative sample of farmers, employing the following formula [44]:

$$n = \frac{\sum(N_h.S_h)^2}{N^2.D^2 + \sum(N_h.S_h^2)} \quad (1)$$

$$D^2 = d^2/z^2 \quad (2)$$

where: n = Sample size, N = Number of farms in the population, N_h = Number of farms in stratum h, S_h = Variance of stratum h, D^2 = Permissible error margin, z = Standard normal distribution value for the given confidence level.

With a 10% error margin and a 90% confidence level (z = 1.645), the calculated sample size was 141.In distributing the sample volume to the strata, stratum variances were taken as basis, and the following formula was used for this purpose [44].

$$n_h = \frac{N_h.S_h.n}{\sum N_h.S_h} \quad (3)$$

Stratification was based on variance values, ensuring that each stratum contained at least 30 farmers for meaningful comparisons. Accordingly, farmers were categorized into three strata based on cultivated area: less than 4 hectares (Group 1), 4-13 hectares (Group 2), and more than 13 hectares (Group 3). The final sample included 41 farmers from Group 1, 62 from Group 2, and 38 from Group 3 (Table 1).

Table 1. Stratified sample size

Farmer groups	Strata (ha)	Frequency	Variance	Mean (ha)	Sample size	%
1	<4	1,119	89.34	1.67	41	29.08
2	4-13	294	524.38	6.79	62	43.97
3	>13	42	2,252.70	18.85	38	26.95

Source: Own Calculation.

The number of farmers interviewed in each settlement was determined based on their proportional representation in the total population. The final selection of farmers was made using a random number table. The study was conducted during the 2021 production season, with surveys administered between November 2021 and January 2022.

The study first examined the socio-economic characteristics of farmers, followed by input usage of grain maize production. At this stage, the average input amounts used per hectare were determined. To determine the technical efficiency of grain maize production, Data Envelopment Analysis (DEA) was used. The data were analysed under constant returns to scale (CRS) and variable returns to scale (VRS) models, generating efficiency scores for each assumption. The input-oriented model approach aimed to achieve the same output with minimal input usage, promoting resource efficiency. The output-oriented and variable returns to scale model was represented as follows [13]:

Maximum: η
X_{0t}-$X_{\mu} \geq 0$
ηy_{0t}-$Y_{\mu} \geq 0$
$\mu \geq 0$

where:

- η represents the output factor weight vector
- y_{0t} is the output produced by the decision-making unit t
- Y is the total output produced by all decision-making units
- μ represents the output weight factor
- X_{0t} is the input consumed by the decision-making unit t
- X is the total input consumed by all decision-making units

The total efficiency (TECRS) obtained from the constant return to scale Data Envelopment Analysis (DEA) is divided into two components: scale efficiency and pure technical efficiency. When the values of technical efficiency (TEVRS) under constant

returns to scale and variable returns to scale differ for a specific production unit, it indicates that the production unit has scale inefficiency. In this case, scale efficiency (SE) can be derived from the technical efficiency values obtained under two assumptions as follows [24]:

$$TECRS = TEVRS \times SE \quad (4)$$

$$\text{Total Technical Efficiency} = \text{Pure Technical Efficiency} \times \text{Scale Efficiency} \quad (5)$$

Scale efficiency reveals the losses resulting from not operating at an optimal scale. If the efficiency value decreases with either a reduction or an increase in the scale of operations, it can be concluded that the relevant production unit has scale inefficiency. By decomposing scale efficiency, pure technical efficiency can be calculated. This decomposition also helps identify the source of inefficiency.

RESULTS AND DISCUSSIONS

Socio-Economic Characteristics of Farmers

The age of the farmers surveyed ranged from 23 to 71 years, with an average age of 47.91 years. Their education levels varied between 5 and 16 years, with an average of 7.94 years. The experience of farmers in grain maize farming ranged from 3 to 40 years, with an average of 15.52 years (Table 2). A similar study conducted in Kahramanmaras province, Türkiye found that the average experience of grain maize farmers was 11 years [34].

The total population in the surveyed farms was 560, with an average household size of 3.97 people. Women constituted 50.88% of the total population. It was observed that only 40% of the available family labour was utilized in agricultural activities, while the remaining 60% remained idle (Table 2).

Table 2. Socio-economic characteristics of farmers

Characteristics	Farm groups			
	Group 1 (<4 ha)	Group 2 (4-13 ha)	Group 3 (>13ha)	General
Age of farmer (year)	49.02	47.24	47.79	47.91
Education period of farmer (year)	7.78	7.87	8.21	7.94
Maize experience of farmer (year)	14.63	15.32	16.82	15.52
Household size	3.74	4.14	3.72	3.97
Family labour utilization rate (%)	35.26	35.45	53.84	40.00
Land size (ha)	6.61	15.18	31.80	17.17
Grain maize production area (ha)	2.20	6.98	22.04	9.65
Equity rate (%)	82.85	64.40	67.94	67.92
Cooperative participation rate (%)	63.41	66.13	71.05	66.67

Source: Results of this study.

The average farm size is 17.17 hectares. The most significant share of total land consists of fields (90.89%) and vegetable areas (4.57%). The primary crops grown on farmlands are grain maize and cotton. The grain maize production areas of farmers range from 0.3 to 54 hectares, with an average of 9.65 hectares (Table 2). A study conducted in Kahramanmaras province determined the average grain maize production area to be 8.15 hectares [34], while another study in Konya province, Türkiye found it to be 10.40 hectares [9].

The total average active assets of enterprises amount to 52.8 million TL, with 94.56% of these assets consisting of land ownership. Meanwhile, 67.92% of liabilities consist of equity capital. Among the examined enterprises, 66.67% of farmers are members of an agricultural cooperative, with most being affiliated with the Agricultural Credit Cooperative (Table 2). A study conducted in Konya province, Türkiye found that 87.77% of grain maize farmers were members of an agricultural cooperative [10].

Input Use in Grain Maize Growing

The inputs and quantities used by farmers in

grain maize production are presented in Table 3. It was determined that farmers carried out seed sowing between April 2 and May 24. The amount of seed used per hectare ranged between 20 and 35 kg, with an average of 30.10 kg. A study conducted in Konya province found that 29.40 kg of seed was used per hectare [9], while a study in Tokat province, Türkiye determined this amount as 20 kg [46]. According to study results, 65.96% of farmers (93 farmers) do not conduct soil analysis. When asked for their reasons, they stated that they were unaware of where to conduct analyses, found the costs too high, distrusted the results, or did not have time. Farmers used the following chemical fertilizers in grain maize production: compound fertilizers (15-15-15, 18-18-18, 20-20-20), ammonium nitrate (26%), DAP (18-46), ammonium sulphate, urea, potassium sulphate, and foliar fertilizers. The amount of plant nutrients applied per hectare was determined as 445.40 kg of nitrogen and 179.80 kg of phosphorus (Table 3). A study in Konya province, Türkiye found that 246.60 kg of nitrogen and 145.10kg of phosphorus were used per hectare [9].

Farmers use chemical pesticides to control weeds, leaf borers, grain maize earworms, and red spiders. The amount of herbicide used per hectare is 12.80 kg, while insecticide usage is 3.20 kg per hectare (Table 3). A study in Konya province found that 35.40 kg of chemical pesticides were used per hectare [9], whereas in Tokat province, Türkiye, 2 kg of pesticides per hectare was recorded [46]. A study in Izmir province, Türkiye found that 12 kg of herbicide and 2.80 kg of insecticide were used per hectare [36].

Table 3. Input use in grain maize production

Inputs	Farm groups			
	Group 1 (<4 ha)	Group 2 (4-13 ha)	Group 3 (>13ha)	General
Seed (kg/ha)	29.80	30.20	30.50	30.10
Fertilizer(kg/ha)				
N	439.00	443.50	455.30	445.40
P2O5	181.70	173.40	188.20	179.80
K2O	71.90	70.20	80.30	73.40
Pesticide(kg/ha)				
Herbicide	10.20	13.50	14.20	12.80
Insecticide	2.90	3.20	3.40	3.20
Human labour (h/ha)	59.00	61.90	62.40	61.20
Sowing	12.00	12.60	12.40	12.30
Fertilization	2.90	3.10	3.40	3.10
Spraying	2.70	2.70	2.90	2.80
Irrigation	3.20	3.10	3.20	3.10
Tillage	24.10	23.90	24.20	24.00
Hoeing	7.60	7.70	8.20	7.80
Harvest	6.50	8.80	8.10	8.10
Machine labour (h/ha)	38.30	39.80	41.60	39.90
Number of irrigations	7.71	7.64	7.50	7.62

Source: Results of this study.

The amount of labour used per hectare varies between 35 and 90 hours, with an average of 61.20 hours. Labor is mainly used in soil preparation and planting stages. Farmers mainly use artesian wells for irrigation, and the number of irrigation cycles varies between 4 and 12, with an average of 7.62 irrigation cycles per production period (Table 3).

In grain maize production, mechanical power usage per hectare ranges between 24 and 70 hours, with an average of 39.90 hours (Table 3). A study conducted in Kahramanmaras province found that 23 hours of mechanical power and 50.80 hours of labour per hectare were used [12]. A study in Konya province found that 16.20 hours of mechanical power and 65.90 hours of labour per hectare were used [9], while another study in Tokat

province, Türkiye determined 80 hours of labour per hectare [46].

Input Use Efficiency in Grain Maize Growing

In this study, Data Envelopment Analysis (DEA) was used to determine efficiency scores. The analysis was conducted with one output and seven inputs, using an output-oriented approach. The output considered in the analysis was land productivity, while the inputs included grain maize production area, seed amount, nitrogen fertilizer amount, labour input, mechanical power usage, pesticide amount, and number of irrigations. The descriptive statistics for these variables are presented in Table 4. The grain maize yield per hectare varies between 11,000 and 17,000 kg, with an average of 13,879.30 kg/ha (Table 4).

Table 4. Descriptive statistics of output and input

Farm groups	Means							
	Yield (kg/ha)	*G*rain maize production area (ha)	Seed (kg/ha)	Fertilizer (N) (kg/ha)	Machine labour (h/ha)	Human labour (h/ha)	Pesticide (kg/ha)	Number of irrigations
Group1 (<4 ha)	13,920.20	2.20	29.80	439.00	38.30	59.00	13.10	7.71
Group 2 (4-13 ha)	13,850.10	6.98	30.20	443.50	39.80	61.90	16.70	7.64
Group 3 (>13 ha)	13.890.00	22.04	30.50	455.30	41.60	62.40	17.60	7.50
General	13,879.30	9.65	30.10	445.40	39.90	61.20	16.00	7.62
Farm groups	Standard errors							
Group 1 (<4 ha)	11,896.00	0.95	3.00	48.50	9.90	14.30	3.10	1.89
Group 2 (4-13 ha)	16,250.00	2.52	3.20	52.50	11.00	12.20	4.40	1.74
Group 3 (>13 ha)	13,546.00	11.50	2.70	64.80	6.70	10.70	4.20	1.50
General	14,290.00	9.96	3.00	55.00	9.70	12.50	4.40	1.71

Source: Results of this study.

The differences among groups in terms of variables indicate that different farm types were represented in the sample.

The efficiency scores were estimated under Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions, allowing for the calculation of Scale Efficiency (SE) as well. The efficiency scores for each farm group are presented in Table 5.

Table 5. Technical efficiency scores

Farm groups	CRS	VRS	SE	Max. (CRS)	Max. (VRS)	Max. (SE)	Min. (CRS)	Min. (VRS)	Min. (SE)	Rate of efficient farms		
										CRS	VRS	SE
Group 1 (<4 ha)	0.95	0.96	0.99	1.00	1.00	1.00	0.76	0.78	0.91	56.10	68.29	63.41
Group 2 (4-13 ha)	0.89	0.91	0.98	1.00	1.00	1.00	0.66	0.71	0.78	29.03	40.32	48.39
Group 3 (>13 ha)	0.86	0.88	0.98	1.00	1.00	1.00	0.67	0.69	0.86	15.79	21.05	50.00
General	0.90	0.91	0.98	1.00	1.00	1.00	0.66	0.69	0.78	33.33	43.26	53.19

Source: Results of this study.

According to the results:

-*In Group 1* (<4 ha), 56.10% of farms were fully efficient under CRS, while 62.29% were fully efficient under VRS.

-*In Group 2* (4-13 ha), 29.03% of farms were fully efficient under CRS, while 40.02% were fully efficient under VRS.

-*In Group 3* (>13 ha), 15.79% of farms were fully efficient under CRS, while 21.05% were fully efficient under VRS.

Overall, 33.33% of farms were fully efficient under CRS, and 43.26% were fully efficient under VRS.

The average efficiency scores ranged between 0.86 and 0.99.A study conducted in the Eastern Mediterranean Region, Türkiye estimated the

technical efficiency of grain maize farms at 81% [30].

In another study conducted in Adana province, Türkiye, the average technical efficiency of grain maize farms under VRS was 0.887 [7].

Table 6 presents the scale efficiency of farms and their operational returns to scale. The results indicate that:

-*In Group 1* (<4 ha), 14.63% of farms operated under increasing returns to scale (IRS), 21.95% under decreasing returns to scale (DRS), and 63.42% under constant returns to scale (CRS).

-*In Group 2* (4-13 ha), 14.51% operated under IRS, 37.10% under DRS, and 48.39% under CRS.

-*In Group 3* (>13 ha), 15.79% operated under IRS, 34.21% under DRS, and 50.00% under CRS.

Overall, 14.89% of farms exhibited increasing returns to scale, 31.92% showed decreasing returns to scale, and 53.19% operated under constant returns to scale. Table 7 outlines the potential input reductions that could be achieved without reducing output levels. Since the analysis is output-oriented, these percentages indicate the extent to which input use could be reduced while maintaining the same level of grain maize production.

The results suggest that farms could reduce:

- Seed usage by 2.65%
- Fertilizer (nitrogen-N) usage by 1.12%
- Machine labour usage by 48.74%
- Human labour usage by 4.12%
- Pesticide usage by 34.87%
- Number of irrigations by 11.94%

The results indicate that small farms (<4 ha) were the most efficient in terms of input use, while larger farms (>13 ha) had the highest potential for input optimization.

Table 6. The working styles of farms according to scale

Farm groups	**Description**	**Number of farms**	**%**
Group 1 (<4 ha)	IRS	6	14.63
	DRS	9	21.95
	CRS	26	63.42
Group 2 (4-13 ha)	IRS	9	14.51
	DRS	23	37.10
	CRS	30	48.39
Group 3 (>13 ha)	IRS	6	15.79
	DRS	13	34.21
	CRS	19	50.00
General	IRS	21	14.89
	DRS	45	31.92
	CRS	75	53.19

Source: Results of this study.

Table 7. Input use reduction rates for efficiency limit (%)

Farm groups	Grain maize production area	Seed	Fertilizer (N)	Machine labour	Human labour	Pesticides	Number of irrigations
Group 1 (<4 ha)	1.25	0.53	0.73	35.47	2.03	19.18	4.74
Group 2 (4-13 ha)	14.21	3.60	1.28	38.29	4.11	33.80	10.02
Group 3 (>13 ha)	43.18	3.36	1.28	78.18	6.23	49.25	23.11
General	31.18	2.65	1.12	48.74	4.12	34.87	11.94

Source: Results of this study.

CONCLUSIONS

According to the study results, the average maize production area in farms was 9.65 hectares. The average grain maize yield was determined as 13,879.30 kg/ha. 33.33% of farms were fully efficient under CRS, and 43.26% were fully efficient under VRS. The average efficiency scores ranged between 0.86 and 0.99. The average technical efficiency (CRS) was determined as 0.90.14.89% of farms exhibited increasing returns to scale, 31.92% showed decreasing returns to scale, and 53.19% operated under constant returns to scale. Even if farms reduce machine labour usage by 48.74% and pesticide usage by 34.87%, they will be able to produce the same amount.

Ensuring efficiency in input use in grain maize-producing farms can have a positive impact on production costs. Therefore, programs should be developed to educate farmers and establish measures to optimize input combinations. The rising costs of agricultural inputs increase production expenses. To address this issue, area-based input subsidies should be increased,

and tax reductions on agricultural inputs should continue. Maize is a crop that requires a lot of irrigation. Farmers have difficulty in covering water costs. Therefore, farmers should be informed about the use of alternative irrigation techniques and encouraged through financial methods [37].

A significant number of farmers do not conduct soil analysis. To prevent over-fertilization and its environmental impact, farmers should be encouraged to perform soil testing, and mobile soil testing services should be expanded. Grain maize production faces various pests and diseases. To enhance effective pest management, training programs should be developed, and the use of biological pest control methods should be promoted. Additionally, breeding pest-resistant grain maize varieties should be prioritized.

To reduce dependency on imported grain maize seeds, research institutes should continue developing domestic grain maize varieties, R&D investments should be increased, and adequate funding should be allocated to this area. The development and promotion of high-yield grain maize varieties should be emphasized. Many farmers do not keep records, which prevents them from monitoring and controlling costs. To address this, record-keeping systems should be developed, and farmers should be encouraged to use them. Farmers also seek more technical guidance on grain maize production. Therefore, extension services should be expanded, and provincial and district agricultural directorates should develop region-specific training programs.

ACKNOWLEDGEMENTS

The authors would like to thank Ege University Scientific Research Projects Coordination Unit for providing financial support for this research under the project number FGA-2020-21074

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE ROLE OF THE FOOD AND BEVERAGE SECTOR IN TÜRKİYE'S ECONOMIC STRUCTURE AND ANALYSIS OF SECTORAL ENTERPRISE-CPI CORRELATION

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Abstract

Food and beverages are basic physiological needs and are essential elements of a healthy diet and survival. Thus, although food prices increase, there is no significant change/decrease in the total food demand of the individuals. This study was conducted to determine the role of the food and beverage sector in Türkiye's economic structure, and to analyze the correlation between the sectoral enterprise and the Consumer Price Index (CPI). The main material of this study consists of data organised from the "Annual Industry and Services Statistics", "Foreign Trade Statistics", "Household Consumption Expenditures Statistics", and "Consumer Price Index (CPI)" of the Turkish Statistical Institute (TURKSTAT). The data were analysed in a computer-aided programme. According to the findings of the research, it has determined that the food and beverage sector has a significant share in the manufacturing industry. In the 11-year period, the export value of the sector increased by 81.8%, and reached 22 917 million USD. In the 13 years, 12.0% of the employees in the manufacturing industry were employed in the food and beverage sector. In the period analysed, the number of enterprises in the sector also increased along with the CPI. CPI increased 14.1 times, and the number of enterprises in the sector increased 1.7 times. In the study where CPI data were regarded as the independent variable and the number of enterprises in the sector as the dependent variable, and analysed with the single linear regression model, it was detected that the relationship between the variables was statistically significant. The study serves as a reference in terms of raising awareness on the economic importance of the food and beverage sector.

Key words**:** *linear regression model, manufacturing industry, food and beverage, employment, consumer price index, international food trade*

INTRODUCTION

Nutritional adequacy is essential for good health and a productive life. Although foods are of plant and animal origin [9], most of the food needs of humans are provided by plant-based foods [19]. In general, most of the food is produced in the agricultural sector.

Vegetables are the most important nutritional source. They are very useful for both health protection and disease prevention. Vegetables contain important food components for the development and repair of the body. They are rich in minerals, vitamins, and fibre [3].

Chemical compounds that are naturally found, especially in vegetables and fruits from plant foods, and have strong antioxidant properties are generally called polyphenols. Polyphenols are of much essence in terms of health because they have an antioxidant structure [22]. They have the potential to neutralise free radicals and fight cancerous cells. They also have the effect of reducing the risk of heart disease. Polyphenols, which can also lower blood sugar levels, have been proven to have positive effects on brain health, the immune system, and the digestive system [8]. Fruits, vegetables, some spices, cereals, nuts, flax seeds, flax seeds, leaves of plants, olive and olive oil, coffee, and cocoa are natural nutritions with polyphenol compounds [5]; [25].

Food and beverage manufacturing is an integral part of the food chain, which encompasses the production, distribution and storage, wholesale, retail, foodservice, and catering of agriculture and fisheries and other food and beverage [16]. Since the demand-price elasticity of food products is generally low, the impact of price changes on demand is limited. The reason is that these products are mostly absolute necessities, but on the other

hand, there is a limit to how much an individual can eat and drink. There are many factors affecting the demand for food and beverage products. These are the demographic and socio-economic changes and differences of society, their lifestyles and revenues, changes in prices, health and nutrition conditions, and migrations [7]; [15].

The food and beverage sector is a sector that has a significant share in Türkiye's foreign trade [17]. According to 2024 data, Türkiye gained a total income of 22,917 million USD from food and beverage exports and received a share of 9.3% of the total manufacturing industry export value [28]. Türkiye has been an important power in its region in exports of food and beverage products to European and Middle Eastern markets [29].

There is a total of 58,299 enterprises in the food and beverage sector in Türkiye [26]. The total number of enterprises in the sector is 12.6% of the total manufacturing industry. 12% of the employees in the manufacturing industry were employed in the food and beverage sector [26]. Thus, the food and beverage sector is in the largest employer position in Türkiye.

As of 2023, the food and beverage sector accounted for 14.8% of production value and turnover, and 11.6% of the value added of the total manufacturing industry. Over the 13 years, the production value, turnover, and value added of the sector increased by 65.6%, 65.3%, and 114.4%, respectively. In the same period, while the food and beverage CPI increased 14.1 times, the number of enterprises in the sector increased 1.7 times. In other words, both CPI and the number of sectoral enterprises increased.

Although there are many studies conducted on the food and beverage sector in the literature, there is no study on the place of the sector in the economy and the correlation of the number of enterprises in the sector with the CPI. Some of these studies are:

In the study entitled ‘Fast food applications in the food and beverage sector and evaluation of the franchising systeuctedm’ which [11] conducted in 2011, he examined how the fast food sector is positioned in the food and beverage industry, the historical development process in the world and Türkiye and the franchising system of the sector in this process. In the study entitled ‘Evaluation of New Trends in Food and Beverage Consumption’ by [13], new trends in food and beverage consumption were revealed, and the usage patterns of these trends in the Turkish food and beverage sector were determined. In [14]'s study titled ’Knowledge, opinions and behaviours of food and beverage personnel about food waste: The case of Eskişehir province’, the knowledge, opinions, and behaviours of the kitchen staff regarding food waste were detected. In their study entitled ‘Sustainability and innovative approaches in the food and beverage sector’, which [24], they emphasised the importance of alternative and innovative sustainable practices in the food and beverage sector. In the study titled ‘New Technologies and New Foods in the Food Industry’ by [31], new foods and food ingredients, other food technology trends that are expected to transform the food sector, meat production in the laboratory, and climate change and food security issues were investigated.

In this study, the economic role of the food and beverage sector in Türkiye was examined, and the correlation between sectoral enterprise and CPI was analyzed.

MATERIALS AND METHODS

The main material of this study consists of data organised from "Annual Industry and Service Statistics", "Foreign Trade Statistics", "Household Consumption Expenditure Statistics", and "Consumer Price Index (CPI)" of the Turkish Statistical Institute (TURKSTAT).

The data covers the periods 2010-2023 and 2010-2024. A computer-based program (Microsoft Excel) was used in the analysis of the data. In the analysis, tables and figures appropriate to the purpose of the study were created and interpreted. The tables provide the number of enterprises in the food and beverage sector, the number of employees, production value, turnover, created added value, foreign trade values, developments in sectoral enterprise and CPI, and statistical analysis results. The figures provide annual

developments in sectoral CPI and annual developments in the number of enterprises.

In statistical models, it is necessary to examine how a change in any variable affects the value of another variable. One of the models used in the analysis of the correlation between variables is the single linear regression model. The relationship between X and Y values is best expressed in the single linear regression model. In this study, the linear regression model was used, and the equation of the model is given in the equation below [18]; [23]; [4].

$$Y = a + b.x \quad \text{.....(1)}$$

In the function above, the food consumer price index figures (X) were regarded as the independent variable, and the number of enterprises in the sector (Y) as the dependent variable. In the linear regression equation, a indicates the point where the curve intersects the Y-axis, and b indicates the regression coefficient. The following equations were used in the analysis [21]; [6]; [12]:

Regression coefficient:

$$b = \frac{\sum d\,x^{-}.dy^{-}}{\sum dx^{-}2} \quad \text{.....(2)}$$

Regression variance:

$$S^2 = \frac{\sum dyx2}{n-2} \quad \text{.....(3)}$$

Regression standard deviation:

$$S = \sqrt{S2} \quad \text{.....(4)}$$

Regression coefficient standard deviation:

$$S_b = \frac{Syx}{\sqrt{dx2}} \quad \text{.....(5)}$$

t-test;

$$t = \frac{b}{Sb} \quad \text{.....(6)}$$

Correlation coefficient;

$$r = \frac{\sum d\,x^{-}.dy^{-}}{\sqrt{(\sum dx2).(\sum dy2)}} \quad \text{.....(7)}$$

RESULTS AND DISCUSSIONS

The role of the food beverage industry in the economic structure

The food and beverage sector makes a significant contribution to the macroeconomy in terms of employment and income [20]. The sector's employment and income contribution to the Turkish economy is also extremely significant. Enterprises in the food and beverage sector have a more substantial work capacity than other sectors. These are: raw milk and dairy products, red meat slaughterhouses, poultry meat slaughterhouses, meat cutting and processing, aquaculture processing, animal by-product processing, and egg and egg products enterprises [10].

The findings regarding the role of the food and beverage sector in the economic structure and its place in the manufacturing industry in Türkiye are given below:

Number of enterprises and employment in sector

According to TUIK's 2023 data, the number of food and beverage enterprises was 58,299, which was 12.6% of those in the total manufacturing industry. In the 13 years between 2010 and 2023, the number of enterprises in the food and beverage sector increased by 69.6% (1.7 times). In 2023, a total of 609,021 employees were employed in the food and beverage sector, 589,988 of whom were in the food sector and 19,033 of whom were in the beverage sector (Table 1).

In the same year, 12% of total manufacturing industry employment was in the food and beverage sector. In the 13 years, employment in the sector increased by 78.6%.

Developments in the production value, turnover and added value of the sector

Developments in the production value, turnover and value added of the food and beverage sector were reviewed, and given in Table 2.

In 2023, the production value of the sector was approximately 96,488 million USD. In the same year, the turnover of the sector was 102,525 million USD, and the value added 18,642 million USD. In the 13 years between 2010 and 2023, the sector's production value increased by 65.6%, turnover by 65.3% and value added by 114.4%. In 2023, the food and beverage sector received a share of 14.8% from the standpoint of production value and turnover, and also 11.6% from the standpoint of value added in the total manufacturing industry.

Table 1. Number of Enterprises and Employees of the Food and Beverage Sector

Sector	Number of enterprises in the sector								
	2010		2015		2020		2023		Index
	(number)	(%)	(number)	(%)	(number)	(%)	(number)	(%)	(2010=100)
Food manufacturing	33,727	10.3	43,733	11.6	52,871	12.9	57,606	12.5	170.8
Beverage manufacturing	639	0.2	557	0.2	658	0.2	693	0.1	108.4
Total	34,366	10.5	44,290	11.8	53,529	13.1	58,299	12.6	169.6
Manufacturing industry total	326,925	100.0	375,480	100.0	409,482	100.0	461,644	100.0	141.2.
	Number of employees								
Sector	(person)	(%)	(person)	(%)	(person)	(%)	(person)	(%)	Index (2010=100)
Food manufacturing	328,118	12.5	451,263	12.5	497,519	12.4	589,988	11.7	179.8
Beverage manufacturing	12,847	0.5	15,508	0.4	17,152	0.4	19,033	0.3	148.1
Total	340,965	13.0	466,771	2.9	514,671	12.8	609,021	12.0	178.6
Manufacturing industry total	2,617,991	100.0	3,621,817	100.0	4,009,649	100.0	5,051,468	100.0	192.9

Source: [26].

Table 2. Production value, turnover and value added of the sector for the period 2010-2022

Sector	Production value of the sector								
	2010		2015		2020		2023		
	(1,000 USD)	(%)	(1,000 USD)	(%)	(1,000 USD)	(%)	(1,000 USD)	(%)	Index 2010=100
Food manufacturing	54,666,178	15.2	62,851,299	15.3	58,664,021	14.5	91,892,457	14.1	168.1
Beverage manufacturing	3,608,420	1.0	3,440,564	0.8	2,777,737	0.7	4,595,405	0.7	127.3
Total	58,274,598	16.2	66,291,863	16.1	61,441 ,758	15.2	96,487,862	14.8	165.6
Manufacturing industry total	359,227,772	100.0	410,605,647	100.0	405,410,689	100.0	653,216,720	100.0	181.8
	Turnover								
Food manufacturing	58,387,123	15.2	68,088,390	15.4	63,874,160	14.7	98,066,811	14.2	167.9
Beverage manufacturing	3,630,117	0.9	3,416,172	0.8	2,767,287	0.6	4,458,460	0.6	122.8
Total	62,017,240	16.1	71,504,562	16.2	66,641,447	15.3	102,525,271	14.8	165.3
Manufacturing industry total	384,850,629	100.0	442,512,648	100.0	435,983,952	100,0	690,167,936	100.0	179..3
	Value added								
Foodmanufacturing	7,747,390	11.8	9,684,717	11.2	9,212,623	10.0	17,640,334	11.0	227.7
Beverage manufacturing	948,926	1.4	757,913	0.9	517,230	0.6	1,001,823	0.6	105.6
Total	8,696,316	13.2	10,442,630	12.1	9,729,853	10.6	18,642,157	11.6	214.4
Manufacturing industry total	65,939,645	100.0	86,482,826	100.0	92,020,324	100.0	160,794,814	100.0	243.8

Source: [26].

Foreign trade of the sector

Türkiye ranked 22nd in the world in exports of food and beverage sector products [29].

Table 3 shows the developments in the food and beverage sector foreign trade value in the period 2013-2024. According to this information, it was observed that there was a significant increase in the export value of the sector over the 11 years. Exports of food and beverages were 12,532 million USD in 2013, while it was 12,705 million USD in 2015, 14,289 million USD in 2020, and 22,917 million USD in 2024. In the 11 years, the export value of the sector increased by 82.8%. In the same period, the import value of it also increased, and this increase was 69.7%. The share of exports of the sector in exports of total manufacturing sector was 9.3%, while the share of imports of sector in imports of total manufacturing sector was 4.2%.

Table 3. Foreign trade values of the sector for period 2013-2024

Sector	Export value of the sector								
	2013		2015		2020		2024		Index (2013=100)
	(1,000 USD)	(%)	(1,000 USD)	(%)	(1,000 USD)	(%)	(1,000 USD)	(%)	
Foodmanufacturing	12,259,401	8.1	12,418,086	8.7	14,000,134	8.7	22,420,788	9.1	182.9
Beverage manufacturing	272,828		286,854	0.2	288,867	0.2	496,171	0.2	181.8
Total	12,532,229	8.3	12,704,940	8.9	14,289,001	8.9	22,916,959	9.3	182.8
Manufacturing industry total	151,483,194	100.0	142,267,945	100.0	159,952,829	100.0	246,528,954	100.0	162.7
	Export value of the sector								
Foodmanufacturing	6,461,589	3.1	5,817,862	3.4	6,118,258	3.4	10,603,765	3.8	164,1
Beverage manufacturing	516,934	0.3	456,814	0.2	537,063	0.3	1,241,430	0.4	240.1
Total	6,978,523	3.3	6,274,676	3.6	6,655,321	3.7	11,845,195	4.2	169.7
Manufacturing industry total	206,177,969	100.0	173,110,264	100.0	179,808,651		280,075,297	100.0	135.8

Source: [28].

Analyzing the correlation of sectoral enterprise with *the* Consumer Price Index (CPI)

Developments in the number of enterprises and the (CPI) in the sector

In the study, in the 2010-2023 period, the developments in the CPI data on the food sector and the number of enterprises in the sector were also analysed and presented in Table 4.

Table 4. Developments in the consumer price index and number of enterprises

Year	Sector CPI		Number of enterprises in the sector	
	(2003=100)[1]	Annual increase rate[2] (%)	(Number)[3]	Annual increase rate (%)[4]
2010	189.21	-	34,366	-
2011	212.33	12.2	35,635	3.7
2012	220.80	4.0	40,174	12.7
2013	242.31	9.7	42,488	5.7
2014	273.27	12.8	45,541	7.2
2015	302.95	10.9	44,290	- 2.7
2016	320.14	5.7	46,127	4.1
2017	364.20	13.8	48,212	4.5
2018	455.89	25.2	49,653	3.0
2019	505.94	11.0	51,987	4.7
2020	610.32	20.6	53,529	3.0
2021	879.70	44.1	58,216	8.7
2022	1,565.83	78.0	59,778	2.7
2023	2,675.31	70.8	58,299	-2.5

Source: [1] [27] ; [3] [26] ; [2,4] Research results.

According to this information, both the number of enterprises in the sector and the sector CPI increased every year in the period studied. As from 2020, there has been a higher increase in CPI, which was at its highest level with 78% in 2022. It was conspicuous that the high increase in CPI coincided with the period of the COVID-19 pandemic. Household food expenditures increased during the pandemic period, and while 20.8% of household consumption expenditures were food expenditures in 2019, this rate increased to 22.9% in 2022 [27]. In the period analysed, CPI increased 8.3 times, while the number of enterprises in the sector increased 1.7 times.

The highest increase in the number of enterprises was in 2012 (12.7%) and 2021 (8.7%). [2], in his study, analyzed the distribution of consumption expenditures of households according to the main source of income.

According to this, food expenditures received

the highest share in household expenditures, with 23.1%, and health expenditures received the lowest share, with 2%.

The sector's annual CPI data and the developments in the number of enterprises were also given in Figures 1 and 2. When the data are analysed, it is seen that there was an increase in both variables, but that in the CPI was higher.

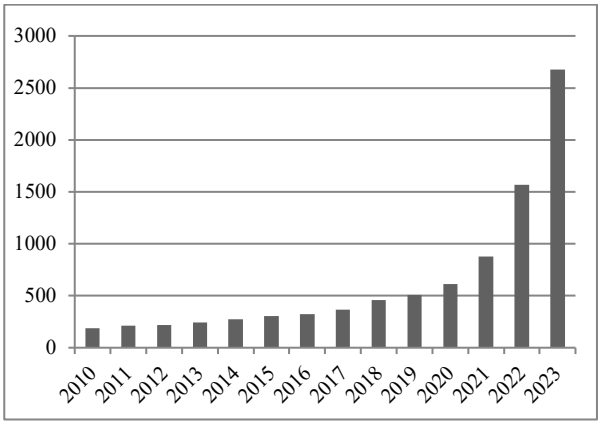


Fig. 1. Annual developments in the food and beverage sector CPI in Türkiye
Source: Created using the data in [27].

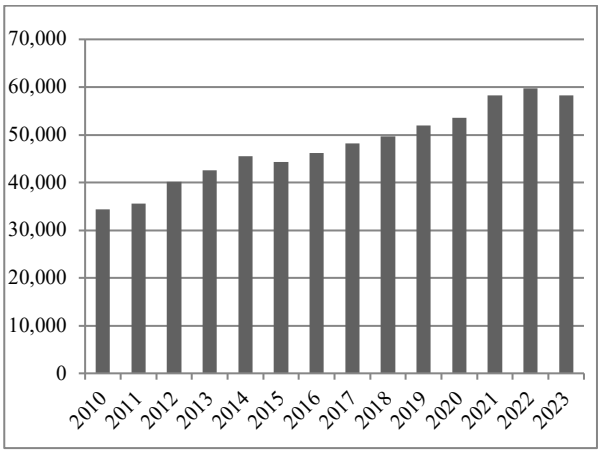


Fig. 2. Annual developments in the food-beverage sector enterprise number in Türkiye
Source: Created using the data in [26].

Statistical analysis

One of the most commonly used methods in the measurement of the correlation between variables is the single linear regression model. In the study, sectoral CPI data were regarded as the independent variable, and the number of enterprises in the sector was regarded as the dependent variable.

The independent variable was denoted by X, and the dependent variable was denoted by Y.

In the study, statistical information on the variables and the correlation of the variables were given in Table 5.

Regression coefficient

The regression coefficient is the value of the change in the dependent variable in response to a unit change in the independent variable. The regression coefficient (b) was detected as 9.20. This shows that a one-unit change in the independent variable changes the dependent variable by 9.20 units.

A positive regression coefficient means that as X increases, Y also increases.

In this context, a possible increase in food and beverage prices positively affects the food sector entrepreneurship. In other words, an increase of one lira in food and beverage prices causes an average increase of 9.20 units in the number of enterprises in the sector.

Regression function

In the study, the regression function was obtained as:

$$Y=41{,}201.04+9.20x\ldots\ldots..\ldots\ldots\ldots\ldots..(8)$$

Deviation from regression

Deviation from regression is a measurement of the distance or proximity between the dependent variable Y values and the calculated *Y* function values.

The deviation values from the regression calculated from the formula dyx= Y- *Y* are given in Table 6.

The standard deviation of the regression coefficient (S_b) was calculated as 4,88.

t-test:

H_o: There is no correlation between variables ($t_{calculation} < t_{table}$).

H_1: There is a no correlation between variables ($t_{calculation} > t_{table}$).

t value was 1.89.

Degrees of freedom SD = 15-2=13, and t_{table} is 1.77 for a confidence interval of 95% and an error margin of 5% (p= 0.05). Due to the $t_{calculation} > t_{table}$, H_o hypothesis was rejected, and H_1 hypothesis was accepted. There was a correlation between sectoral enterprise and CPI, which was statistically significant.

Table 5. Variables and statistical calculations

X	**Y**	x- $\bar{x}$ = d $\bar{x}$	y- y = dy	**d $\bar{x}^2$**	**d y^2**	d $\bar{x}$. dy
176.79	32,475	-422.88	-14243	178827.49	202863049	6023079,84
189.21	34,366	-410.46	-12352	168477.41	152571904	5070001,92
212.33	35,635	-387.34	-11083	150032.27	122832889	4292889,22
220.80	40,174	-378.87	-6544	143542.48	42823936	2479325.28
242.31	42,488	-357.36	-4230	127706.17	17892900	1511632.8
273.27	45,541	-326.40	-1177	106536.96	1385329	384172.8
302.95	44,290	-296.72	-2428	88042.76	5895184	720436.16
320.14	46,127	-279.53	-591	78137.02	349281	165202.23
364.20	48,212	-235.47	1494	55446.12	2232036	-351792.18
455.89	49,653	-143.78	2935	20672.69	8614225	-421994.3
505.94	51,987	-93.73	5269	8785.3	27762361	-493863.37
610.32	53,529	10.65	6811	113.42	46 389721	72537.15
879.70	58,216	280.03	11498	78416.80	132204004	3219784.94
1,565.83	59,778	966,16	13060	933465.14	170563600	12618049.6
2,675,31	58,299	2,075.64	11581	4308281.41	134119561	24037986.84
Σx=8,994.99 $\bar{x}$=599.67	y=700,770 y=46.718	-	-	Σ=6446483.44	Σ=1068499 980	Σ=59327448.93

Source: Research results.

Table 6. Deviation values from regression

Y-Y=dyx	**dyx^2**
32,475-42,827.51= -10,352.51	107174463.30
34,366-42,941.77 = -8 ,575.77	73543831.09
35,635-41,506.25 = -5,871.25	34471576.56
40,174-43,154.47 = -2,980.47	8883201.42
42,488-43,430,29 = -942.29	887910.44
45,541-43,715,12 = 1,825.88	3333837.77
44,290 -43,988,18= -301.82	91095.31
46,127-44,146,33 = 1,980.67	3923053.65
48,212-44,551,68 = 3,920.45	15369928.20
49,653-45,395,23 = 4,257.77	18128605.37
51,978-45,855,69 = 6,122.31	37482679.74
53,529-48,805,39 = 4,723.61	22312491.43
58,216-49,294,28= 8,921.72	79597087.76
59,778-55,606,67 = 4,171.33	17399993.97
58,299-65,813.89 = -7,514.89	5647351.71

Source: Research results.

In the study, a correlation analysis between variables was performed, and the direction of the relationship was also determined. The correlation coefficient (r) was calculated as 0.715. There was a positive and high-level correlation between the variables. Although the correlation between the variables was significant, It should be considered that CPI might not be the only factor, and variables such as credit interest rates, investment incentives and investment costs might also affect in the number of enterprises.

The fact that the price elasticity of demand for food and beverage sector products is less than 1, but is not negative, and that these products are the foodstuff of the population, results in favor of the total amount of demand. Since the total population increases every year, this will also increase the total demand. At the same time, the idea of stockpiling food formed in consumers during periods when CPI increases, also increases the total demand for food [30]. These characteristics of food are thought to set off sectoral entrepreneurship. They are effective in new sectoral investments.

[1], in their study entitled “Demand elasticities of important food products in Turkey”, they conducted on food, expressed that the price elasticity of demand of food and beverage sector products is less than 1, but not negative. In the study entitled “The economıc characterıstıcs of food products and beverages industry” conducted by [2], it was stated that the need for food and beverages is one of the basic and indispensable needs, these needs are of vital importance, and the food and beverage sector is the source of economic development all over the world.

In conclusion, although there was a direct correlation between CPI and the number of sectoral enterprises, the possible relationship of the sector, except for CPI, with other variables should be analyzed by studies to be conducted. In Table 7, the analysis results are given.

Table 7. Summary analysis results

$\sum = d\,\bar{x}^2$ = **6446483,44**	$\sum = d\,y^2$ = **1068499980**	$\sum = d\,\bar{x} \cdot dy$ = **59327448,93**
Regression coefficient: $b = \frac{\sum dx.dy}{\sum dx2} = \frac{59327448,93}{6446483,44} = 9.20$		
Deviation from regression: $\sum dyx^2 = 2000696219,52$ Regression variance: $S2 = \frac{dyx2}{n-2} = \frac{2000696219,52}{13} = 153899709,1938$		
Regression standard deviation: $S = \sqrt{S2} = \sqrt{153899709,1938} = 12\,405,6321$		
Regression coefficient standard deviation; $Sb = \frac{S}{\sqrt{dx2}} = \frac{12405,6321}{\sqrt{6446483,44}} = \frac{12405,6321}{2538,9926} = 4.88$		
t-test: Ho: There is no correlation between variables ($t_{calculation} < t_{table}$). H1: There is a no correlation between variables ($t_{calculation} > t_{table}$). $t = \frac{b}{Sb} = \frac{18,34}{3,75} = 1.89$ SD = 15-2=13 For a confidence interval of 95% and an error margin of 5% (p=0.05): t_{table} :1.77 There is a statistical correlation between the variables.		
Correlation coefficient *:* $r = \frac{\sum dx.dy}{\sqrt{(\sum dx2).(\sum dy2)}} = \frac{59327448,93}{\sqrt{(6446483,45).(1068544980)}} = \frac{59327448,93}{\sqrt{(6888835752915058 1)}} = \frac{59327448,93}{82996129,6034} = 0.715$ Statistically, there is a high level of positive correlation between the variables.		

Source: Research results.

CONCLUSIONS

This article was designed to analyze both economically and statistically the structure of the food and beverage sector in Türkiye. For this purpose, the study offers a new methodological approach to raise awareness of sectoral investments.

The food and beverage sector provides a large part of its raw materials from agriculture. While the agricultural sector is the sector where raw products are harvested, the sector where these products are processed is also the food sector. Therefore, the food sector has a strategic role.

In light of the findings of the study, it was concluded that the food and beverage sector has preserved its continuity, and sectoral enterprises have continued even in periods when CPI is high. This can be explained by the fact that food is an absolute consumable item for the people and consumer demand increases depending on the increase in product stockpiling in high inflation. In this context, the food sector is the only sector that can be ventured in periods when macroeconomic developments are unfavourable and the economy is stagnant.

The fact that food has a dominant role in economic activities ensures that the sector remains a player in every period. For the development of the sector, rational precautions should be taken by the state, and sector enterprises should be supported with low-cost credits.

Although the correlation of enterprise with CPI has been revealed in the study, other variables other than CPI should also be considered, and they should be analysed in studies to be conducted.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MEASUREMENT AND MODELLING OF RESPIRATION RATE AND ENERGY BALANCE OF BANANAS AND ITS ECONOMIC IMPACT DURING THE STORAGE

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Abstract

The aim of this study the effect of respiration rate and ventilation rate in the fruit ripening models and estimate the oxygen consumption and CO_2 production. In this investigation, with three banana ripening models .Model 1's have 72 m³ space had thermally insulated cement walls that were 30 mm thick; Model 2's 60 m³ area was similarly insulated with cement walls, but these walls were 12.5 mm thick; and Model 3's 38 m³ area was insulated with ceramic walls, 24 mm thick. The measurement indicators were the oxygen consumption, CO_2 production, Ventilation Rate, Temperature-Dependent Respiration Rate, heat production during respiration and energy balance. The findings demonstrated that the three ripening models' data were considerably impacted by temperature, model size, and banana ripening stages, where ripe bananas in model 1 (the largest) recorded the highest values in respiration rate, ventilation requirements and respiration temperature of bananas, where the values reached 187.556 g CO_2/kg/h, 2.55 m_3/h and 82.57 kW, respectively. The economic impact of banana storage reflects an increase in the profit period and thus a shortened investment Payback period.

Key words: *banana, ripening, respiration and ventilation rate, energy balance, economic efficiency*

INTRODUCTION

The word "banana" (*Musa paradisiaca* L.) refers to a variety of species or hybrids of the Musaceae family's genus Musa. Grown in almost 120 countries, bananas are a staple item that is essential to the economic and nutritional health of millions of people in the poor globe [12].

In 2023, 139 million tons bananas were produced at the global level. Bananas are mostly produced in Asia, Africa, South America and Central America. The largest producer of bananas is India.

The main exporting countries are Ecuador, Philippines, Costa Rica and Guatemala [20].

The United Nations Food and Agriculture Organization reports that banana exports were constant in 2023, increasing by 0.29% year over year to 19.17 million metric tons. Another FAO report stated that 19.1 million metric tons of bananas were exported in 2022 [9].

Improper handling and ripening techniques could lead to bananas losses.

The losses could emerge during various stages along the fruit supply chain.

First, it could be mentioned harvesting and pre-harvesting, then transportation, storage, processing, packing, and marketing.

Various authors researched studied the causes which determine losses of bananas weight and quality and proposed strategies to reduce them throughout the chain of supply [17, 16, 19, 2, 12, 4].

Table 1 lists the reasons why bananas are lost during the supply chain. Table 1 lists the supply chain's phases.

Harvested plant products' living cells constantly breathe, taking in oxygen (O_2) from the surroundings and exhaling carbon dioxide (CO_2).

Table 1. The stages along the supply chain when bananas could achieve losses

Supply chain stages	Causes of banana losses
(i)Harvesting and pre-harvesting	Spoilage and trimming
(ii)Transport	Bruising, breakage and infection as a result of dust, heat, rain and humidity
(iii)Storage	Over or under ripening.
(iv)Processing and packing	Incorrect processing and inefficient packing
(v) Marketing	Multi-level handling, weight loss, quality loss.

Source: Adapted by author based on [17].

Numerous compounds present in the cells undergo oxidation-reduction processes during respiration, converting them to CO_2. It is one of the main causes of perishables' postharvest losses both quantitatively and financially, with a deep impact of the famers' and ripeners' income. Fresh produce's postharvest respiratory response is influenced by the temperature of the storage air as well as its O_2, CO_2, and ethylene content [3].

In general, low temperature, low O_2, and slightly higher CO_2 reduce enzyme activity, which slows the pace at which substrates (such carbohydrates, organic acid, and other reserves) are used and prolongs the fruit's postharvest life beyond its normal range.

Therefore, two important external parameters that may be controlled to retain the fruit in perfect condition as long as possible after its typical season are the storage temperature and the composition of the storage air [18].

Bananas are picked green and then delivered to the market areas, where they are allowed to mature. Fruits often split and get mealy when allowed to ripen on the tree. For importers and ripeners, the pre-climacteric period after harvesting is critical because bananas are shipped before they ripen. Mature green fruits produce nearly no ethylene during this time, and their basal respiration rate is modest. The "green life" (GL) is another name for this time frame, and the longest feasible "pre-climacteric period" is desired. The duration of this period depends on several factors, including as temperature, relative humidity (RH), and the amount of ethylene present in the ambient air. As the fruit ripens, respiration and autocatalytic ethylene production rise quickly in climacteric fruits, such as bananas. In actuality, the GL period ends at this critical point when the ripening process is initiated by a number of enzymes involved in the ethylene synthesis pathway [10].

In order to provide the energy needed by the product to advance its metabolic processes, a number of substrates are oxidized during the respiration process. Approximately 2,880 kJ, or the energy needed to fully oxidize one mole of hexose, is released during aerobic respiration. The rate of respiration is closely related to the amount of oxygen in the surrounding atmosphere since respiration is dependent on the presence of oxygen. Reduced oxygen partial pressure delays ripening, which also lowers respiration rate and the quantity of chemical energy released that can be used to carry out the product's metabolic processes [14].

The temperature and composition of the storage air, specifically the amounts of O_2, CO_2, and ethylene, affect the post-harvest respiratory response of fresh food. Reduced enzymatic activity caused by low temperature, low O_2, and slightly elevated CO_2 usually results in a slower rate of substrate consumption (carbohydrates, organic acid, and other reserves), extending the fruit's post-harvest life beyond its regular lifetime. Thus, the storage temperature and the air composition in the storage are two crucial external factors that may be managed to maintain the fruit in optimal condition for as long as feasible after its typical season [19].

Fruits and vegetables release CO_2, break down carbohydrates into their more basic forms, and absorb O_2 from the atmosphere. The rate of biochemical and physiological processes is determined by the fresh product's respiration rate, which is influenced by the temperature and various gas concentrations in the storage location. The respiration rate is often linked to the deterioration of fresh fruits and vegetables. The exchange of oxygen and carbon dioxide gases is the main process of respiration, and the experiment is conducted in an airtight chamber. The variation in O_2 and CO_2 gas concentrations within the closed chamber explains the fresh product's respiration rates.

The product's freshness can be preserved by increasing the CO_2 content and decreasing the oxygen content [11].

The most obvious ripening-related change in banana fruit is the color shift from green to yellow. Softening, variations in sugar and acidity, and the emergence of volatile scents are further aspects of fruit ripening that increase the fruit's commercial appeal. To increase the fruit's nutritional content and reduce postharvest losses, it is crucial to comprehend the mechanisms underlying fruit ripening. The phytohormone ethylene affects a variety of aspects of plant growth and development, including senescence, organ abscission, and fruit ripening. Fruit ripening is categorized as either climacteric or non-climacteric based on whether a peak in ethylene release and an increase in respiration is linked to the process. By controlling the expression of genes involved in several biological processes, ethylene controls the ripening of fruit, such as enhanced respiration, autocatalytic ethylene synthesis, color accumulation, texture alterations, and the development of overall fruit quality attributes [8].

Takes time and specialized gas analysis equipment to measure the gas composition and produce respiration rate at a certain storage temperature. To connect the respiration rate to various storage parameters, such as temperature and gas composition (e.g., O2 and CO2), numerous mathematical models have been devised. Enzyme kinetics is the basis of the more current method for estimating respiration rate using the Michaelis-Menten type equation. Assuming that the transport and solubility of O_2 and CO_2 in plant tissue govern allosteric enzyme-catalyzed reactions, this provides a fundamental explanation of respiration [5].

Fresh fruits are usually in high demand on the market. Fruits, however, have a short shelf life and are perishable items. Fruit degeneration starts as soon as the fruit is separated from the parent plant and is associated with physiological and biochemical processes. Cells in living plant products breathe continuously, absorbing oxygen (O_2) from their environment and releasing carbon dioxide (CO_2). During respiration, a sequence of oxidation-reduction reactions converts several molecules within the cells to CO_2 [7].

Transpiration and respiration are the two physiological processes that most frequently take place when bananas ripen. The green banana exhibits a momentary decrease in transpiration rate. The ripening stage of bananas is when the transpiration rate peaks. The physical and chemical alterations that take place during the ripening and storage phases of banana fruit have a major influence on the fruit's skin color. As the banana fruit ripens and is preserved, it changes from green to yellow [1].

Technology for atmospheric preservation is essential for controlling respiration and microbial development when storing fruits and vegetables. Respiration is a metabolic process that generates energy. Plants can breathe in one of two ways, depending on the amount of oxygen they consume. Along with the oxidative breakdown of organic reserves into simpler molecules like CO_2 and water, aerobic respiration releases energy. Anaerobic respiration produces ethanol by decarboxylating pyruvate to CO_2 without the use of oxygen during fermentation metabolism. Anaerobic respiration is undesirable due to the unpleasant Odor created by the large amounts of ethanol, acetaldehyde, and other compounds that accumulate during the storage of F&V. Therefore, one key strategy for reducing loss and preserving quality during the postharvest ripening processes is to regulate respiration [4].

Fruits and vegetables remain alive even after harvest. Because of this, transpiration is often the main cause of postharvest loss; but, in humid regions where transpiration is low, respiration may become more important. Increased respiration leads to increased consumption of nutrients, which accelerates aging and reduces the shelf life of fruits and vegetables [13].

Throughout the ripening and storage phases, banana fruit experienced a variety of physiological, biochemical, and nutritional quality changes. One such process is enzymatic browning, which breaks down starch into simpler sugars. The sugar content of fresh pulp

green banana fruit ranges from 1% to 2%, up to 20% as it ripens. Citric and malic acids work together to give the green (unripe) banana fruit its acidity. Furthermore, the texture of banana fruit changes as it ripens, which directly affects the fruit's quality. The concentration of pectin and the softening of bananas are strongly correlated. As pectin polysaccharides become more soluble, banana hardness diminishes [14].

The main objectives of this study were to estimate the oxygen consumption and CO_2 production and their effect on the respiration rate and ventilation rate in the fruit ripening for modelling of respiration rate and energy balance of bananas storage duration. Also, the study examined the economic impact during bananas storage.

MATERIALS AND METHODS

Three banana ripening models were used in the experiment, which was carried out in the city of Santa, Gharbia Governorate, between July 2024 and September 2024 for the summer and November 2023 to December 2023 for the winter. To estimate the amount of respiration heat and amount of O_2 consumption and CO_2 production released by banana and their effect on the respiration rate and Ventilation Rate in the fruit ripening models. The three rooms were equipped with a cooling and air conditioning unit, a ventilation and humidity control system, and gas distribution devices. Electricity, ethylene, supervisors, and maintenance workers were used.

The production capacity

Model 1 reached 12 tons with dimensions of (6 m length x 4 m width x 3 m height),

Model 2, which was 5 m in length, 4 m in breadth, and 3 m in height, weighed 8 tons and *Model 3* weighed 6 tons and measured 3 meters long by 4 meters wide by 3 meters high.

Measurements and determinations

Respiration Rate as a Function of Temperature in Banana Ripening rooms

Calculating the respiration rate of bananas in ripening refrigerators involves understanding the physiological processes that lead to the release of carbon dioxide (CO_2), consumption of oxygen (O_2), and the production of heat [6].

Respiration Rate for Oxygen Consumption (R_{O2})

$$R_{O_2} = \frac{V_{mo} \times G_{O_2}}{K_{mo} + (1 + \frac{G_{CO_2}}{K_{io}}) \times G_{O_2}} \quad \text{..... (1)}$$

where:

V_{mo}:Maximum oxygen consumption respiration rate (mg O_2/kg·h).

K_{mo}: Michaelis constant for O_2, (kPa).

K_{io}: Inhibition constant for O_2, (kPa).

G_{O2}: O_2 partial pressure in the room, (kPa).

G_{CO2}: Partial pressure of CO_2, starting (kPa).

Respiration Rate for CO_2 Production (R_{CO2})

$$R_{CO_2} = \frac{V_{mc} \times G_{O_2}}{K_{mc} + (1 + \frac{G_{CO_2}}{K_{ic}}) \times G_{O_2}} \quad \text{..... (2)}$$

where:

V_{mc}: Maximum respiration rate for CO_2 consumption, (mg CO_2/kg·h).

K_{mc}: Michaelis constant for CO_2, (kPa).

K_{ic}: Inhibition constant for CO_2, (kPa).

The respiratory quotient (RQ)

$$RQ = \frac{R_{O_2}}{R_{CO_2}} \quad \text{..... (3)}$$

Temperature-Dependent Respiration Rate (R_m)

$$R_m = R_p \times e^{-(\frac{E_a}{RT})} \quad \text{..... (4)}$$

where:

Rp: Baseline respiration rate, (mg CO_2/kg·h)

E_a: Activation energy (J/mol)

R: Universal gas constant, (8.314 J/mol·K).

T = Absolute temperature (K)

Ventilation Rate

$$\text{Ventilation Rate} = \frac{\textit{Heat production rate during respiration } (kJ/kg \cdot h)}{\text{Target } CO_2 \text{ concentration(g/m3)}}. \quad (5)$$

Heat Production During Respiration

The heat generated by the respiration process is critical for ripening and cooling system design:

$$Q = R_m \times H \quad \text{..... (6)}$$

where:

Q = Heat production rateduring respiration (kJ/kg·h)

H = Heat of respiration (0.44 W per mg CO_2/kg/h) for bananas.

The energy balance

The energy balance equation for a fruit ripening room helps in determining the energy input and output required to control the room's

temperature, humidity, and airflow [21] can be calculated as follows:

$$\boldsymbol{Q_{in} = Q_{out} + Q_{storage}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where:

Q_{in}: Energy entering the room, such as heating, cooling, respiration heat from the fruit, and other inputs (W).

Q_{out}: Energy lost through walls, windows, ventilation, and other exits (W).

$Q_{storage}$: Change in internal energy storage, accounting for heat stored in fruit mass and room structure (W).

Heat Addition (Q_{in}):

$$\boldsymbol{Q_{in} = Q_{heating} + Q_{respiration} + Q_{ventilation}} \ldots (8)$$

where:

$Q_{heating}$: External heating system input, essential for maintaining room temperature, typically 5-10 kWh per ton of fruit per day.

$Q_{respiration}$: Heat generated from the ripening process, typically around 3-5 W/kg depending on the fruit type and stage of ripening

$Q_{ventilation}$: Energy from ventilation systems, if necessary to control gas concentrations (like ethylene) and remove heat from respiration. can be calculated as:

$$\boldsymbol{Q_{ventilation} = v \times \rho \times C_P \times \Delta T} \ldots\ldots\ldots\ldots (9)$$

where:

ρ: air density (1.2 kg/m³).

Cp: specific heat of air (1.005 kJ/kg).

v: air flow rate (m³/s).

ΔT: difference between outside air temperature and room temperature.

Heat Loss (Q_{out}):

$$\boldsymbol{Q_{out} = Q_{conduction} + Q_{infiltration} + Q_{radiation}} \ldots (10)$$

$$\boldsymbol{Q_{conduction} = A \times U \times \Delta T} \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$\boldsymbol{Q_{infiltration} = \frac{ACH \times V \times \rho \times C_P \times \Delta T}{3{,}600}} \ldots\ldots\ldots\ldots\ldots (12)$$

where:

$Q_{conduction}$: Heat lost through walls, floors, and ceilings.

$Q_{infiltration}$: Heat lost due to air leakage, which can be significant if doors are frequently opened or if insulation is poor.

$Q_{radiation}$: is Radiation heat Losses and sometimes neglected in insulated ripening rooms.

A: a surface area (m²)

U: thermal conductivity (W/m²°C)

V: room volume (m³)

ACH is air changes per hour.

3,600 is the number of seconds in an hour to convert the flow rate into m³/s.

Internal Storage ($Q_{storage}$):

$$Q_{\text{storage}} = m \times C_{\text{P}} \times \Delta T \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where:

m: Mass of fruit in the room (kg).

Cp: Specific heat capacity of the fruit, typically around ranges from 3.6 to 4.0 kJ/kg°C, depending on moisture content.

RESULTS AND DISCUSSIONS

Respiration Rate as a Function of Temperature in Banana Ripening models

The respiration rate for carbon dioxide production and oxygen consumption, respiratory quotient, temperature-dependent respiration rate, ventilation needs, and heat load of banana respiration prior to, during, and following ripening in the three ripening models are displayed in Figures 1, 2, 3, 4, and 5.

For green bananas, oxygen consumption and carbon dioxide production were at their lowest, with values for Model 1 of 11.28 mg O_2/kg/h and 10.46 mg CO_2/kg/h, Model 2 of 9.97 mg O_2/kg/h and 9.08 mg CO_2/kg/h, and Model 3 of 9.41 mg O_2/kg/h and 8.29 mg CO_2/kg/h.

As bananas begin to ripen, oxygen consumption and carbon dioxide production increase, with values for Model 1 being 30.94 mg O_2/kg/h and 36.27 mg CO_2/kg/h, Model 2 being 27.06 mg O_2/kg/h and 30.81 mg CO_2/kg/h, and Model 3 being 22.81 mg O_2/kg/h and 24.32 mg CO_2/kg/h.

At full ripening stage, oxygen consumption and carbon dioxide production decrease but are higher than the values for green bananas. The values for Model 1 were 21.32 mg O_2/kg/h and 20.85 mg CO_2/kg/h; Model 2 were 19.83 mg O_2/kg/h and 18.93 mg CO_2/kg/h; The model 3 was 18.06 mg O_2/kg/h and 16.72 mg CO_2/kg/h.

Thus, the respiration quotient (the balance between CO_2 production and oxygen consumption) of model 1 is about 0.93, 1.17 and 0.39; of model 2 is about 0.91, 1.14 and 0.95; and of model 3 is about 0.88, 1.06 and 0.93 for green, ripe and fully ripe bananas, which is a dimensionless ratio.

The temperature-dependent respiration rate is highest in ripe bananas at about 187.656, 113.225 and 76.802 g CO_2/kg/h in the three models, respectively. As for the ventilation requirements, they are determined by the balance between ethylene application and removal, as well as the respiration rates of bananas.

For the largest model 1 (72 m³), the lowest ventilation rates for green bananas were estimated due to the lowest respiration rate, with values of 2.53, 1.52 and 1.03 m³/h for the three ripening models.

As for the respiration heat, it decreases with decreasing temperature in the three models and as the ripening process continues, with values of 82.14, 49.56 and 33.61 kW at the full ripening stage, respectively.

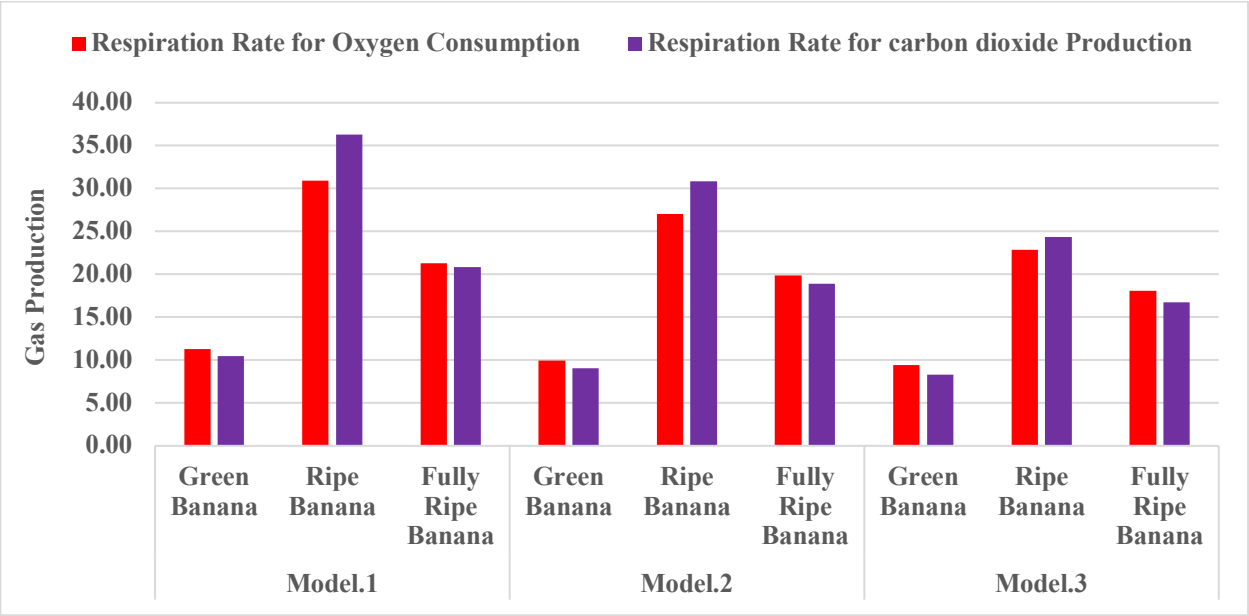


Fig. 1. The respiration rate for O_2 consumption and for CO_2 production of banana fruits in the three ripening models
Source: Authors' determination.

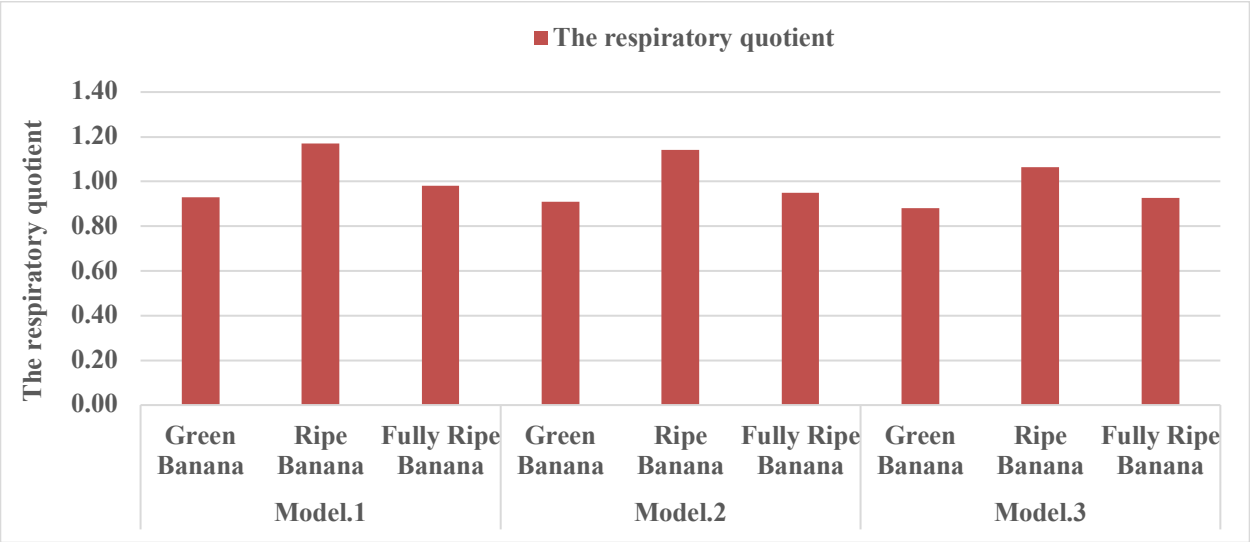


Fig. 2. The respiratory quotient of banana fruits using the three models for ripening
Source: Authors' determination.

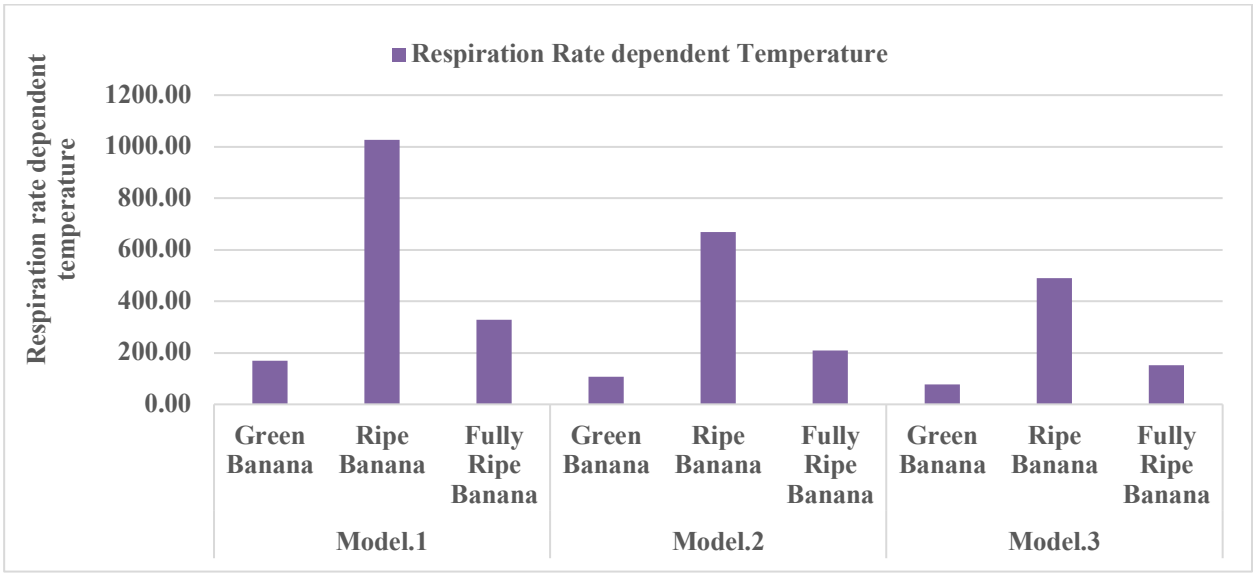


Fig. 3. Respiration Rate Dependent Temperature of the three ripening models for banana fruits
Source: Authors' determination.

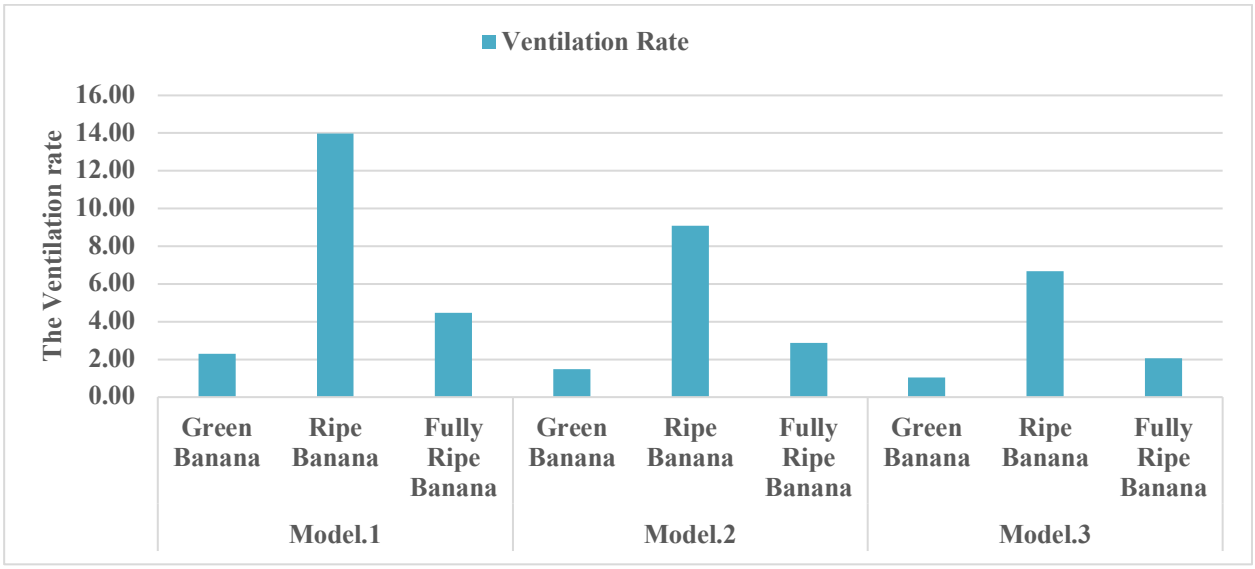


Fig. 4. The Ventilation Needs in the three ripening models
Source: Authors' determination.

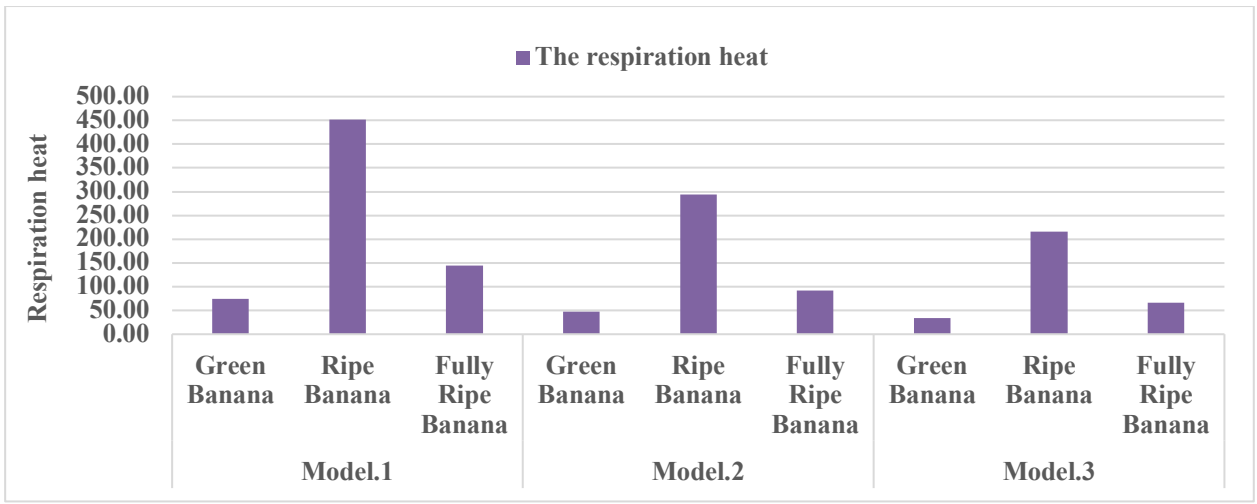


Fig. 5. The Respiration heat among the three models of ripening
Source: Authors' determination.

Energy balance

Figure 6 shows that the energy entering of the three ripening models in kW was compared to estimate the value of the energy entering generated by heating, cooling, ventilation, and lighting systems, and it was found that it has a direct relationship with the size of the model and an inverse relationship with the type of insulation, as the amount of energy entering decreases with the shrinkage of the model size, while it increases with the change in the type of insulation.

For 1,000 kg of bananas in models 1 and 2 insulated with cement, the energy entering decreases from 20.469 to 15.762 kW due to the small size of the model, while it increases in the third model insulated with ceramic to 11.799 kW due to the change in the type of insulation. Also, the energy entering for 10,000 kg of bananas decreases from 91.276 to 85.078 kW, respectively, in models 1 and 2 insulated with cement, while it increases to 88.967 kW in the third model insulated with ceramic.

Figure7 shows that the type of the size of the model affects the amount of energy lost through walls, windows, ventilation, and other exits. As the room size increases, the lost energy increases. In model 1, the lost energy was 14.192 kw because it is the largest area, and it decreased to 8.441 kw in model 2, and then reached 3.224 kW in model 3 because it is the smallest area.

Figure8 shows that the change in the internal energy storage of banana fruits in the three ripening models was compared, which changes with the change in the temperature of the fruits and the mass of the fruits.

For 1,000 kg of bananas in the three models, the values were 6.617, 7.194 and 8.222 kw, respectively. As for 10,000 kg of bananas, the values were 61.667, 71.944 and 82.222 kw, respectively.

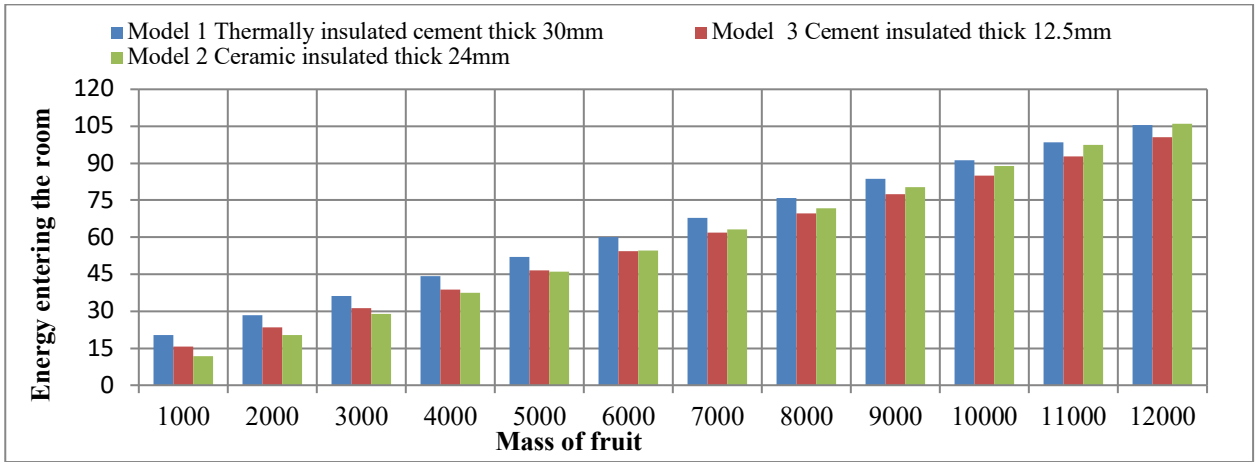


Fig. 6. Energy entering for the three modes of ripening
Source: Authors' determination.

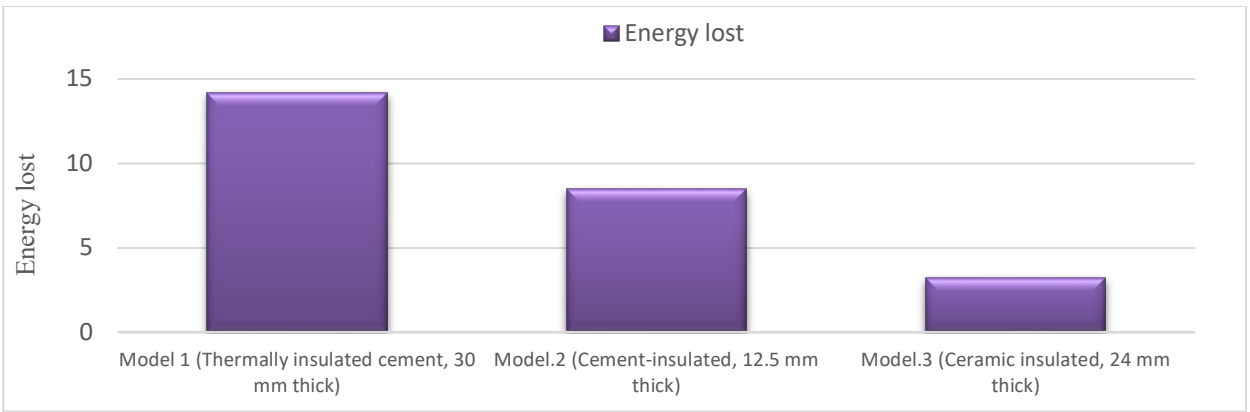


Fig. 7. The Energy loss for the three ripening models
Source: Authors' determination.

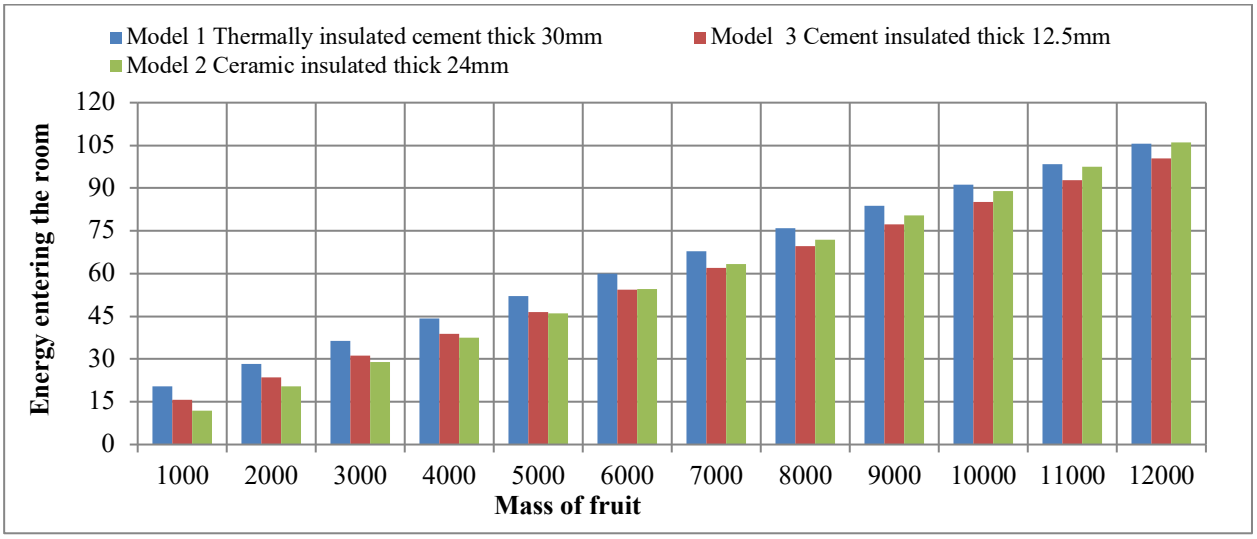


Fig. 8. The three ripening models' effects on the internal energy storage of banana fruits
Source: Authors' determination.

Economic impact of the three tested models during banana storage

Figures 9 and 10 show the relationship between total investment costs (EGP) and actual and approximate total monthly operating costs (in EGP). Investments were made at values lower than the approximate costs by about 58,000 EGP, 47,700 EGP, and 25,000 EGP in the third rooms, respectively. Operating costs were spent at values lower than the approximate operating costs by about 4,400, 3,000, and 1,700 EGP in the third rooms, respectively.

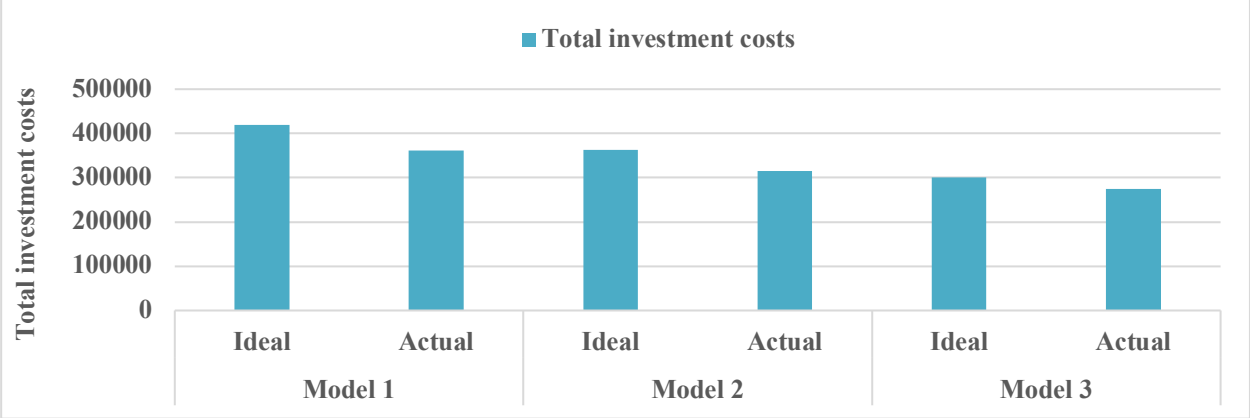


Fig. 9. The relationship between actual and approximate total investment costs in the three ripening models
Source: Authors' determination.

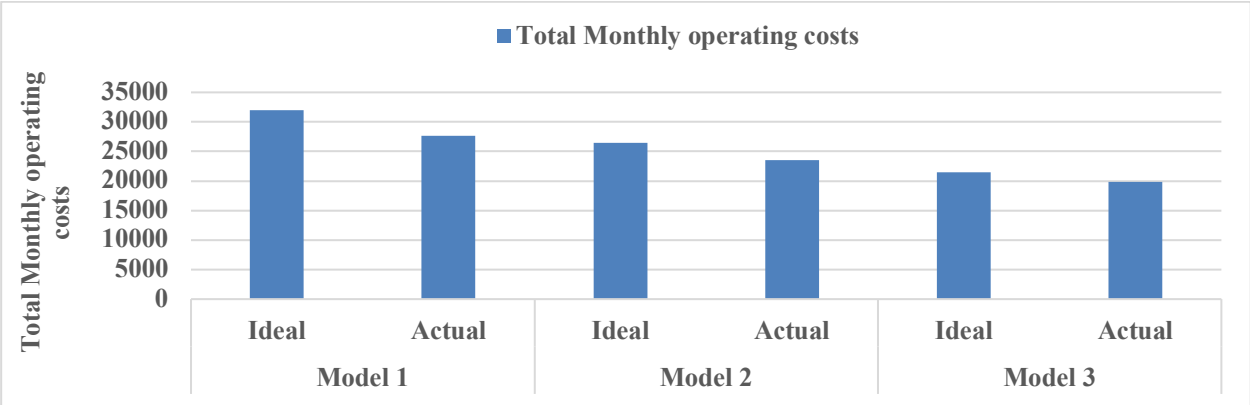


Fig. 10. The relationship between actual and approximate total monthly operating costs in the three ripening models
Source: Authors' determination.

CONCLUSIONS

The results showed that the respiration rate in bananas depends on their ripening stage and storage temperature, where metabolic processes, oxygen consumption (O_2) and carbon dioxide production (CO_2) are low in green bananas, then gradually increase to their highest levels with the onset of ripening and then decrease again with the progress of ripening, and ventilation and temperature requirements increase with the increase in respiration rate.

Therefore, it is necessary to control the temperature and air flow and prevent the accumulation of gases in the ripening rooms to maintain the quality of bananas and extend their storage life.

Otherwise, it could be registering quantitative losses and also the bananas will be of a lower quality.

In this way banana market offer will suffer and consumers as well, because they will not buy bananas of a lower quality.

The bananas of a lower quality will have to be sold at a lower price or transformed in wastes, and as a result the ripeners will diminish their income.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

BANANAS RIPENING MODELS IN A COOLING SYSTEM: COEFFICIENT OF PERFORMANCE, DIFFUSION FLUX OF ETHYLENE AND ECONOMIC IMPACT

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Abstract

The aim of this study is to determine the rate of ethylene diffusion and the heat load that the cooling system must handle and its effect on the coefficient of performance (COP). In this investigation, we experimented three banana ripening models in the Gharbia Governorate's city of Santa between December 2023 and January 2024. Model 1 was 72 m³ with thermally insulated cement walls that were 30 mm thick; Model 2 was 60 m³ of cement walls that were also insulated, but they were 12.5 mm thick; and Model 3 had 36 m³ built with ceramic walls of 24 mm thick. The measurement indicators were the respiration heat of bananas (Qr), the external heat load (Qext), the cooling load in a banana refrigerator (Qc), the coefficient of performance (COP) and the rate of ethylene diffusion. The findings can be summed up as follows: the model size has a direct link with the respiration temperature, cooling load, and coefficient of performance (COP), and it has an inverse relationship with the ethylene diffusion rate, internal temperature, and external temperature. The economic impact of banana storage reflects an increase in accrued revenues and thus an increase in net profit.

Key words: *bananas, ripening, COP, respiration, heat and energy, molecular diffusion of ethylene, economic Impact*

INTRODUCTION

Bananas are a popular fruit that originated primarily in tropical and subtropical climates. Egypt produced 1.21 million tons of bananas in 2022. At an average yearly rate of 5.52%, Egypt's banana production grew from 101 thousand tons in 1973 to 1.21 million tons in 2022 [8].

Egypt exported $1.91M in bananas, making it the 70th largest exporter of bananas in the world. And Egypt imported $4.19M in bananas, becoming the 88th largest importer of bananas in the world. In 2023, it registered a slight increase year-on-year of 0.29%, totalling 19.17 million metric tons [7].

When it comes to climacteric fruits, quality cannot be maintained during marketing and storage, even though controlled atmospheric storage or low temperature storage can increase shelf life. Fruit quality can be preserved for long-distance domestic and international shipping, and the product's shelf life can be increased with appropriate post-harvest processing and storage practices [13].

Fruits that are stored at a lower temperature have a longer shelf life and less respiratory activity. After further research revealed that the gaseous composition plays a significant role in the fruits' longer shelf-life, the concept of a controlled atmosphere (CA) with low O_2 and high CO_2 content in the storage environment was developed for the long-term preservation of fresh fruits [20].

The efficiency of a machine is related to its coefficient of performance (COP), which is the ratio of the energy required (i.e., input) to generate the refrigerating effect to the heat removed (i.e., output) from the chilled body. The coefficient of performance, or COP, is the quantity of heat that a thermoelectric

refrigerator can generate for every unit of electrical power supplied [10].

The performance of any process or device can be computed by dividing the intended impact by the production cost. The compressor's work input in the Reversed Carnot Cycle is the cost of achieving the desired result, which is the heat absorbed from the low-temperature heat source, also known as the refrigerating effect. The Reversed Carnot Cycle's prior performance metric was the Coefficient of Performance (COP) [14].

Damage to bananas may result from improper handling and ripening methods. The losses can show up at different points in the fruit supply chain. Harvesting and pre-harvesting could be discussed first, followed by marketing, packing, processing, storage, and transportation. Numerous writers investigated the factors that influence banana weight and quality losses and suggested methods to lower them along the supply chain [16,15, 1,11,2].

Post-ripe fruits are usually chosen at a low level of maturity because their storage life is limited when fully ripe. But the fruit is inedible since it is hard and has few soluble solids. Therefore, for fruit to become edible, it must ripen, either naturally or artificially. Customers have issues with the fruit's natural ripening process, including a lengthy ripening period and subpar flavour quality. For peeled and post-ripe fruits, postharvest ripening is therefore crucial. The foundation of ripening technology and essential components of the fruit supply chain are temperature regulation and gas conditioning. Direct ethylene ripening is currently one of the most popular ripening methods. This method was used in the past to speed up the metabolic process and significantly alter the characteristics of the internal components. Ripening can be efficiently hastened using 100 ppm ethylene at 20–23 °C by regulating the amounts of ethylene, CO_2, and O_2 [21].

It is common for fruit companies to place the ethylene generator in the storage area, operate it for ten hours or so, and then let the ethylene gas to exhaust itself. Ripening storage is then maintained between 17 and 20 °C. The temperature and humidity are then manually adjusted to allow the fruit to mature. For post-ripe fruits, precise ethylene monitoring during ripening is required. The ripening effect is influenced by temperature, CO_2, ethylene, and other factors. Temperature and ethylene content are the two most crucial variables [9].

One of the most significant fruits in the world is the banana. It is regarded as a good source of energy because of its high carbohydrate content. It has a distinct PR climacteric phase following harvest since it is a climacteric fruit. Because of its low respiration rate and low degree of ethylene production, the fruit does not ripen during this time. As the temperature drops between 40 and 15°C, this time frame may lengthen. The fruit's respiration rate rises after this time. This rise is strongly linked to the evolution of ethylene, the breakdown of peel chlorophyll, the conversion of starch to sugar, and the softening of pulp. The shelf-life of banana fruit is double and the processing duration is prolonged when it is ripened at a low temperature (15°C) [17].

In the ripening chamber, fruits treated with ethylene gas were kept for 36 hours at 200°C and 85–90% relative humidity. There were notable changes in the fruit's colour, going from green to yellow. In contrast, the chemical parameters TSS, reducing sugar, and total sugar exhibited an increasing tendency as concentration and post-treatment duration increased. As the ripening process progressed and the concentration of ethylene gas and ethephon grew, titratable acidity steadily reduced. The ethylene gas-treated fruits displayed less acidity. It was found that the physiological loss in weight (PLW) rose with storage duration, up to eight days in ambient conditions, irrespective of therapy. Banana fruits treated with 150 ppm ethylene gas showed the highest PLW in comparison to other treatments. Higher amounts of ethylene gas have been found to accelerate the ripening of bananas. The sensory score for banana fruits treated with ethylene gas increased significantly on the fourth day of ripening, indicating that the maturing banana fruits were favourably received. The safest method for ripening bananas is to use a cheap ripening chamber with 150 ppm ethylene gas for 36 hours at 200°C and 85–90% relative humidity [22].

Ethylene (ET) is a phytohormone that is crucial for regulating plant responses to stress. Numerous other plant traits that are critical to crop productivity and nutritional value are also under its control. ET has long been thought to be a ripening hormone in climacteric fruit. The functions of different ET generation and signalling components during the ripening process have been the subject of numerous studies. According to recent studies, heat stress (HS) dramatically reduces fruit output, quality, and postharvest stability by changing the regulation of several ethylene biosynthesis and signalling genes and interfering with fruit ripening. The relationship between ET, ripening, and HS remains unclear despite the tremendous advancements made in this field in recent years [19].

It takes time and specialized gas analysis equipment to measure the gas composition and produce respiration rate at a certain storage temperature. Many mathematical models have been developed to relate the respiration rate to different storage properties, including temperature and gas composition (e.g., O_2 and CO_2). The more recent technique for approximating respiration rate using the Michaelis-Menten type equation is based on enzyme kinetics. Assuming that the transport and solubility of O_2 and CO_2 in plant tissue govern allosteric enzyme-catalyzed reactions, this provides a fundamental explanation of respiration [3].

Autocatalytic ethylene production and respiration both rapidly increase as climacteric fruits, like bananas, ripen. Since external ethylene causes ripening and suppression of its synthesis stops it, ethylene is regarded as the trigger in these fruits. They discovered that two important elements in the control of ethylene production seem to be the availability of ACC (1-aminocyclopropane-1-carboxylic acid) and the tissue's capacity to convert ACC to ethylene [4].

In apples and other fruits including avocado, banana, and tomato, the ethylene production pathway was clearly seen. When fruit begins to ripen, several ACC synthesis genes become active, increasing the amount of ACC produced. ACC oxidase subsequently converts this ACC to ethylene.ACC synthase activity usually determines the rate of ethylene synthesis. Ethylene biogenesis is triggered in naturally ripening banana fruit by certain factors that control the aging process.

Protein synthesis inhibitors were used to increase ethylene synthesis, which meant that they had an impact on tissue-level ripening equilibrium mechanisms. In actuality, the integrity of the cell membrane is frequently linked to the climacteric peak and the ability to produce ethylene. It's possible that a rigorous repair process that heavily relies on protein synthesis is what keeps the ethylene content in fruit tissues below its threshold level during fruit GL [6].

The banana fruit ripens in seven phases, and GL covers the first two. For the Cavendish cv., the CO_2 respiration is roughly 4 mg CO_2 $kg^{-1}.h^{-1}$, the sugar concentration is almost 0%, and the starch content is continuously high (23–25%). The only discernible characteristic of the green life stage is the peel's gradual change from deep green to green with a faint yellow hue due to a progressive decrease in chlorophyll.

Since starch hydrolysis does not occur during GL, we were unable to connect histological alterations like starch hydrolysis to variations in fruit GL. While the water-soluble tannin content of banana peel steadily declined during storage, particularly during ripening, the water-soluble tannin content of banana pulp first declined and subsequently increased during ripening [12].

Water stress actually increased the production of ethylene in pre-climacteric fruits, which led to an increase in respiratory metabolism, as seen in vegetative tissues. The fruit's autocatalytic ethylene production and the climacteric surge in respiration were probably caused by the ethylene that water stress created. Indeed, it is commonly known that storing fruits at low relative humidity (RH) accelerates water loss and causes early changes in respiration and ethylene production. Furthermore, it was observed that pulp and peel stored at high relative humidity showed a consistent increase in ACO activity [18].

The aim of this study is to determine the rate of ethylene diffusion, the heat load that the cooling system must manage, and how these

factors affect the coefficient of performance (COP). Also, the study examined the economic impact during banana storage.

MATERIALS AND METHODS

Three banana ripening models were used in the experiment, which was carried out in the city of Santa, Gharbia Governorate, between July 2024 and September 2024 for the summer and November 2023 and December 2023 for the winter.

To estimate the amount of metabolic heat released by the fruit as they respire and its effect on the energy balance in the fruit ripening models and thus on the Coefficient of performance (COP).With dimensions of 6 m length x 4 m width x 3 m height, the model 1's production capacity was 12 tons; the model 2's was 8 tons with dimensions of 5 m length x 4 m wide x 3 m height; and the model 3's was 6 tons with dimensions of 3 m length x 4 m width x 3 m height. as shown in Fig.1 and Fig. 2.

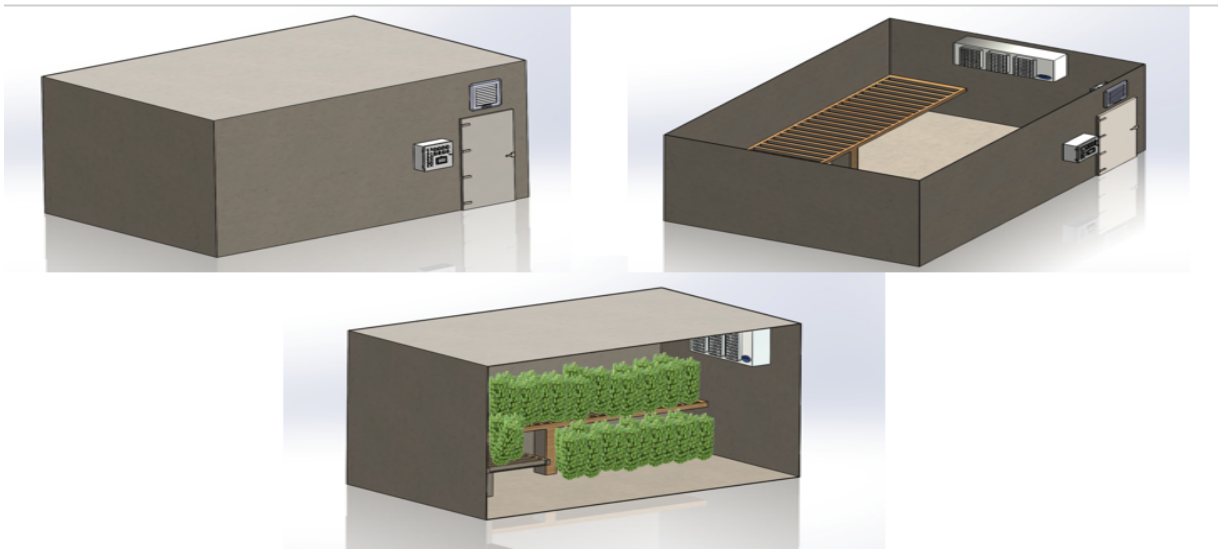


Fig. 1 Banana Ripening model
Source: Authors' determination.

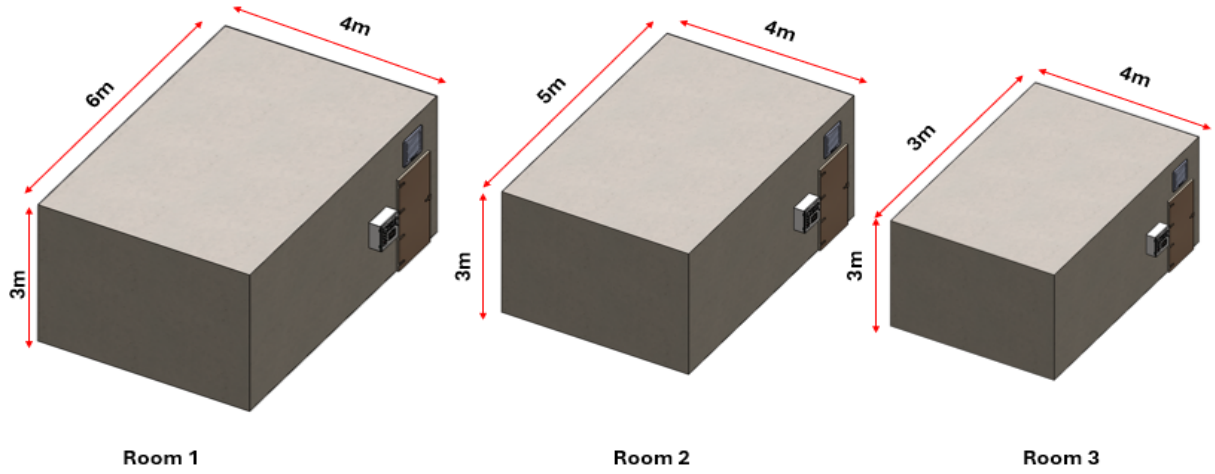


Fig. 2. Specifications of the Three Banana Ripening models
Source: Authors' determination.

Measurements and determinations

A set of mathematical equations was used to calculate the molecular diffusion of ethylene, respiration rate of banana fruit and the coefficient of Performance (COP)[20], which were calculated as:

-Respiration Heat of Bananas

Bananas, like other fruits, continue to respire after harvesting, producing heat and CO_2. The

rate of heat production due to respiration depends on the storage temperature and the maturity of the fruit. and can be calculated from:

$$\mathbf{Q_r = R \times H \times Massoffruit} \ldots\ldots\ldots\ldots \quad (1)$$

where:
Q_r is the respiration heat (W/kg or J/s).
R is the respiration rate of the banana (mg CO_2/kg/h)
H is the heat of respiration, which is typically around (0.44 W per mg CO_2/kg/h) for bananas.

-***The external heat load***

$$\mathbf{Q_{ext}} = \frac{\mathbf{K \times A \times \Delta T}}{\boldsymbol{d}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where:
Q_{ext} is the external heat load (W).
k is the thermal conductivity (W/m·K). (for typical cement, k≈0.7 W/m.K). for ceramic k≈1.5 W/m.K).
A is the surface area of the walls (m^2).
ΔT is the temperature difference between the outside and inside of the refrigerator (K).
d is the thickness of the cement wall (m).

-***Cooling Load in a Banana Refrigerator***

$$\mathbf{Q_c = Q_r + Q_{ext}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where:
Qc is the total heat load
Qr is the heat generated by respiration.
Qext is the heat from external sources (which depends on the design of the refrigerator, insulation, ambient conditions, etc.).

-***Coefficient of Performance (COP)***

Once you have the cooling load and the work input, the COP can be calculated using the standard COP formula for cooling:

$$\mathbf{COP}_{\text{cooling}} = \frac{\mathbf{Q_c}}{\boldsymbol{W}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

where:
Qc is the total cooling load (in watts or joules per second), including respiration and other heat loads.
W is the work input, is the electrical energy consumed by the refrigeration system (in watts or joules per second).

The coefficient for Ethylene in Banana Ripening rooms

The coefficient of molecular diffusion D, governs the rate at which ethylene spreads throughout the ripening chamber by molecular motion. This process plays a critical role in the uniform ripening of bananas, since ethylene is the hormone responsible for triggering ripening [5].

***Fick's First Law*:**

This law gives us the flux of ethylene molecules moving through the air. It assumes steady-state diffusion, meaning the concentration gradient does not change with time. The equation is:

$$\boldsymbol{J} = -\mathbf{D}\frac{\boldsymbol{dC}}{\boldsymbol{dx}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where:
J is the diffusion flux in mol/m^2/s,
D is the diffusion coefficient of ethylene in air (m^2/s)
C is the concentration of ethylene (mol/m^3)
x is the distance along the diffusion path (m).
dC/dx is the concentration gradient (mol/m^3).

The concentration of ethylene in the room

$$\mathrm{C} = \frac{\mathrm{n}}{\mathrm{V}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

where:
C is the concentration of ethylene in moles per cubic meter (mol/m^3)
n is the number of moles of ethylene (mol)
V is the volume of the room in cubic meters(m^3)

***Volume of Ethylene Gas from Liquid*:**

To determine how much gas is produced from liquid ethylene, we can use the **ideal gas law** and density data.

$$\text{Mass of ethylene} = \text{Volume of ethylene} \times \text{Density of ethylene} \ldots\ldots\ldots\ldots \quad (7)$$

$$\text{Moles of ethylene gas (mol)} = \frac{\text{Mass of ethylene}}{\text{Molecular Weight}} \ldots\ldots\ldots\ldots \quad (8)$$

$$\text{Volume of ethylene gas (Lit)} = \frac{\text{Mass}}{\text{Molecular Weight}} \times 22.4 \ldots\ldots\ldots\ldots \quad (9)$$

where:

Density of liquid ethylene at its boiling point (-103.7°C) is (0.57 g/ml).
Molecular weight of ethylene (C_2H_4) = 28.05 g/mol
One mole of any gas occupies 22.4 L/mol.

The concentration gradient

$$\frac{dC}{dx} = \frac{C_{max} - C_{min}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where:
C_{max} is the concentration at the point closest to the ethylene generator
C_{min} is the concentration at the farthest point (near zero concentration)
L is Length the room

Diffusion Coefficient for Ethylene in Air

To estimate the diffusion coefficient for ethylene (C_2H_4) in air, we can use Fuller's equation:

$$D_{AB} = \frac{0.00143T^{1.75}}{P\times(M_{C_2H_4}+M_{air})^{0.5}\times(\sum v_{C_2H_4}+\sum v_{air})^2} \ldots\ldots (11)$$

where:
D_{AB} is the diffusion coefficient of ethylene (cm^2/s)
T is the temperature (Kelvin)
P is the pressure in atmospheres (atm)
M_{C2H4} and M_{air} are the molecular weights of ethylene (28.05 g/mol) and air (29.00 g/mol), respectively
$\sum v_{C2H4}$ and $\sum v_{air}$ are the diffusion volumes for ethylene (20.3) and air (20.1).

Energy Cost Calculation

$$\text{Energy Consumption} = \frac{\text{Power Usage (kW)}}{COP} \times$$

$$\text{Operating Hours} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

$$\text{Operating Hours} = 24 \text{ hours/day} \times$$

$$\text{Ripening Duration} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$\text{Total Cost} = \text{Energy Consumption} \times$$

$$\text{Electricity Cost per kWh} \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Revenue Calculation

$$\text{Sellable Product} = \text{Total Load} \times (1 -$$

$$\text{Percentage of Product Loss \%}) \ldots\ldots\ldots\ldots (15)$$

$$\text{Revenue} = \text{Sellable Product} \times$$

$$\text{Market Price per Ton} \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Net Profit Calculation

$$\text{Net Profit} = \text{Revenue} - \text{Energy Cost} \ldots\ldots\ldots (17)$$

RESULTS AND DISCUSSIONS

The concentration of ethylene

Fig. 3 shows the rate of ethylene diffusion in each of the three models. It was found that the size of the model affects the rate of ethylene diffusion. The rate of ethylene diffusion is slower in large rooms because the concentration is spread across a larger area. In all three models, the projected values ranged from 0.000039 to 0.000048 to 0.000111 $mol/m^2.sec$.

Coefficient of Performance (COP)

Fig. 4 shows that the type of insulation and the size of the model affect the amount of heat generated from the external thermal load. In models 1 and 2 which insulated with cement. The amount of heat generated from the external thermal load increases from 2.52 to 2.64 kw due to the small size of the model. While it increases in the third model insulated with ceramic due to the difference in the type of insulation, its value is 5.04 kw. As for the amount of heat generated from the internal thermal load, it increases from 0.65 kw in the first model to 0.95 in the second model and reaches the highest value in the third model insulated with ceramic to become 1.05 kw.

Fig. 5 shows that all three models show a clear positive correlation between banana weight and respiration heat. As banana weight increases, the generated respiration heat also increases linearly in all models. For Green bananas, the values were 74.833, 451.725 and 144.355 kw in the three ripening models, respectively; for ripe bananas, the values were 47.664, 294.329 and 92.482 kw; and for fully ripe bananas, the values were 33.64, 215.964 and 66.751 kw in the same three ripening models, respectively. Also shows that the type of insulation and the size of the model affect the cooling load. For Model.1, the values were 78.653, 455.545 and 148.175 kw for Green Banana, Ripe Banana, and Fully Ripe Banana, respectively; For Model.2, the values were 51.570, 298.235 and 96.388 kw for Green Banana, Ripe Banana, and Fully Ripe Banana, respectively; and for Model.3, the values were 39.730, 222.054 and 72.841 kw for three stages of banana ripening.

Fig. 6 shows that cooling demand is directly related to temperature and volume, Increasing the size increases the thermal loads, requiring the compressor to work harder to maintain the internal temperature, thus increasing the coefficient of performance. The values of the coefficient of performance in Model 1 ranges from 4.916 to 5.2, in Model 2 from 4.77 to 5.1, and in Model 3 from 4.7.2 to 5, respectively.

Economic impact of the three tested models during banana storage

Fig. 7 shows the total costs, revenues and net profit for the three models over one cycle. It was found that the first model achieved the highest revenue, estimated at 234360 EGP, compared to the revenues of the other two models.

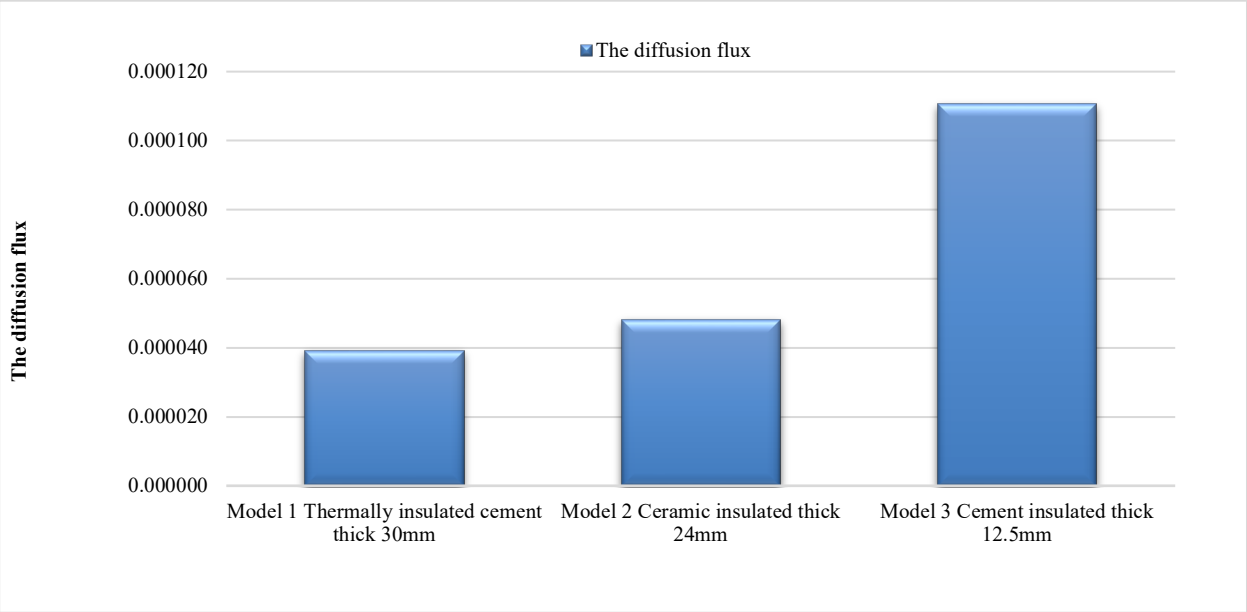


Fig. 3. The ethylene diffusion flux in the three ripening models
Source: Authors' determination.

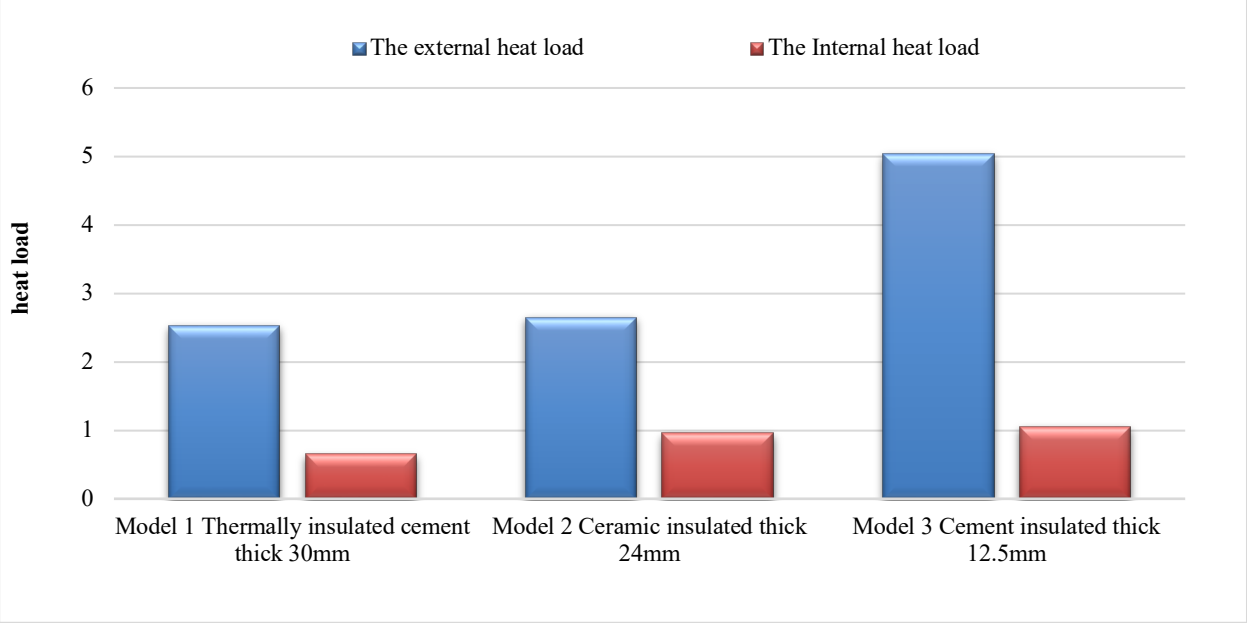


Fig. 4. Three ripening models' internal and exterior heat loads.
Source: Authors' determination.

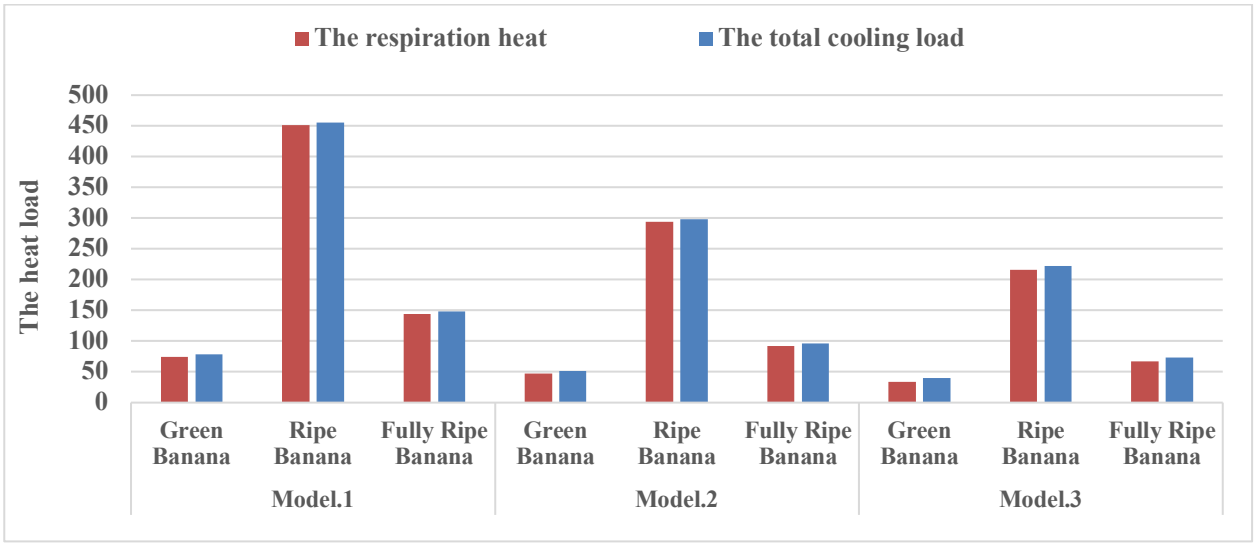


Fig. 5. Banana fruit respiration heat and overall cooling load in the three-ripening models.
Source: Authors' determination.

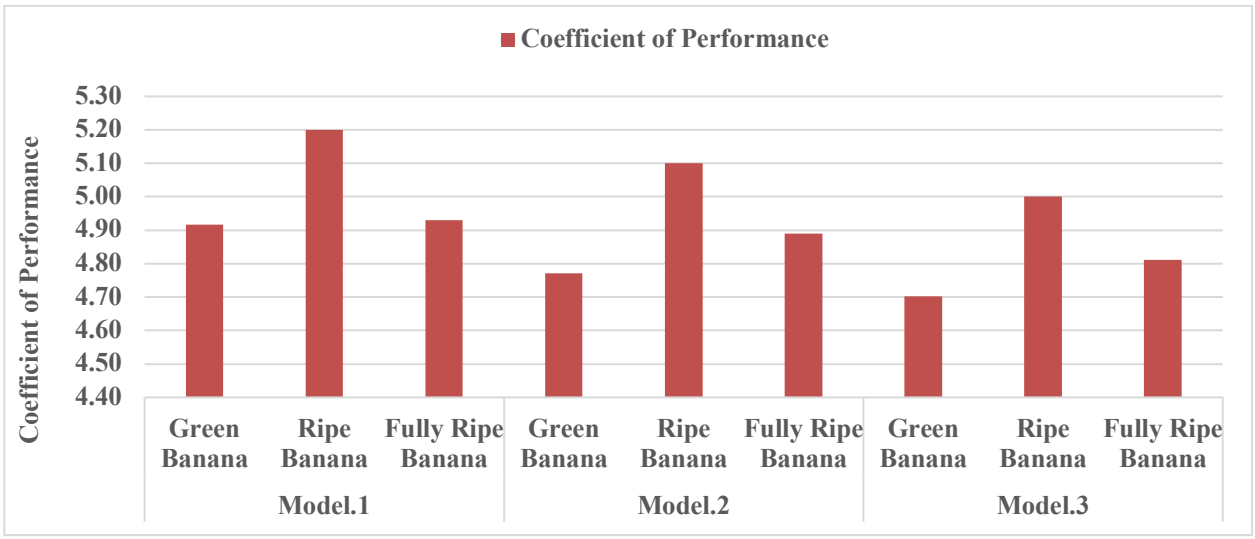


Fig. 6. The coefficients of performance for the three ripening models
Source: Authors' determination.

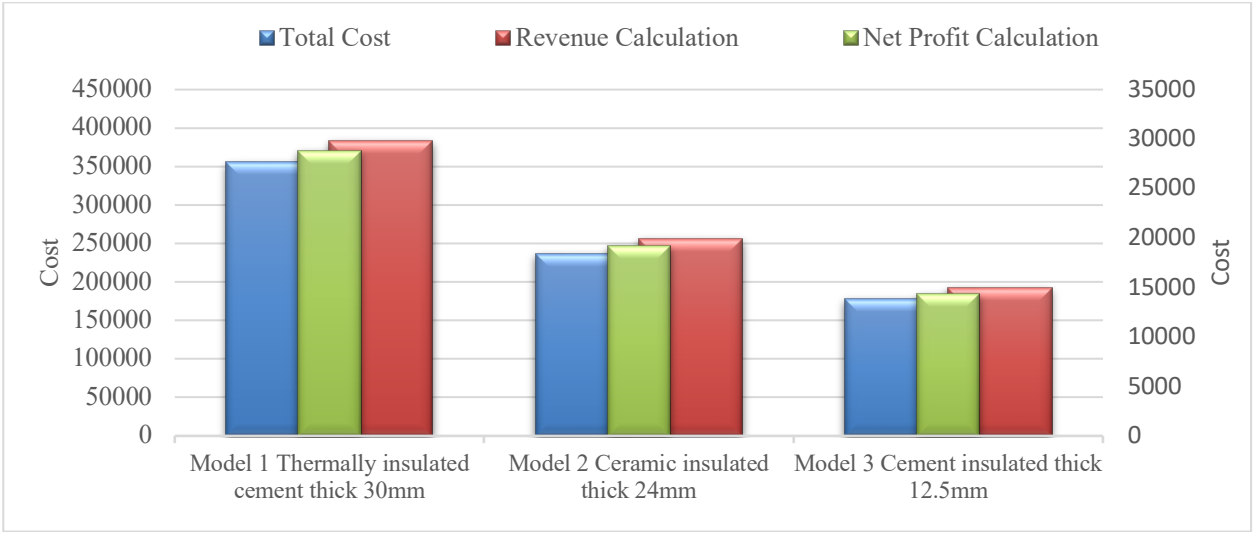


Fig. 7. The three ripening models' total expenses, total income, and total net profit
Source: Authors' determination.

CONCLUSIONS

The findings demonstrated that the three ripening models' measurements were substantially impacted by the models' sizes, temperature, and banana quantity, where the larger the quantity of bananas and the larger the room size, the higher the respiration rate and the greater the need for air cooling, and also the higher the temperature, the lower the energy consumption, which leads to an increase in the system efficiency (COP).In order to guarantee the quality of the finished product, enhance the models' operational efficiency, and extend the shelf life of ripe bananas while lowering losses during storage and transit, it is vital to keep an eye on temperature, humidity, ethylene gas concentration, and banana respiration temperature. And meeting market requirements and thus achieving sustainability and improving profitability. In short, the performance factor in banana ripening refrigerators plays a pivotal role in ensuring product quality, improving operational efficiency, and reducing costs, which benefits both producers and consumers.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

NON-DESTRUCTIVE BANANA RIPENESS DETECTION USING OPTICAL SPECTRAL BANDS AND WASTE AND ECONOMIC LOSS FROM WASTE AND BANANA COLOR CHARACTERISTICS

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Abstract

Vegetation indices using Red Green Blue- RGB bands are useful tools for assessing plant health and vigor. They can provide insights into the photosynthetic activity, chlorophyll content, and overall condition of vegetation. When applied to banana plants, these indices can help monitor the ripening stages by analyzing changes in color and other physiological parameters. The objective of this research was to study of the correlation between the banana's color changed during ripening stages and RGB color indices. Dessert bananas (Musa sap.) from nearby, specially designed banana ripening rooms in the city of Santa, Gharbia Governorate, were chosen for experimental work in this study in January 2024. A lot of data analysis was conducted on the RGB bands vegetation indices and the browning index of bananas during the ripening stages. The simple red-green ratio, green-red, hue, VEG, red and blue bands, green-red, and all vegetation index were evaluated to track the ripening stages by color analysis.The results recorded that there was a rise in the blue band band's color from 59 to 123 during the three stages of maturity, following the same pattern as the red and blue band's color. also, Brown index changed from 15.05 to 62.89 as a result of bananas reaching the brown stage. In contrast, the hue dropped from 121.89 to 41.45. The values of RGB bands vegetation indices are highest in the vegetative stage due to the high chlorophyll content in the banana fruit, so the value of NDVI Index is 0.43, VARI Index is 0.62, MGRVI Index is 0.72 and NGBDI Index is 0.41. The maximum values RGBVI1,2,3 Index were at the green stage (unripe banana) at 0.7, 1.48 and 3.68 respectively. In contrast, the maximum values BGI2 and RGRI Index were at the Brown Stage (Overripe Bananas) at 0.66 and 0.94 respectively. Banana waste results in significant economic losses throughout the supply chain, from farmers to consumers. By improving storage, transportation, retail strategies, and consumer habits, businesses and individuals can reduce waste and maximize banana value.

Key words: *banana, ripening rooms, fruit, RGB bands, colour, indicators, vegetation indicators, economic loss*

INTRODUCTION

Bananas are a popular fruit that are mostly grown in tropical and subtropical regions of the world. 1.21 million tons of bananas were produced in Egypt in 2022. Between 1973 and 2022, Egypt's banana production increased at an average annual rate of 5.52%, from 101,000 tons to 1.21 million tons [9]

Bananas are the most wasted fruit in shops because of their brown spots and rapid ripening, which lowers their appeal to consumers. The Food and Agriculture Organization (FAO) estimates that incorrect handling, storage, and maturity control cause 14% of bananas to be lost before they are consumed. Up to 40% of bananas are wasted at the retail and consumer levels in various nations [1].

Research shows that post-harvest banana losses can differ greatly depending on the area and how they are handled. For example, studies conducted in Northeast India found that poor post-harvest handling practices resulted in losses of up to 4.7% during the ripening stage. Banana waste is greatly influenced by consumer preferences. Even though they are still edible, many people throw away bananas with brown patches because they believe they are overripe. Banana waste in households is

significantly increased by this tendency. An estimated 50 million tons of bananas are wasted every year worldwide as a result of browning and over ripeness, which causes large financial losses [5,18, 24, 30].
The causes of banana waste occur along the supply chain as presented in Table 1.

Table 1. The stages in which banana waste occurs and Economic Impact

Stage	Cause of Waste	Economic Impact
Farm Level	Oversupply, cosmetic imperfections, early spoilage	Loss of income for farmers
Transport & Shipping	Overripening, temperature mismanagement, ethylene exposure	Rejected shipments, lost export revenue
Retail & Supermarkets	Overstocking, consumer rejection of spotted bananas	Discounts, disposal costs
Consumer Level	Overbuying, poor storage	Household financial loss

Source: Adapted by author based on [18].

Among all fruits, bananas are among the most affordable, tasty, and nutritious. People of all ages prefer it. It also has a number of therapeutic qualities. Various elements of bananas act as food medicines for the treatment of diseases like diabetes, hypertension, cancer, diarrhea, Alzheimer's, and infections, according to numerous in vitro research, animal model studies, and clinical trials. The banana is a climacteric fruit that ripens naturally at 200°C, showing a respiratory peak after harvest. The color, flavor, and texture of the fruit deteriorates rapidly after harvesting, resulting in a sharp decline in fresh banana quality. In the summer, its post-harvest shelf life is a mere two to three days. It has therefore always been regarded as a problematic fruit. Investigating the potential for turning bananas into goods with value additions is one way to tackle this issue. Enzymatic browning of banana pulp is a processing issue. When exposed to oxygen, it quickly browns enzymatically due to cellular breakdown from peeling, slicing, and pulping processes [19].
Fruit maturity is indicated by the softening of the peels' texture and a shift in their golden hue. While peel color reflects shelf life, texture suggests eating quality. One of the key elements of retail distribution is shelf life. Global production exceeds 67 million metric tons, according to FAO (2002). Bananas that are uniformly green and matured are typically harvested in order to prolong their shelf life and minimize loss during transit. They don't undergo any appreciable chemical or physical (color and texture) changes; they stay green and hard. Bananas are mostly judged on the color of their skin by consumers. The color of the peel reflects changes that occur both chemically and physically during the ripening process. Bananas are typically graded commercially by visual assessment [10].
Ripeness is assessed using defined color schemes. The seven ripening stages of the color charts are used to distinguish between different skin tones. Instrumental methods are sometimes used to estimate ripeness as well. The initial stage of ripening is the disintegration of cell walls. The middle lamella becomes less cohesive as a result of the solubilization of pectic compounds. Second, osmosis causes water to migrate from the skin into the flesh. When a Musa cavendish reaches full ripening, the processes of starch hydrolysis and sugar synthesis are finished. However, the process goes on until a highly mature and senescent stage in other species of Musa [26].
The determination of color properties in plants is essential for understanding their biochemical composition and ecological roles. This process involves analyzing the pigments responsible for coloration, such as chlorophyll, carotenoids, and anthocyanins. These pigments not only give plants their distinctive colors but also play vital roles in processes like photosynthesis and the level of ripeness. Researchers study the color properties of plants to understand their ecological roles, nutritional value, and potential applications in industries like food, cosmetics, and textiles. By studying these color properties, scientists can also improve plant breeding programs, predict the quality of fruits and vegetables Also in design of processing systems for these fruits and vegetables Many studies have been reported on the color properties of fruits and vegetables, such as melon [7], Potato Sticks [11]Faba bean

and corn [12], orange [13], soybean seeds [14], and green leafy [15].

Food preparation and preservation impact food's color, texture, flavor, and nutritional content. Food safety and quality are never entirely compatible. Modified environment storage is one method of food preservation that increases the shelf life of food products without sacrificing their natural quality. The storage life of food products is greatly increased by changing the atmosphere surrounding the food, which lowers the respiration rate of the food items and the activity of insects or bacteria in the food [8].

When fruit ripens, it experiences a number of physical changes. The most obvious change that many fruits undergo during the ripening process is to their exterior color. Ripening rooms require a good temperature control system, effective air circulation, an efficient fresh air supply mechanism, and gas tightness. If ventilation is not done on a regular basis, ripening may take longer or take on peculiar features [29].

The effects of ripening treatment on the qualities of banana fruit are discovered to be related to temperature. Additionally, research was done on the reciprocal effects of fruit length, temperature, and storage humidity on banana fruit attributes. the variations in banana texture and color when being stored at 10 and 20 degrees Celsius. The M. Cavendish samples showed a gradual change in peel color from green to yellow during storage, but the M. Paradisiacal variety showed a distinct pattern, staying green for the first eight days before abruptly shifting to a yellow tone starting on day twelve. While the M. Cavendish type bananas' flesh texture softened quite quickly after storage, the M. Paradisiacal variety's flesh texture changed more slowly and the flesh hardness values did not change much over the course of the storage period [27].

The peel of "Dwarf Cavendish" bananas showed brownish-red coloring after 40 minutes of exposure to 30 W UV-C at a distance of 45 cm. Another report reported a similar observation in a "Williams Cavendish" banana that was exposed to 1.2 W/m^2 UV-C radiation for 10 minutes at a distance of 18 cm. Both reports, however, did not list a fatal dose that results in browning bananas. Prior its application on a commercial scale, information regarding the lethal dose is required [28].

In Malaysia, the most popular banana fruit for dessert is called Brangan. When ripe, the fruit, which ranges in size from medium to large, has a beautiful orange-yellow peel and pale orange pulp. The most popular dessert among the locals is banana. The Cavendish and Brangan bananas have the same genome, which is AAA, however the fruit of the Brangan banana may ripen at a tropical temperature of 27 °C. After being exposed to UV-C radiation, Brangan banana fruit experienced browning just as Cavendish banana fruit [6].

Studies on the shelf life of bananas assessed the bananas' level of ripening based only on color; however, no quantitative analysis of their quality indices was conducted. To our knowledge, there has never been a case when the external color of a banana was used to determine its quality, though. Fruit quality is first assessed based on color, gloss, and size; it is then assessed based on texture, total soluble solids (TSS) concentration, and acidity. When selecting a food source, consumers may find this information to be helpful. In trading, attribution of quality should be given particular consideration. Ripening indices: these are commonly used to assess changes in volatile chemicals, soluble solids concentration, titratable acidity, softening, and skin color. However, the use of sensors—such as chemical, optical, and tactile ones—offers a strong association with human senses [3].

The quality indices of bananas were estimated using artificial neural networks (ANN) based on color features (L*a*b*, HSV, and YUV) at various storage temperatures (20, 25, 27.5, and 30 ◦C) during the ripening process. The banana's hardness and TSS were successfully anticipated by the ANN model, but the pH and pulp-to-peel ratio were not well predicted. Furthermore, the RPD values showed good predictive power for TSS and hardness, but not for pH or the pulp-to-peel ratio. At the laboratory level, a deep learning image processing system could be a helpful tool for predicting banana quality indices. Their study showed that consumers and employees in the general supply chain may be able to judge food

quality using a smartphone's camera. To compensate for changing ambient light, the process of capturing images can be made simpler. For example, a gray color chart placed next to the fruit could be used [4].

The biochemistry and physiology of the fruit alter during the final stage of growth, known as ripening, which improves the fruit's texture, flavor, and appearance and makes it more palatable and pleasurable to eat. Most of the fruit's sensory and nutritional properties occur during ripening, therefore controlling it is crucial to maintaining the fruit's quality traits throughout its postharvest shelf life. Banana quality and postharvest life are dependent on how they ripen and are treated postharvest. In the wild, bananas ripen slowly, which results in severe weight loss, desiccation, uneven ripening, and poor color and scent production. Marketable quality is therefore deteriorating [21].

One of the fundamental physical characteristics of agro-food items is color. As a matter of fact, color is a significant factor in the assessment of exterior quality in the food engineering and food industry. While color plays a significant role in assessing food quality, researchers have not yet fully examined the potential of using color factors to forecast particular food quality indicators. An online imaging system was used to monitor and control the quality of industrial food products. On the other hand, the kinetics of green-yellow conversions in fruits and vegetables have been the subject of very few investigations [25].

The main objectives of this study were monitored the ripening stages of bananas using various color characteristics indices, including intensity, brown index, and hue. Also, the study examined the waste and economic loss from banana color characteristics.

MATERIALS AND METHODS

The investigation was carried out. To confirm the color features indices for banana ripening stages, a variety of dessert bananas (Musa sap.) with varied maturity stages were procured from adjacent authorized banana ripening rooms located in Santa, Gharbia Governorate, in January 2024. These features were employed to investigate the changes brought about by the various stages of banana ripening in refrigerators used for banana manufacturing. Samples were chosen at random and manually cleaned.

Measurements and determinations

The color characteristics of the three banana ripening stages were determined by averaging 100 repetitions of banana fruits as shown in Photo 1.



Photo 1. Changes in color and brown spot development
Source: Authors' determination.

The three primary colors of banana ripening stages were measured using MATLAB software The values RGB denoted by 'R', 'G', and 'B' stand for the red, green, and blue bands, respectively. Hue, the intensity and RGB bands vegetation indices for banana was also measured. Additionally, (La b) was measured using a digital colorimeter for computed the browning index. Here are some key equations used to analyze banana color properties:

-Intensity, candela= lumen per Ste radian [23]

$I = \frac{1}{3}(R + G + B)$……..... (1)

I2 = (R-B)/2……..... (2)

-Browning Index [23]

BI $= \frac{100*(X-0.31)}{0.17}$……..…… (3)

$$X = \frac{a+1.75L}{5.645L+a-0.3012b} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

-Hue (Hue) [11]

$$Hue = COS^{-1}\left(\frac{(2R-G-B)/2}{(R-G)^2+(R-B)(COSG-B)^{0.5}}\right) \ldots. (5)$$

-Normalized Difference Vegetation Index (NDVI) Adaptation [17]

$$NDVI = \frac{G-R}{G+R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

-Visible Atmospherically Resistant Index (VARI) [16]

$$VARI = \frac{G-R}{G+R-B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

-Modified Green-Red Vegetation Index (MGRVI) [2]

$$MGRVI = \frac{G^2-R^2}{G^2+R^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

-Normalized Green-Blue Difference Index (NGBDI) [20]

$$NGBDI = \frac{G-B}{G+B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

-Simple blue–green ratio (BGI2) [32]

$$\mathbf{BGI2} = \frac{B}{G} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

-Red-Green Ratio Index (RGRI) [22]

$$RGRI = \frac{R}{G} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

-RGB-based vegetation index (RGBVI) [2]

$$\mathbf{RGB}VI = \frac{G^2-(B\times R)}{G^2+(B\times R)} \ldots\ldots\ldots\ldots\ldots (12)$$

-RGB-based vegetation index 2 (RGBVI2) [2]

$$\mathbf{RGB}VI2 = \frac{G-R}{R} \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

-RGB-based vegetation index 3 (RGBVI3) [2]

$$\mathbf{RGB}VI3 = \frac{G+R}{R} \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

-Triangular Greenness Index (TGI) [14]

$$TGI = -0.5 \times (190(R-G) - 120(R-B)) \ldots (15)$$

-Excess Green Index (ExG) [31]

$$ExG = 2G - R - B \ldots\ldots\ldots\ldots (16)$$

where:
RGB Red, Green, Blue Bands
L= lightness of the colour, which range from 0 (dark) to 100 (white).
a = indicates green colour.
-b = indicates blue colour
+b = indicates yellow colour

RESULTS AND DISCUSSIONS

The optical properties, RGB bands vegetation indices and browning index of banana during ripening stages were statistically examined. and red and blue bands, Hue, VEG, the simple red–green ratio, green–red and all vegetation index were tested to monitor the ripening stages by analysing changes in color. The banana's color changed during ripening stages, according to the results.

Figure 1 shows the how the color features indices for banana ripening stages. The red band's color increased from 55 to 174 during the three stages of maturity, also the green band's color increased from 139 to 186, following the same pattern as the blue band.

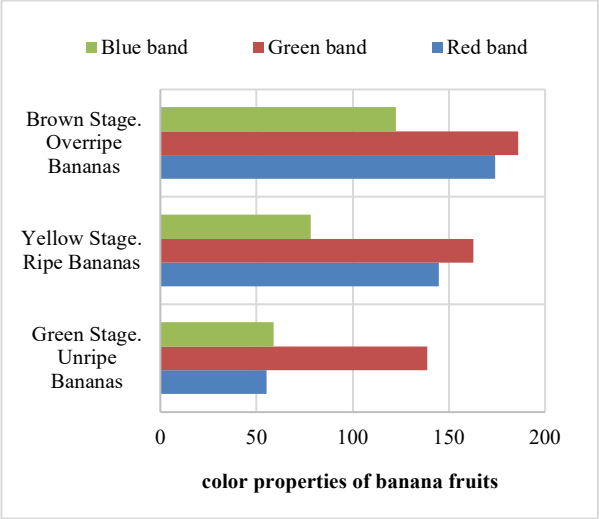


Fig. 1. The RGB bands Indices of banana during ripening stages
Source: Authors' determination.

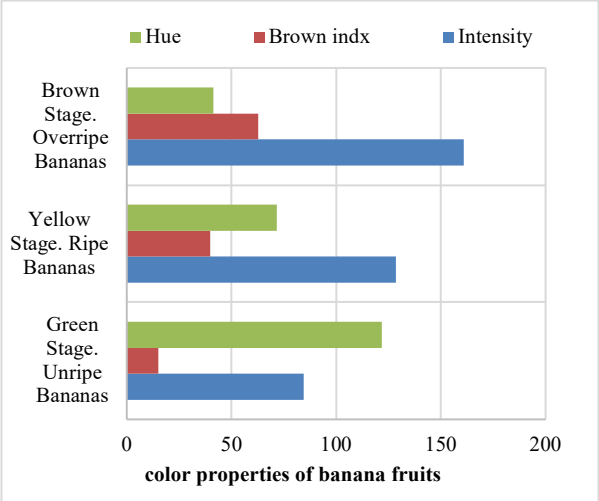


Fig. 2. The Hue, intensity and browning index of banana during ripening stages
Source: Authors' determination.

Figure 2 shows the intensity, hue and Brown index. which Brown index went from 15.05 to 62.89 during the three stages of maturity following the same pattern as the intensity. In contrast, the hue dropped from 121.89 to 41.45.

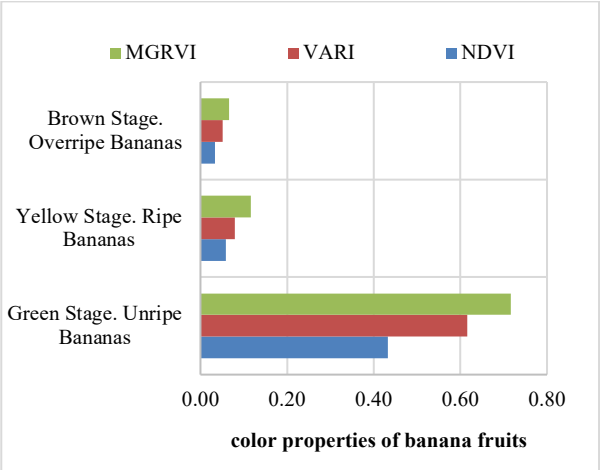


Fig. 3. The normalized Difference Vegetation Index, Visible atmospherically resistant index and modified green–red vegetation index of banana during ripening stages
Source: Authors' determination.

Figure 3 shows that the normalized Difference Vegetation (NDVI) index can indicate changes in chlorophyll content as bananas ripen. Its value increases in the green stage (unripe bananas) and gradually decreases in the yellow stage (ripe bananas) until it reaches its lowest value in the brown stage where the bananas are overripe, so the values are 0.43, 0.06, and 0.03 respectively. While the Visible atmospherically resistant (VARI) index provides a measure of ripening progress. Its value rises when the bananas are green (unripe), progressively falls when they are yellow (ripe), and finally reaches its lowest value when the bananas are brown (overripe), its values 0.62, 0.08, and 0.05, respectively.As for modified green–red vegetation (MGRVI) index highlighting the intensity differences between green and red. Its value ranges between 0.72, 0.12 and 0.07 during the three stages of maturity.
Figure 4 illustrates the convergence between the values of Simple blue–green ratio (BGRI) and Red-Green Ratio Index (RGRI) in the green stage (unripe bananas) which were 0.43 and 0.4. While in Yellow Stage (Ripe Bananas), the values of the RGRI index increase over the BGRI index by 0.41, and the values of the same two indices also increase by 0.28 in Brown Stage (Overripe Bananas) .On the contrary, the NGBDI index decreases from 0.41 then 0.35 then 0.21 in the last stage, which is the brown stage.

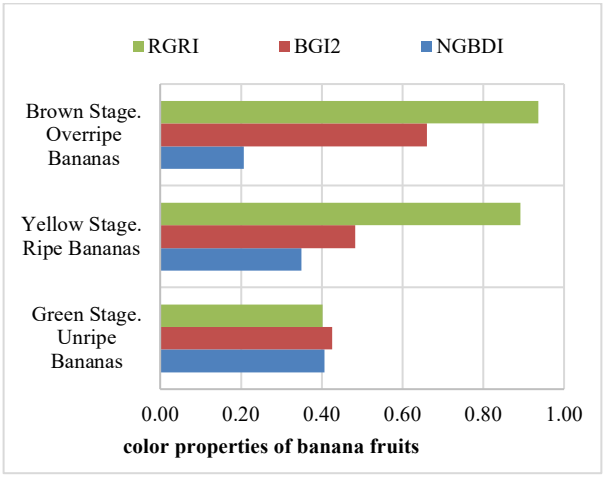


Fig. 4. The normalized green-blue difference index, Simple blue–green ratio and Red-Green Ratio Index of banana during ripening stages
Source: Authors' determination.

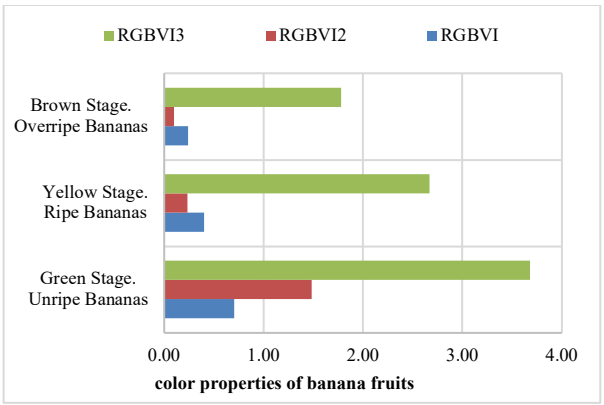


Fig. 5. RGB-based vegetation index, RGB-based vegetation index 2 and RGB-based vegetation index 3 of banana during ripening stages
Source: Authors' determination.

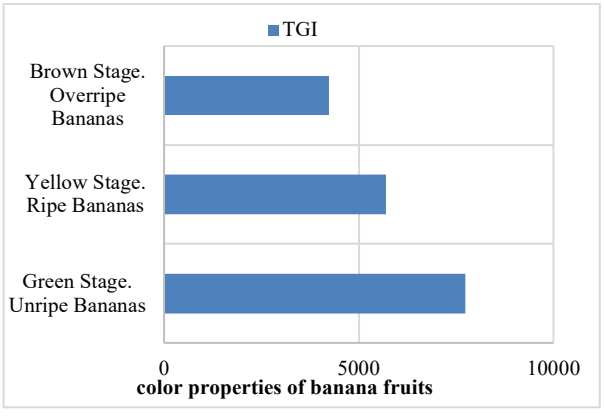


Fig. 6. The triangular Greenness Index of banana during ripening stages
Source: Authors' determination.

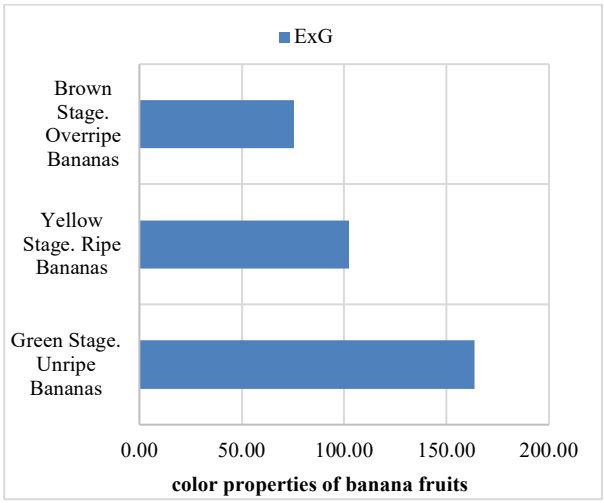


Fig. 7. The excess green index of banana during ripening stages
Source: Authors' determination.

As shown in Figure 5, the RGB-based vegetation 1, 2, 3 index that useful for vegetation detection. Their maximum values were at the green stage (unripe banana) at 0.7, 1.48 and 3.68 respectively and decreased to 0.24, 0.1 and 1.78 at the Brown Stage (Overripe Bananas), respectively. The TGI provides a measure of greenness and is useful for assessing the initial stages of ripening as green bananas turn yellow.

Figure 6, the Triangular Greenness Index (TGI) values decrease from 7732 to 5700 and then 4230 as the bananas lose their green color.

As in Figure 7, the Excess green index (ExG) value decreases, indicating a reduction in chlorophyll, as bananas ripen and turn yellow from 163.7 to 102.5 then 75.5 respectively.

Waste and Economic Loss from Banana Color Characteristics

Figure 8 shows that for one ton of bananas, the highest waste occurs in the brown stage where 60% are discarded, resulting in an economic loss estimated at 9252 EGP.

In the green stage, about 20% are wasted, resulting in an economic loss of 3084 EGP.

While in the yellow stage, this stage has the lowest waste, where 5% are discarded, corresponding to an economic loss of 771 EGP.

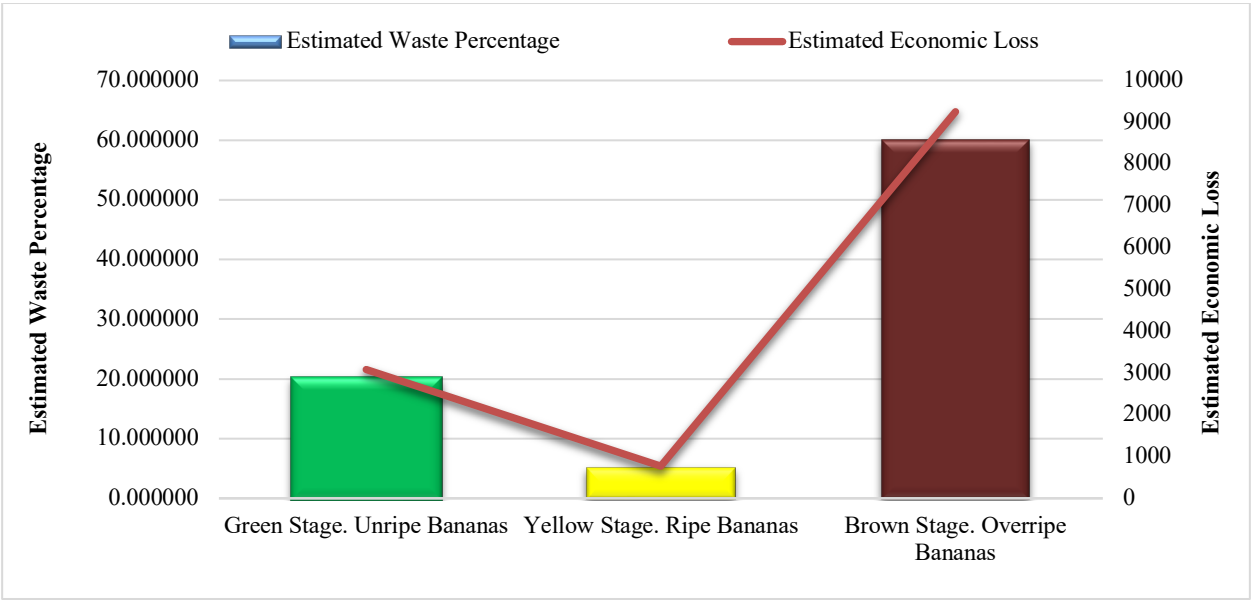


Fig. 8. The Estimated Waste Percentage and Economic Loss of banana during ripening stages
Source: Authors' determination.

CONCLUSIONS

A banana's color changes significantly as it ripens, and RGB color indices can be used to objectively assess these variations.

The optical spectral bands reflex from Bananas are initially green because they contain chlorophyll.

As ripening advances, the chlorophyll breaks down, revealing yellow carotenoids, which results in a decrease in the green component (G) value and an increase in red (R) and blue (B) values, shifting the banana's color towards yellow. RGB-based vegetation indices, which combine these RGB values, can offer a more detailed analysis of these changes, providing a

quantitative way to monitor the ripening process.

These indices help in accurately determining the ripeness stage, aiding in decisions related to harvesting, storage, and predict the best time to consumption.

Banana color is a crucial economic factor, influencing price, waste, consumer behavior, and supply chain logistics. Innovations in storage, transport, and alternative markets help mitigate losses associated with color changes.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF COMPETITIVENESS AND VOLATILITY IN THE BENINESE COTTON MARKET

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Abstract

The objective of this research is to analyze the competitiveness and volatility of Benin's cotton export prices. The study utilizes monthly data covering the period from January 2010 to December 2023, collected from the FAO (Faostat) and the International Trade Centre (ITC) and analyzed using EViews 12 software. Competitiveness was assessed using the Revealed Comparative Advantage (RCA) and Net Export Index (NEI). Price volatility was examined through the ADF stationarity test and time series econometric models, specifically ARIMA, ARCH, and GARCH. The findings from the NEI and RCA indices indicate that Benin consistently exports more cotton than it imports and holds a substantial comparative advantage in this sector. In terms of price fluctuations, the GARCH(1,1) model, chosen according to statistical criteria, highlights notable and sustained volatility. Projections from this model suggest a rising trend in price volatility, pointing to an upcoming period of increased uncertainty in Benin's cotton export markets. These findings provide crucial insights for the development of economic and trade policies aimed at mitigating market risks, optimizing investments, and improving decision-making among stakeholders in the cotton sector.

Key words**:** *volatility, ARCH model, GARCH model, cotton, Benin*

INTRODUCTION

Cotton is one of the most widely produced raw materials in the world. In 2023, global cotton production exceeded 74 million tonnes, cultivated over more than 32 million hectares. The global average yield per hectare stood at over 2 thousand kilograms. In terms of production volume and cultivated area, the leading cotton-producing countries are China, India, the United States, Brazil, and Pakistan. However, the highest yields per hectare are recorded in China, Mexico, Turkey and Brazil [9]. In 2023, cotton production in Benin reached 597 thousand tonnes over a cultivated area of 508 thousand hectares, ranking the country 14th worldwide and 3rd in Africa, behind Burkina Faso and Mali. In 2010, national production was only 136 thousand tonnes over approximately 137 thousand hectares. Thus, between 2010 and 2023, Benin more than doubled both its cotton production and cultivated area, with a peak of 766 thousand tonnes recorded in 2021. However, the yield per hectare did not increase proportionally, rising from 1,000 kg/ha in 2010 to 1,176 kg/ha in 2023, representing only a 15% improvement [9]. The increase in cotton production in Benin has been primarily driven by the expansion of cultivated areas rather than improvements in yield per hectare. According to [10], several factors limit yield improvement in the country, including climatic variability, the absence of irrigation systems, high agricultural input costs, lack of mechanization, insufficient farmer training, and non-compliance with recommended agricultural practices. In contrast, countries such as China (6,635 kg/ha), Mexico (4,518 kg/ha), and Turkey (4,398 kg/ha) achieve significantly higher yields than the global average. While these countries have also expanded their cotton-growing areas, they have primarily focused on implementing efficient irrigation systems and adopting modern technologies to optimize cotton production [22].

Cotton is a central pillar of the economy for many countries, serving as a crucial source of

employment and wealth creation in both rural and urban areas. In Benin, cotton accounts for nearly 50% of export revenues (excluding re-exports) and represents 45% of fiscal revenues (excluding customs duties). Additionally, it provides a livelihood for approximately one-third of the population and constitutes 60% of the physical capital in Benin's industrial sector, where it generates over 3 thousand paid jobs [10]. Despite these benefits for various stakeholders in the cotton industry, fluctuations in global cotton prices can have significant repercussions across the entire value chain. According to [22], the primary determinants of cotton price volatility include production volumes and stock levels in major producing nations, particularly China and the United States, which dominate the global market. Moreover, the production and pricing of alternative textile fibers, such as wool, mohair, and synthetic fibers, also influence cotton price formation. Ultimately, the exchange rate of the U.S. dollar against other currencies significantly influences these price variations.

In existing research, several econometric approaches, including ARCH, GARCH, and EGARCH models, have been utilized to analyze market price volatility. The use of ARCH-GARCH models for volatility analysis is justified by the limitations of linear models, which struggle to accurately model time series that do not follow a normal distribution. In 1982, Engle introduced the ARCH(q) model, where q denotes the number of past periods taken into account, to capture the changing variance of error terms over time [23]. This model posits that the variance at a given moment is influenced by previous squared errors. Expanding on this concept, Bollerslev developed the GARCH(p, q) model in 1986, which enhances the ARCH framework by incorporating both past squared errors and the conditional variance of prior errors, along with the latest volatility dynamics [23, 7].

By employing both symmetric and asymmetric models from the GARCH family, [7] analyzed the volatility characteristics of the Jordanian financial market. The study found that symmetric ARCH and GARCH models effectively captured volatility clustering and leptokurtosis in the Amman Stock Exchange. However, the EGARCH model did not provide evidence of a leverage effect in stock returns. In Turkey, [18] investigated sugar price fluctuations and determined that the GARCH(1,1) model was the most appropriate for modeling price volatility. Moreover, [17] examined the short- and long-term effects of cotton price volatility in Turkey using an asymmetric BEKK-GARCH model with a mean equation. Their results indicated significant volatility in the cotton market, with persistent uncertainty also impacting the maize market.

In Benin, multiple studies have explored agricultural price volatility, including [15], who analyzed the price fluctuations of dried chili peppers across major markets in the country. Using the ARCH model, the study confirmed the presence of significant price volatility across all analyzed markets. Similarly, [12] assessed the impact of the food reserve program on rice price fluctuations using an EGARCH model. Their findings indicated that the program failed to reduce price volatility. When prices were low, stockholders tended to sell more, thereby reducing available stocks for the following period and intensifying future volatility. Conversely, higher prices encouraged stock retention, which in turn limited volatility. In another study, [1] examined how maize producers respond to price volatility. Their findings suggested that farmers increased production and cultivated areas as a strategy to mitigate price instability, ensuring a minimum income despite market fluctuations. Furthermore, [16], using an ARCH-M model, investigated the impact of climatic factors on maize price volatility in Benin. Their study concluded that rainfall and temperature negatively influenced maize price volatility.

Despite the existing literature, few studies have specifically examined the volatility of Benin's cotton export prices.

This research aims to fill this gap by analyzing the competitiveness and volatility of cotton export prices in Benin. The findings will provide policy recommendations to reduce the country's vulnerability in international markets.

MATERIALS AND METHODS

This research relies on secondary data from FAO (production, cultivated area, and yield) and ITC (imports and exports) covering the period 2010–2023. The volatility analysis was conducted using monthly export prices recorded between January 2010 and December 2023. To carry out this study, both descriptive and quantitative analytical approaches were employed. The descriptive approach facilitated the analysis of statistical indicators such as the mean, skewness coefficient, and kurtosis coefficient. Meanwhile, the quantitative approach was used to examine price volatility through the ARCH-GARCH model, utilizing EViews 12 software.

To assess competitiveness, the Revealed Comparative Advantage (RCA) indicator, proposed by Balassa, was calculated. This indicator is determined for a specific commodity in this case, cotton by computing the ratio between the share of this commodity in a country's total exports and its share in global exports. For a given country i and commodity j, the formula is as follows [3]:

$$RCA = (x_j^i / \sum x^i) / (\sum x_j^k / \sum x^k) \quad (1)$$

x_j^i : export value of commodity *j* (cotton) in country *i* ; $\sum x^i$: sum of all export values in country *i* ; $\sum x_j^k$: sum of all export values of commodity *j* in the world; $\sum x^k$: sum of all export values in the world.

When the RCA value is below 1, it indicates that the country lacks a revealed comparative advantage for the product. On the other hand, an RCA greater than 1 suggests that the country holds a revealed comparative advantage in that product. Furthermore, the Net Export Index (NEI) was employed to assess whether Benin functions as a net exporter or importer of cotton. The NEI is calculated as the ratio between the difference in exports and imports of cotton and its total trade (exports + imports) [4].

$$NEI_{ij} = (X_{ij} - M_{ij}) / (X_{ij} + M_{ij}) \quad (2)$$

In equation (2), X: exports, M: imports, j: product (cotton), i: country considered.

The index ranges between [-1; 1]. A NEI value close to -1 indicates that a country is primarily an importer, whereas a NEI value close to 1 suggests that the country is predominantly an exporter.

To analyze volatility in this study, the ARCH-GARCH method was applied through a multi-step process. To ensure data stationarity and enhance the effectiveness of ARCH-GARCH models in capturing volatility dynamics, the raw time series of monthly cotton export prices was transformed into logarithmic returns. This transformation is defined by the following equation:

$$returns = d(\log Prx) \quad (3)$$

where Prx represents the raw price series. The use of returns rather than raw prices is justified by several factors. Logarithmic returns facilitate statistical analysis, improve comparability, yield more normally distributed data, enhance stationarity, and allow for more efficient modeling [8].

The first step involved verifying the stationarity of the return series, as ARCH-GARCH models require stationary data. The Augmented Dickey-Fuller (ADF) test was conducted to check for unit roots [13]. After confirming stationarity, the next phase focused on identifying conditional heteroscedasticity by testing for the presence of the ARCH effect in the residuals. However, before conducting this test, an ARMA or ARIMA model was fitted to capture the structure of returns. The optimal model was selected based on several criteria, including the minimum values of the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC), as well as higher values of Adjusted R^2 and Log-Likelihood [21, 24].

Next, the ARCH-LM (Lagrange Multiplier) test was performed to determine whether the variance of residuals depends on past values [23]. The null hypothesis assumes no ARCH effect, while the alternative hypothesis suggests its presence. If the p-value is below 5%, the null hypothesis is rejected, confirming the existence of the ARCH effect. Once

detected, an ARCH(q) model can be applied, which is formulated as follows [23, 7]:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \quad (4)$$

Where σ_t^2 is the conditional variance, α_0 and α_i are positive parameters, q is the model order, ε_t is the error term, and the sum $\sum \alpha_i$ must be less than 1 to ensure model stability.

If the ARCH(q) model exhibits instability, a GARCH(p, q) model is employed to improve volatility modeling. The GARCH(p, q) model is defined as follows [23, 7]:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \varepsilon_{t-j}^2 \quad (5)$$

Where β_j represents coefficients measuring the impact of past variances, and p is the GARCH order (i.e., the number of past variances considered). The sum $\sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j$ must be positive and less than 1.

Once the GARCH models were estimated, their performance was evaluated based on several criteria, including: sign and significance of coefficients, model stability, Akaike Information Criterion (AIC) and Schwarz Criterion (SC) values.

The optimal model was the one with the highest Log-Likelihood value and the lowest AIC and SC values. Subsequently, a reassessment was conducted to verify whether the residual ARCH effect had been eliminated. Finally, the residuals of the selected model were examined to ensure they were white noise, meaning they exhibited no autocorrelation [14].

RESULTS AND DISCUSSIONS

Competitiveness analysis

Over the past decade, the quantity and value of global cotton exports have increased significantly.

Between 2010 and 2023, the export volume increased from 6 million to over 8 million tons, while the export value doubled, rising from $8 billion to over $16 billion [11].

In 2023, the leading cotton-exporting countries were the United States, Brazil, and Australia. Benin ranked 6th globally, exporting over 239 thousand tons and generating more than $504 million in revenue [11].

Compared to some of its West African neighbors, Benin recorded a relatively high export volume.

For instance, Burkina Faso exported 127 thousand tons of cotton in 2023, generating $255 million, while Côte d'Ivoire exported over 92 thousand tons, valued at $203 million.

Overall, the value and volume of global cotton imports have declined in recent years. Between 2010 and 2023, the imported quantity dropped from 8 to 6 million tons, while the import value slightly decreased from $16 billion to $15 billion.

In 2023, the leading cotton-importing countries were China, Vietnam, and Bangladesh [11].

Benin, like many other African nations, imports almost no cotton. The Net Export Index (NEI = 1) confirms that Benin remained a net exporter of cotton throughout the 2010–2023 period (Table 1).

This result indicates that cotton imports into Benin have not yet significantly developed. Although the country has textile processing units, it continues to prioritize exports to generate foreign exchange earnings.

The Revealed Comparative Advantage (RCA) analysis shows that Benin has a significant comparative advantage (Table 1).

The average RCA between 2010 and 2023 for Benin, Burkina Faso, and Côte d'Ivoire was 522.50, 142.76, and 23.75, respectively.

These findings are consistent with [20], who previously highlighted Benin's strong comparative advantage in cotton production. However, having a comparative advantage does not eliminate sectoral risks.

Analyzing the volatility of export prices remains crucial, even in the presence of a high comparative advantage.

Table 1. RCA and NEI results

	Benin	Burkina-Faso	Côte d'Ivoire
RCA			
2010	206.679	171.580	12.148
2015	589.919	181.376	26.352
2020	646.098	72.482	27.900
2021	725.825	106.986	33.087
2022	727.343	114.265	25.734
2023	677.019	80.837	15.682
Total Average	522.503	142.760	23.745
NEI			
Total Average	1	1	1

Source: Authors' calculations.

Cotton Export Price Volatility Index Benin

The analysis of the raw export price graph reveals an irregular trend, characterized by fluctuations alternating between increases and decreases (Figure 1). These variations are primarily driven by the dynamics of supply and demand in the international cotton market [22]. The low yields, which are below the global average due to various constraints, limit Benin's capacity to supply large quantities of cotton to the global market [10]. Furthermore, export price fluctuations may also be attributed to the quality of Beninese cotton: the lower the quality, the lower the selling price [22].



Fig. 1. Graph of Raw Export Price and Logarithmic Return of Cotton Exports (2010–2023)
Source: Authors' calculations.

However, the main variable analyzed in this study is not the raw price but rather the logarithmic return. The examination of the graph suggests that the logarithmic return appears stationary (though confirmation through the Augmented Dickey-Fuller (ADF) test is required) and that its mean fluctuates around zero.

Figure 2 presents the key descriptive statistics of the return series. The analysis reveals a mean return of 0.12% and a standard deviation of 0.14%. While the mean return is slightly positive, the relatively high standard deviation indicates significant fluctuations around this average, reflecting high volatility and market uncertainty. The skewness coefficient is positive and greater than zero ($0.367 > 0$), indicating a right-skewed distribution. In other words, extreme positive returns occur more frequently than extreme losses. Additionally, the kurtosis coefficient is greater than 3 ($6.550 > 3$), indicating a leptokurtic distribution. This suggests the presence of heavy tails, meaning a higher number of extreme observations compared to a normal distribution (Figure 2). A high Jarque-Bera (JB) statistic (JB = 91.407) suggests a significant deviation from normality. Since the associated probability is less than 5% ($0.000 < 0.05$), the null hypothesis (H0), which assumes a normal distribution, is rejected. The values of the skewness and kurtosis coefficients confirm that the return

distribution is non-normal. The presence of positive skewness and high kurtosis indicates extreme movements and non-constant volatility. To better capture this volatility dynamic, the use of an ARCH-GARCH model is deemed more appropriate. Similar findings have been reported in other studies [7, 2]. In their analyses of return series, the kurtosis statistic was also greater than 3, and the p-value of the Jarque-Bera (JB) test was below 5%, further confirming the non-normality of the distributions examined.

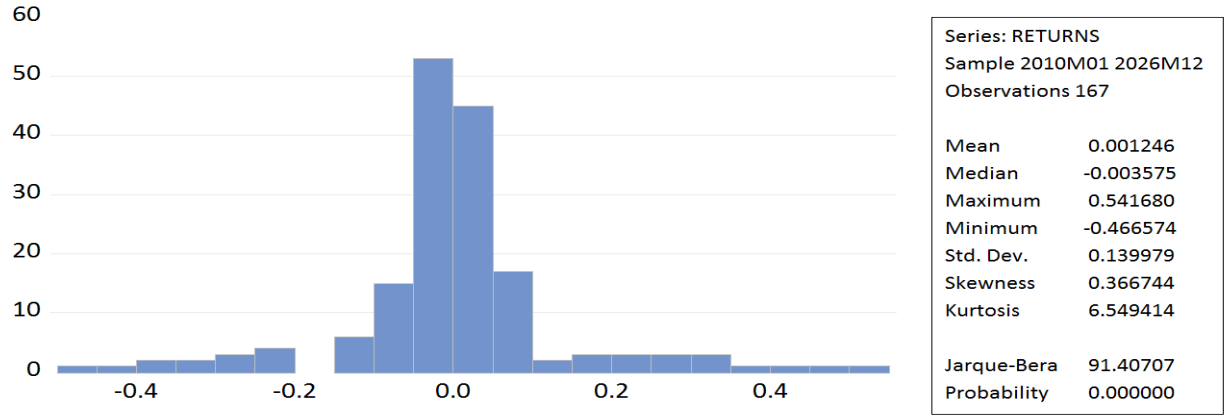


Fig. 2. Descriptive Statistics of the Return Series
Source: Authors' calculations.

Analysis of return series stationarity

For a time series to be used in a predictive model, it is essential that it be stationary. Statistical tests, particularly the Augmented Dickey-Fuller (ADF) test, can be used to assess stationarity. This test compares the computed statistic to a 5% critical value. If the test statistic is lower than this threshold, the null hypothesis is rejected in favor of the alternative hypothesis, which states that the series does not contain a unit root [8]. The analysis of Table 2 indicates that the return series is stationary at level and therefore does not require differencing. The probability associated with the test is below 5%, allowing for the rejection of the null hypothesis, which assumes the presence of a unit root in the series.

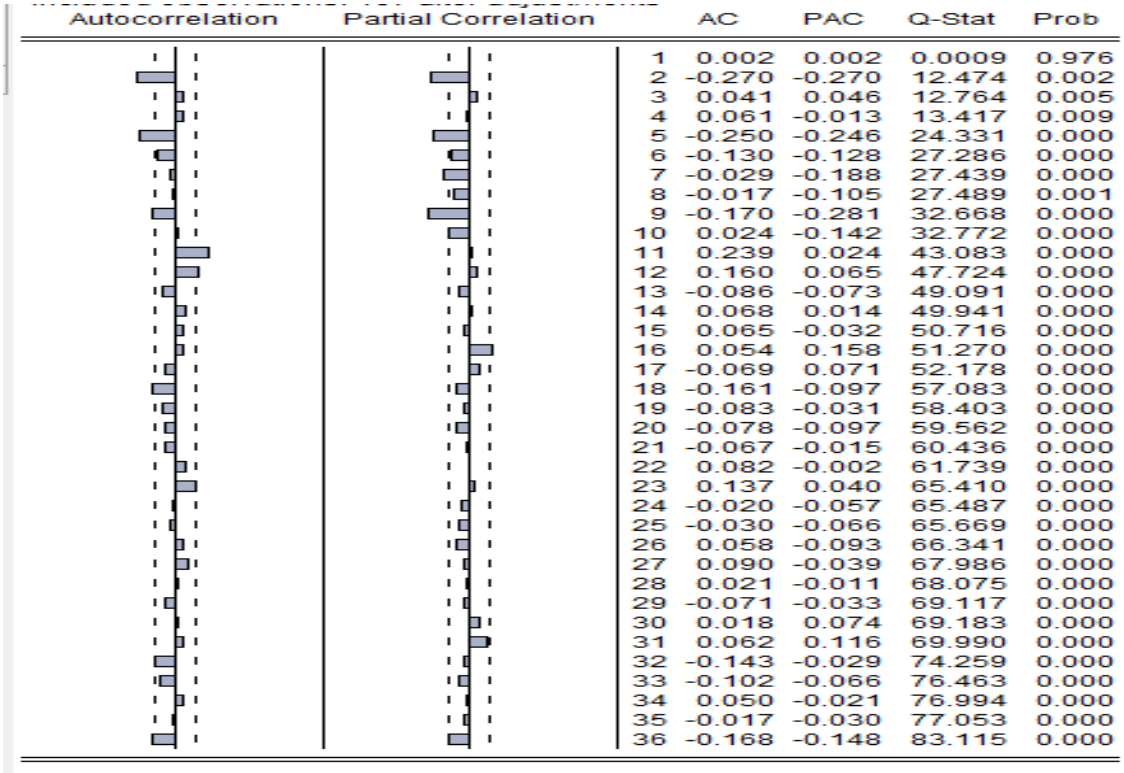
Table 2. ADF test results for the return series

	1%	5%	10%	ADF test	p-value
I(0)	-2.580	-1.942	-1.615	-8.850	0.000

Source: Authors' calculations.

ARMA model estimation

Since the return series is stationary at level, only the p and q components will be identified using the correlogram (Figure 3). The order of the autoregressive (p) component is determined by examining the partial autocorrelation function (PACF) column, while the order of the moving average (q) component is identified through the autocorrelation function (ACF) column. The optimal model is selected based on various criteria, such as the statistical significance of the autoregressive (AR) and moving average (MA) coefficients, the adjusted R^2, and the Log Likelihood value. Additionally, the Akaike Information Criterion (AIC), Schwarz Criterion (SC) and Hannan-Quinn Criterion (HQ) should be minimized. The analysis of Table 3 indicates that the ARMA(5,2) model is the most appropriate, as its coefficients are significant, and it has the lowest values for the AIC, SC, and HQ criteria. These selection criteria have also been applied in numerous previous studies to identify the most suitable ARMA model [5, 24 19].



	AC	PAC	Q-Stat	Prob
1	0.002	0.002	0.0009	0.976
2	-0.270	-0.270	12.474	0.002
3	0.041	0.046	12.764	0.005
4	0.061	-0.013	13.417	0.009
5	-0.250	-0.246	24.331	0.000
6	-0.130	-0.128	27.286	0.000
7	-0.029	-0.188	27.439	0.000
8	-0.017	-0.105	27.489	0.001
9	-0.170	-0.281	32.668	0.000
10	0.024	-0.142	32.772	0.000
11	0.239	0.024	43.083	0.000
12	0.160	0.065	47.724	0.000
13	-0.086	-0.073	49.091	0.000
14	0.068	0.014	49.941	0.000
15	0.065	-0.032	50.716	0.000
16	0.054	0.158	51.270	0.000
17	-0.069	0.071	52.178	0.000
18	-0.161	-0.097	57.083	0.000
19	-0.083	-0.031	58.403	0.000
20	-0.078	-0.097	59.562	0.000
21	-0.067	-0.015	60.436	0.000
22	0.082	-0.002	61.739	0.000
23	0.137	0.040	65.410	0.000
24	-0.020	-0.057	65.487	0.000
25	-0.030	-0.066	65.669	0.000
26	0.058	-0.093	66.341	0.000
27	0.090	-0.039	67.986	0.000
28	0.021	-0.011	68.075	0.000
29	-0.071	-0.033	69.117	0.000
30	0.018	0.074	69.183	0.000
31	0.062	0.116	69.990	0.000
32	-0.143	-0.029	74.259	0.000
33	-0.102	-0.066	76.463	0.000
34	0.050	-0.021	76.994	0.000
35	-0.017	-0.030	77.053	0.000
36	-0.168	-0.148	83.115	0.000

Fig. 3. Level correlogram of the return series
Source: Authors' calculations.

Table 3. Characteristics of candidate ARMA models

ARMA	AR	MA	Adjusted R^2	Log Likelihood	AIC	SC	HQ
(2,2)	0.711	0.060	0.058	98.346	-1.130	-1.055	-1.100
(2,5)	0.000	0.001	0.132	104.989	-1.210	-1.135	-1.180
(5,2)	**0.000**	**0.000**	**0.155**	**107.021**	**-1.234**	**-1.159**	**-1.203**
(5,5)	0.626	0.656	0.048	97.327	-1.118	-1.043	-1.087
(9,2)	0.040	0.000	0.084	100.505	-1.156	-1.081	-1.125
(9,5)	0.053	0.002	0.073	99.462	-1.143	-1.069	-1.113

Source: Authors' calculations.

Detection of the ARCH Effect in Residuals

An ARCH test was conducted to verify the presence of heteroskedasticity in the previously estimated ARMA(5,2) model. The identification of this heteroskedasticity is based on the significance of the probability values associated with the F-statistic and the chi-square statistic at the 5% threshold [13]. The ARCH test detects this effect by testing the null hypothesis (H_0), which states that no ARCH effect exists. The results indicate that the ARMA(5,2) model exhibits an ARCH effect, as evidenced by the probability values of the F-statistic and chi-square statistic (0.0000 < 0.05) (Table 4). Consequently, a more in-depth analysis was conducted by applying an ARCH-GARCH model to better capture the volatility dynamics. Contrary to these findings, [17] highlighted the absence of an ARCH effect in the cotton return series in Turkey.

Table 4. ARCH test results

F-statistic	Obs*R-squared	Prob. F	Prob. Chi-Square
38.458	31.533	0.000	0.000

Source: Authors' calculations.

The examination of Table 5 indicates that the ARCH-GARCH(1,1) model has the lowest AIC and SC information criteria, along with the highest Log Likelihood value, supporting its selection. Furthermore, the ARCH-LM test was performed to assess whether the ARCH

effect remains in the ARCH-GARCH(1,1) model. The probability values of the F-statistic (0.075) and chi-square statistic (0.074) exceed the 5% threshold, confirming the absence of heteroskedasticity in the chosen model. This suggests that the ARCH effect has been successfully removed from the analyzed series. These findings align with those of [2], who, after applying the ARCH-LM test, also confirmed the absence of an ARCH effect in their selected model for volatility analysis.

Table 5. ARCH-GARCH model test results

ARCH-GARCH	ARCH	GARCH	Log Likelihood	AIC	SC
ARCH-GARCH (1,0)	1.002	-	134.657	-1.601	-1.505
ARCH-GARCH (1,1)	0.158	0.840	146.120	-1.730	-1.616
ARCH-GARCH (0,1)	-	0.222	103.519	-1.216	-1.121

Source: Authors' calculations.

To validate the ARCH-GARCH(1,1) model, the Ljung-Box test was employed to assess the independence of the squared residuals. As illustrated in Figure 4, which presents the autocorrelation of the squared standardized residuals, the obtained probability values exceed 5%. These findings suggest that the residuals are independent, confirming the model's adequacy.

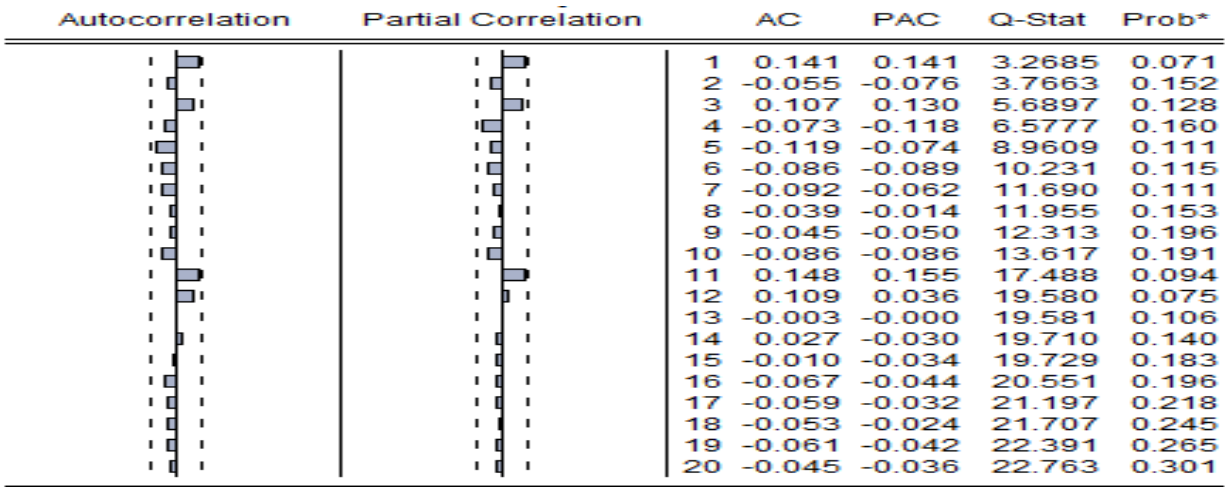


Fig. 4. Correlogram of Standardized Residuals Squared
Source: Authors' calculations.

Results of the GARCH(1,1) Model

Table 6 presents the estimation results of an ARMA-GARCH model, which integrates both a mean equation and a conditional variance equation. The coefficients in the mean equation are negative but statistically significant at the 5% level. The variance equation, employing a GARCH(1,1) framework to model conditional volatility, captures the evolution of volatility over time in response to past shocks and previous volatility levels. The analysis of the conditional variance equation indicates that the coefficients of the GARCH(1,1) model are significant, validating its suitability. This suggests that the GARCH(1,1) model is appropriate for forecasting volatility. Additionally, the results show that volatility is persistent, with a GARCH(-1) coefficient of 0.840, and that past shocks have a strong impact on future volatility, as evidenced by RESID(-1)^2 = 0.158. This implies that following a market shock, volatility does not dissipate immediately but gradually declines over time.

From an economic perspective, this persistence in volatility increases uncertainty for producers in predicting their medium- and long-term revenues. Such uncertainty may hinder investment in modern equipment aimed at improving cotton production and exports, which could partially explain the low cotton yields in Benin. Moreover, if volatility remains

high, it could weaken Benin's comparative advantage and reduce its global market share. According to [17], volatility in the cotton market is particularly high, and the resulting uncertainty affects not only the cotton sector but also other agricultural markets, such as maize. Additionally, external factors such as climate variability, exchange rate fluctuations, and global price volatility can further exacerbate instability in cotton export prices [22].

Table 6. GARCH(1,1) results Model

Mean Equation		
	Coefficient	Prob.
C	0.004	0.161
AR(2)	-0.251	0.006
MA(5)	-0.372	0.000
Variance Equation		
C	9.94E-05	0.028
RESID(-1)^2	0.158	0.001
GARCH(-1)	0.840	0.000

Source: Authors' calculations.

Forecasting Return Series and Variance

The longer the forecasting horizon, the greater the uncertainty in the data due to environmental and anthropogenic constraints [6]. Since volatility follows a stochastic process and future shocks (such as financial crises or geopolitical disruptions) are difficult to anticipate, this study avoids long-term forecasts. However, as part of this exploratory analysis, a volatility projection was conducted for the year 2026 (Figure 5).

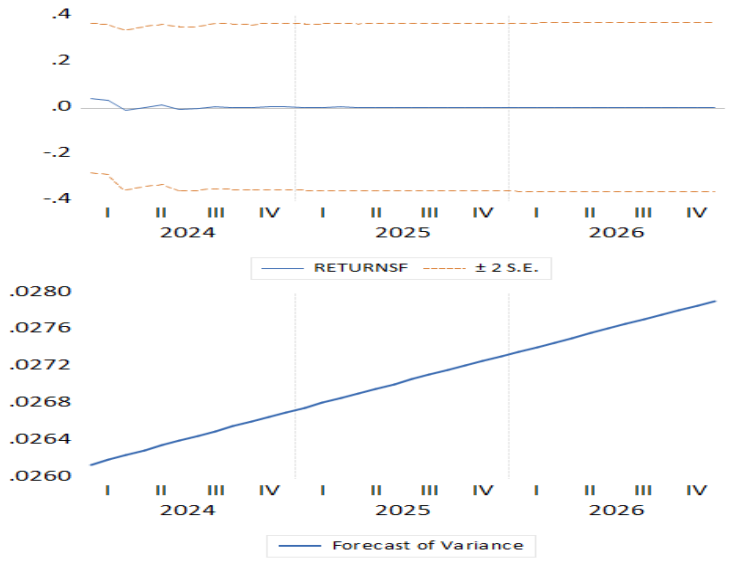


Fig. 5. Return series and volatility forecast plot
Source: Authors' calculations.

The analysis of the graph highlights an increase in the volatility of Benin's cotton export prices, indicating a period of heightened uncertainty in export markets in the coming years. This increased volatility could have significant economic, commercial, and strategic consequences. Indeed, instability in cotton export prices could weaken the sector, impact producers' incomes, and necessitate the implementation of price stabilization policies. In a scenario where prices experience a sudden drop, the impact on the trade balance could be substantial, leading to a reduction in export revenues and, consequently, a decline in foreign currency inflows. At the household level, farmers would face greater uncertainty regarding their earnings. According to [10], a 40% decrease in farm-gate cotton prices would

lead to a 6–8% increase in rural poverty rates. From a macroeconomic perspective, a $1 decline in cotton producers' income would result in a $2.96 decrease in national income. Given these considerations, it becomes imperative to adopt appropriate strategies to mitigate the adverse effects of this foreseeable volatility and to strengthen the resilience of the sector.

CONCLUSIONS

This study analyzed the competitiveness and volatility of the cotton market in Benin. The findings highlighted that Benin is a net exporter of cotton and enjoys a high comparative advantage in this agricultural commodity. However, a strong comparative advantage does not necessarily ensure stability in export prices. To assess price stability, an analysis of the monthly export price return series was conducted. The results revealed non-constant volatility, characterized by positive skewness (Skewness > 0) and a leptokurtic distribution (Kurtosis > 3). To capture this volatility dynamic, a GARCH model was estimated. Before estimating the GARCH model, an ARMA(5,2) model was selected to specify the mean equation, based on statistical criteria that identified the most suitable model among several candidates. The estimation of the GARCH(1,1) model allowed for the modeling of conditional volatility through the variance equation. The results indicate that volatility is persistent and that periods of high volatility tend to last before gradually dissipating. A short-term forecast suggests that this volatility will remain elevated in the coming years.

Based on these findings, several recommendations have been formulated. Given the anticipated increase in volatility, the government could consider implementing stabilization funds or support policies for producers to mitigate the impact of price fluctuations. The adoption of agricultural contract services could also help protect farmers' incomes against price shocks. Furthermore, the government could explore new market opportunities and strengthen existing trade agreements to reduce the country's dependence on a limited number of major buyers.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

IMPORTANCE AND ROLE OF LOCAL INITIATIVE GROUPS (LAGS) FOR THE DEVELOPMENT OF RURAL AREAS IN THE REPUBLIC OF BULGARIA

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Abstract

This study examines local initiative groups as influential structures that can initiate a sequence of changes taking place in a given community (e.g., a transition from the phase of agrarian development to the creation of businesses and activities that assume high efficiency and indicate ways and means to achieve the goals. The purpose of this study is to analyze and assess the role of local initiative groups in the development of rural areas of the Republic of Bulgaria. The main methods used in the study are the survey method and the focus group method. Based on the various aspects of regional development, strategic planning, the LEADER program and business management in rural areas, effective regional policies can be implemented through LAGs that emphasize the importance of integrated approaches and local initiatives for achieving sustainable development.

Key words**:** *rural areas, area, development, Local Initiative Groups (LAG), LEADER approach, efficiency*

INTRODUCTION

Within the European community, it was concluded that the formed rural areas needed support. The assessment and analysis of rural development highlighted that they needed a better emphasis on decentralization of management, creation of local capacity and more active participation of local stakeholders in regional economic development. Thus, in 1991, the LEADER I program was launched, which was a response to the need for a new approach to the development of rural areas in Europe. The traditional regional policies applied until then proved insufficient to address the specific challenges of these areas, where economic stagnation, depopulation and social marginalization were observed. LEADER emerged as a novel approach designed to empower local communities by encouraging their direct participation in planning and executing development initiatives tailored to their specific needs. Bulgaria's engagement with rural development policies took shape in the early 2000s, as part of the country's preparation for European Union membership. This process was supported by the SAPARD programme (Special Accession Programme for Agriculture and Rural Development), which aimed to foster agricultural growth and improve rural areas across Central and Eastern European countries ahead of their EU accession. The establishment of Local Initiative Groups (LAGs) is a central element of the program. LAGs are public-private partnerships involving representatives of local authorities, business and the non-governmental sector [20, 21]. Their role is to develop and implement integrated strategies for the development of their regions. In this regard, out of a total of 264 municipalities in Bulgaria, 231 are designated as rural municipalities, which makes the program an essential element of regional development policy. In addition, due to the dispersed population in rural areas of Bulgaria, there is often a lack of qualified personnel, which necessitates joining forces between several municipalities and forming

associations in the form of Local Initiative Groups (LAGs).

The purpose of these structures between two or three municipalities is to share capacity and seek common ground to solve common problems such as poor infrastructure, conditions for local development in rural areas, development of local businesses, education, etc. As a sustainable result, it is necessary for these local initiative groups to aim at creating new jobs, primarily in the field of small businesses. Local development on a local scale means improving the living and working conditions of residents and is related to improving the functioning of the infrastructure, improving services, housing conditions, the aesthetics of the landscape, etc.

This study aims to examine and evaluate the impact of local initiative groups on the development of rural regions in the Republic of Bulgaria. Its primary objective is to determine the extent to which such structures can serve as an effective framework and practical instrument for driving rural development. Because the development of rural areas also means improving the level of public welfare, creating a more favorable image of a given place from the outside - among potential investors and customers. The local economy is stimulated, among other things: equipping a given area with infrastructure, simplifying local regulations, applying various types of relief, selling neglected or poorly used premises, creating information or consulting centers.

Thus, in this presentation, local initiative groups are considered structures with influence that can initiate a sequence of changes taking place in a given community (for example, a transition from the phase of agrarian development to the creation of businesses and activities assuming high efficiency and indicating ways and means to achieve the goals (for example, through the organization of labor, training, implementation of smart technologies, environmental activities, etc.).

The next important thing is to impose the programming model with a focus on the content of the actions taken (taking into account, for example, the creation of temporary or permanent structures, local institutions, etc.). Likewise, increasing the level of socialization and collective endeavor aimed at introducing the implementation of common policies [1]. The practical approach corresponds to the term community development adopted by the UN (and even represents its expansion), but is also based on the principle of "subsidiarity", which comes from the teaching of the faith and compliance with Christian-democratic values.

Its main components are: a specific goal (project) of activities aimed to improve the widely understood living conditions of the local community and the voluntary participation, efforts and mutual assistance of residents. Here it is worth emphasizing that changes in the environment and community should occur mainly through the efforts of the residents themselves. In this direction, the participation of the population is voluntary and only such participation guarantees the authenticity of the movement, because the fundamental problems of the given regions are rooted in the people themselves, stemming from their passivity, helplessness, lack of knowledge and organizational skills [2].

In order to improve the condition of a given rural region, an effort is needed to overcome the insufficient civilizational development, which would increase the level of education and form appropriate attitudes and habits of the population. Thus, one such tool can be the local initiative group (LAG), it should be so developed that residents can strongly identify with it, it should take into account the most important needs of citizens (both material, physical and spiritual), and the goals and tasks set cannot exceed their capabilities [5]. Creation and development of Local Initiative Groups (LAGs) at the rural level is a way to build true local democracy, a higher social culture, and can be an important educational tool and method of cooperation between the authorities and society.

After 2000, the programme was improved and renamed LEADER +. The aim of this change was to respond to the new realities in rural areas, which required an even greater emphasis on sustainability and innovation. The programme aimed to integrate different sectors and promote transnational cooperation, with

the aim of exchanging experience and expanding opportunities for local development [4].

In 2005, the regulatory document "Council Regulation (EC) 1698/2005" was adopted, which made the approach a mandatory element of the Rural Development Policy of the Common Agricultural Policy (CAP) and transformed it from a separate pilot initiative into a horizontal priority and a core part of this policy. The fundamental legal changes defining the 2007–2013 programming period began with the CAP reform in 2003, which also led to changes in its objectives towards the integration of sectoral (agricultural) and territorial policies (regional convergence). Thus, for our country, after our actual membership in the EU since the beginning of 2007, the Rural Development Program has become an essential element of the implementation of agricultural policy. At the same time, an important factor for the development of rural areas in Bulgaria is the formation of "Local Initiative Groups (LAGs)". In practice, "Local Initiative Groups (LAGs)" have been operating for nearly 16 years, attempting to make changes in the methods of development management, which are mainly manifested in the reference to local resources, experience and traditions [8]. The initiation of the LAG as a concept must be supported by appropriate legal acts and strategic documents, which have an important significance for the promotion of cooperation between municipalities in rural areas. The implementation of the policy for the development of local initiatives is assigned to the municipal councils, which have the rights to make decisions to establish such institutions, which over time have acquired legal personality, their own sources of income, autonomy and the authority to independently manage their affairs [8]. Although they are formed thanks to local public administration, these structures carry out a specific process of promoting local economic development, involving local governments, formal and less formal organizations and individuals, in order to use the resources of the geographical environment and the capabilities of the inhabitants and to carry out activities in different areas for the benefit of specific communities [9]. It can lead to:

-achieving socio-economic stabilization through the use of knowledge about the above-mentioned resources, their availability and possibilities for mobilization,

-creating a diversified economic base that meets the needs and preferences of residents.

Here it is worth emphasizing that local development is territorial, not sectoral, which includes material and immaterial elements of the environment, natural conditions, culture, traditions, entrepreneurship, etc. Another important element is planning, which plays a very important role in local development, but is a difficult, complex process that carries a certain risk [9]. It consists of the following stages: collection, analysis and assessment of baseline data, selection of a local development strategy, definition of goals and directions of activities, determination of possible and optimal ways of implementing the program, preparation of action projects (taking into account their profitability, sources of financing, implementation deadlines), and on their basis of the general development plan, implementation of the provisions of the plan. [10].

Since the beginning of the political transformation in Bulgaria, the idea of empowering local communities has been gaining increasing popularity. It strongly emphasizes the influence of human activities on the socio-economic structure and emphasizes the need to activate residents. It is related to the idea of participation - social participation, which also emphasizes the importance of including people in local affairs. The more the inhabitants of a given area identify with it, the more they feel the need to act for the common good and the more they see the possibility of making joint decisions on the development of a given area or creating clusters of activities that will promote regional economic development in rural areas, the more likely it is to stimulate social activity. Monitoring and evaluating the implementation of strategies allows local, regional and national authorities to monitor progress towards achieving objectives and make the necessary adjustments if necessary. Regular monitoring

provides information on the results achieved and identifies problems and challenges that arise during the implementation of strategies. This allows for timely adjustments and adaptation of strategies to changing conditions, which increases the chances of success [15].

Literature review

Rural Development and Impact Methodology. The lack of a vision for the future of a particular territorial or settlement unit is a significant barrier that prevents it from seeing development opportunities. However, establishing a certain direction of development has a positive impact through the formation of public management structures that can have a positive impact on its current functioning, socio-economic growth and living and working conditions of its residents. Each of the concepts presented deserves attention and consideration when building local development programs [15]. The usefulness of individual ideas varies and requires verification. The existing literature largely focuses on themes such as multifunctional and ecological rural development, yet it frequently overlooks the importance of building institutional capacity and establishing dedicated structures to support rural progress. From a broader perspective, it is essential to recognize that agricultural modernization must go hand in hand with the development of alternative, non-agricultural income sources. This underscores the necessity for socio-economic growth in rural areas to be driven not only by local community engagement but also by external support mechanisms. (state policy and territorial authorities). Thus, in spatial and territorial terms, the economic revitalization of rural areas is possible thanks to the development of small businesses and a clear profiling based on strengths [19]. On the other hand, a necessary condition for supporting entrepreneurship and socio-economic growth is the improvement of the qualification of the rural population. These methodological assumptions are certainly debatable in theoretical terms, but they are focused on the issue of legality, emphasize the role of social conditions of development, and deduce the importance of spatial and technical-technological factors [22].

Despite some weaknesses of local initiative groups (LAGs), they have not been studied in depth and their role in solving local development problems has not been discussed. Thus, social and economic research is carried out rather than the role of the institutional approach of local initiative groups (LAGs) on rural areas being studied. Of course, they are partially applied in annual public reports or multidisciplinary studies, it is necessary to disseminate their results and the experience of other countries under the LEADER+ programs and to promote positive examples. It is also good to derive reliable data and statistical information, which is often not outdated or incomparable [22]. Many valuable local initiatives are not implemented due to lack of adequate support or fail due to inaccurate goal setting and outdated demographics.

Modelling the development of rural areas in Bulgaria. Peripheral and rural areas often suffer from poor infrastructure, which limits their economic integration and access to markets. Infrastructure connectivity is a key factor for regional development, as it allows for better integration of regions into the EU single market and provides better access to economic opportunities. This is where the LEADER approach comes in, which is a tool for local self-government and strategic planning that gives local communities the opportunity to take a leading role in the development of their territories. This approach, which emerged as part of the European Union's rural development policy, emphasizes decentralization of management, participation of local stakeholders and an integrated approach to development. LEADER is based on the belief that local communities are best equipped to identify their needs and develop solutions that will lead to sustainable development of their regions. However, in this direction, there are a number of difficulties in Bulgarian conditions [17].

Planning the development of municipalities in rural areas of Bulgaria is becoming an increasingly fundamental task of the authorities, with a need for high-quality practical implementation of self-government. The focus of development of rural municipalities in Bulgaria should set

stereotypes for residents, so that they are encouraged to assess the socio-economic situation of their regions themselves and present proposals for their development, without waiting for decisions from above. Particular attention should be paid when preparing development plans to those municipalities that, for various reasons (unemployment, depression, depopulation) seek assistance from the European Union structural funds. An essential element of the proper management of a municipality is the preparation of a plan or strategy for local development. In fact, the derivation of the concept of strategy means a well-thought-out plan that must be applicable in the respective rural area [12]. It is essential to highlight that a targeted approach enables the exploration of diverse development pathways, the identification of tailored solutions, and the active involvement of local communities throughout each stage of the process. In the implementation of regional development policies, it is good to have a differentiated approach, where strategies can be replaced by specific sustainable policies or visionary with the preparation and implementation of guiding or perspective plans. This highlights LAGs the need for the Local Action Groups (LAGs) to develop a strategic development programme that contributes to the socio-economic growth of rural areas and improves the lives of their inhabitants. This programme is always preceded by a detailed analysis of the state of the economy, which allows for better use of available resources and indicates areas for cooperation with neighbouring regions. Moreover, engaging local institutions, organizations, and residents in the strategy development process helps to energize ongoing initiatives, foster collaboration, and cultivate a shared sense of responsibility for leveraging opportunities to advance rural development. It is crucial that planning frameworks and related documents support rural progress by facilitating income generation and enabling access to diverse forms of external support. Thus, the role of the "Local Initiative Groups (LAGs) for the development, revitalization and diversification of the rural economy in individual rural areas, so as to generate the creation of new jobs [12], can be taken into account. The question is to what extent the relevant Local Initiative Groups (LAGs) can cover a wider field, starting from local entrepreneurship, moving on to improving the technical infrastructure, identifying centers for economic development, protecting the natural and cultural heritage, reaching the improvement of the qualifications of residents. Thus, Local Initiative Groups (LAGs) cannot be the main driver of regional development in rural areas, but they can support local authorities and supplement the project potential for regional economic well-being of the population. This means that Local Initiative Groups (LAGs) must have a development vision that is understandable to residents, indicating the directions of action for several years. Each municipality has individual conditions, resources and development opportunities. Therefore, there is no single model for a development strategy [11]. Building a strategy is a continuous process and cannot be considered a document that will remain in force unchanged, which indicates the directions of action for several years.

Strategy development is a continuous process and cannot be considered a document that will remain in force unchanged.

Definition and spatial assessment of approaches to rural areas within the national territory. Rural areas are usually defined by a combination of demographic, geographical, economic and social characteristics. Some of the main criteria used to define rural areas are related to the determination of the population density indicator. Rural areas have a smaller population compared to cities, with the population having a lower degree of territorial distribution. The next indicator is the determination of employment in agriculture and natural resources [14]. In rural areas, a large part of the economic activity is related to agriculture, livestock, forestry or other sectors related to natural resources. The gravitational potential associated with the distance to urban centers is also important: Rural areas are often located in remote places from large urban centers, where the infrastructure is less developed. Improving the level of rural areas,

which are characterized by predominant natural landscapes such as forests, fields, meadows and other undeveloped areas. This means quality certification and maintenance of the natural environment and agricultural lands. Achieving stable economic development. This is necessary because rural areas are usually less economically active, have lower incomes than urban areas, and have lower levels of industrialisation and urbanisation. Improve the level of infrastructure and business and public services. In practice, rural areas often lack certain public services, such as health and education, or are more difficult to access than urban areas. Promote state aid and programme support with a specific financial package. Depending on the country and the number of rural areas available, each government may have its own definition of rural areas, based on specific legislative acts, administrative boundaries or statistical criteria to pursue targeted support policies in them [14].

These factors may vary considerably depending on the region or country, but the general understanding is that rural areas are characterised by lower population density, greater dependence on natural resources and a lower level of urbanisation. There is considerable diversity in the definitions of rural areas across the EU Member States. In some countries, more than one definition is used, the choice depending on the specific issues being addressed. The differences are not limited to the indicators used and their thresholds for distinguishing rural from urban areas but also include the variety of territorial units. In most EU countries, municipalities are the main element for delineating rural areas. A small number of countries use settlement boundaries or built-up areas for this purpose. The most commonly used criteria for delineation are the number and density of the population – either at settlement level or at the level of the municipality as a whole [18]. However, the thresholds for these criteria vary considerably between countries. Some countries also include other factors in their definitions, such as the structure of employment in different sectors or commuting patterns.

Establishing uniform criteria for defining rural areas across the European Union is a complex task, primarily due to the considerable variations in social and economic development that exist not only between countries but also among regions within a single country [18].

The methodology used to define rural areas in the EU has evolved considerably over the last decades. In the surveys on labour force and living conditions, the European Commission uses its official spatial concept, which it applies for statistical purposes and is regulated by Eurostat. This classification is used by Eurostat to define the character of a given territory at local level (LAU2).

According to this concept, areas are divided into three types: densely populated, intermediate and sparsely populated. The latter category includes a group of local administrative units with a population density of less than 100 inhabitants per square kilometre and a population of less than 50,000. In this way, sparsely populated areas are identified as rural in EU countries. However, this method is based on administrative units (LAU 2) which can vary considerably in area, which makes it difficult to make the results objective and comparable between countries with different sizes of territorial units [6].

In 2010, the European Commission published a new definition of urban and rural areas based on a grid of population cells. This definition introduces the concept of rural grid cells, which are used to define rural areas at local and regional level. In countries such as Denmark, Sweden, Finland, Austria, the Netherlands, Slovenia and Croatia, a spatial database exists that is consistent with the actual results of the population census. For the remaining Member States, the classification is based on a detailed population grid, taking into account data from the territorial level LAU 2 and land cover data. For example, in Bulgaria uses a working definition according to which rural areas are “municipalities whose largest city has a population of less than 30,000 and a population density of less than 150 inhabitants per sq. km”.

This definition was changed in the following programming periods (2007–2013 and 2014–2020), when rural areas were defined as

"municipalities (LAU 1) in which there is no settlement with over 30,000 inhabitants" [6].

In recent years, given the demographic problems of the lagging rural regions and settlements, the corresponding amendments have been required.

Thus, according to the "Strategic Plan for the Development of Agriculture and Rural Areas for the Programming Period 2023–2027", rural areas in Bulgaria are defined as municipalities in which there is no settlement with more than 15,000 inhabitants.

These areas cover about 81.16% of the country's territory and include about 39% of its population. Under the new definition, 215 out of a total of 265 municipalities in the country are classified as rural [6].

MATERIALS AND METHODS

Assessment of the contribution of Local Initiative Groups (LAGs) to the development of rural areas and support for regional development.

To evaluate the role of Local Initiative Groups (LAGs) in fostering rural and regional development, we conducted a survey-based study aimed at assessing their impact and identifying key challenges. This approach allowed for a detailed analysis of how LAGs contribute to the growth and revitalization of rural areas. Here it is worth emphasizing that data collection is carried out using the survey method and the focus group method. The survey was carried out in the period January – April, 2024 in the manner of face-to-face. When determining the sample (the group of respondents to whom the survey is directed), the "random principle method" [10] was used and on this basis we included districts and municipalities where Local Initiative Groups are located and they are working successfully.

Additionally, the participants in the focus groups were selected from participants in measures included in the "LEADER" axis. The organization and conduct of the survey was carried out with the assistance of the National Agricultural Advisory Service of the Republic of Bulgaria.

The survey also included other questions that related to other policies and forms of monitoring, going beyond the object and subject of this presentation.

In the study of the impact of the LEADER approach, 27 local initiative groups were identified and surveyed based on the above criteria, out of nearly 54 registered on the first ballot from different territories of the country. A minimum of 10 local representatives were surveyed from each local initiative group, with the total number of respondents being 278.

In order to obtain the necessary data for analysis and assessment of the role of the LEADER approach, the following questionnaire was developed, as shown in Table 1.

Table 1. Questionnaire for assessing the contribution of the LEADER approach

Questionnaire card			
To what extent do you think the LEADER approach has contributed to:	***Low 1***	***Mean 2***	***High 3***
1. Strengthening governance in rural areas entails	5	9	13
2. Unlocking the internal development potential of rural areas	0	8	19
3. Adopting multi-sectoral approaches and encouraging cooperation are key strategies for effectively implementing rural development programs.	12	11	4
4. The priorities of axes 1, 2 and 3?	8	11	8
5. Introducing innovations in rural areas	5	9	13
6. Encouraging cooperation and the exchange of best practices	0	9	18
7. How can the objectives of one or more of the other three axes be more effectively achieved?	2	8	15
8. Increasing the capacity of LAGs and other partners involved in the implementation of local development strategies?	0	0	27
9. Increasing capacity for LEADER implementation?	0	9	18
10. Who are the main beneficiaries of funds allocated by the LAG /give a quantitative measure - number or percentage of total/ ……			

Source: Own interpretation.

Each respondent was asked a total of 10 questions, which needed to be answered using a three-point scale as follows: 1 – low importance of the contribution, 2 – medium importance of the contribution and 3 – high importance of the contribution.

Group discussions (focus groups) were used as a method in the study, which allows for in-depth exploration of the research topic, while also taking advantage of the group effect [5].

During the discussions, through spontaneous and detailed discussion of previously determined conclusions from the survey in small groups of people, it is clearly formulated which are the main factors of local initiative groups that contribute to the development of rural areas [16].

The discussions are organized and guided by a moderator (a person from the research team) who sets the questions for discussion, ensures equal participation of the individuals, and guides in new interesting directions spontaneously expressed by the participants.

Table 2. Schedule for conductingthe on-site investigation

No.	City	Home /time/	Date
Field survey			
1	Plovdiv	14.00	27/01/2024
2	Pazardzhik	14.00	28/01/2024
3	Pleven	10.00	28/01/2024
4	Veliko Tarnovo	10.00	29/01/2024
5	Haskovo	10.00	29/01/2024
6	Yambol	12.30	30/01/2024
7	Sliven	11.00	30/01/2024
Focus groups			
1	Plovdiv	14.00	20/03/2024
2	Pazardzhik	14.00	21/03/2024
3	Pleven	10.00	28/03/2024
4	Veliko Tarnovo	10.00	29/03/2024
5	Haskovo	10.00	29/03/2024
6	Yambol	12.30	01/04/2024
7	Sliven	11.00	01/04/2024

Source: Own interpretation.

RESULTS AND DISCUSSIONS

Analysis and evaluation of survey data.

A number of 270 respondents, representatives of the selected local initiative groups, took part in the survey and focus groups.

According to their information, Figure 1 shows the structure of beneficiaries who have projects administered by local initiative groups (LAGs).

It is noteworthy that in the surveyed local initiative groups, the agricultural producers are the most active in the defined measures - 33% of the total beneficiaries.

The key participants in executing the local development strategy (LDS) are those who are most knowledgeable about the administered measures and frequently visit the LAG offices. The active involvement of agricultural producers in utilizing the funds allocated under the LAG's local development strategy can be attributed to the fact that the application process for projects is more straightforward compared to the procedure followed by the Paying Agency.

The next in terms of activity under the LAG measures are small businesses - 25% and Non-Governmental Organizations (NGOs), respectively 19% of the total respondents. The low share of participation in the implementation of the LAG local development strategy by municipal structures is striking - only 7%.

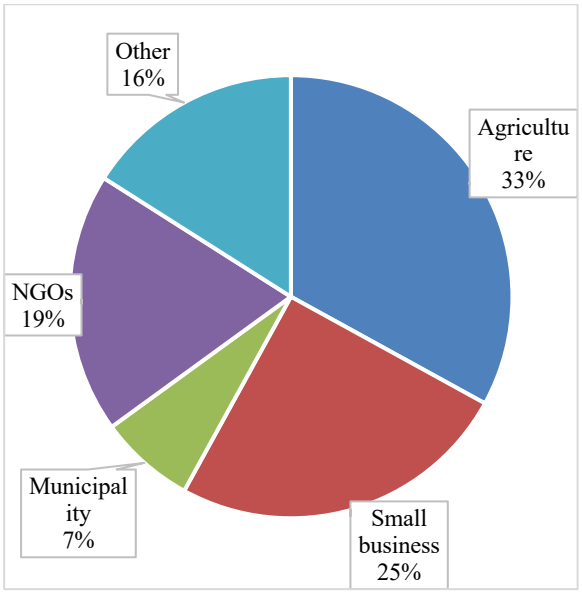


Fig. 1. Beneficiary groups under the measures administered by the LAG.
Source: Own survey among 270 respondents. Period January – April, 2024.

Nearly 90% of the respondents, representatives of the surveyed LAGs, respond that they know

about the existence of the Local Initiative Group (LAG) on the territory of the municipality in which their business is located. And over ¾ are familiar with the local development strategy in detail. All persons familiar with the strategy know that the agriculture and small business sectors are subject to financing.

The share of persons recognizing the Municipal Government as a beneficiary under the measures of the Strategy is also high (over 2/3).

Only the financing of activities of non-governmental organizations is considered possible by only 20% of the respondents.

Figure 2 present the results regarding identification of stakeholders as potential beneficiaries of the C&D.

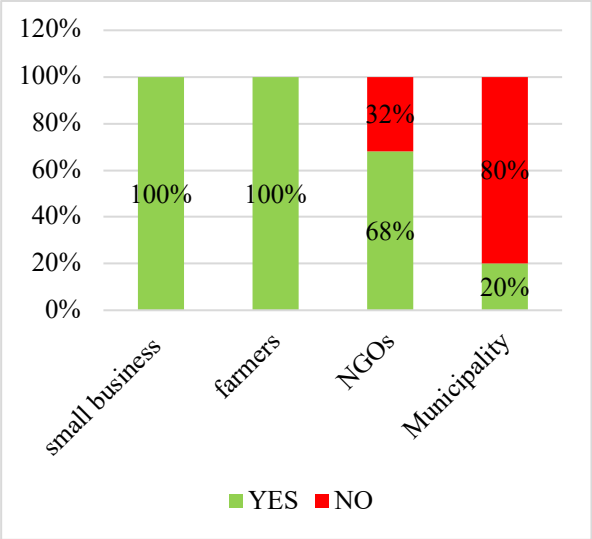


Fig. 2. Identification of stakeholders as potential beneficiaries of the C&D.
Source: Own survey among 270 respondents. Period January – April, 2024.

The participants in the focus groups were asked whether they knew which project financing measures was included in the local development strategy of their LAG. The responses were categorized according to support sectors. Notably, a significant percentage of respondents were aware of the measures included in the local development strategy - over 90% of farmers and small businesses, and around 65% of NGOs. (Figure 3).

About 70% of the respondents answered that they could name at least one application measure administered by the LAG. Of interest is the question of whether local businesses and other beneficiaries of the measures administered by the LAG visit the office of the structure and whether they often seek information about its activities – the answer is that 1/3 of them state that they have made such visits. The information that is mainly sought concerns what investments can be financed and to what extent, as well as what documents are needed and what assistance they can receive for their procurement [5].

When asked what contributions the implementation of the local development strategy has brought to their LAGs, 40% of the individuals answered that it improved the living environment, about 30% indicated an increase in the potential of the local economy, 10% could not assess, and about 20% categorically believe that no such contributions have been realized (Figure 4).

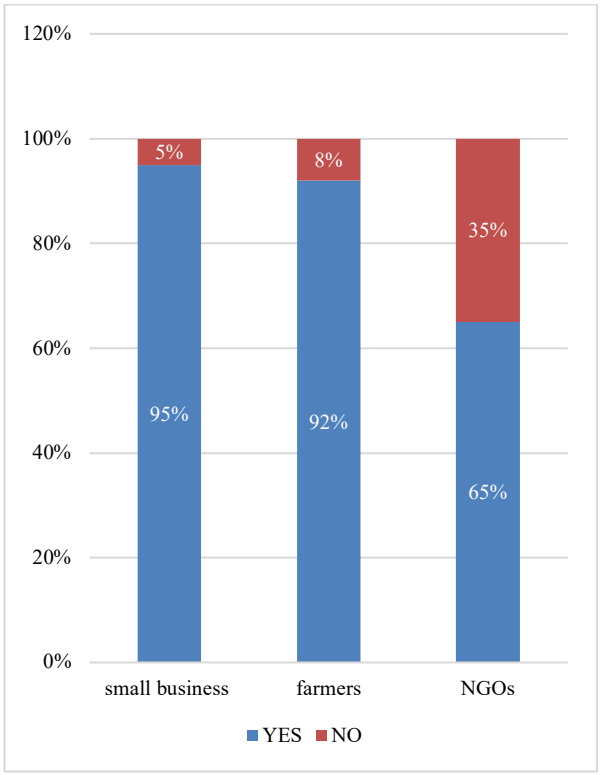


Fig. 3. Knowledge of measures of stakeholders who are administered by the LAG, Bulgaria
Source: Own survey among 270 respondents. Period January – April, 2024.

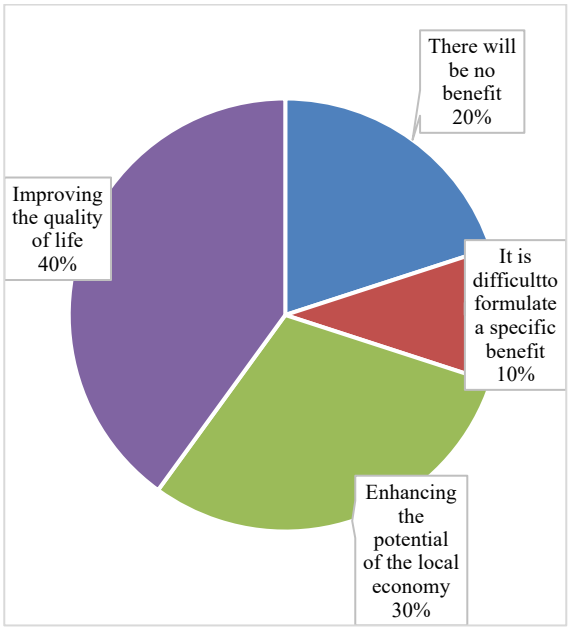


Fig. 4. Benefits of implementation of the LAG local development strategy.
Source: Own survey among 270 respondents.Period January – April, 2024.

Figure 5 presents the survey results on the outcomes of the LEADER approach in relation to the specific objectives set within this axis. Overall, the assessment indicates that the approach is considered successful in achieving its objectives. It is evident that the two measures have primarily contributed to enhancing the capacity of LAGs in executing the local development strategy (with the highest score of 3 on the assessment scale), mobilizing internal resources for rural development (scoring 2.7, which represents a significant contribution on the used scale), and increasing the capacity to implement the local development strategy. The lowest impact of the approach is observed in efforts to promote cooperation for the implementation of the Rural Development Program. The LEADER approach's contribution to achieving the priorities of the other three axes is evaluated as moderate.

Alongside the quantitative assessments of the LEADER approach's contribution to building capacity in the rural areas involved, respondents also shared their views on the challenges faced during the program's implementation (Figure 6). The primary issues and challenges identified in relation to the two measures encountered by the LAGs were frequently mentioned in focus groups and include delays in finalizing contracts for financing local development strategies, which shortened the implementation period. The assessment and analysis revealed that delays in project negotiations led to the demotivation of potential beneficiaries and a reluctance to proceed with investment plans. Additionally, delays in the approval of costs and activities (such as the LAG's annual budget) resulted in a reduced timeframe for implementing planned activities, which posed a risk to adhering to the 60% to 40% rule. These delays also undermined the financial stability of the LAG and caused setbacks in the signing of annexes for the transfer of financial resources between measures in the execution of the local development strategy. Furthermore, delays in approving reports for activity reporting and payment requests for incurred costs in the implementation of projects were also significant challenges.

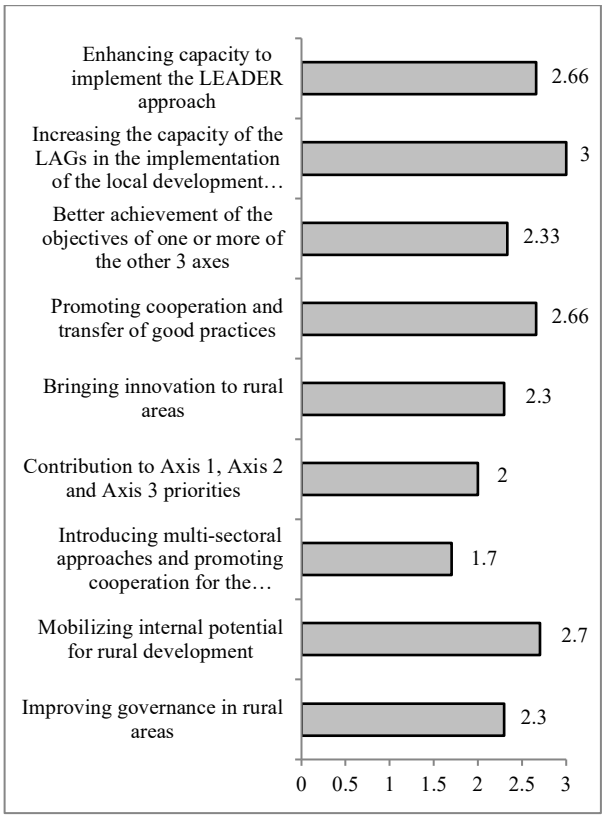


Fig. 5. The achieved effects of the LEADER approach on the main sub-objectives set.
Source: Own survey among 270 respondents (the scores are the arithmetic mean). The rating scale is three-point – 1 – low, 2 – medium and 3 – strong. Period January – April, 2024.

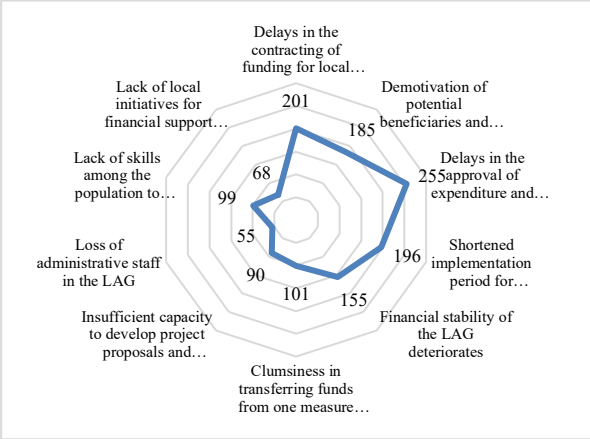


Fig. 6. Challenges in implementing the LEADER approach.
Source: Own survey among 270 respondents who participated in the focus groups. Period January – April, 2024.

Business and rural development with tools for local development. While rural areas have traditionally been linked to agriculture, today these regions provide a diverse array of business opportunities, driven by advancements in technology, tourism, the processing industry, and other sectors [5]. Thus, the opportunities through Local Initiative Groups (LAGs) to promote business development in rural areas are accompanied by a number of challenges, but also significant opportunities for growth and sustainable development.

So in the Rural areas offer a wide range of resources and advantages that can be used to develop a variety of business activities. The role of agriculture and agribusiness is important [18].

In practice, traditionally Rural areas are associated with agriculture and livestock. These sectors continue to be the backbone of the economy in many rural communities, offering opportunities for innovation in organic farming, sustainable production and agro-technologies. The possibilities for processing agricultural products and adding value also offer prospects for the development of agricultural production. Rural areas are increasingly relevant and ideal for the development of various forms of tourism. They can develop types of tourism such as ecotourism, cultural tourism, rural tourism and agro-tourism. The way in which relevant tourism services are provided to people seeking an escape from city life and moving towards natural and authentic experiences in the villages is of great importance [7]. These regions offer beautiful landscapes, traditional culture and cuisine, as well as opportunities for active recreation - walking, cycling, hunting and fishing. It is also of great importance with still operating programs related to the processing industry. There is still the necessary human potential for the development of these sectors and the support of Local Initiative Groups (LAGs) can play a significant role. Because many rural areas have natural resources that can be processed locally. Processing local products such as dairy products, meat, fruit and vegetables can create new jobs and add value to the regional economy. Local products often have unique characteristics and high quality, making them attractive to both local and international markets [15]. Another essential element in rural areas is preserved brands and folklore. This means supporting projects to create collections and local products based on specific crafts. In rural areas, old crafts and traditional production methods are often maintained. Craft businesses can include the production of handmade products such as textiles, ceramics, furniture, food and drinks. These products often have a unique value for consumers who are looking for authentic and handmade goods. Next in line is creating conditions for improving the water supply system and obtaining "green energy" [23]. This could also become a priority for Local Action Groups (LAGs), because rural areas offer significant potential for the development of green energy projects – solar and wind farms, bioenergy plants and other sustainable energy solutions. Investments in green technologies can contribute to reducing energy consumption and protecting the environment. Business management and rural development require a comprehensive approach that takes into account the specific needs and challenges of these territories [7]. Rural areas often face multiple economic, social and infrastructure problems that require targeted and well-considered development strategies. For this reason, Local development instruments aim to

stimulate economic activity, create jobs and improve the quality of life in rural communities. By implementing these instruments, local authorities, together with the business sector and civil society, can develop and implement sustainable development strategies that meet the specific needs and potential of their regions [7].

There are various instruments for local development and Local Action Groups (LAGs), which can be used to manage businesses and rural areas. These tools include development strategies and programs, financial mechanisms, public-private partnerships, networks and cooperatives, as well as various forms of support for small and medium-sized enterprises [13]. Of course, programs, strategies and development plans remain only "good wishes" on paper if these regional planning and management tools are not financially justified and adequately supported financially. When considering the full range of measures and financial instruments aimed at supporting rural development, particularly within the framework of the Rural Development Program, it becomes clear that the financial contribution of the LEADER approach plays a symbolic role in this support. According to data from the Ministry of Agriculture and Food of the Republic of Bulgaria, as of December 31, 2020, only 103,368,572 BGN (52,851,512 EUR) had been spent under the LEADER approach for the implementation of investment projects within local development strategies. [15]. This represents only 3% of the total expenditure carried out within the framework of the Rural Development Program of the Republic of Bulgaria.

CONCLUSIONS

The impact of the LEADER approach on a specific territory and its local community is diverse and can be evaluated from several perspectives, including economic, social, and environmental dimensions. A keyway the approach influences a territory is by fostering economic development in rural areas. In this context, Local Initiative Groups (LAGs) emerge as an important factor in the development of rural areas in Bulgaria. This highlight the results of the implementation of the Local Initiative Groups (LAGs) approach, which has varying degrees of effectiveness depending on the awareness of its applicability and efficiency. Overall, this approach contributes to the creation of new jobs by encouraging the development of new businesses and supporting existing enterprises in rural areas [14]. This is particularly important for retaining young people in these areas, where there is often a lack of sufficient economic opportunities. Increased employment leads to improved living standards and reduced migration to larger cities. An example of this is the development of agri-tourism in some rural areas, where thanks to the Local Initiative Groups (LAG) and the implementation of a number of projects, new tourist sites and services are created that attract visitors and generate income for the local economy. Businesses and services are also created that are not provided in the territory of the specified rural areas at the time of application. This not only increases the number of employed people, but also contributes to the economic sustainability and innovation of the area by expanding sources of income. The implementation of the approach promotes social inclusion and the reduction of inequalities. Local Action Groups (LAGs) and the implementation of their strategies provide opportunities for participation of all groups in society, including vulnerable and marginalized groups, such as women, young people, the elderly and ethnic minorities. This is done by financing projects that aim to create new jobs, provide education and training, and provide social services. Through projects supported by Local Initiative Groups, training centers and social services can be created to provide support to unemployed youth or women who want to start their own businesses. The approach can finance initiatives to build composting facilities that turn organic waste into valuable fertilizers for farmers. In addition, local communities can be encouraged to participate in waste reduction and separate collection campaigns, which also contribute to environmental protection and reduce waste management costs. Finally, for Local Initiative

Groups (LAGs) to succeed, it is crucial for them to implement high-quality regional development policies that align with demographic trends, such as population aging and urban migration. Social inclusion, enhancing access to services, and reducing inequalities are key priorities that must be incorporated into development strategies. Based on the various aspects of regional development, strategic planning, the LEADER program and business management in rural areas, effective regional policies can be implemented through LAGs, emphasizing the importance of integrated approaches and local initiatives for achieving sustainable development.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SMART RURAL DEVELOPMENT - EDUCATION FOR THE 2030 AGENDA IN RURAL SMART EDUCATIONAL CENTERS

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Abstract

The article explores the concept of intelligent villages as a model of sustainable rural development, with a special emphasis on the role of Smart educational centers in reducing educational inequalities, poverty, limited access to technology, as well as in ensuring food security and reducing rural-urban migration. Smart educational centers combine modern infrastructure, digital tools, and sustainability principles to increase the quality of education, improve agricultural productivity, and strengthen local economic opportunities, thus supporting young people in their communities.The research is based on an analysis of the specialized literature, a contextual evaluation of the rural-urban discrepancies in Romania, and the elaboration of a conceptual framework for the implementation of Smart educational centers. There is a methodological note regarding the comparative selection of three relevant international models (Estonia, Finland, India), as well as a case study applied from Ciugud commune, which illustrates the practical feasibility and the potential for replicating the proposed model. The results highlight the transforming potential of education in rural areas by reducing economic inequalities, increasing food security, and strengthening socio-economic resilience. Although there are challenges related to financing and infrastructure, the article identifies public-private partnerships, continuous training of teachers, and digital inclusion strategies as essential for the success of these initiatives. The implementation of SMART educational centers can contribute significantly to achieving sustainable development objectives, especially in the fields of quality education, poverty eradication, food, decent work, the action for climate, and the development of sustainable communities. These centers can become strategic pillars in the process of sustainable transformation of villages in Romania and can offer valuable models for other countries in similar situations.

Key words**:** *smart villages, education for sustainability, smart educational centers, SDGs, smart rural development*

INTRODUCTION

The idea of smart villages emerged in response to the pressing needs of rural communities, which are facing educational, economic and social challenges. This model proposes an integrated approach to rural development, which includes modern technologies and sustainable practices (Marin Ilie et al., 2022) [12]. Smart villages are designed as future solutions for rural areas, promoting innovation, collaboration between local actors and alignment with the international strategic directions established by the 2030 Agenda for Sustainable Development. (Adamowicz &Zwolińska-Ligaj, 2020; Alabdali et al., 2023) [1, 2].

Education is a key element in achieving the Sustainable Development Goals, especially SDG 4: Quality Education, which promotes equal access to inclusive, equitable and quality education for all. In rural areas, this goal is often affected by major deficiencies in educational infrastructure, limited access to teaching resources and reduced opportunities for students, as well as the phenomenon of youth migration to urban areas in search of better development conditions. At the same time, education in rural areas needs adaptations to respond to other SDGs, such as SDG 8:

Decent work and economic growth, SDG 11: Sustainable cities and communities, and SDG 13: Climate action. (del Arco et al., 2021) [5].

This article explores the potential of quality education in Romanian rural areas, integrated into the Smart Village concept, and proposes the creation of an innovative educational framework that responds to current challenges. By promoting educational centers based on smart principles, the aim is to develop an educational model oriented towards technology, sustainability and global connectivity, but with strong local roots. In Romania, these centers could be the core of a fundamental transformation in rural education, placing a special emphasis on practical skills, education for sustainability, and community collaboration (Firoiu et al., 2019; Brezuleanu et al., 2024) [8, 3].

The proposed educational programs in Romania should be aligned with the goals of SDG 4, including, for example, access to digital resources, practical courses on sustainability and modern agriculture, as well as environmental awareness activities. (Mihai &Iatu, 2020) [13].

At the same time, they should contribute to the achievement of SDG 8, by supporting young people in developing the skills needed to access decent work opportunities in their communities. Also, through education focused on environmental protection and resource efficiency, these initiatives can also respond to the goals of SDG 13. (Grosseck et al., 2020, Ianoş et al., 2021) [10, 11].

The study provides an in-depth perspective on how education, when supported by innovative Smart Village initiatives, can become a decisive factor in the revitalization of rural communities. The proposed educational centers are designed as central elements of this process, facilitating the transition towards a sustainable rural development model, characterized by social equity and increased capacity to adapt to the challenges of the future.

The present paper brings an original contribution by proposing a conceptual educational framework integrated into smart rural development strategies, with a focus on achieving the Sustainable Development Goals (SDGs), in particular SDG 4, SDG 1 and SDG 2. In addition, by including a methodological note justifying the comparative international selection (Estonia, Finland, India) and by presenting a relevant case study from Romania (Ciugud Commune), the paper offers a practical vision of the real possibilities of implementing the concept. This approach responds to the requirement to bring applicative and contextualized value to the analysis of rural education.

MATERIALS AND METHODS

Methodological note-Justification of the comparative international selection

To contextualize the challenges and opportunities of rural education in Romania, a comparative approach was applied, by analysing three relevant international models: Estonia, Finland and India. These countries have not been chosen at random, but based in clear strategic criteria:

1. Estonia – is an European leader in digital education, with a entire digitized system in the rural areas. Estonia is a reference point for Romania, due the demographic similarities, its EU membership and efficient use of the EU funds for the rural digital infrastructure.
2. Finland – was selected for its excellence in education recognized at the global level and for its equitable policies, especially in assuring the access to education of quality in the disadvantaged zones. Finland i an example of good practice regarding the formation of teaching staff and reduction of the urban-rural inequalities.
3. India – was included as an example of a developing country which implemented digital educational solutions and having smart educational centers in complex rural areas. India offers valuable lessons about the implementation on a large scale of the accessible technologies and community formation.

These countries reflect three complementary prospects:

- Estonia –digital transformation in an EU small-sized country;
- Finland – pedagogical quality and educational equity in the rural areas;

- India – innovation and extend in the rural development of the emergent economies.

The analysis is on the topic and illustrative, and not a statistical one, aiming to identify good practices and transferable ideas, not achieving a rigorous benchmarking,

Despite that there are utilize identical indicators for a systematic comparison, the selection of the countries is methodologically grounded and thematically aligned to the objectives of the paper.

Smart Village Educational Centers are proposed as innovative solutions to achieve the Sustainable Development Goals, with a focus on combating poverty, reducing hunger and ensuring access to quality education in rural areas. These centers are designed as essential infrastructures, combining education, technology and sustainability principles, offering tailored responses to the specific needs of rural communities.

-*Review of the specialized literature*

An analysis of international and national literature was conducted to identify examples of good practices and educational solutions implemented in rural environments.

Relevant studies were assessed to understand how quality education (SDG 4) can facilitate poverty reduction (SDG 1) and ensure food security (SDG 2).

-*Comparative analysis*

The challenges facing rural areas in Romania were compared with those in other European and global states, emphasizing limited access to education, digital resources, and professional training opportunities.

Data from reports from the United Nations, UNESCO, and other organizations were analyzed to understand how smart educational centers can contribute to reducing the gaps between urban and rural areas.

-*Defining a conceptual framework for smart educational centers*

The proposed educational centers are designed as hubs integrated into Smart Villages, offering:

-Access to modern technology, namely computers, high-speed internet, and digital tools.

- Educational programs aligned with the Sustainable Development Goals (SDGs), focused on practical skills in sustainability, modern agriculture and rural entrepreneurship.

- Community support through partnerships between local authorities, the private sector and NGOs.

- *Aligning smart educational centers with the priorities of the 2030 Agenda (SDGs)*

According to the proposed conceptual framework, the education offered in these centers must become a catalyst for rural development, integrating the principles of SDG 4 (Quality Education) and at the same time addressing objectives such as poverty reduction (SDG 1), ensuring food security (SDG 2), stimulating economic growth (SDG 8) and protecting the environment (SDG 13).

The educational programs proposed within the smart centers are designed in accordance with the Sustainable Development Goals (SDGs), providing students and learners with practical skills in essential areas such as sustainability, modern agriculture and rural entrepreneurship. These centers rely on community support, through active collaborations between local administration, the private sector and non-governmental organizations, to support the educational process. The conceptual framework of these centers is based on the idea that education must be the engine of rural development, directly integrating the principles of SDG 4 (Quality Education) and responding to broader needs, such as poverty reduction (SDG 1), food security (SDG 2), economic growth (SDG 8) and environmental protection (SDG 13).

-*Analysis tools and methods*

The study used qualitative methods, such as case study analysis and secondary data processing, to assess the potential of smart educational centers in the context of smart villages. Statistical reports and evaluations of educational policies in Romania were analyzed in order to highlight existing gaps and to substantiate the proposals formulated in the paper. The applied methodology provides a coherent framework for the evaluation and development of smart educational centers, considered sustainable solutions for the transformation of the rural environment, with education at the center of Smart Village initiatives.

RESULTS AND DISCUSSIONS

Access to quality education in rural areas (SDG 4)

In Romania, one of the most persistent challenges of the education system is represented by the major differences between the urban and rural areas. These discrepancies are the result of a combination of factors, such as the insufficiently developed educational infrastructure, the shortage of qualified teachers and the economic difficulties faced by families in rural areas. The school dropout rate in rural areas has reached 24%, compared to 15.6% at the national level and 9.6% at the European Union level, which reflects not only the lack of access to quality education, but also the impact of socio-economic problems (European Commission, 2023) [7].

An aggravating factor is the long distances that students have to travel daily to get to school, which clearly discourages participation in classes, especially in the case of those in middle and high school. Also, limited access to technology and digital resources accentuates this inequality: less than half of rural schools benefit from digital equipment and smart laboratories (European Commission, 2023) [7], which seriously limits the possibilities for digital learning and the application of modern teaching methods.

In comparison, in urban areas, the percentage of schools with functional internet is significantly higher, approaching 95%.

Table 1. Distribution of access to digital education in rural vs. urban areas in 2023

Indicator	Rural (%)	Urban (%)	Difference (%)
Internet access	45	95	50
Specialized IT teachers	20	70	50
Computers per student	0.3	1.2	0.9

Source: European Commission, 2023; National Institute of Statistics Romania, 2023[7, 15].

This gap is also reflected in the use of technology by students: in rural areas, only 0.3 computers are available per student on average, while in urban areas the ratio is 1.2 computers per student (Table 1).

These figures illustrate not only the insufficiency of the digital infrastructure, but also a significant difference in the quality of the educational act.

The shortage of qualified teachers in rural areas also exacerbates this inequality. Recent data shows that only 20% of teachers in rural schools are specialized in using technology in the educational process, compared to 70% in urban areas (Figure 1).

This limits the ability of schools in rural areas to integrate digital education into the curriculum, preventing students from developing essential skills for the modern labor market.

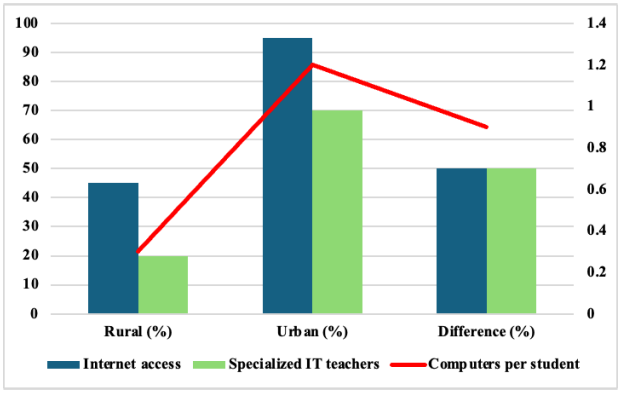


Fig. 1. Disparities in digital education between rural and urban schools in Romaniain 2023

Source: by authors based on the data fromEuropean Commission, 2023; National Institute of Statistics Romania, 2023 [7, 15].

These problems are compounded by the difficult economic conditions of many rural families, who cannot afford to support the costs associated with education, such as the purchase of textbooks, electronic devices, or even the transportation of children to school. In this context, the educational gap between rural and urban areas not only persists but tends to widen in the absence of structured interventions (Firoiu et al., 2019) [8].

The integration of smart educational centers in rural areas can be a viable solution to reduce these disparities. These centers could provide free access to the internet, computers, interactive whiteboards and other digital resources, while supporting teacher training in the use of technology in the teaching process. By addressing these basic issues, smart educational centers could fundamentally transform the educational act in rural areas, providing equal opportunities for education and contributing to reducing the gaps between

rural and urban areas.

By comparison, in Estonia, a global leader in digitalization, all rural schools are connected to high-speed internet, and every student has access to personal devices. (World Bank, 2024)[26].This was made possible by an ambitious government program, supported by European funds. Similarly, in Finland, rural education programs include digital training sessions for teachers, which has contributed to increasing academic performance by 30% in disadvantaged areas (World Bank, 2024) [26].

Therefore, the educational disparities between rural and urban areas in Romania can be reduced by creating smart educational centers, integrated into the concept of Smart Villages. These centers represent a viable solution to provide modern digital infrastructure and educational opportunities that meet the needs of students and teachers in rural areas.

An essential first step is to equip these centers with state-of-the-art technological resources. Free access to high-speed internet would allow students and teachers to use online educational platforms, access interactive materials and participate in virtual lessons. In addition, IT laboratories, equipped with computers, interactive whiteboards and other modern devices, would create an attractive and efficient learning environment. This infrastructure would transform educational centers into multifunctional hubs, capable of supporting both formal education and technology-based extracurricular activities.

Another essential aspect is teacher training. The integration of technology into the educational process depends largely on the skills of teachers. Therefore, training programs would be needed to provide rural teachers with practical skills in using digital tools and integrating them into teaching activities. These programs could include in-service training courses, mentoring sessions and access to e-learning platforms, where teachers can share their experiences and learn from each other.

The establishment of these smart educational centers should start with pilot projects in priority regions, where educational gaps are most acute. The centers could be used not only for teaching, but also for innovative extracurricular activities, such as robotics workshops, programming or the use of drones in agriculture. These activities would encourage creativity and the development of practical skills of students, better preparing them for the challenges of the future.

Dobrota et al (2020) affirmed that initiative actions are useful for sustaining the smart development of rural areas [6].

Tita et al. (2018) designed a model of smart economy and education related to environment based on system dynamics principles [24].

The impact of implementing these centers would be significant. They would contribute to reducing the educational gap between rural and urban areas, increasing the school retention rate and improving the quality of education.

Moreover, through access to modern resources and adequate training, students would have the chance to develop essential digital skills, thus increasing their chances of integration into the labor market.

At the same time, these centers would become reference points for the community, providing spaces for collaboration and continuous learning for students and adults.

By equipping them with modern technology, training teachers and integrating innovative activities, the smart educational centers in Smart Villages could represent a fundamental change for rural education in Romania.

They would not only ensure better access to quality education but would also contribute to reducing inequalities and the sustainable development of rural communities.

Sasu et al (2024) sustain that LEADER intervention offers a financial support for sustaining projects destined to the development of smart villages [20].

Reducing poverty and increasing incomes (SDG 1)

In Romania, important economic and social discrepancies are visible among the urban areas and the rural ones (Popescu et al., 2018) [19].

According to data provided by the World Bank (World Bank, 2024) and the National Institute of Statistics (2023), education has a direct and significant impact on individual incomes in Romania.

Young people from rural areas who have completed high school earn an average

monthly income of 500 euro, while those from urban areas, with the same level of education, earn approximately 800 euro. People without formal education earn about 300 euro in rural areas, compared to 500 euro in urban areas(Table 2).

Table 2. Impact of education on average monthly income in 2023

Education Level	Rural Average Income (€)	Urban Average Income (€)
No studies	300	500
High school studies	500	800
Higher education	800	1,200

Source: National Institute of Statistics Romania, 2023 [15].
Note: National Bank of Romania, Exchange rate: Euro 1 = Lei 4.9773.

These percentage differences — 66.67% in favor of urban areas, regardless of education level — highlight the major economic gap between the two environments. Even for people with higher education, urban salaries are two-thirds higher than rural ones. These figures indicate a clear relationship between educational level and income, but also an unequal distribution of economic opportunities across Romania. (World Bank, 2024; National Institute of Statistics Romania, 2023) [25, 26]
Average income per household is higher in the rural areas than in the rural ones as found by Popescu et. al (2019) [18].
The percentage differences between rural and urban areas reveal that people without formal education earn, on average, 66.67% more in urban areas than in rural areas. Similarly, high school graduates in urban areas have incomes that are 66.67% higher than their rural counterparts. In addition, people with higher education in urban areas earn, on average, 66.67% more than those with the same level of education in rural areas.
These figures emphasize the persistent economic disparity between rural and urban areas.
Although higher education levels contribute to income growth in both contexts, the financial benefits of completing tertiary education are not sufficient to reduce the income gap.
The fact that across all education categories, urban incomes are consistently 66.67% higher suggests not only a greater availability of well-paying jobs in cities, but also a potential lack of economic opportunities in rural areas (Figure 2).

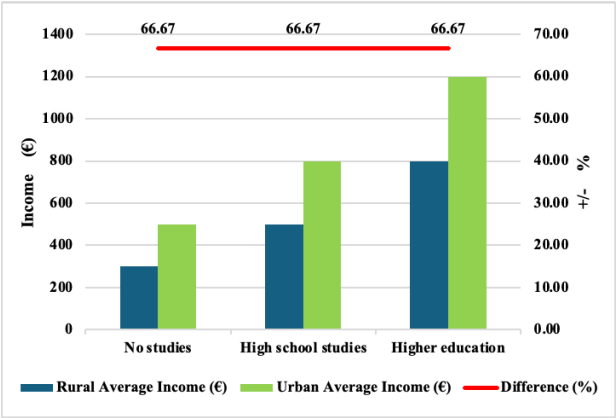


Fig. 2. Romania's disparities in average income between rural and urban areas by education level in 2023
Source: by authors based on the data fromNational Institute of Statistics Romania, 2023 [15].

In Vietnam, educational programs for rural youth increased household incomes by 20% through technical and entrepreneurial training, while in Kenya, integrated rural education initiatives reduced extreme poverty rates by 15% in a decade (Nguyen et al., 2019; Saidi et al. 2024) [16, 19].
Therefore, smart educational centers can contribute to increasing the level of education and implicitly to reducing poverty. They should offer courses in practical skills, such as the use of green technologies and entrepreneurial management.

Contribution to Food Security (SDG 2)

In rural areas of Romania, agriculture is the main source of income for most households, but productivity remains far below potential due to the lack of modern knowledge and advanced technologies. This situation is exacerbated by post-harvest losses, estimated at around 20%, compared to only 5% in developed countries, according to FAO (2023) [9]. These losses are caused by the lack of storage infrastructure, inadequate crop handling, and traditional practices that are not optimized for efficiency.
Smart education, delivered through smart education centers within Smart Villages, could directly address these challenges. These

centers, equipped with modern technologies and digital educational resources, would allow rural farmers to access up-to-date information on sustainable agricultural practices, tailored to the specific needs of their communities. Through interactive courses, hands-on workshops, and access to digital platforms, farmers could learn innovative methods to reduce losses and maximize productivity.

For example, within these centers, farmers could participate in training sessions on the use of drones to monitor crop health, advanced irrigation systems that optimize water use, or modern storage and packaging techniques that reduce crop degradation. Access to digital simulators could also allow farmers to virtually test different planting and harvesting scenarios, thus evaluating the impact of sustainable practices on production.

A similar model has been successfully implemented in India, where farmers in rural areas benefited from training through digital community centers. As a result, post-harvest losses were reduced by 50% and productivity increased by 30% (Sudheer et al., 2021; Sengupta et al., 2024) [23, 21]. Such an impact could be replicated in Romania, adapting the curriculum of smart centers to the specifics of local agriculture.

Table 3. Agricultural productivity before and after farmer training in India (pilot example)

Indicator	Before training	After training	Growth (%)
Cereal production (kg/ha)	3,000	4,000	33
Post-harvest losses (%)	20	10	-50

Source: Sudheer et al., 2021; Sengupta et al., 2024 [23, 21].

In addition to directly training farmers, smart education centers could also engage young people in rural communities, providing them with skills that will transform them into local innovators. They could learn about precision agriculture, the use of artificial intelligence for crop management, or even digital marketing methods for selling agricultural products on national and international markets.

By reducing post-harvest losses and increasing crop yields, smart education in these centers would contribute not only to the economic development of rural households but also to ensuring food security.

A good example of smart communities are the villages dealing with agro-tourism in Sibiu County (Moise et. al, 2023), [14] and also the Ciugud Commune, Alba County, the only community which received the award "The Best Smart Village Project" at the end of the year 2020 for the development of a creative-intelligent community by the implementation of digitization in the local administration, education, local economy and environment protection [4].

In addition, by promoting sustainable agriculture, these initiatives would support SDGs, such as SDG 2: Zero Hunger and SDG 13: Climate Action, creating a more prosperous and climate-resilient rural environment.

Thus, smart education offered through educational centers in Smart Villages represents not only a solution to current agricultural problems, but also an opportunity to transform Romanian agriculture into a sustainable and innovative.

-*Challenges and limitations*

While smart education centers have transformative potential for rural development in Romania, their implementation faces significant challenges that need to be addressed to ensure long-term sustainability. Establishing these centers is an ambitious initiative that requires well-structured solutions and collaboration between key stakeholders.

Funding for infrastructure and educational programs remains a major barrier. Equipping the centers with modern technology, IT labs, high-speed internet, and interactive tools requires substantial investments, often exceeding local budgets. In addition, training and attracting qualified staff requires ongoing financial support. Without consistent funding, these initiatives risk remaining isolated pilot projects with limited impact on rural communities in Romania.

Another challenge is the low level of awareness among rural communities about the long-term benefits of smart education centers. Some communities may perceive these centers as too ambitious a change or as an initiative that is not suitable for their immediate needs.

This skepticism is often fueled by a lack of prior access to the technology or limited experiences with similar projects. In the absence of ongoing dialogue with community members and their active involvement in the decision-making process, the implementation of these centers may encounter resistance.

The lack of qualified human resources is another major barrier in Romania.In rural areas, the shortage of teachers well-trained in the use of modern technologies is a recurring problem. Many teachers in rural areas have not had access to continuous training, and the migration of teachers to urban areas exacerbates this shortage. This lack of qualified personnel can hinder the integration of technology into the educational process, thus reducing the efficiency of smart educational centers.

-Proposed solutions

Reducing the obstacles that hinder the development of smart educational centers in rural areas requires the adoption of coherent solutions, which bring together institutional support and private initiative. An efficient collaboration model can be created by the active involvement of the business environment, together with local and central authorities, in supporting educational infrastructure. Public investments can thus be complemented by resources from the private sector, especially from companies interested in training young people as future employees. IT companies can contribute by providing modern technologies, and those in agriculture or industry can facilitate access to practical internships and specialized training. The success of these initiatives depends on the formalization of partnerships through transparent agreements, which clearly define the obligations of each actor involved and ensure the continuity of long-term interventions.

Mentoring programs dedicated to teachers in rural areas represent a promising direction of intervention. Experienced teachers, whether from urban centers or from other European regions or countries, can be involved in directly supporting local teachers, through practical training sessions and personalized counseling. Activities can include thematic workshops, exchanges of good practices and digital platforms through which a constant professional dialogue can be maintained. The use of online learning platforms facilitates teachers in remote areas' access to modern educational resources and updated pedagogical methods. These digital tools contribute to reducing the professional training gap between urban and rural teachers, offering them opportunities for self-training, virtual collaboration and participation in interactive courses tailored to their real needs.

In addition to mentoring, it is important to provide financial and professional incentives for teachers who choose to work in rural areas. Subsidies, performance bonuses, or priority access to professional development programs could attract more qualified teachers to rural areas.

Organizing local public information and consultation campaigns can play a key role in changing rural communities' perceptions of the usefulness of smart education centers. These efforts should focus on long-term benefits, such as improved access to quality education, increased employment opportunities, and local economic development. Involving local leaders, teachers, and parents in the decision-making process helps build community trust and support for these initiatives.

These measures, if integrated into a coherent national strategy, could transform smart educational centers into a central element of rural development in Romania, contributing both to reducing educational inequalities and to increasing the resilience of rural communities.

Case study - Smart Educational Strategy in Ciugud commune, Romania

Ciugud commune, located in Alba County, has become a model recognized at the national level of intelligent rural development, being awarded with the distinction "Best Smart Village project" at the Smart City Awards Gala in 2020 (Ciugud City Hall, 2021) [4]. This success is the result of a coherent local strategy, which combines innovation, digitization and involvement of the community, having as central pillar the education and retention of young people in the rural area.

One of the most important elements of the transformation in Ciugud was the investment in the educational digital infrastructure. The local administration equipped the school in the commune with interactive tables, tablets for students and high-speed internet connection. Thus, the school has become a digital educational hub, allowing students from rural environments to access a learning environment comparable to urban areas. The teachers benefited from specialized training in the use of digital tools, ensuring

Thus not only the presence of technology, but also its effective integration in the educational process.

Another essential aspect is the involvement of the local community and the private sector. Ciugud City Hall has concluded partnerships with IT companies and educational NGOs, which offered digital resources, training modules and mentoring for teachers and students. These partnerships have also expanded beyond the classroom, through extracurricular activities such as programming workshops, robotics clubs and competitions on topics of green technologies (Ciugud City Hall, 2021) [4].

In terms of durability, the school in Ciugud integrated environmental education into the curriculum, students being actively involved in

Table 4. Educational differences between Ciugud Commune versus the normal schools in Romania

Indicator	Ciugud's school	Average rural school (2023)
Internet access in all classrooms	100%	~ 45%
Number of digital devices per student	1 device/ student	0.3 devices/
Teachers trained in digital pedagogy	80%	student
Partnerships with private sector	Yes	20%
Education for environment integrated into curriculum	Yes (applied projects)	rare
Smart extracurricular activities	Weekly	Sporadic

Sources: Ciugud City Hall (2021) [4]; European Commission (2023) [7].

Recycling campaigns, energy saving projects and climate change awareness. These initiatives directly contribute to the achievement of the SDG 13 Sustainable Development objective: Action for climate and cultivate a civic responsibility for protecting the local environment (Ciugud City Hall, 2021) [4]. Table 4 synthesizes the main educational differences between Ciugud commune and ordinary rural schools in Romania.

This case study shows that a clear local vision, supported by targeted investments and external partnerships, can lead to significant progress in rural education. The replicability of the Ciugud model depends on: the will of the local authorities to adopt Smart Village strategies; access to financing mechanisms (eg Leader, PNRR); the existence of an involved teaching body; support of community and private actors. In the context of this work, Ciugud represents an example of good practice, which offers empirical support for the proposed conceptual model. It shows that Smart educational centers are not only a theoretical construct, but practical and efficient solutions for rural development, when implementing strategies are adapted to local realities.

CONCLUSIONS

The implementation of smart educational centers within Smart Villages represents a viable and innovative solution for combating educational inequalities, reducing poverty and promoting sustainable development in rural areas. These centers are not just spaces dedicated to learning, but multifunctional hubs that integrate modern technology, quality education and community support, becoming catalysts for social and economic change under the environment protection against various climate phenomena (Stojanova et al., 2021) [22].

One of the most important advantages of smart educational centers is their ability to provide access to digital resources and educational programs that are traditionally limited in rural areas. By equipping them with high-speed internet, IT labs, and interactive equipment, these centers provide students and teachers with the tools they need to bridge the gap with urban areas. At the same time, by training teachers and integrating technology into the

educational process, the centers contribute to improving the quality of teaching and developing digital skills, essential for the future of the labor market (UNDP, 2023; World Bank, 2024) [25, 26].

For Romania, another key role of these centers is combating poverty and enhancing food security across the entire food chain, including crop and animal production. By training farmers in sustainable agricultural practices, precision farming, and modern livestock management, smart educational centers help reduce post-harvest and post-production losses, optimize resource use, and improve overall productivity. These initiatives increase rural incomes, strengthen local and regional food supply chains, and enhance economic resilience, ultimately contributing to a more sustainable agri-food system and reducing migration to urban areas.

In addition, the smart education offered in these centers supports the achievement of the SDGs, in particular SDG 4: Quality Education, SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 8: Decent Work and Economic Growth, and SDG 13: Climate Action. By taking an integrated approach to these goals, smart education centers become an example of good practices for sustainable rural transformation.

However, the successful implementation of smart education centers depends on overcoming key challenges, such as securing financing, raising awareness in rural communities, and attracting qualified personnel. Public-private partnerships, mentoring programs for teachers, and community engagement are essential to ensure their sustainability.

In the long term, these centers can radically transform rural Romania, serving as hubs for formal education, vocational training, local collaboration, and innovation. By expanding access to quality education and promoting sustainability, they contribute to a more prosperous, resilient, and globally connected rural environment.

More than just a response to current challenges in rural areas, smart education centers represent a strategic investment in Romania's sustainable development. They can transform rural communities into models of resilience and innovation, reducing socio-economic disparities, and fostering a more equitable and inclusive society. Future policies should integrate these centers into national rural development strategies, ensuring sustainable funding, teacher training, and investments in digital infrastructure to reduce educational disparities and boost economic opportunities. Incorporating them into long-term rural development frameworks would allow Romania to become a regional leader in innovative and sustainable educational solutions.

In addition, the article offers a strategic direction for the formulation of coherent educational and rural policies, based on innovation, sustainability, and digital inclusion. The case study on Ciugud demonstrates the feasibility of implementing such a model and its potential for replication in other rural communities in Romania. Thus, the contribution of the work consists not only in the analysis of an emerging concept, but also in offering a concrete, contextualized and anchored solution in good practices.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PERFORMANCE OF AGRITOURISM AND ITS FUTURE DEVELOPMENT IN MARAMUREȘ COUNTY, ROMANIA - A SWOT-BASED ASSESSMENT OF INNOVATION POTENTIAL

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Abstract

The paper examines the potential for digital innovation within agritourism development in Maramureș County, Romania. Using tourism data from the National Institute of Statistics and a SWOT-based framework, the study analyses the region's readiness to adopt immersive technologies, with a particular focus on virtual reality. Between 2020 and 2024, agritourism guesthouses in Maramureș increased by 47.5%, from 185 in 2020 to 273 in 2024, while domestic overnight stays nearly tripled, from 54,487 in 2020 to 143,866 in 2024. Although foreign tourist numbers remain relatively low, their overnight stays increased more than tenfold during the same period, from 433 to 4,868, despite the lingering effects of the pandemic. Even if virtual reality is not currently implemented, the region shows structural and cultural features that could support future adoption. The SWOT analysis identifies both enabling factors and critical barriers, such as digital infrastructure deficits and institutional fragmentation. The article provides insights into the region's current position and the conditions needed to enable future digital engagement in rural tourism.

Key words: *agritourism, Maramureș country , innovation in rural tourism, SWOT analysis, virtual tourism*

INTRODUCTION

Tourism continues to be one of the most adaptive and economically impactful sectors worldwide, with major contributions to employment, GDP and regional development [20, 8]. Nevertheless, the industry has proven vulnerable to global crises, the most recent and disruptive being the COVID-19 pandemic, which led to border closures, flight cancellations and lockdowns, causing a drastic decline in both international and domestic travel [13]. The large-scale repatriation of hundreds of thousands of citizens required swift coordination between multiple stakeholders [13], thus exposing the fragility of the tourism system and sparking critical discussions on the need for more adaptive, sustainable and resilient models of tourism development.

In Romania, the most critical phase occurred between March and June 2020, followed by a partial recovery during the summer [30]. Despite this rebound, the sector incurred significant losses, with many businesses closing permanently. Domestic tourism became a crucial buffer, as Romanians turned to national destinations, especially countryside, coastal and mountain areas, in search of nature, cultural authenticity and slower-paced experiences [30].

Agritourism, a subcategory of rural tourism, offers visitors engagement with agricultural life and local heritage [5]. It is commonly practiced on working farms and agri-business properties, where guests participate in recreational and cultural activities such as food experiences, farm tours and artisanal crafts [27]. More than diversifying rural economies, agritourism contributes to mitigating rural depopulation and revitalizing abandoned land through sustainable, place-based experiences [1].

Europe currently dominates the global agritourism market, accounting for over 47% of the global share in 2019 [10]. The region's dense network of small family farms and strong hospitality traditions makes it a natural leader in agritourism. With the market expected to grow from USD 69.24 billion in

2019 to USD 197.37 billion by 2032, this sector is driven by growing interest in sustainable, nature-based travel and increasing public support. A key trend is agri-food tourism, which blends gastronomy, farming and heritage into unique experiences, offering local producers' new ways to promote their skills, products and identity to both national and international visitors [10].

In Romania, Maramureș is widely regarded as one of the most culturally intact and authentic rural regions, with strong potential for agritourism development. The area is known for its traditional wooden houses, family-run guesthouses and deep connection between people, land and heritage [6]. Its identity is shaped by elements such as carved wooden gates, festive rituals and wooden churches, some included on the UNESCO World Heritage list [33], which together reflect a living spirituality rooted in local tradition.

Covering 6,303 km² and home to approximately 512,588 people, Maramureș county includes 2 municipalities, 11 towns, 63 communes and over 200 villages [32]. In 2022, agritourist accommodations represented 34.1% of total lodging capacity, with 3,666 available beds. Efforts to promote the county as a rural and cultural destination have intensified in recent years under the "Visit Maramureș" identity that included participation in national tourism fairs and integration into thematic national routes such as the "Traditional Architecture Villages Route" and the "Romanian Traditional Gastronomy Trail" [32]. Visitors can enjoy a rich culinary heritage that includes dishes such as balmoș, sarmale, smoked sausages and homemade bread, all prepared with natural ingredients from household farms and often served with local preserves and țuică [7]. These attributes make Maramureș an ideal case for exploring agri-food tourism as a pillar of rural development. Yet challenges persist, including seasonality, limited digital visibility and low levels of innovation [23].

Meanwhile, digital technologies are reshaping tourist behaviour. Travelers are now highly connected to online spaces that allow them to explore destinations, plan journeys and share experiences in real time [29]. This possibility has increased demand for immersive and interactive formats that extend beyond conventional visual or textual content.

Within this evolving digital landscape, virtual reality (VR) is gaining recognition as a strategic tool for destination promotion, tourists' engagement and market expansion [4, 28], typically through the use of head-mounted displays [2]. It creates navigable 3D environments that simulate real-time sensory experiences [14].

This growth has enabled new narrative formats in tourism. Digital narrative-based formats have proven effective in capturing attention by drawing audiences into the emotional atmosphere of a destination [21]. Virtual previews of touristic locations delivered through immersive environments have been found to generate a strong sense of spatial presence and positively influence attitudes and visitation intent [39].

A recent report titled *Tourism in the Metaverse: Can Travel Go Virtual?* published by McKinsey & Company (2025) [24], outlines early hybrid applications, including travel inspiration, edutainment and virtual events. These touchpoints, while not replacing physical travel, offer profitable and low-risk avenues for integration. The report encourages tourism actors to begin developing metaverse strategies [24]. As Pestek & Sarvan (2021) [28] argue, a forward-looking approach is essential for technological adaptation in the tourism and hospitality sectors.

Given these developments, in rural areas such as Maramureș, VR could strategically complement traditional tourism, enhancing visibility to broader audiences and addressing seasonality.

Although emerging technologies have been increasingly examined in tourism literature [40, 22], the application of VR in agritourism development and branding lacks in-depth analysis [26, 11], particularly in Romania, despite its potential to support competitiveness in travel and hospitality sector.

To address this gap and examine the relevance of immersive technologies in agritourism development, this study combines recent tourism statistics from Maramureș with conceptual perspectives on virtual reality and

employs a SWOT framework to assess the feasibility and strategic implications of its local adoption.

As a strategic planning tool, S.W.O.T. helps highlight internal strengths and weaknesses alongside external opportunities and threats in order to generate coherent strategies and support decision-making processes [12].

The article is structured into three main sections: first section outlines the methodological approach of the study; the second one presents a contextual synthesis of recent research on VR in tourism, recent statistical data from Maramureș and a S.W.O.T. analysis and the last one presents the conclusions derived from the analysis.

MATERIALS AND METHODS

This study has an exploratory, mixed-method perspective to examine how Virtual Reality (VR) could be integrated into the agritourism sector of Maramureș, Romania. The approach is built around three elements: (1) review of recent academic work regarding the use of VR in rural, cultural and heritage tourism. The review focuses on how immersive technologies contribute to visibility, audience engagement and sustainability; (2) statistical analysis – empirical data on agritourism were sourced from the National Institute of Statistics, Romania (NIS Tempo Online), covering the period 2020–2024. The analysis includes both absolute indicators (number of beds, tourist arrivals, overnight stays) and relative measures (year-on-year change, operational capacity, regional share).

The objective is two-fold: to map the post-pandemic evolution of agritourism in the North-West region of Romania, with emphasis on Maramureș County and to assess the region's developmental trajectory and infer its strategic potential for innovation and internationalization in agritourism; (3) a S.W.O.T. analysis to examine the strategic feasibility of adopting VR in Maramureș agritourism.

RESULTS AND DISCUSSIONS

Virtual reality (VR) and tourism development: a context-based review

Virtual reality is increasingly recognized as a transformative tool in tourism, helping destinations and businesses to promote themselves, engage visitors and rethink the delivery of experiences [4]. For virtual reality to bring real value in tourism, particularly within rural or emerging destinations, its use cannot be detached from the visitors' willingness to interact with such tools. The degree to which potential users are ready to adopt immersive technologies determines how effective these applications can be. In this light, segmenting audiences according to their technological openness becomes essential when shaping agritourism strategies. Studies indicate that travelers who display higher levels of digital openness are more inclined to perceive VR encounters as immersive, authentic and engaging, which in turn positively strengthens their overall perception of the destination [35].

Virtual reality has the capacity to deepen the emotional bond that visitors develop with natural environments. This, in turn, can encourage more responsible behavior and directly support the goals of sustainable tourism [36]. In this perspective, agritourism, as a particular form of rural tourism, remains anchored in agriculture, local traditions and natural landscapes, elements that both characterize the identity of rural communities [31] and position agritourism as an integral part of sustainable tourism.

Education and experiential values are not the only advantages of using virtual reality; it also increases the possibility of tourists' desire to visit destinations in person after exploring them virtually [16]. In practice, this was shown in China, where VR systems tested in the villages of Dazhai, Xidi and Jingzhu led to a 10–15% increase in awareness and promotional effectiveness and the intention to visit increased from 8.16 to 98.57. In the same time, due to a more compelling content, the engagement duration and costs efficiency also brought improved results that ultimately led to higher booking conversion rates [15].

A similar effect was seen in an interactive VR project that presented the Cloisonné art

experience at the Beijing Enamel Factory [17]. Using 360° video tutorials, visitors were introduced to traditional metal inlay and painting methods, while interactive options such as changing camera angles or pausing the session made the learning process more engaging [17].

Another example comes from Heraklion, Greece, where a cultural VR tourism project incorporated gamification, 360° videos and virtual guides. Visitors followed a treasure-hunt narrative while interacting with historical content and receiving personalized storytelling from human-like avatars [19]. This improved cultural learning and emotional involvement while demonstrating that gamified VR formats can make underexposed heritage more attractive and educationally impactful [19].

In Bali, a study identified virtual reality marketing (VRM) as an emerging promotional practice used by businesses to target niche segments, such as returning tourists and mobility-constrained individuals. While not tested directly on users, the study revealed that VRM is perceived by stakeholders as a strategic response to pandemic disruptions, with potential benefits for sustainable tourism and economic revitalization at the local level [37].

In Romania, a VR-based web platform was created to offer virtual tours of wooden churches located in rural areas of Bihor County, with the goal of promoting sustainable tourism while safeguarding fragile cultural heritage. Through the use of photogrammetry and 360° imagery, the project enabled immersive and interactive access to remote ecclesiastical landmarks without exposing them to physical degradation. The initiative served not only to simulate authentic visitation experiences but also to build a digital bridge between the sites and potential visitors, encouraging active cultural learning and raising awareness among both the general public and local authorities about the churches' importance for tourism and the rural economy [3].

These cases present the possibilities that virtual reality offers to connect tourists from different parts of the world with destinations that are more difficult to reach, while at the same time creating a genuine motivation to visit them in real life. This is especially true for culturally distinctive regions such as Maramureș, where agritourism has continually expanded.

The dynamics of agritourism in the North-West of Romania, with Maramureș County as a focal point.

Although the pandemic formally ended in 2023 [34], its effects reshaped travel behaviours. Travelers increasingly avoided crowded urban areas, turning instead to rural regions that offered space, safety and personalized experiences [30].

In Maramureș, agritourism proved to be a resilient alternative [32] as the region has continued to attract visitors through its well-preserved rural lifestyle and distinctive culinary offer [38, 33].

The analysis below relies on data that is provided by the National Institute of Statistics (NIS) to outline the development of agritourism in Romania's North-West region, with particular attention to Maramureș County.

As presented in Table 1, agritourism guesthouses in Romania's North-West region increased from 616 in 2020 to 872 in 2024, totalling 256 new units, an overall growth of around 41.5%.

The highest annual rise was recorded in 2021, with 134 new guesthouses, an increase likely driven by growing interest in countryside escapes due to Covid-19 pandemic. The following years brought further additions: 56 units in 2022, 29 in 2023 and 37 in 2024.

In Maramureș county, the growth path was more uneven but followed a similar direction. In 2021, the number of guesthouses jumped from 185 to 264 (+79), responding to demand for rural, low-density travel options. A decrease in 2022 (down to 227) may reflect updated records or operational closures, followed by new increases in 2023 (+27) and 2024 (+19), reaching a total of 273 units in 2024.

Despite yearly variations, Maramureș consistently moved forward in expanding its agritourism accommodation offer, maintaining strong position in the regional tourism landscape.

Other counties also registered positive changes. Cluj started with 166 agritourism

guesthouses in 2020 and reached 228 by 2024. The growth was slow and incremental, with only a few new units added each year, 220 in 2022, 227 in 2023 and just one more in 2024. Bihor followed a steadier upward trend, culminating in its highest value in 2024. Interestingly, during the pandemic period, Bihor had already reached a peak of 195 guesthouses in 2023, likely reflecting the easing of restrictions and the formal end of the health crisis.

Bistrița-Năsăud showed more fluctuation, including a decline in 2023, but has managed to reach 110 agritourism guesthouses in 2024. Satu Mare, on the other hand, experienced a clear decline, with no change in 2021 and fewer guesthouses recorded in 2024 compared to 2020.

Table 1. Number and annual variation of agrotourism guesthouses in the North-West Region, 2020–2024

Type of Tourist Accommodation Structure	Development Region / County	2020	2021	Δ 2021–2020	2022	Δ 2022–2021	2023	Δ 2023–2022	2024	Δ 2024–2023
Agritourism Guesthouses	North-West Region Total	616	750	134	806	56	835	29	872	37
	Bihor	144	139	-5	190	51	195	5	206	11
	Bistrița-Năsăud	73	86	13	110	24	103	-7	110	7
	Cluj	166	203	37	220	17	227	7	228	1
	Maramureș	**185**	**264**	**79**	**227**	**-37**	**254**	**27**	**273**	**19**
	Satu Mare	18	18	0	16	-2	11	-5	9	-2
	Sălaj	30	40	10	43	3	45	2	46	1

Source: Calculation based on data from NIS Tempo Online, TUR101D [25] .

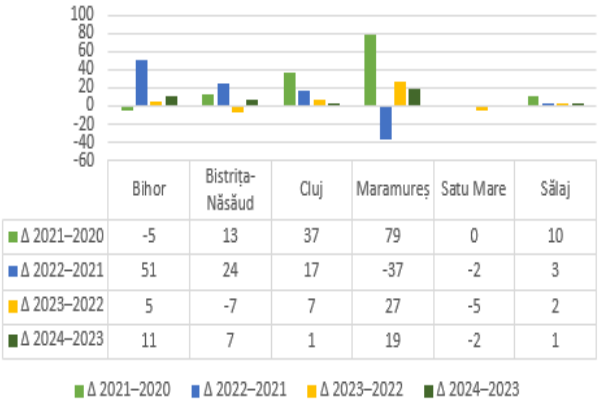


Fig.1. Yearly variation (Δ) in the number of agritourism guesthouses across counties in Romania's North-West region, 2020–2024.
Source: Author's calculation based on data from NIS Tempo Online, TUR101D,[25]

In Figure 1, the evolution of agritourism guesthouses is displayed through annual variations (Δ) across six counties in Romania's North-West region between 2020 and 2024, offering a clearer view of intra-regional dynamics.

Maramureș recorded the sharpest increase in 2021 (+79), followed by a drop in 2022 (−37), and a renewed rise in 2023 and 2024 (+27 and +19). Cluj, showed bigger growth in 2021 (+37) and in 2022 (+17), afterwards, the increase was not significant, respectively, 7 in 2023 and just 1 in 2024. Bihor had a drop in 2021 (−5), followed by recovery in 2022 and modest annual increases in 2023 and 2024. Bihor had a drop in 2021 (−5), followed by recovery and modest annual increases. Satu Mare showed a declining pattern overall, with stagnation in 2021, then gradual losses (−2 in 2022 and 2024) while Sălaj had minor variations, with small positive gains each year (Fig. 1).

Table 2 presents bed capacity compared to the number of agritourism guesthouses in the North-West region of the country.

According to National Institute of Statistics (NIS) methodology, bed capacity reflects the number of officially certified accommodation places, based on the most recent classification documents. Temporary beds are excluded, while complementary units (e.g., huts, campsites) are included under their primary structures. The data indicate growth across most counties. Maramureș leads in both guesthouse numbers (from 185 to 273) and bed capacity (from 3,218 to 4,371), pointing to sustained investment and high regional appeal.

Cluj and Bihor also recorded growth, each exceeding 3,500 beds by 2024.
In Bistrița-Năsăud, the number of guesthouses grew moderately, but bed capacity more than doubled (from 600 to 1,477), possibly due to reclassification or expansion of existing units. Satu Mare and Sălaj remained largely unchanged, each staying below 50 guesthouses and 650 beds, reflecting limited development or demand (Table 2).

Table 2. Agritourism and bed capacity in North-West Romania by county, 2020–2024

North-West Region - County	Agritourism Guesthouses 2020	Beds 2020	Agritourism Guesthouses 2021	Beds 2021	Agritourism Guesthouses 2022	Beds 2022	Agritourism Guesthouses 2023	Beds 2023	Agritourism Guesthouses 2024	Beds 2024
Bihor	144	3,103	139	3,014	190	3,565	195	3,723	206	3,819
Bistrița-Năsăud	73	600	86	703	110	868	103	846	110	1477
Cluj	166	2,862	203	3,323	220	3,477	227	3,571	228	3,546
Maramureș	185	3,218	264	3,961	227	3,666	254	4,078	273	4,371
Satu Mare	18	282	18	284	16	208	11	168	9	175
Sălaj	30	433	40	538	43	585	45	613	46	628

Source: NIS Tempo Online, TUR101D and 102D [25].

While the previous tables illustrated the structural growth of agritourism in the North-West region, Figures 2 and 3 provide a clearer view of how bed capacity evolved across space and time between 2020 and 2024.

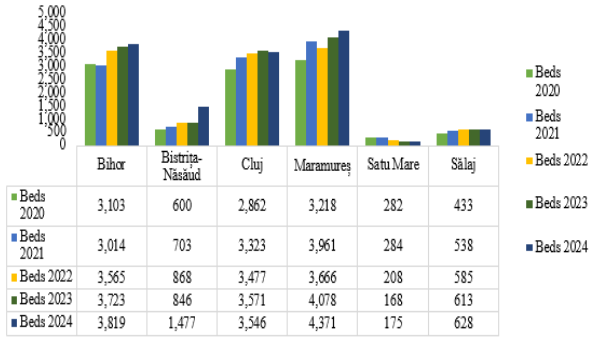


Fig. 2. Comparative evolution of bed capacity in agritourism guesthouses by county, 2020–2024
Source: NIS Tempo Online, 102D [25].

Although Maramureș and Cluj led in total bed capacity, reaching 4,371 and 3,546 beds respectively by 2024, the highest percentage increase was recorded in Bistrița-Năsăud, where bed numbers grew from 600 to 1,477, a growth of 146.2%. Sălaj also showed expansion (+47.3%), despite its smaller size. Maramureș grew by 35.8%, while Cluj and Bihor registered similar increases of 23.9% and 23.0%. By contrast, Satu Mare experienced a decline of 37.9%, remaining the only county with negative growth over the period.

Figure 3 focuses on Maramureș, where the number of bed capacities grew in 2021, only to drop again in 2022, most likely due to reclassification processes or temporary closures. Growth picked up once more in 2023 and continued into 2024, when the county reached 4,371 beds distributed across 273 agritourism guesthouses. This recovery points to the resilience and adaptability of the sector in the aftermath of the global health crisis.

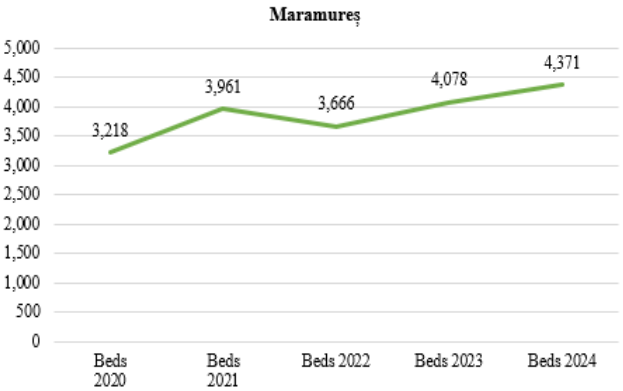


Fig. 3. Evolution of bed capacity in Maramureș agritourism,2020–2024
Source: NIS Tempo Online, TUR102D [25]

Table 3 outlines how agritourism infrastructure was actually used in the North-West region during 2020–2024, showing the gap between total capacity and the number of overnight stays. In Maramureș, bed capacity almost doubled, from 631,129 to 1,257,783 bed-days,

yet occupancy remained modest, fluctuating only between 8.7% and 11.8%. The numbers suggest that demand failed to keep pace with the rapid expansion of infrastructure.

Table 3. Operational rate (%) of agritourism beds in North-Western Romania, 2020–2024

Year	County	Available bed-days	Overnight stays (Romanian and Foreign)	Operational Rate (%)
2020	Bihor	440,097	104,420	23.7
2021		636,302	134,769	21.2
2022		808,252	173,854	21.5
2023		808,368	175,201	21.7
2024		921,390	165,747	18.0
2020	Bistrița-Năsăud	184,103	32,260	17.5
2021		251,558	30,234	12.0
2022		301,998	38,643	12.8
2023		395,098	50,780	12.9
2024		407,162	58,485	14.4
2020	Cluj	461,435	82,648	17.9
2021		789,010	130,619	16.6
2022		904,867	152,929	16.9
2023		909,349	157,965	17.4
2024		916,948	145,767	15.9
2020	Maramureș	631,129	54,920	8.7
2021		965,553	101,274	10.5
2022		1,095,827	116,973	10.7
2023		1,261,548	126,486	10.0
2024		1,257,783	148,734	11.8
2020	Satu Mare	44,727	10,509	23.5
2021		65,836	11,718	17.8
2022		64,123	14,697	22.9
2023		63,875	20,733	32.5
2024		64,050	23,093	36.1
2020	Sălaj	95,727	4,802	5.0
2021		139,119	11,219	8.1
2022		183,633	14,754	8.0
2023		195,047	15,233	7.8
2024		204,895	13,668	6.7

Source: Calculation based on data from NIS Tempo Online, TUR103B and 105D [25].

Cluj maintained a large capacity, but its operational rate hovered around 16–18%, showing persistent underuse. Bihor performed better, with consistent rates above 21%, indicating more efficient use of available beds. In Bistrița-Năsăud and Sălaj, rates stayed below 13%, with minimal yearly changes, pointing to slow recovery and limited tourist flows. Satu Mare saw a sharp rise in 2024, reaching 36.1%, the highest in the region, despite smaller infrastructure, possibly due to more stable local tourism.

Overall, the data confirm a mismatch between supply and demand in most counties, reinforcing the need for better planning, targeted promotion and tools to increase year-round occupancy.

Figure 4 illustrates the annual operational rate (%) of tourist accommodation beds in Maramureș county between 2020 and 2024.



Fig. 4. Annual operational rate (%) of tourist accommodation beds in Maramureș county, 2020–2024
Source: Calculation based on data from NIS Tempo Online, TUR103B and 105D [25].

Despite a visible positive trend, from 8.7% in 2020 to 11.8% in 2024, the whole level of utilization remains low. The most significant growth occurred between 2020 and 2021, followed by a slight plateau in 2022 and a minor decline in 2023. The increase in 2024 suggests modest improvement in demand or management efficiency, yet the figures confirm that a large share of available capacity remained underused throughout the period. These results prove persistent imbalance between infrastructure development and consistent tourist flows, confirming the need for diversification strategies and more effective year-round promotion (Fig. 4).

Table 4 presents a comparative view of tourist arrivals across different types of rural

accommodation in North-Western Romania between 2020 and 2024, distinguishing between Romanian and foreign visitors.

The data confirm that domestic tourists consistently preferred tourist and agritourism guesthouses, with agritourism experiencing the most visible growth.

Arrivals in agritourism guesthouses almost doubled over five years, from 142,582 in 2020 to 281,218 in 2024. Although foreign arrivals remained modest, they followed an increasing trend, from just 1,215 in 2020 to over 11,200 in 2024, suggesting that rural destinations were gradually gaining attention on the international market as well.

Looking at the wider trend, the pandemic seems to have strengthened the appeal of rural destinations, with every category of rural accommodation in the North-West region showing positive tourist numbers over the five-year period (Table 4).

Table 4. Distribution of domestic and foreign tourist arrivals by rural accommodation type in North-West Romania, 2020–2024

Types of Tourist Accommodation Facilities in North-Western Romania	Type of tourists	2020	2021	2022	2023	2024
		Number of people				
Inns	Romanian	:	:	:	:	244
	Foreign	:	:	:	:	25
Tourist villas	Romanian	23,463	38,940	52,127	56,040	55,213
	Foreign	954	2,759	7,180	5,699	5,753
Tourist cabins	Romanian	7,446	11,463	10,365	10,347	9,467
	Foreign	49	36	287	240	406
Bungalows	Romanian	554	906	1,644	2,910	2,544
	Foreign	:	8	20	:	16
Campgrounds	Romanian	1,388	1,035	1,263	2,795	1,697
	Foreign	40	410	235	454	270
Tourist cottages	Romanian	495	1,295	2,380	4,092	4,130
	Foreign	19	4	10	61	233
Tourist guesthouses	Romanian	84,588	105,882	121,901	123,640	127,317
	Foreign	2,779	4,560	6,924	8,616	8,892
Agritouriosm guesthouses	**Romanian**	**142,582**	**212,950**	**257,979**	**276,244**	**281,218**
	Foreign	**1,215**	**4,588**	**7,848**	**11,564**	**11,215**

Source: NIS Tempo Online, 104B [25]

Table 5 presents tourist arrivals in agritourism guesthouses across North-Western Romania, broken down by county and visitor origin.

Maramureș recorded 27,551 domestic tourist arrivals in 2020 and by 2024, surpassed Cluj with 74,835 arrivals, exceeding it by 1,739 visitors, despite starting from a much lower baseline. In contrast, Cluj maintained the lead in terms of foreign visitors, with 5,845 arrivals in 2024, while Maramureș reached only 2,667, approximately half.

In Bihor, domestic arrivals peaked in 2023 at 79,529, overpassing Cluj and Maramureș, while foreign arrivals also reached their highest point that year with 1,719 tourists.

Sălaj registered the lowest domestic arrival numbers across the region, starting at 2,543 in 2020, peaking at 8,141 in 2023 and slightly declining to 7,113 in 2024.

Satu Mare recorded the lowest foreign arrivals, with only 14 visitors in 2020, a short-lived increase to 140 in 2021 and zero reported arrivals in both 2023 and 2024, indicating either a sharp decline or missing data.

Table 5. Number of domestic and international tourists' arrivals in agritourism establishments by county in the North-West region, 2020-2024

Types of Tourist Accommodation Facility in North-Western Romania	Type of tourists	County	2020	2021	2022	2023	2024
			Number of people				
Agritourism guesthouses	Romanian	North-West region	142,582	212,950	257,979	276,244	281,218
		Bihor	46,901	59,571	77,499	79,529	76,224
		Bistrita-Nasaud	13,893	15,188	17,864	25,465	28,876
		Cluj	41,814	69,304	79,283	78,354	73,096
		Maramures	27,551	52,305	61,982	65,694	74,835
		Satu Mare	9,880	10,669	13,599	19,061	21,074
		Salaj	2,543	5,913	7,752	8,141	7,113
	Foreign	North-West region	1,215	4,588	7,848	11,564	11,215
		Bihor	191	499	1,218	1,719	1,518
		Bistrita-Nasaud	99	59	200	112	509
		Cluj	509	2,729	4,799	6,606	5,845
		Maramures	262	806	963	2,364	2,667
		Satu Mare	14	140	34	:	:
		Salaj	140	355	634	763	676

Source: NIS Tempo Online, 104B [25]

Table 6 provides an overview of overnight stays recorded in agritourism guesthouses, between 2020 and 2024, in both domestic and foreign visitors.

At regional level, the numbers of Romanian tourists grew from 287,384 in 2020 to 533,324 in 2024, showing that rural tourism remained attractive even in the challenging pandemic years.

Most overnight stays came from Romanian tourists and by 2024, Maramureș had taken the lead in this segment, reaching 143,866 stays, almost triple compared to 2020. In 2020, Cluj had been ahead, with over 81,800 stays, but by

2024, it reached 134,000, slightly behind Maramureș.

Table 6. Yearly overnight stays in agritourism guesthouses, broken down by county and by tourist origin, North-West region of Romania, 2020–2024

Types of tourist reception structures	Type of tourists	North-West region of Romania	2020	2021	2022	2023	2024
			Overnights stays - number				
Agritourism guesthouses	Romanian	North-West region of Romania	287,384	412,085	498,186	525,668	533,324
		Bihor	103,964	133,675	171,403	171,158	162,252
		Bistrita-Nasaud	32,053	30,160	38,323	50,535	57,209
		Cluj	81,830	126,453	144,856	147,101	134,533
		Maramures	54,487	99,684	115,309	122,506	143,866
		Satu Mare	10,495	11,578	14,657	20,733	23,093
		Salaj	4,555	10,535	13,638	13,635	12,371
	Foreign	North-West region of Romania	2,175	7,748	13,664	20,730	22,170
		Bihor	456	1,094	2,451	4,043	3,495
		Bistrita-Nasaud	207	74	320	245	1,276
		Cluj	818	4,166	8,073	10,864	11,234
		Maramures	433	1,590	1,664	3,980	4,868
		Satu Mare	14	140	40	:	:
		Salaj	247	684	1,116	1,598	1,297

Source: NIS Tempo Online, 105D [25].

For international visitors, Cluj remained in front, with more than 11,200 stays, while Maramureș followed with 4,868, up from just 433 in 2020.

Bihor showed strong numbers as well in domestic overnight stays, especially in 2022 when it reached its peak of 171,403 stays. Bistrița-Năsăud had slower, but steady growth, both in domestic and foreign stays. Meanwhile, Satu Mare and Sălaj remained well below regional levels, suggesting lower visibility or limited development in this tourism segment.

Foreign overnight stays across the region grew more than ten times over, from 2,175 in 2020 to 22,170 in 2024. While the increase is encouraging, the total remains small compared to domestic tourism. Still, it signals that rural areas in Maramureș and Cluj are starting to gain attention beyond Romania's borders and the interest seems to go beyond the short-term effects of the pandemic.

Table 7 reflects the growing prominence of Maramureș in the regional agritourism landscape.

For Romanian overnight stays, the county recorded a considerable rise, growing from 54,487 in 2020 to 143,866 in 2024. In term of regional share, this translated into an increase from 18.96% to nearly 27%, indicating that over one in four domestic overnight stays in the North-West took place in Maramureș by 2024. This might suggest a strengthened tourism infrastructure and sustained visitor interest in the area.

On the foreign tourism side, although the share remained relatively stable, oscillating around 20–22%, the absolute number of international overnight stays in Maramureș surged from just 433 in 2020 to 4,868 in 2024. This more than tenfold growth points to a significant improvement in international visibility, even if the regional share did not drastically change.

Maramureș increased its absolute performance and strengthened its regional leadership, particularly among domestic tourists, while making steady progress in attracting foreign visitors.

Table 7. Share of overnight stays in agritourism guesthouses: Maramureș vs. North-West region, 2020–2024

Year	Maramureș (Romanian) - overnights	NW Region (Romanian) - overnights	Share (%)	Maramureș (Foreign) - overnights	NW Region (Foreign) - overnights	Share (%)
2020	54,487	287,384	18.96%	433	2,175	19.89%
2021	99,684	412,085	24.19%	1,590	7,748	20.52%
2022	115,309	498,186	23.14%	1,664	13,664	12.18%
2023	122,506	525,668	23.30%	3,980	20,730	19.20%
2024	143,866	533,324	26.97%	4,868	22,170	21.96%

Source: Calculation based on data from NIS Tempo Online, 105D [25].

SWOT analysis: implementing virtual reality (VR) in agritourism development in Maramureș county

Given the structural growth of agritourism in

Maramureș and the rising interest in immersive technologies, a SWOT analysis was conducted to explore the region's strategic readiness for innovation.

Table 8. SWOT analysis – virtual reality (VR) in agritourism development (Maramureș)

STRENGTHS	WEAKNESSES
🔹 Strong cultural heritage and beautiful nature landscapes offer great support for immersive formats	🔻 Digital infrastructure and VR equipment are still limited
🔹 Local tourism is already align with global preferences for authentic, nature-based and sustainable experiences.	🔻 Rural operators lack the necessary skills or confidence to adopt new, emerging technologies
🔹 The diversity of crafts, gastronomy, architecture offers rich content for VR storytelling	🔻 Insufficient or weak links between local producers or agritourism operators and potential technology partners.
🔹 The increasing popularity of the region offers a good starting point for testing VR solutions and adjusting them to visitors' needs.	🔻 Public institutions often lack the necessary know-how to secure financing or attract investors for projects based on emerging technologies.
🔹 The presence of many small guesthouse owners and local producers forms a network that could support collaborative projects in rural and agri tourism.	🔻 The destination continues to rely on conventional forms of tourism promotion rather than digital or technological solutions.
	🔻 There is no clear institutional framework or shared local strategy to guide digital tourism development for the next 5-10 years in accordance with rapid technology developments, including artificial intelligence and metaverse.
	🔻 Many communities are still not fully aware of the benefits that immersive technologies could offer for safeguarding traditions and cultural heritage and this lack of trust often slows down their acceptance.
OPPORTUNITIES	**THREATS**
🌿 European programs provide consistent support for rural development and digital transformation, with funding opportunities available through the Common Agricultural Policy (CAP), the European Agricultural Fund for Rural Development (EAFRD) and the Digital Europe Programme.	⚠️ Traditional communities sometimes view new technologies with caution, fearing they may alter established ways of life.
🌿 The use of virtual reality technology (VR) provides opportunities to collect and analyze visitor data, which could help shape better tourism policies and destination management strategies.	⚠️ Risk of loss of authenticity through "virtual commercialization"
🌿 Younger generations, especially Gen Z and Millennials, are drawn to digital formats, interactive ways of exploring and immersive storytelling.	⚠️ Limited digital infrastructure in remote rural areas, reducing the feasibility of VR adoption
🌿 Virtual platforms can raise international visibility at the county level and showcase varied tourism opportunities.	⚠️ Accelerated digital innovation in other regions may outpace Maramureș, reducing its competitive positioning
🌿 Local producers and guesthouse owners can use VR to present their products and services, while also offering options for direct booking and online sales.	⚠️ Possible lack of continuity in funding or institutional support
🌿 Virtual reality can open up alternative sources of income for public authorities, such as: digital ticketing, licensing or data-based tourism planning.	⚠️Overreliance on external technologies and lack of local digital content providers
🌿 Technology pilot initiatives could benefit from transnational collaboration, linking Romania with broader European or global networks.	⚠️Immersive content that lacks local authenticity may fail to meet visitor expectations and damage destination credibility
🌿 The demand for personalized, emotion-driven tourism experiences connects closely with what VR, through its immersive nature, can provide.	
🌿 The expanding of digital tourism content is creating new business opportunities for entrepreneurs in rural areas.	

Source: Authors' own assessment.

Rather than assessing existing VR initiatives, which are currently absent, this section aims to identify the main enablers and constraints that could shape the adoption of virtual reality in agritourism.

The analysis takes into account internal aspects, including cultural authenticity, quality of infrastructure, as well as factors which are external, such as technological advances, policies and tourists' expectations.

Strengths

Maramureș has some specific features that could support a gradual transition towards integrating virtual reality into agritourism. We are not just talking about well-preserved cultural heritage or beautiful landscapes, although these contribute a lot to the region's visual identity and storytelling potential. What sets Maramureș apart is the richness of its everyday life: a diversity of living practices, from crafts and gastronomy to rural architecture, that offer authentic content, ready to be adapted into interactive digital experiences without losing their meaning. Maramureș is not held back by outdated digital systems, which opens the possibility to develop flexible and up-to-date solutions that match today's realities. But attention must be paid because this "blank page" can also become a vulnerability if it is not completed with local resources. If local resources, be they human, technical or institutional, do not appear, this land free from constraints can remain just an empty space, without the capacity to generate its own solutions. In other words, the lack of barriers can itself become a barrier, in the absence of strategic investment in what is to be built. One last but not least element worth noting is the presence of small-scale producers and guesthouse owners who are already active in the local tourism landscape. While they may not yet be formally connected, their experience and visibility within the community suggest they could support the digital development of rural tourism, as long as efforts are aligned with the local values and practices [5].

Weaknesses

Despite its rich cultural and natural assets, Maramureș faces several structural weaknesses that could delay or hinder the integration of virtual reality in agritourism. The most pressing issue is the absence of digital infrastructure and access to basic VR equipment, which makes it difficult to imagine immediate or scalable implementation. This minus is further compounded by limited digital competencies among rural tourism operators and agri-business owners, many of whom are unfamiliar with immersive technologies or digital promotion tools. There is currently no established connection between local producers, guesthouses and technology providers, a missing link that prevents coordinated development [23]. While starting from a clean digital slate may be seen as an opportunity, in practice, it requires significant capacity-building and institutional support to avoid fragmentation and wasted efforts. Without structured training, accessible public funding and partnerships with digital innovators, the potential of Maramureș risks remaining untapped, especially in a context where tourism innovation increasingly relies on technological integration.

Opportunities

Maramureș finds itself in a favourable policy and technological climate that could support the introduction of virtual reality in rural tourism. At the European level, there are many funding instruments, including Common Agricultural Policy (CAP), the European Agricultural Fund for Rural Development (EAFRD) [9] and the Digital Europe Programme that create frameworks for digital transformation in rural areas, including tourism. These programs are not only about infrastructure, they promote innovation, entrepreneurship and smarter destination management through tools like data collection and digital mapping.

Virtual reality also aligns well with the preferences of younger generations, particularly Gen Z and Millennials, who are more inclined toward interactive exploration and emotionally engaging formats [18].

These attributes open the door for new types of experiences that go beyond traditional tourism, allowing rural destinations like Maramureș to gain visibility on international platforms without relying exclusively on physical infrastructure.

Local producers and guesthouse owners can benefit directly from VR applications by showcasing their offerings in engaging digital environments to a multinational audience, enabling direct bookings, virtual tastings or storytelling-based product sales.

Public authorities may tap into alternative revenue streams through digital ticketing systems, licensing of digital experiences, even more effective planning based on user interaction data.

More than this, as digital tourism content becomes a growing niche, rural areas have a real chance to develop creative industries adapted to their context. Transnational pilot projects could offer both visibility and capacity-building, helping regions like Maramureș position themselves as testing grounds for smart rural tourism solutions.

Threats

Despite the opportunities offered by immersive technologies, several structural and cultural risks may hinder the adoption of virtual reality in Maramureș. First, a degree of cultural resistance or suspicion towards digital tools remains prevalent in more traditional communities, where innovation is sometimes perceived as incompatible with established rural lifestyles. This reluctance can delay adoption or undermine local engagement with new platforms.

In parallel, the risk of "virtual commercialization", where immersive content prioritizes spectacle over substance, may lead to a loss of perceived authenticity, one of the region's most valuable assets. If VR representations fail to reflect local voices and practices, they may weaken the credibility of Maramureș as a genuine rural destination.

Infrastructure deficiency remains another critical barrier. Limited internet connectivity and outdated equipment in remote areas, to a large extent, reduce the feasibility of implementing VR solutions at scale. Most probably, faster-paced innovation in other regions may widen the digital divide, causing Maramureș to fall behind in terms of competitiveness and visibility.

Discontinuity in funding, fragmented institutional support or overdependence on external technologies and service providers may also compromise long-term sustainability. Without locally rooted content creators and technical capacities, immersive experiences may fail to evolve in line with community needs. This can lead to VR content that lacks cultural depth, ultimately failing to meet visitor expectations or contribute positively to rural development.

CONCLUSIONS

This study examined the potential role of virtual reality (VR) in advancing agritourism in Maramureș, Romania, through a SWOT-based assessment. Although VR technologies are not yet implemented in the region, the findings suggest that Maramureș possesses several unique attributes, such as: cultural richness, a strong visual identity and diverse rural practices, that make it particularly well-suited for immersive content development.

The consistent growth in domestic arrivals and overnight stays underlines the county's increasing relevance as a tourism destination with expanding infrastructure and stable demand.

The integration of VR could play a dual role: first, by creating digital platforms through which guesthouse owners and small-scale agri-food producers can gain visibility, promote authentic rural experiences and generate supplementary income, whether through virtual farm tours, immersive tastings or storytelling-based product showcases; second, by strengthening the region's visibility on international markets.

At the same time, several structural and institutional weaknesses must be addressed before digital innovation can take root. These include the lack of digital infrastructure, limited technical skills and the absence of coordinated public strategies to integrate technology into rural tourism.

The SWOT analysis highlights both opportunities, such as: EU funding, emerging digital markets and younger generations' affinity for immersive media and threats, including cultural resistance, risk of de-authentication and overreliance on external providers.

This article is not offering one-size-fits-all model but an exploration of possible directions for VR implementation to support the sustainable development of agritourism in Maramureș, pathways that may also be transferable to other rural regions in Romania if adapted with sensitivity to local contexts.

Policymakers, local actors and rural entrepreneurs are encouraged to pursue pilot initiatives, capacity-building programs and creative partnerships aligned with the region's identity and values, turning virtual innovation into tangible benefits for agritourism stakeholders.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

AGRICULTURAL PRODUCTIVITY AND LAND USE EFFICIENCY IN ROMANIAN ARABLE CROPS: A REGIONAL ANALYSIS OF WHEAT AND SUNFLOWERSEED (1990–2023)

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Abstract

This study examines the agricultural productivity and land use efficiency of two key arable crops, wheat and sunflower seed, across all 41 Romanian counties for a period of 34 years, from 1990 to 2023. The research aims to measure and compare crop productivity, overall efficiency, identify high and under-performing counties, and propose interventions for enhancing regional agricultural performance. Data on crop yields (output per hectare) and land use efficiency (relative to the baseline year of 1990) are analyzed to identify trends and regional disparities in agricultural performance. The findings highlight significant variability in productivity and efficiency across counties, with certain regions, such as Călărași and Timiș, consistently outperforming others. In contrast, counties like Tulcea and Harghita exhibit moderate performance with room for improvement in both productivity and efficiency. This study identifies key factors influencing agricultural performance, such as technological adoption, infrastructure, and climate conditions, and suggests targeted interventions, including technology adoption, farmer education, infrastructure improvements and financial support, to enhance the agricultural output and resource use efficiency in underperforming counties. The findings offer insights into the regional disparities in agricultural performance and provide a framework for policy interventions aimed at boosting the productivity and sustainability of Romanian agriculture.

Key words*: *p*roductivity, efficiency, agriculture, wheat, sunflower seed***

INTRODUCTION

Agriculture remains a vital component of Romania's economy, particularly in rural areas where it continues to provide employment and income for a significant portion of the population. As of 2022, approximately 23% of Romania's labor force was employed in agriculture, the highest percentage among EU member states [10]. In agriculture, the most dramatic form of restructuring is the break-up of state and collective farms into individual farms [19]. With over 13 million hectares dedicated to agriculture, Romania possesses substantial agricultural potential, however since the early 1990s, the sector has undergone significant transformations due to land reforms, the restitution process, structural fragmentation, and the gradual integration into the European Union's Common Agricultural Policy (CAP). After the restitution process, the citizens' participation in the social-political life of the local community and as a whole was quite low. The main cause would be the concept according to which the state is obliged to do everything [7].The analysis of the technical efficiency in Romanian agriculture highlights the importance of farm size in the efficient use of production factors [4]. Determinants of technical efficiency in agriculture differ among new EU member states, reflecting diverse structural and policy environments [3]. Also, climate change effects on crop yield anomalies in Europe underscore the need for resilient agricultural practices [20].

Moreover, technical efficiency in cereal production varies across EU countries, influenced by several socio-economic factors. Efficiency levels are correlated with access to credit, input use intensity, and policy support mechanisms. The findings suggest that enhancing rural infrastructure and extension services could close efficiency gaps [1].Land

fragmentation remains a persistent issue in Southern Romania, affecting agricultural productivity and land use efficiency. One study emphasizes that fragmented land holdings hinder the adoption of modern agricultural technologies and efficient resource management. This structural issue remains a key obstacle to achieving higher productivity and spatial equity in Romanian agriculture [9]. The 1991 restitution law led to the liquidation of approximately 3,700 collective farms, returning land to households that had relinquished it during collectivization. This process resulted in a highly fragmented agricultural structure, with 90% of farms operating on less than 5 hectares [10,11]. Also, land reform processes in Central and Eastern Europe have led to significant land fragmentation, posing challenges for efficient agricultural production. The restitution-based reforms prioritized ownership justice over functional land consolidation. As a result, many farmers ended up with small, scattered plots, leading to inefficiencies in both cultivation and mechanization [14]. Moreover, the non-parametric analysis reveals disparities in technical efficiency among Bulgarian farms, highlighting areas for improvement. The study concludes that smaller farms often operate below their efficiency potential due to lack of access to capital and advisory services. Policy interventions should thus focus on supporting modernization and structural adjustments [12]. These developments have generated substantial regional disparities in land use and productivity, influenced by a combination of natural factors (soil quality, climate), socio-economic conditions (farm size, technology adoption), and policy frameworks. Sunflower crops in Europe are vulnerable to climate change, necessitating adaptation and mitigation strategies. The study highlights that heat stress during flowering and drought during grain filling are critical yield-reducing factors. Strategies such as optimized sowing dates and breeding for drought tolerance are discussed as key adaptive responses [8]. Studies have highlighted significant spatial differences in agricultural performance across Romania's regions, with socio-economic determinants playing a crucial role in these disparities [16]. Also, the CAP subsidies have a significant impact on the technical efficiency of Romanian farms, as demonstrated by the stochastic frontier analysis [13].

As Romania continues to align its agricultural practices with EU standards, the efficient use of arable land and the improvement of productivity remain crucial objectives for ensuring food security and rural development. Also, climate change effects on crop yield anomalies in Europe underscore the need for resilient agricultural practices. The research documents statistically significant links between climate extremes and yield variability across multiple EU regions. It argues for investment in predictive models and early-warning systems to mitigate risks to food production [18].

The purpose of this study is to conduct a detailed, county-level analysis of productivity and land use efficiency in Romanian arable agriculture over the period 1990–2023. With the help of panel data techniques, we aim to identify spatial and temporal patterns in output performance, highlighting regional differences.

More specifically, the objectives of this research are: a) To measure and compare crop productivity (output per hectare) across Romanian counties over time; b)To evaluate land use efficiency for selected arable crops such as wheat and sunflower seed; c) To identify high-performing and underperforming counties in terms of productivity and efficiency; d) To discuss potential interventions for enhancing regional agricultural performance.

By focusing on the local dimension of agricultural output, this paper contributes to the broader literature on land productivity in post-socialist economies and offers a useful empirical basis for future policy design and resource allocation in Romanian agriculture.

Productivity and land use efficiency are essential pillars in agricultural performance analysis, especially in countries experiencing structural transformation. In arable farming, productivity typically refers to output per hectare, while land use efficiency captures the effectiveness of utilizing land resources to generate agricultural output [6].

Various analytical approaches have been developed to assess agricultural efficiency. Among them, Data Envelopment Analysis (DEA) has become a standard method for evaluating technical efficiency across heterogeneous production units. DEA constructs an efficiency frontier based on observed input-output combinations and compares each unit relative to the best performers, without assuming a specific production function [5]. However, DEA requires at least two inputs and one output to produce valid results [5], and it is typically applied in contexts where data on multiple production factors—such as land, labor, and capital are available [15].

While DEA provides comprehensive insights, the current study adopts a simpler yet robust alternative. Specifically, we use efficiency scores based on the ratio between agricultural output and land use (tonnes per hectare), benchmarked against the year 1990. This reference year allows us to assess relative efficiency trends over time, by comparing subsequent yearly productivity levels to the baseline performance. The approach enables a long-term evaluation of how productively arable land has been used across counties, even in the absence of multi-input data.

Romanian agriculture presents a complex structural landscape, with significant disparities in performance linked to both natural conditions and socio-economic factors. Regions in the south and west consistently achieve higher productivity levels compared to those in the northeast, a pattern largely explained by differences in farm consolidation, infrastructure quality, and access to CAP subsidies [16, 7, 2]. The dualistic farm structure dominated by a large number of small farms and a minority of commercial enterprises has further contributed to persistent inefficiencies [15].

In addition, agricultural productivity is shaped by factors such as precipitation variability, soil quality, and mechanization. These drivers have been found to correlate strongly with regional yield differentials, particularly in cereal crop production [18].

Although recent research has explored Romanian agricultural efficiency using various econometric methods and regional aggregations, few studies offer long-term, county-level assessments based on simple efficiency metrics. As it was shown in a recent study, climate change has notably impacted the yields of wheat, maize, and sunflower in Romania between 2017 and 2021, temperature anomalies and reduced rainfall during critical growth periods contributed to yield volatility. The authors recommend adopting resilient crop varieties and adaptive practices tailored to local agro-climatic zones [17].

This paper addresses that gap by employing a 34-year panel dataset (1990–2023) to evaluate spatial and temporal trends in land productivity for key arable crops, such as wheat and sunflower.

MATERIALS AND METHODS

This study is based on official agricultural statistics published by the Romanian National Institute of Statistics [21] covering the period 1990–2023. The dataset includes annual data for all 41 counties (plus the municipality of Bucharest, where applicable), and is disaggregated by crop type. Two core indicators are extracted:

Crop production (dataset: AGR109A) – total output (in tonnes);

Cultivated area (dataset: AGR108A) – total area used for each crop (in hectares).

These indicators are available for a wide range of arable crops, with a focus in this study on wheat and sunflower seed, due to their strategic importance in Romanian agriculture.

To Begin with, for each county i, crop c, and year t, we have computed the Productivity function as: $P_{ict} = \frac{Production_{ict}\,(tonnes)}{Area_{ict}\,(hectares)}$. The productivity function allows us to gain insights regarding the average production in tonnes per hectare for each of the abovementioned county i, crop c, and year t. The following process in our analysis was to measure the Efficiency Score computed as: $E_{ict}\frac{P_{ict}}{P_{ic1990}}$.Where P_{ic1990} represents the productivity level in the baseline year 1990. This benchmark allows us to evaluate the relative evolution of land use efficiency over time. A score greater than

100% indicates an improvement relative to 1990, while a score below 100% suggests declining efficiency.

To reduce the influence of extreme outliers (e.g., due to weather anomalies or reporting errors), basic data cleaning or smoothing techniques are applied, including the analysis of aberrantvalues in the top and bottom 1st percentile for each crop and year. We have also computed a transversal analysis between counties for each year as well as the yearly evolution analysis for each county with the help of general statistics indicators e.g. standard deviation, denoted and computed as $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(x_i - \mu)^2}$ and variance denoted and computed as $\sigma^2 = \frac{1}{N}\sum_{i=1}^{n}(x_i - \mu)^2$, where N is the size of the population consisting of $x_1, x_2, \ldots x_N$ and μ is the population mean.

Unlike DEA, which requires at least two input variables (e.g., land and labor) and one output variable [5], the current approach uses a single-input/single-output ratio, which simplifies analysis and allows direct intertemporal comparisons. This method is particularly appropriate when data on secondary inputs such as fertilizers, irrigation, or capital investments are not consistently available over time or across all counties.

Efficiency scores are computed separately for wheat and sunflowerseed, providing insight into regional specialization and crop-specific performance.

By visually mapping the results over time, we can use a color scheme to illustrate which counties have improved or regressed in their land use efficiency relative to the early post-socialist baseline as well as different trends regarding specific years.

All calculations and visualizations are performed using Microsoft Excel.

The panel structure of the dataset enables the use of summary statistics, time series plots, and regional comparisons to support empirical findings while the visual maps offer a holistic approach regarding the overall performance and trends.

RESULTS AND DISCUSSIONS

The analysis of average crop productivity (output per hectare) for wheat across Romanian counties (Table 1 and Table 2– illustrated on rows) from year 1990 to 2023 (Table 1 and Table 2 - illustrated on columns) reveals significant regional variations and trends over time.

The chosen color scheme red – for the least productive and green – for the highest output, as well as the geolocation of each county has been closely correlated for a holistic picture that offers meaningful insights.

For instance, we can observe that in the year 2003 there has been exogenous factors that have negatively impacted the overall productivity, with a median value of 1.32 tonnes per hectare.

On the other hand, in the year 2021 the median productivity was 4.61 tonnes per hectare.

Wheat productivity, measured in tonnes per hectare, shows considerable variation across counties. High-performing counties such as Timiș (with a median value of 3.54 tonnes perhectare and a variance of 1.04), Călărași (with a median value of 3.51 tonnes per hectare and a variance of 1.83), and Satu Mare(with a median value of 3.44 tonnes per hectare and a variance of 0.43) consistently achieve higher yields, with some counties reporting production levels exceeding 5tonnes per hectare (Călărași and Timiș).

On average, wheat production across most counties fluctuates around 2 and 3 tonnes per hectare, with an average yield across counties and analysed period of 3.02 tonnes per hectar. This variability suggests that factors such as weather conditions, agricultural practices, and technological advancements play a significant role in influencing productivity.

Table 1. Visual map for wheat output in tonnes per hectare (average productivity for each county for 1990-2006 period)

Counties/Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Bihor	3.06	2.89	1.82	2.31	3.50	3.05	2.12	2.39	2.49	2.17	2.08	3.11	2.67	2.83	3.95	3.17	2.83
Bistrita-Nasaud	2.34	1.80	1.66	2.09	2.22	3.20	1.84	2.54	2.27	2.25	1.78	2.59	2.56	2.20	3.18	2.91	2.60
Cluj	2.38	1.92	2.16	1.87	3.18	3.37	2.17	2.82	2.48	2.30	1.69	2.75	2.95	2.40	3.84	2.96	2.83
Maramures	2.23	1.81	1.69	1.93	2.06	2.46	1.89	2.10	1.96	2.03	1.82	2.55	2.37	2.02	3.21	2.47	2.10
Satu Mare	3.54	3.17	2.74	2.42	3.65	3.83	2.77	2.90	2.33	2.59	2.46	3.45	3.36	2.85	4.20	3.67	3.06
Salaj	2.62	1.73	1.53	1.89	2.66	3.21	2.26	2.35	2.41	2.09	1.94	2.71	2.49	2.21	3.13	2.85	2.22
Alba	2.84	2.01	2.05	2.17	3.32	3.40	1.81	2.94	2.34	2.27	2.13	2.63	3.00	2.57	3.49	2.90	2.42
Brasov	3.21	2.20	2.40	2.99	2.97	3.30	2.21	2.85	2.84	2.99	2.74	3.39	2.62	2.48	2.28	2.62	2.22
Covasna	3.20	2.44	2.52	2.89	3.04	3.57	2.62	3.19	3.18	3.22	2.89	3.76	3.37	2.46	3.86	3.16	3.24
Harghita	2.37	1.94	1.80	1.94	2.25	2.55	1.94	2.16	2.11	2.18	1.89	2.73	2.23	1.60	2.80	2.87	1.94
Mures	3.54	2.55	2.26	2.37	3.54	3.72	2.42	3.04	2.24	2.20	2.08	3.05	2.76	2.45	4.01	3.44	2.60
Sibiu	2.93	1.53	2.23	2.26	2.50	3.12	1.74	2.54	2.07	2.20	2.04	2.56	2.64	2.56	3.49	2.98	2.45
Bacau	3.23	1.66	1.88	3.19	2.81	3.19	1.22	2.81	2.45	2.76	1.88	2.97	2.77	1.33	2.99	3.04	2.74
Botosani	3.08	2.26	1.70	2.30	2.01	2.76	0.32	2.23	2.47	2.28	1.40	2.20	2.79	0.17	0.80	2.69	2.51
Iasi	2.91	2.19	2.05	2.80	2.69	3.23	0.72	2.75	2.99	2.65	1.96	3.04	2.88	0.49	1.74	3.08	2.69
Neamt	3.93	2.15	2.22	3.61	3.73	3.62	1.33	2.94	2.34	2.87	2.20	3.25	2.95	1.02	2.80	3.04	2.70
Suceava	3.04	1.81	2.03	2.73	2.99	3.04	0.97	2.66	2.53	2.61	2.16	2.91	3.01	1.31	3.02	2.47	2.79
Vaslui	2.04	1.88	1.37	2.39	1.69	2.23	0.95	2.42	2.55	2.22	1.33	2.94	2.24	0.78	2.61	3.41	3.53
Braila	3.30	3.26	2.55	2.68	1.82	2.95	2.22	3.42	2.62	3.16	2.28	2.70	2.49	0.80	3.86	3.21	3.69
Buzau	1.98	2.78	2.40	1.69	0.73	2.61	1.37	3.13	2.26	2.83	2.44	2.87	0.57	0.05	2.83	2.67	2.48
Constanta	3.64	2.66	1.75	2.12	1.69	3.19	2.54	3.65	2.69	3.07	2.51	1.74	1.83	0.10	3.20	3.39	3.53
Galati	1.94	2.51	1.82	2.68	1.43	2.61	1.40	3.04	2.24	2.74	1.80	2.64	2.02	0.85	2.91	2.72	2.47
Tulcea	2.26	2.70	1.64	2.14	0.61	1.93	1.44	2.25	1.76	2.18	1.33	1.92	2.12	0.49	3.09	2.65	2.61
Vrancea	2.14	2.04	1.84	2.76	2.10	2.82	1.56	2.94	2.59	2.98	2.30	2.90	1.36	0.88	2.94	2.58	2.53
Arges	4.61	2.39	2.04	2.10	2.93	3.62	1.11	2.55	2.39	1.98	2.14	3.54	1.68	1.11	3.79	2.65	2.75
Calarasi	3.76	2.95	3.27	2.79	2.18	3.45	1.44	4.14	2.84	3.57	3.31	3.87	1.75	0.40	4.14	3.23	3.21
Dambovita	3.77	1.62	2.36	1.90	2.34	3.36	1.11	2.56	2.31	2.53	1.74	3.33	1.66	1.17	3.79	3.11	2.51
Giurgiu	3.66	1.79	2.65	2.74	2.21	3.09	1.35	2.78	2.41	2.73	2.46	3.15	1.61	1.10	3.65	2.24	2.41
Ialomita	3.52	2.93	2.90	1.86	1.40	2.89	1.83	3.95	2.64	3.30	2.89	2.64	1.36	0.26	3.13	2.89	2.48
Prahova	3.99	2.67	2.90	2.67	1.65	3.61	1.40	3.46	2.78	3.08	2.03	2.76	0.70	0.71	3.51	2.71	2.27
Teleorman	4.04	3.31	2.38	2.30	2.13	3.12	2.00	2.57	2.60	2.87	2.39	3.51	2.19	0.72	3.25	2.60	2.75
Ilfov	1.00	-	-	-	-	-	-	-	-	-	2.47	3.07	1.58	0.72	3.36	2.85	3.20
Bucharest	1.00	-	-	-	-	-	-	-	-	-	2.55	3.58	0.69	0.12	1.65	1.65	2.09
Dolj	4.06	2.95	2.15	1.57	3.10	2.26	1.07	2.82	2.42	2.63	1.78	2.85	0.26	1.44	3.19	3.17	2.50
Gorj	2.45	1.43	1.81	2.62	3.80	3.44	1.68	2.96	2.85	2.52	2.37	3.26	1.01	1.99	3.51	2.89	2.32
Mehedinti	2.85	2.10	1.41	1.89	2.74	3.08	1.04	3.57	2.78	2.28	1.89	3.36	2.51	2.43	3.63	3.11	2.72
Olt	3.91	3.21	2.80	2.05	3.56	3.74	1.02	2.87	2.55	2.87	2.49	3.66	1.21	0.97	3.30	2.56	2.09
Valcea	3.82	2.68	2.75	3.46	4.74	4.07	2.14	4.07	2.78	2.97	2.61	4.17	1.18	2.22	3.39	3.26	2.69
Arad	3.50	2.83	1.68	2.50	3.61	3.27	2.84	3.07	2.65	2.69	2.25	3.13	2.54	2.70	3.39	3.02	3.26
Caras-Severin	2.59	1.76	1.35	2.14	2.87	2.78	2.05	2.16	2.70	2.65	2.98	3.25	2.87	2.63	3.52	2.78	2.73
Hunedoara	2.43	1.90	2.04	2.38	2.91	3.34	2.16	2.64	2.56	2.54	2.53	2.84	2.84	2.53	3.70	2.80	2.84
Timis	3.44	3.00	1.95	2.63	4.00	3.39	2.31	2.89	3.18	2.74	2.57	3.74	3.21	3.32	4.63	3.53	3.08

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

Similarly, sunflowerseed productivity demonstrates regional differences, with the average crop productivity (output per hectare) across Romanian counties (Table 3 and Table 4 – illustrated on rows) from 1990 to 2023 (Table 3 and Table 4 – illustrated on columns) reveals significant regional variations and trends over time.

The chosen color scheme, with red representing the least productive counties and green for the highest output, as well as the geolocation of each county, has been closely correlated for a holistic view that offers meaningful insights.

For instance, in the year 2007, we can observe that exogenous factors, such as unfavorable weather or market conditions, resulted in a significant dip in productivity, with a median value of 0.72 tonnes per hectare. In contrast, in 2019 the productivity reached its peak, with a median value of 2.76 tonnes per hectare.

There is shown a considerable variation across counties for sunflower seed productivity, measured in tonnes per hectare.

Although there are high-performing counties such as Brașov (with a median value of 1.94 tonnes per hectare and a variance of 0.58), the total cultivated area as well as the period analyzed is not representative. Cluj, Neamț and Prahova on the other hand, obtained a median yield above 1.7 tonnes per hectare.

These counties report productivity levels in some of the years exceeding 3tonnes per hectare, with Vaslui standing out as the highest performer in 2018 with an average yield of 3.92 tonnes per hectare.

On average, sunflower seed production across counties fluctuates around 1 to 2 tonnes per hectare, with an average yield across counties for the analyzed period of 1.57tonnes per hectare and a median value of 1.46 tonnes per hectar.

Table 2. Visual map for wheat output in tonnes per hectare (average productivity for each county for 2007-2023 period)

Counties/Year	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bihor	2.28	3.74	1.88	3.12	3.92	2.95	3.98	3.76	3.78	2.94	4.11	4.17	4.36	4.07	4.17	3.83	4.11
Bistrita-Nasaud	2.51	3.04	2.17	1.95	3.62	2.19	2.74	3.30	3.24	3.14	3.15	3.18	3.27	3.78	4.08	3.90	3.39
Cluj	2.49	3.23	2.55	3.12	3.21	2.88	3.58	4.09	4.29	3.91	4.45	4.13	4.15	3.11	4.61	4.36	4.08
Maramures	2.01	2.72	2.31	1.93	3.08	2.39	2.75	3.19	3.29	3.27	3.98	4.12	3.98	3.46	4.54	5.00	3.79
Satu Mare	2.64	3.30	2.92	2.89	3.42	3.22	3.88	4.09	4.26	4.20	4.71	4.73	3.47	3.47	4.17	3.94	4.21
Salaj	2.00	2.96	1.52	2.05	2.95	2.55	2.95	3.29	3.18	3.31	3.99	3.87	3.51	3.61	3.59	3.54	3.29
Alba	2.58	3.08	2.10	2.94	3.61	2.55	3.57	4.29	4.00	4.15	4.48	4.63	4.30	3.28	4.87	4.51	4.85
Brasov	2.78	3.35	3.03	2.68	3.75	2.82	3.41	3.71	3.77	3.86	4.15	3.86	3.73	3.80	4.35	4.49	5.12
Covasna	2.78	4.05	3.28	2.65	3.88	2.58	3.01	3.29	3.20	3.40	4.54	4.11	4.04	3.31	3.93	3.76	3.65
Harghita	2.19	2.43	2.46	2.28	3.25	2.25	2.44	2.80	3.07	3.22	3.48	3.30	3.20	3.15	3.78	3.58	3.64
Mures	2.33	3.30	2.86	2.97	3.69	2.84	3.68	3.98	4.23	4.13	4.31	4.60	4.66	4.52	4.89	4.57	5.42
Sibiu	2.27	2.87	2.69	2.48	3.32	2.63	3.22	3.70	3.57	3.56	3.84	3.74	3.36	3.30	3.81	3.80	3.73
Bacau	1.84	3.09	2.28	2.71	3.68	2.39	3.28	3.11	3.17	3.59	4.30	4.47	3.85	3.37	4.38	2.53	3.22
Botosani	1.81	2.97	2.31	2.97	3.17	2.41	3.04	3.20	2.89	3.02	4.36	4.31	4.20	2.87	4.86	3.00	3.59
Iasi	1.29	2.99	2.04	2.54	3.10	2.24	3.06	3.18	3.01	3.61	4.40	4.16	4.08	3.04	4.66	2.56	3.88
Neamt	2.03	3.26	2.86	2.91	4.00	3.26	3.53	4.07	3.97	4.52	4.89	4.59	4.38	2.83	4.83	3.97	4.52
Suceava	2.96	2.97	2.98	2.50	3.07	2.42	2.74	3.26	2.67	3.23	4.00	3.80	3.78	3.53	3.83	3.63	4.79
Vaslui	1.42	3.69	3.00	2.54	3.37	1.99	3.24	3.34	2.80	3.67	4.05	3.77	3.87	2.40	4.38	2.71	3.37
Braila	1.96	3.95	2.60	3.11	3.81	3.36	4.41	4.07	4.38	4.97	5.25	5.27	5.12	2.09	5.37	3.75	4.71
Buzau	1.10	3.19	2.58	3.13	3.34	1.98	3.13	3.36	3.61	4.41	5.19	5.16	5.24	1.59	5.03	1.80	3.53
Constanta	1.45	3.92	2.18	2.63	4.31	3.04	2.92	3.28	3.79	4.01	5.41	5.68	4.75	0.98	5.09	4.99	4.05
Galati	1.54	3.41	1.79	2.45	3.15	1.14	3.10	3.63	3.06	4.20	4.19	3.74	4.09	1.60	5.43	1.73	2.49
Tulcea	0.86	3.03	1.35	2.41	3.41	1.23	2.97	3.66	3.72	4.07	4.71	4.59	3.71	1.58	4.74	3.21	2.99
Vrancea	1.57	3.69	2.50	2.52	3.37	2.02	3.21	3.07	3.01	3.44	4.47	4.51	4.19	1.26	4.41	1.37	3.61
Arges	1.68	3.24	2.81	2.36	3.57	3.13	3.14	2.83	2.67	2.87	4.22	3.54	4.20	3.01	4.49	3.77	4.24
Calarasi	1.16	3.88	2.13	2.50	4.04	2.88	4.59	4.24	5.12	5.05	5.55	5.65	5.79	1.81	5.33	5.04	4.25
Dambovita	1.49	3.07	2.67	2.19	3.33	2.01	3.05	3.00	2.77	3.07	3.90	3.32	4.20	3.00	3.59	3.96	4.69
Giurgiu	1.22	3.35	2.52	2.89	3.62	2.82	3.76	3.72	3.72	3.47	4.68	4.78	4.95	3.75	4.71	4.48	4.11
Ialomita	1.20	3.73	2.11	2.88	4.18	2.79	4.50	4.51	5.04	5.21	5.99	5.85	5.31	1.63	4.98	4.59	4.51
Prahova	1.56	3.17	2.82	2.60	3.47	2.20	3.58	3.44	3.72	4.09	4.59	3.59	5.06	2.24	4.41	3.99	5.01
Teleorman	1.17	3.40	2.28	2.64	3.79	2.42	3.11	3.39	3.46	3.61	5.11	4.78	5.03	4.21	4.94	4.37	4.42
Ilfov	1.00	3.37	2.22	3.01	3.79	2.85	4.17	4.04	4.23	4.16	4.58	4.27	4.60	3.35	5.04	4.39	4.53
Bucharest	0.70	-	-	4.53	-	-	-	3.75	-	-	-	-	5.71	-	-	-	-
Dolj	0.67	2.96	2.59	2.62	3.06	2.33	2.83	3.13	3.32	3.36	4.51	4.52	4.49	3.27	4.67	3.89	3.96
Gorj	1.58	2.84	2.66	2.68	3.56	2.22	3.12	3.30	3.07	3.18	4.41	4.48	3.72	3.21	3.66	3.73	3.38
Mehedinti	0.61	3.28	2.69	2.77	3.33	2.51	2.90	3.10	3.08	3.66	4.90	4.95	4.66	3.36	3.78	3.49	3.61
Olt	0,83	3.11	2.56	2.14	3.37	2.49	2.76	3.30	3.43	3.17	5.07	4.99	5.19	3.86	5.04	4.33	4.48
Valcea	2,05	3.18	3.17	2.82	3.61	2.47	3.23	3.27	3.30	3.11	4.03	3.79	4.79	3.59	3.93	3.24	3.31
Arad	2,63	3.41	2.50	3.22	3.92	3.75	4.47	4.22	4.30	4.93	5.31	5.38	5.18	3.72	5.05	4.41	4.81
Caras-Severin	2,06	2.90	2.83	2.72	3.11	2.74	2.98	3.31	2.80	3.98	4.68	4.23	4.35	4.41	4.63	4.31	4.14
Hunedoara	1,79	2.98	2.05	2.70	3.78	2.74	3.39	3.71	3.57	3.75	4.09	4.17	4.15	3.91	3.94	3.78	3.80
Timis	2,92	3.55	3.01	2.92	4.18	4.12	4.45	3.97	4.73	4.62	5.40	5.12	5.50	4.72	5.53	5.49	5.27

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

This variability suggests that factors such as soil quality, crop management practices, and climatic conditions play a significant role in influencing sunflower seed productivity.

This analysis underscores the importance of regional variations and highlights the need for tailored interventions to improve productivity in underperforming areas.

The evaluation of land use efficiency (Table 5 and Table 6), calculated as the percentage of efficiency relative to the baseline year of 1990, highlights significant regional differences in the effective use of resources for wheat and Table 7 and Table 8 for sunflower seed cultivation across Romanian counties.

Counties such as Cluj, Buzău, and Galați exhibit consistently high efficiency scores compared to the baseline year 1990 indicating that these regions have effectively optimized their use of resources.

These counties maintain efficiency levels above 1.0 for most years, suggesting that they have successfully increased their resource utilization.

In contrast, counties such as Argeș, Neamț and Prahovaillustrates greater variability in efficiency scores, with most years falling below baseline 1.0.

This suggests inefficiencies in resource use in these regions, likely influenced by factors such as inconsistent input use, suboptimal farming practices, or climatic conditions. Using a corroboration method between the average output (Table 1 and Table 2) and efficiency (Table 5 and Table 6) for wheat, we can visualize patterns and similarities.

For instance, both the production and efficiency for the year of 2003 were suboptimal, indicating negative exogenous factors, while for the year 2018 the production and efficiency were the highest, with median values around 2.6.

Table 3. Visual map for sunflower seed output in tonnes per hectare (average productivity for each county for 1990-2006 period)

Counties/Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Bihor	1.15	0.87	0.90	1.31	1.20	1.39	1.38	0.76	0.97	1.15	0.76	1.14	1.43	1.57	1.92	1.64	1.59
Bistrita-Nasaud	1.08	1.16	1.22	1.15	1.00	1.50	1.31	1.75	1.08	1.12	1.11	1.33	1.44	1.84	1.71	1.40	1.47
Cluj	1.11	1.11	0.79	1.35	0.99	1.11	1.35	1.42	1.03	1.09	0.99	1.43	1.92	1.98	1.86	1.75	1.88
Maramures	1.42	1.13	1.12	1.31	0.98	1.18	1.44	1.13	0.90	1.14	1.19	1.10	1.29	1.21	1.49	1.42	1.26
Satu Mare	1.02	0.95	1.36	1.13	1.31	1.37	1.48	0.77	0.86	1.24	1.19	1.21	1.39	1.60	1.80	1.45	1.61
Salaj	0.98	1.34	1.08	1.19	1.14	1.31	1.17	1.06	1.49	1.09	0.90	1.08	1.32	1.50	1.42	1.24	1.40
Alba	0.92	0.92	0.73	1.08	1.15	1.08	1.15	1.42	0.92	1.12	0.92	1.36	1.40	1.23	1.77	0.38	1.54
Brasov	-	0.32	1.06	-	-	-	-	-	-	-	-	2.00	0.96	-	-	-	-
Covasna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harghita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mures	0.75	0.75	0.80	1.32	1.39	1.53	1.39	1.27	0.97	1.17	1.21	1.35	1.44	1.55	1.61	1.20	1.63
Sibiu	-	-	-	0.90	1.25	1.31	1.27	0.72	0.35	0.70	0.41	0.95	1.11	0.73	1.00	0.96	1.43
Bacau	1.04	1.21	0.91	1.54	1.38	1.20	1.35	1.40	1.10	1.44	0.94	1.28	1.45	1.44	1.41	1.12	1.53
Botosani	1.25	1.15	1.11	1.34	1.13	1.06	0.95	1.07	0.94	1.48	0.96	1.21	1.80	1.55	0.94	1.16	1.28
Iasi	1.27	1.10	0.92	1.35	1.09	1.26	1.18	1.34	1.30	1.58	1.22	1.54	1.50	1.33	1.47	1.36	1.74
Neamt	-	0.67	0.87	1.25	1.30	1.65	1.06	1.41	1.09	1.38	1.32	1.39	1.49	1.70	1.69	1.17	1.73
Suceava	-	0.78	0.82	1.55	1.33	1.07	0.96	1.28	1.24	1.51	1.11	1.09	1.44	1.46	1.51	1.46	1.51
Vaslui	0.97	1.22	1.06	1.27	0.74	0.82	0.96	1.24	1.16	1.25	0.72	0.92	1.60	1.31	1.27	1.34	1.27
Braila	1.64	1.12	1.53	1.61	1.12	1.22	1.18	1.04	1.24	1.41	1.11	1.00	1.52	1.53	1.58	1.61	1.76
Buzau	1.60	1.51	1.53	1.64	1.39	1.54	1.32	1.21	1.19	1.49	1.15	1.06	0.51	1.67	1.64	1.35	1.49
Constanta	1.27	1.19	1.14	1.19	1.20	1.33	1.14	1.35	1.25	1.34	1.01	0.45	0.85	1.06	1.54	1.66	1.79
Galati	1.03	1.32	1.20	1.43	1.12	1.13	0.92	1.24	1.05	1.39	0.87	0.82	1.17	1.35	1.64	1.51	1.51
Tulcea	0.74	0.93	0.81	1.12	0.67	0.73	0.74	0.85	0.84	1.12	0.66	0.49	1.21	1.06	1.32	1.20	1.26
Vrancea	1.33	1.23	1.15	1.75	1.68	1.36	1.17	1.60	1.40	1.45	1.07	1.11	1.02	1.29	1.86	1.45	1.73
Arges	1.82	1.13	1.44	1.07	1.52	1.36	1.58	0.80	0.99	0.83	0.50	1.01	0.98	1.17	1.73	1.05	1.43
Calarasi	1.77	1.41	1.66	1.55	1.57	1.49	1.35	1.32	1.40	1.37	0.87	1.31	1.13	1.33	1.89	1.34	1.57
Dambovita	1.46	0.79	1.15	1.20	1.63	1.62	1.31	0.91	1.06	0.85	0.39	1.06	0.94	1.14	1.97	0.94	1.03
Giurgiu	1.81	0.90	1.08	1.08	1.38	1.26	1.12	0.96	1.04	1.03	0.49	1.19	0.91	1.00	1.55	0.98	1.30
Ialomita	1.84	1.42	1.77	1.54	1.47	1.40	1.33	1.37	1.38	1.52	1.17	1.11	0.87	1.25	1.84	1.14	1.67
Prahova	1.94	1.13	1.71	1.76	1.83	1.71	1.69	1.28	1.12	1.23	0.81	1.29	0.73	1.04	1.49	1.07	1.06
Teleorman	1.42	1.60	1.26	0.65	1.26	1.24	1.11	0.97	1.00	1.15	0.45	1.41	1.08	1.00	1.59	1.35	1.54
Ilfov	-	-	-	-	-	-	-	-	-	-	0.69	1.19	1.28	0.94	1.62	0.92	1.17
Bucharest	-	-	-	-	-	-	-	-	-	-	0.56	-	0.52	-	1.17	1.38	1.04
Doli	1.20	1.35	1.08	0.42	1.67	1.36	1.12	1.05	0.93	1.02	0.41	0.80	0.14	0.85	1.65	1.70	1.56
Gorj	1.27	1.24	1.02	0.93	1.38	0.80	0.91	1.11	0.81	0.82	0.44	0.93	0.46	0.91	1.12	1.00	-
Mehedinti	0.66	1.58	0.86	0.48	1.48	1.17	0.77	1.40	0.89	1.03	0.45	1.18	0.32	1.36	1.71	1.31	1.86
Olt	1.30	1.69	1.26	0.80	1.51	1.53	1.26	0.96	1.08	1.27	0.43	1.36	0.69	0.95	1.47	1.50	1.42
Valcea	-	-	1.07	1.05	1.58	2.23	2.22	1.51	1.18	0.85	0.33	0.75	1.19	1.27	2.39	0.71	1.52
Arad	1.49	1.24	1.31	1.44	1.58	1.48	1.39	0.82	0.94	1.11	0.93	1.32	1.64	1.56	1.57	1.34	1.49
Caras-Severin	1.06	0.68	0.75	0.77	0.98	1.13	0.89	0.78	1.22	1.25	0.92	1.51	1.40	1.70	1.86	1.28	1.59
Hunedoara	-	-	0.45	0.90	1.33	1.56	1.06	0.65	0.64	0.67	0.92	0.85	0.53	1.08	1.31	1.20	1.68
Timis	1.61	1.21	1.08	1.22	1.39	1.35	1.36	0.88	1.10	0.96	1.03	1.34	1.70	2.06	1.58	1.69	1.42

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

The evaluation of land use efficiency for sunflower seed cultivation (Table 7 and Table 8), calculated as the percentage of efficiency relative to the baseline year of 1990, reveals notable regional differences in the effective use of resources across Romanian counties.

Table 4. Visual map for sunflower seed output in tonnes per hectare (average productivity for each county for 2007-2023 period)

Counties/Year	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bihor	1.11	2.41	1.14	1.12	1.74	1.09	1.82	2.00	1.57	1.98	2.50	2.07	2.89	2.37	2.13	1.62	1.98
Bistrita-Nasaud	1.10	1.52	1.41	1.26	1.37	0.43	1.21	1.37	0.89	1.11	2.31	2.13	3.12	2.15	2.28	2.12	1.83
Cluj	1.20	1.84	1.74	1.71	2.16	1.43	2.33	2.49	2.16	2.31	2.60	3.14	3.05	2.49	2.71	2.13	2.21
Maramures	0.85	1.12	1.29	1.17	1.71	0.99	1.09	1.34	0.82	1.49	2.87	2.68	3.79	2.45	2.71	2.44	1.94
Satu Mare	1.09	1.72	2.13	1.59	2.09	1.87	2.37	2.14	1.76	2.16	3.55	3.58	2.97	2.45	2.71	1.82	1.86
Salaj	0.76	1.68	1.06	1.03	1.56	1.66	2.03	1.99	1.57	1.89	2.56	2.68	2.76	2.11	2.01	1.47	1.66
Alba	1.13	1.62	1.51	1.81	2.06	1.49	0.64	2.51	2.16	2.45	2.53	2.61	2.87	2.42	2.50	2.37	2.51
Brasov	-	1.50	-	-	-	-	-	-	1.85	1.91	1.98	2.74	2.12	1.50	2.65	2.44	3.13
Covasna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harghita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mures	1.32	1.67	1.41	1.82	2.24	1.36	2.24	2.26	2.08	2.19	2.96	3.05	2.62	2.44	3.03	2.93	2.93
Sibiu	0.90	1.19	0.98	1.40	1.56	1.11	1.39	1.73	1.67	1.75	2.12	2.53	2.38	2.24	2.09	2.27	2.48
Bacau	0.72	1.55	1.53	1.40	1.96	1.49	1.93	2.18	1.75	1.57	2.83	2.76	2.80	1.90	2.44	1.67	1.88
Botosani	0.90	1.41	1.42	1.43	1.64	0.90	1.99	2.17	1.63	1.41	3.04	3.07	2.07	1.87	2.71	1.78	2.03
Iasi	0.62	1.55	1.35	1.63	1.74	1.08	2.01	1.95	1.65	1.57	2.59	2.35	3.02	1.82	2.27	1.29	1.86
Neamt	1.06	1.84	1.90	1.40	1.95	1.87	2.58	2.34	2.03	2.25	2.90	3.32	2.91	1.91	2.56	2.12	2.41
Suceava	1.34	1.35	1.97	1.54	1.76	1.51	1.74	1.94	1.77	1.35	2.46	2.73	2.31	2.88	2.03	2.07	2.85
Vaslui	0.34	1.29	1.04	1.50	1.85	1.13	1.85	1.93	1.46	1.22	3.21	3.92	2.24	1.53	2.19	1.20	1.08
Braila	0.92	1.65	1.50	1.84	2.13	1.57	2.24	2.38	1.91	2.27	3.19	2.95	2.82	1.57	2.48	1.99	1.84
Buzau	0.53	1.02	1.66	1.66	1.63	1.14	1.73	1.92	1.53	2.02	3.08	2.91	2.99	1.52	2.50	1.18	1.46

Constanta	0.96	1.52	1.07	1.54	1.34	1.13	1.49	1.83	1.60	1.50	3.18	3.71	2.66	1.11	3.41	2.38	1.22
Galati	0.54	1.34	1.26	1.59	1.62	0.76	1.98	2.03	1.67	2.00	2.64	2.72	2.49	1.33	3.03	0.99	1.11
Tulcea	0.32	1.02	0.93	1.09	1.35	0.89	1.42	1.83	1.54	1.81	2.77	3.45	2.16	1.17	2.44	1.86	1.76
Vrancea	0.75	1.16	1.55	1.77	1.98	0.97	2.37	1.71	1.32	1.35	2.47	2.20	2.53	1.06	2.52	1.03	1.77
Arges	0.62	1.20	1.64	1.50	1.91	1.28	2.01	1.80	1.57	1.38	2.70	2.74	2.53	2.03	1.91	2.29	2.46
Calarasi	0.36	1.59	1.48	1.67	1.91	1.75	2.39	2.42	2.43	2.68	2.89	3.75	2.80	1.74	2.72	2.55	1.75
Dambovita	0.62	1.27	1.71	1.12	1.73	1.04	2.07	1.71	1.37	1.67	2.58	2.16	2.29	2.14	2.12	2.26	2.30
Giurgiu	0.21	1.09	1.66	1.51	1.95	1.40	2.46	2.30	1.92	1.71	2.88	2.97	2.45	1.98	2.21	2.57	2.22
Ialomita	0.42	1.46	1.42	1.74	2.05	1.68	2.33	2.57	2.19	2.50	3.12	2.67	2.73	1.36	2.64	2.48	2.01
Prahova	0.65	1.09	1.80	1.27	1.73	1.42	2.03	2.14	2.05	2.45	2.45	2.04	2.41	2.16	2.52	2.17	2.32
Teleorman	0.46	1.17	1.67	1.79	2.09	1.24	2.03	2.24	1.76	1.99	3.04	3.59	2.65	2.19	2.25	2.15	2.01
Ilfov	0.40	1.12	1.58	1.48	1.78	1.35	1.94	1.87	1.82	1.92	2.48	2.17	2.65	2.06	2.11	2.08	1.78
Bucharest	-	1.00	-	-	-	-	-	-	-	-	2.00	-	-	-	1.00	-	-
Dolj	0.43	1.49	1.67	1.80	1.83	1.21	1.78	2.21	1.66	1.70	3.03	2.77	2.95	2.04	2.83	2.04	2.01
Gorj	-	-	-	1.04	1.04	0.73	1.41	1.78	0.95	1.19	2.62	2.75	3.07	1.50	1.54	2.26	1.84
Mehedinti	0.18	1.22	1.48	1.79	1.67	1.12	1.60	1.91	1.42	2.41	3.71	3.70	3.31	2.37	2.06	1.83	1.78
Olt	0.41	1.39	1.60	1.69	1.62	1.19	1.86	2.18	1.63	1.28	3.20	3.27	3.06	1.96	2.24	2.13	2.02
Valcea	0.46	0.94	0.84	0.73	1.36	0.82	1.60	0.97	0.69	0.90	2.70	2.94	3.30	2.21	2.45	1.91	1.91
Arad	1.19	1.61	1.73	1.55	1.84	1.62	2.03	2.83	2.16	2.79	3.03	3.08	3.50	2.43	2.46	1.57	2.17
Caras-Severin	1.36	1.21	1.43	1.35	1.66	1.65	1.71	1.47	1.29	2.38	1.48	2.18	1.70	2.20	2.18	1.56	1.62
Hunedoara	0.23	1.36	0.72	1.58	2.02	1.27	1.99	2.02	1.43	1.65	1.46	2.67	2.28	1.84	2.16	1.58	2.06
Timis	1.13	1.90	1.99	1.58	2.42	1.92	2.80	3.36	2.20	2.99	2.20	2.55	3.53	2.83	2.46	2.04	2.60

Source: Authors' processed, analyzed and computed data from [21] dataset : AGR108A & AGR109A.

Table 5. Visual map for wheat efficiency having the year 1990 as baseline (for each county between 1991-2006 period)

Counties/Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Bihor	100%	95%	60%	76%	114%	100%	69%	78%	81%	71%	68%	102%	87%	92%	129%	104%	93%
Bistrita-Nasaud	100%	77%	71%	89%	95%	137%	79%	108%	97%	96%	76%	111%	109%	94%	136%	124%	111%
Cluj	100%	81%	91%	79%	134%	142%	91%	119%	104%	97%	71%	116%	124%	101%	161%	125%	119%
Maramures	100%	81%	76%	86%	92%	110%	85%	94%	88%	91%	81%	114%	106%	91%	144%	111%	94%
Satu Mare	100%	89%	77%	68%	103%	108%	78%	82%	66%	73%	70%	97%	95%	80%	118%	104%	86%
Salaj	100%	66%	59%	72%	102%	123%	86%	90%	92%	80%	74%	104%	95%	84%	120%	109%	85%
Alba	100%	71%	72%	76%	117%	120%	64%	104%	83%	80%	75%	93%	106%	91%	123%	102%	86%
Brasov	100%	69%	75%	93%	92%	103%	69%	89%	89%	93%	85%	105%	81%	77%	71%	82%	69%
Covasna	100%	76%	79%	90%	95%	111%	82%	100%	99%	100%	90%	118%	105%	77%	120%	99%	101%
Harghita	100%	82%	76%	82%	95%	108%	82%	91%	89%	92%	80%	115%	94%	68%	118%	121%	82%
Mures	100%	72%	64%	67%	100%	105%	68%	86%	63%	62%	59%	86%	78%	69%	113%	97%	74%
Sibiu	100%	52%	76%	77%	85%	106%	60%	87%	71%	75%	70%	87%	90%	88%	119%	102%	84%
Bacau	100%	51%	58%	99%	87%	99%	38%	87%	76%	85%	58%	92%	86%	41%	93%	94%	85%
Botosani	100%	74%	55%	75%	65%	90%	11%	73%	80%	74%	46%	72%	91%	5%	26%	87%	82%
Iasi	100%	75%	70%	96%	92%	111%	25%	94%	103%	91%	67%	104%	99%	17%	60%	106%	92%
Neamt	100%	55%	57%	92%	95%	92%	34%	75%	60%	73%	56%	83%	75%	26%	71%	77%	69%
Suceava	100%	59%	67%	90%	98%	100%	32%	87%	83%	86%	71%	96%	99%	43%	99%	81%	92%
Vaslui	100%	92%	67%	117%	83%	109%	47%	119%	125%	109%	65%	144%	110%	38%	128%	167%	173%
Braila	100%	99%	77%	81%	55%	89%	67%	103%	79%	96%	69%	82%	75%	24%	117%	97%	112%
Buzau	100%	140%	121%	85%	37%	131%	69%	158%	114%	143%	123%	145%	29%	3%	143%	135%	125%
Constanta	100%	73%	48%	58%	46%	88%	70%	100%	74%	84%	69%	48%	50%	3%	88%	93%	97%
Galati	100%	130%	94%	138%	74%	135%	72%	157%	116%	142%	93%	136%	104%	44%	150%	140%	128%
Tulcea	100%	119%	72%	95%	27%	85%	64%	99%	78%	96%	59%	85%	94%	22%	136%	117%	115%
Vrancea	100%	96%	86%	129%	98%	132%	73%	138%	121%	140%	107%	136%	64%	41%	138%	121%	119%
Arges	100%	52%	44%	45%	64%	79%	24%	55%	52%	43%	46%	77%	37%	24%	82%	58%	60%
Calarasi	100%	78%	87%	74%	58%	92%	38%	110%	76%	95%	88%	103%	47%	11%	110%	86%	85%
Dambovita	100%	43%	62%	50%	62%	89%	29%	68%	61%	67%	46%	88%	44%	31%	101%	83%	67%
Giurgiu	100%	49%	72%	75%	60%	85%	37%	76%	66%	75%	67%	86%	44%	30%	100%	61%	66%
Ialomita	100%	83%	82%	53%	40%	82%	52%	112%	75%	94%	82%	75%	39%	8%	89%	82%	70%
Prahova	100%	67%	73%	67%	41%	90%	35%	87%	69%	77%	51%	69%	17%	18%	88%	68%	57%
Teleorman	100%	82%	59%	57%	53%	77%	50%	64%	64%	71%	59%	87%	54%	18%	80%	64%	68%
Ilfov	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bucharest Municipality	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dolj	100%	73%	53%	39%	76%	56%	26%	69%	60%	65%	44%	70%	6%	35%	78%	78%	61%
Gorj	100%	58%	74%	107%	155%	140%	68%	121%	116%	103%	97%	133%	41%	81%	143%	118%	95%
Mehedinti	100%	74%	50%	66%	96%	108%	37%	125%	98%	80%	66%	118%	88%	85%	127%	109%	96%
Olt	100%	82%	72%	52%	91%	96%	26%	73%	65%	73%	64%	93%	31%	25%	84%	66%	53%
Valcea	100%	70%	72%	91%	124%	106%	56%	106%	73%	78%	68%	109%	31%	58%	89%	85%	70%
Arad	100%	81%	48%	71%	103%	93%	81%	88%	76%	77%	64%	89%	73%	77%	97%	86%	93%
Caras-Severin	100%	68%	52%	83%	111%	107%	79%	83%	104%	102%	115%	125%	111%	102%	136%	107%	105%
Hunedoara	100%	78%	84%	98%	120%	137%	89%	109%	106%	105%	104%	117%	117%	104%	153%	115%	117%
Timis	100%	87%	57%	77%	117%	99%	67%	84%	92%	80%	75%	109%	93%	97%	135%	103%	90%

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

High-performing counties such as Mureș, Mehedinți and Tulcea exhibit consistently high efficiency scores, indicating that these regions have successfully optimized their resource use over time.

These counties maintain efficiency levels well above 1.0 (100%) for most years, suggesting that they have effectively increased their resource utilization since 1990.

For instance, Mehedinți consistently achieves high efficiency, with an average score above 2.4, indicating the effective management of land and resources in sunflower seed production.

However, the higher values could be correlated to a lower baseline production in the year 1990.

Table 6. Visual map for wheat efficiency having the year 1990 as baseline (for each county between 1997-2023 period)

Counties/Year	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bihor	75%	122%	62%	102%	128%	96%	130%	123%	124%	96%	134%	136%	143%	133%	137%	125%	134%
Bistrita-Nasaud	107%	130%	93%	83%	154%	93%	117%	141%	138%	134%	134%	136%	140%	161%	174%	167%	145%
Cluj	105%	136%	107%	131%	135%	121%	150%	172%	181%	165%	187%	174%	175%	131%	194%	183%	172%
Maramures	90%	122%	104%	87%	138%	107%	123%	143%	147%	147%	179%	185%	179%	155%	203%	224%	170%
Satu Mare	74%	93%	83%	82%	97%	91%	109%	115%	120%	119%	133%	133%	98%	98%	118%	111%	119%
Salaj	77%	113%	58%	79%	113%	98%	113%	126%	122%	127%	153%	148%	134%	138%	137%	136%	126%
Alba	91%	109%	74%	104%	127%	90%	126%	151%	141%	146%	158%	163%	151%	116%	172%	159%	171%
Brasov	87%	104%	94%	83%	117%	88%	106%	116%	118%	120%	129%	120%	116%	118%	135%	140%	160%
Covasna	87%	126%	103%	83%	121%	80%	94%	103%	100%	106%	142%	128%	126%	104%	123%	117%	114%
Harghita	93%	103%	104%	96%	137%	95%	103%	118%	130%	136%	147%	140%	135%	133%	160%	151%	154%
Mures	66%	93%	81%	84%	104%	80%	104%	113%	119%	117%	122%	130%	132%	128%	138%	129%	153%
Sibiu	78%	98%	92%	85%	113%	90%	110%	126%	122%	122%	131%	128%	115%	113%	130%	130%	127%
Bacau	57%	96%	71%	84%	114%	74%	102%	97%	98%	111%	133%	139%	119%	104%	136%	79%	100%
Botosani	59%	97%	75%	97%	103%	78%	99%	104%	94%	98%	142%	140%	137%	93%	158%	97%	117%
Iasi	44%	103%	70%	87%	106%	77%	105%	109%	103%	124%	151%	143%	140%	104%	160%	88%	133%
Neamt	52%	83%	73%	74%	102%	83%	90%	103%	101%	115%	124%	117%	111%	72%	123%	101%	115%
Suceava	97%	97%	98%	82%	101%	79%	90%	107%	88%	106%	131%	125%	124%	116%	126%	119%	157%
Vaslui	70%	181%	147%	125%	165%	97%	159%	164%	137%	180%	199%	185%	190%	118%	215%	133%	165%
Braila	59%	120%	79%	94%	115%	102%	133%	123%	133%	150%	159%	160%	155%	63%	163%	113%	143%
Buzau	56%	161%	130%	158%	169%	100%	158%	170%	182%	222%	261%	260%	264%	80%	253%	91%	178%
Constanta	40%	108%	60%	72%	118%	84%	80%	90%	104%	110%	149%	156%	130%	27%	140%	137%	111%
Galati	80%	176%	92%	126%	163%	59%	160%	187%	158%	217%	216%	193%	211%	82%	280%	89%	129%
Tulcea	38%	134%	60%	107%	151%	54%	131%	162%	164%	180%	208%	203%	164%	70%	209%	142%	132%
Vrancea	73%	173%	117%	118%	158%	95%	150%	144%	141%	161%	209%	211%	196%	59%	206%	64%	169%
Arges	36%	70%	61%	51%	78%	68%	68%	61%	58%	62%	92%	77%	91%	65%	97%	82%	92%
Calarasi	31%	103%	57%	66%	108%	77%	122%	113%	136%	134%	148%	151%	154%	48%	142%	134%	113%
Dambovita	40%	81%	71%	58%	88%	53%	81%	80%	74%	81%	104%	88%	112%	79%	95%	105%	125%
Giurgiu	33%	92%	69%	79%	99%	77%	103%	102%	102%	95%	128%	131%	135%	102%	129%	122%	112%
Ialomita	34%	106%	60%	82%	119%	79%	128%	128%	143%	148%	170%	166%	151%	46%	141%	130%	128%
Prahova	39%	79%	71%	65%	87%	55%	90%	86%	93%	102%	115%	90%	127%	56%	110%	100%	125%
Teleorman	29%	84%	56%	65%	94%	60%	77%	84%	86%	89%	127%	119%	125%	104%	122%	108%	110%
Ilfov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100%
Bucharest Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100%
Doli	17%	73%	64%	65%	75%	57%	70%	77%	82%	83%	111%	111%	111%	81%	115%	96%	98%
Gori	64%	116%	108%	109%	145%	91%	127%	135%	125%	129%	180%	183%	152%	131%	149%	152%	138%
Mehedinti	21%	115%	94%	97%	117%	88%	102%	109%	108%	129%	172%	174%	164%	118%	133%	122%	127%
Olt	21%	80%	65%	55%	86%	64%	71%	84%	88%	81%	130%	128%	133%	99%	129%	111%	115%
Valcea	54%	83%	83%	74%	94%	65%	85%	86%	86%	81%	105%	99%	125%	94%	103%	85%	86%
Arad	75%	97%	71%	92%	112%	107%	128%	121%	123%	141%	152%	154%	148%	106%	144%	126%	138%
Caras-Severin	79%	112%	109%	105%	120%	106%	115%	128%	108%	153%	181%	163%	168%	170%	179%	166%	160%
Hunedoara	74%	123%	84%	111%	156%	113%	139%	153%	147%	154%	169%	172%	171%	161%	162%	156%	157%
Timis	85%	103%	88%	85%	122%	120%	130%	116%	138%	135%	157%	149%	160%	137%	161%	160%	153%

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

In contrast, counties such as Argeș, Giurgiu and Prahova show greater variability in their efficiency scores, with many years falling below the baseline of 1.0.

This suggests inefficiencies in land use in these regions, which could be due to factors such as inconsistent input use, suboptimal farming practices, or adverse climatic conditions.

For example, Argeș demonstrates fluctuating efficiency scores, often dipping below 0.5.

This points to the challenges faced in these areas in optimizing land resources for sunflower seed cultivation.

Using a corroboration method between the average output (Table 3 and Table 4) and efficiency (Table 7 and Table 8) for sunflower seed, we can observe clear patterns and correlations.

For example, in 2007, both sunflower seed production and efficiency were suboptimal across many counties, with low efficiency scores correlating with reduced productivity. Conversely, in 2018, both sunflower seed production and efficiency were at their peak, with counties like Brașov and Timiș.

This shows a high production level and efficiency scores exceeding 2.44, indicating an optimal use of resources in the both counties.

Counties such as Mehedinți, Cluj and Satu Mare exhibit a strong and consistent performance in sunflower seed efficiency during the period 1991–2006 (Table 7). These counties register values well above the baseline of 100% in most years, with peaks exceeding 150%–160%, suggesting a significant improvement in land use efficiency relative to 1990.

Table 7. Visual map for sunflower seed efficiency having the year 1990 as baseline (for each county between 1991-2006 period)

Counties/Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
Bihor	100%	75%	78%	114%	105%	121%	120%	66%	85%	100%	66%	99%	124%	137%	167%	143%	138%
Bistrita-Nasaud	100%	108%	113%	107%	93%	139%	122%	163%	101%	104%	103%	124%	134%	171%	159%	131%	137%
Cluj	100%	100%	71%	122%	89%	100%	122%	127%	92%	98%	89%	129%	173%	178%	168%	157%	170%
Maramures	100%	80%	79%	92%	69%	83%	101%	80%	63%	80%	83%	78%	91%	85%	105%	100%	88%
Satu Mare	100%	93%	133%	111%	128%	134%	144%	75%	84%	121%	116%	118%	135%	157%	176%	141%	157%
Salaj	100%	137%	110%	121%	116%	133%	119%	108%	152%	111%	92%	110%	134%	153%	145%	126%	143%
Alba	100%	100%	80%	119%	126%	118%	125%	155%	101%	123%	101%	148%	153%	134%	194%	41%	169%
Brasov	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Covasna	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harghita	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mures	100%	100%	107%	176%	185%	203%	184%	169%	129%	155%	160%	179%	191%	206%	214%	159%	216%
Sibiu	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bacau	100%	116%	88%	148%	133%	116%	129%	135%	106%	139%	90%	123%	139%	139%	135%	107%	147%
Botosani	100%	92%	89%	107%	90%	85%	76%	86%	75%	118%	76%	97%	144%	124%	75%	93%	102%
Iasi	100%	87%	73%	106%	86%	99%	93%	106%	103%	125%	96%	122%	119%	105%	116%	107%	137%
Neamt	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suceava	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaslui	100%	125%	109%	130%	76%	84%	98%	127%	119%	128%	74%	94%	165%	134%	131%	138%	131%
Braila	100%	68%	94%	98%	68%	75%	72%	63%	76%	86%	68%	61%	93%	93%	96%	98%	107%
Buzau	100%	94%	96%	103%	87%	96%	83%	76%	74%	93%	72%	66%	32%	105%	103%	84%	93%
Constanta	100%	94%	90%	94%	95%	105%	90%	106%	98%	105%	80%	36%	67%	83%	121%	131%	142%
Galati	100%	128%	117%	139%	109%	110%	89%	120%	103%	135%	85%	80%	114%	131%	159%	147%	147%
Tulcea	100%	126%	109%	151%	90%	99%	99%	115%	113%	151%	89%	66%	163%	143%	178%	162%	170%
Vrancea	100%	93%	86%	132%	126%	103%	88%	121%	106%	109%	81%	84%	77%	97%	140%	109%	130%
Arges	100%	62%	79%	59%	84%	75%	87%	44%	54%	45%	28%	55%	54%	64%	95%	58%	79%
Calarasi	100%	79%	93%	87%	88%	84%	76%	75%	79%	77%	49%	74%	64%	75%	106%	75%	89%
Dambovita	100%	54%	78%	82%	112%	111%	89%	63%	72%	58%	27%	73%	64%	78%	135%	64%	71%
Giurgiu	100%	50%	60%	59%	76%	70%	62%	53%	58%	57%	27%	66%	50%	55%	86%	54%	72%
Ialomita	100%	77%	96%	84%	80%	76%	72%	74%	75%	82%	64%	60%	47%	68%	100%	62%	91%
Prahova	100%	59%	89%	91%	94%	88%	87%	66%	58%	64%	42%	67%	38%	54%	77%	55%	55%
Teleorman	100%	113%	89%	45%	89%	87%	78%	68%	70%	81%	32%	99%	76%	70%	112%	95%	108%
Ilfov	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bucharest Municipality	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dolj	100%	112%	90%	35%	139%	114%	93%	88%	77%	85%	34%	67%	12%	71%	138%	142%	130%
Gorj	100%	98%	80%	73%	109%	63%	72%	88%	64%	65%	35%	73%	36%	72%	88%	79%	-
Mehedinti	100%	239%	129%	72%	223%	176%	117%	212%	134%	156%	68%	178%	48%	205%	257%	197%	281%
Olt	100%	130%	97%	62%	116%	118%	97%	74%	83%	98%	33%	104%	53%	73%	113%	115%	110%
Valcea	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arad	100%	84%	88%	97%	106%	99%	93%	55%	63%	75%	62%	89%	111%	105%	106%	90%	100%
Caras-Severin	100%	64%	70%	73%	92%	107%	84%	73%	115%	118%	86%	142%	132%	160%	175%	120%	150%
Hunedoara	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Timis	100%	75%	67%	75%	86%	84%	84%	55%	68%	59%	64%	83%	105%	128%	98%	105%	88%

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A

For instance, Mehedinți stands out in 2006 with an efficiency score of 281%, confirming the successful optimization of agricultural practices and stable productivity gains in the eastern region of the country.

On the other hand, counties such as Argeș, Giurgiu, and Ialomița show prolonged inefficiencies across the same period, with efficiency values often below 70%, and in some years even below 50%. These patterns highlight persistent structural challenges in these regions, including possible underinvestment, low technological uptake, and suboptimal input allocation in sunflower cultivation.

Between 2007 and 2023 (Table 8), the efficiency dynamics evolve further. Alba, Mureș, and Mehedinți emerge as top performers, consistently scoring over 140%, with several years peaking above 200%. This reflects long-term improvements in agricultural productivity, mechanization, and climate adaptation strategies. Mureș, in particular, reaches an efficiency score of 388% in 2023, reinforcing its position as a benchmark county for optimal land use in sunflower production.

In contrast, Călărași, Constanța, and Buzău continue to display low efficiency scores, remaining below baseline in numerous years. Notably, Călărași only rarely surpasses 100%, while Constanța falls below 100% in the year 2023. These trends underline enduring regional disparities and the need for targeted agricultural policy interventions.

Additionally, the southern and south-eastern counties, such as Galați, demonstrate moderate yet steadily improving efficiency trajectories, often crossing the 120% mark post-2015. These gains may be associated with better irrigation systems and favorable climatic conditions in recent years.

Overall, the spatial and temporal patterns identified in Tables 7 and 8 confirm the existence of regional inequalities in sunflower efficiency across Romania.

Table 8. Visual map for sunflower seed efficiency having the year 1990 as baseline (for each county between 2007-2023 period)

Counties/Year	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bihor	96%	209%	99%	97%	151%	94%	158%	174%	136%	172%	218%	180%	251%	206%	185%	141%	172%
Bistrita-Nasaud	102%	141%	131%	117%	128%	40%	113%	127%	83%	104%	215%	198%	290%	200%	212%	197%	170%
Cluj	109%	166%	156%	154%	194%	129%	210%	224%	195%	208%	234%	283%	275%	225%	244%	192%	199%
Maramures	60%	78%	91%	82%	120%	70%	77%	94%	57%	104%	202%	188%	266%	172%	191%	171%	136%
Satu Mare	106%	168%	208%	155%	204%	182%	232%	209%	171%	211%	347%	350%	291%	239%	265%	178%	182%
Salaj	78%	171%	108%	105%	158%	169%	207%	203%	160%	192%	261%	273%	281%	215%	205%	150%	170%
Alba	124%	178%	165%	198%	225%	163%	70%	275%	236%	268%	276%	285%	313%	264%	274%	259%	274%
Brasov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Covasna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harghita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mures	175%	221%	187%	241%	297%	180%	297%	300%	276%	290%	392%	405%	347%	323%	401%	388%	388%
Sibiu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bacau	70%	149%	147%	135%	189%	143%	185%	210%	168%	151%	272%	265%	270%	183%	235%	160%	181%
Botosani	72%	113%	113%	114%	131%	72%	159%	174%	130%	113%	243%	245%	166%	150%	216%	142%	162%
Iasi	49%	122%	106%	129%	138%	85%	159%	154%	130%	124%	205%	186%	238%	144%	179%	102%	147%
Neamt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suceava	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaslui	35%	132%	106%	154%	190%	116%	190%	199%	150%	125%	330%	402%	230%	157%	224%	123%	111%
Braila	56%	101%	92%	112%	130%	96%	136%	145%	117%	139%	195%	180%	172%	96%	151%	121%	112%
Buzau	33%	64%	104%	104%	102%	71%	109%	120%	96%	126%	193%	182%	187%	95%	157%	74%	91%
Constanta	76%	120%	84%	121%	106%	89%	118%	145%	126%	118%	251%	293%	210%	88%	269%	188%	96%
Galati	53%	130%	123%	154%	157%	74%	193%	197%	162%	194%	257%	265%	242%	129%	294%	97%	107%
Tulcea	43%	137%	125%	147%	183%	120%	192%	247%	208%	244%	374%	465%	291%	158%	329%	251%	238%
Vrancea	56%	87%	116%	133%	149%	73%	178%	128%	99%	102%	186%	165%	191%	80%	190%	78%	134%
Arges	34%	66%	90%	82%	105%	70%	111%	99%	86%	76%	148%	151%	139%	112%	105%	126%	135%
Calarasi	21%	90%	84%	94%	108%	99%	134%	137%	137%	151%	163%	211%	158%	98%	153%	144%	99%
Dambovita	42%	87%	117%	76%	118%	71%	142%	117%	94%	114%	177%	148%	157%	147%	145%	155%	158%
Giurgiu	12%	60%	92%	83%	107%	78%	136%	127%	106%	94%	159%	164%	135%	110%	122%	142%	122%
Ialomita	23%	79%	77%	94%	111%	91%	127%	140%	119%	136%	169%	145%	148%	74%	143%	134%	109%
Prahova	34%	56%	93%	66%	89%	74%	105%	111%	106%	126%	126%	106%	124%	112%	130%	112%	120%
Teleorman	32%	82%	117%	126%	147%	87%	143%	158%	124%	140%	214%	252%	186%	154%	158%	151%	141%
Ilfov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bucharest Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dolj	36%	124%	139%	150%	153%	101%	148%	185%	138%	142%	253%	231%	246%	171%	236%	170%	168%
Gorj	-	-	-	82%	82%	58%	111%	140%	75%	94%	206%	217%	242%	118%	122%	178%	145%
Mehedinti	27%	184%	223%	271%	252%	169%	241%	288%	214%	363%	559%	558%	499%	358%	311%	276%	268%
Olt	31%	107%	123%	130%	125%	92%	143%	168%	126%	99%	247%	252%	236%	151%	173%	164%	156%
Valcea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arad	80%	108%	116%	104%	124%	109%	136%	191%	146%	188%	204%	207%	235%	163%	165%	106%	146%
Caras-Severin	128%	114%	134%	127%	157%	156%	161%	139%	122%	224%	139%	205%	160%	207%	206%	147%	153%
Hunedoara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Timis	70%	118%	123%	98%	150%	119%	174%	208%	136%	185%	137%	158%	219%	175%	152%	127%	161%

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

CONCLUSIONS

The analysis of wheat and sunflower seed productivity and land use efficiency across Romanian counties from 1990 to 2023 reveals significant regional disparities. High-performing counties have consistently optimized resource utilization, maintaining efficiency levels above the baseline year of 1990. These counties not only demonstrate high productivity but also ensure that their resource use is sustainable and effective. In contrast, underperforming counties exhibit greater variability in their efficiency scores, with many years falling below the baseline, indicating challenges in resource optimization. Factors such as inconsistent input use, suboptimal farming practices, and adverse climatic conditions contribute to the inefficiencies observed in these regions.

The correlation between average productivity and efficiency scores highlights critical years where both production and efficiency were suboptimal, such as in 2003, and those where they were at their peak, such as in 2018. These trends emphasize the role of external factors (e.g., climate, soil conditions) in influencing agricultural performance and underscore the importance of stable resource management and adaptation to changing conditions.

We must acknowledge the limitation for the use of 1990 as the baseline for efficiency that may not capture the full spectrum of agricultural changes. Future studies could consider additional baseline years or more granular data to enhance the accuracy of efficiency scores. Inconsistent data reporting across counties may affect the reliability of the analysis. More comprehensive and consistent data would improve the robustness of the findings. Also, factors such as government policies, market fluctuations, and economic crises were not fully considered. These external elements may significantly influence productivity and efficiency, and should be incorporated in future studies. Moreover, briefly mentioned, the impact of climate change and extreme weather events on

productivity and efficiency was not deeply explored. Future studies should consider environmental variability and its effects on crop performance. On the other hand, future research could also consider using multiple baseline years or extending the study period to better understand long-term trends in productivity and efficiency.

In conclusion, while this study provides valuable insights into the agricultural performance of Romanian counties, addressing these limitations in future research will enhance the understanding of the factors influencing land use efficiency and productivity, ultimately leading to more effective interventions for improving agricultural outcomes. For the moment, communication and information exchange on agricultural practices is the relevant intervention with immediate effect, that can take place between high-performing and underperforming counties in order to align yields performance among different geolocations.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ASSESSING REGIONAL WHEAT AND SUNFLOWER PRODUCTIVITY IN ROMANIA PRE AND POST E.U. ACCESSION: A COMPARATIVE STUDY OF 1990–2006 vs 2007–2023

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Abstract

This study examines the evolution of agricultural productivity for two key arable crops: wheat and sunflower cross all 41 Romanian counties (plus the Municipality of Bucharest) by comparing two distinct periods: 1990–2006 and 2007–2023. The analysis aims to quantify changes in crop yields (tonnes per hectare) between the pre and post European Union accession eras, evaluate regional disparities in performance, and assess the consistency and variability of outputs over time. Using official statistics from the Romanian National Institute of Statistics (INS) and summary indicators (period averages, standard deviations, and growth percentages), we find that average wheat yields increased by approximately 40% (from about 2.5 to 3.5 tonnes/ha) and sunflower yields by about 58% (from roughly 1.2 to 1.9 tonnes/ha) between the two periods. These substantial productivity gains are accompanied by notable spatial variability: traditionally high-performing counties – such as Timiș, Călărași, Dolj, and Teleorman – maintained their lead, while several less productive counties (e.g. Botoșani, Vaslui) also improved but continue to lag behind the national average. Variability in yields tended to increase in the latter period, with more pronounced year-to-year fluctuations, likely due to climatic volatility and uneven adoption of modern farming techniques. The findings underscore the impact of post 2007 agricultural policies and investments on crop performance, as well as the enduring influence of structural factors (farm size, infrastructure) and climate. We suggest targeted interventions, including improved irrigation infrastructure, dissemination of advanced agronomic practices, and regions specific support, to enhance productivity in underperforming areas and mitigate the growing yield variability. This comparative regional analysis offers insights for policymakers on how to booster the productivity and resilience of Romanian agriculture in the context of both European integration and climate challenges.

Key words**:** *agricultural productivity, wheat; sunflower, yield variability, impact pre and post EU accession*

INTRODUCTION

Agriculture remains a vital component of Romania's economy and rural livelihood, even as the country underwent major socio-economic transformations in the past three decades. As of 2022, roughly 23% of Romania's labor force is employed in agriculture, the highest share among EU member states [10]. The analysis of the technical efficiency in Romanian agriculture highlights the importance of farm size in the efficient use of production factors [4]. Determinants of technical efficiency in agriculture differ among new EU member states, reflecting diverse structural and policy environments [3]. The technical efficiency in cereal production varies across EU countries, influenced by several socio-economic factors [1]. Sunflower crops in Europe are vulnerable to climate change, necessitating adaptation and mitigation strategies [8]. The country's agricultural sector benefits from extensive arable land (over 13 million hectares) and a favorable climate, giving it significant production potential. Land reform processes in Central and Eastern Europe have led to significant land fragmentation, posing challenges for efficient agricultural production [14]. The CAP subsidies have a significant impact on the technical efficiency of Romanian farms, as demonstrated by the stochastic frontier analysis [13]. In the early 1990s, land reform and restitution policies led to the breakup of former collective farms, returning land to millions of private owners [11]. This process resulted in highly fragmented farm structures – by the late 1990s about 90% of

farms operated on less than 5 hectares [11], which posed challenges for efficient, large-scale production. Land fragmentation remains a persistent issue in Southern Romania, affecting agricultural productivity and land use efficiency [9]. Climate change effects on crop yield anomalies in Europe underscore the need for resilient agricultural practices [20]. Since joining the EU in 2007, Romania has gradually integrated into the Common Agricultural Policy (CAP) framework, accessing subsidies and development programs aimed at modernizing the sector [10]. These changes coincided with increased mechanization, adoption of improved crop varieties, and better farm management practices, which collectively have driven yield growth in many areas. Also, the degree of involvement of the rural population in the decision-making process is an important factor that can influence the adoption of modern technologies in agriculture and, consequently, local productivity [7].

Given this context, this study seeks to analyze wheat and sunflower productivity across Romanian counties by comparing two periods, 1990–2006 and 2007–2023, roughly representing the pre- and post-EU accession eras. By conducting a county-level comparison of average yields, variability (standard deviation), and growth rates, we aim to identify how regional disparities have evolved, which areas have achieved the greatest improvements, and whether the consistency of production has changed over time. This research contributes to understanding the long-term trends in Romanian agricultural performance and provides a basis for discussing policy implications related to regional development, land consolidation, and adaptation to climatic risks. Climate change has notably impacted the yields of wheat, maize, and sunflower in Romania between 2017 and 2021 [17].

Agricultural productivity – commonly measured as crop yield (output per hectare – t/ha) – is a core indicator of performance in the agrarian sector. In transitioning economies like Romania, productivity trends reflect both structural changes (land ownership, farm size, technology adoption) and environmental factors (climate variability, soil conditions) [18, 7]. A body of research has examined the post-socialist evolution of agriculture in Central and Eastern Europe, highlighting that the dismantling of collective farming and the subsequent restitution of land often led to initial declines or stagnation in productivity due to farm fragmentation and loss of economies of scale [19, 13]. A study found that in Romania the early transition period was marked by a sharp drop in agricultural output, followed by gradual improvement as new private farms restructured and adapted [19]. It has been documented how policy shifts and land-use changes in post-communist Romania have unevenly influenced regions, with some areas experiencing intensification of production and others facing persistent inefficiencies [2]. It has been noted significant spatial differences in Romania's farm productivity, correlating these with socio-economic determinants such as farm fragmentation, access to markets, and infrastructure quality [16]. Moreover, the non-parametric analysis also reveals disparities in technical efficiency among ex-communist countries, like Bulgarian farms, highlighting areas for improvement [12]. Counties in the southern plains and western part of Romania generally show higher crop yields, attributed to larger average farm sizes, better soils (e.g. chernozem in the Danube Plain), and greater access to irrigation. In contrast, counties in the north-east (Moldavia region) or those with more difficult terrain (e.g., the Carpathian highlands) often lag in productivity [16]. These disparities align with findings in other post-socialist countries, for instance, a study observed in Poland that farm technical efficiency varied widely by region and was strongly influenced by farm structure and investment levels [15]. Contributing factors for yield improvement include technological adoption, increased fertilizer use, and policy support via the CAP after EU accession [10]. Conversely, factors contributing to lingering inefficiencies and variability include small farm sizes, inadequate farmer training, and climate-related shocks [5, 16].

By building on this literature, our study specifically addresses the gap in understanding how the pattern of productivity has changed

between the pre-2007 and post-2007 periods at a granular (county) level. This focus on a split-period analysis allows us to directly observe the outcomes of the first decades of transition versus the EU-integration era, contributing empirical evidence to the broader literature on post-socialist agricultural development and informing future policy directions.

MATERIALS AND METHODS

This research utilizes longitudinal county-level data on wheat and sunflower production in Romania from 1990 through 2023, drawn from the official statistics of the National Institute of Statistics (INS). Specifically, we extracted annual data on total production (tonnes) and cultivated area (hectares) for wheat and sunflower crops from the INS Tempo-Online databases (datasets AGR109A – "Crop production by county" and AGR108A – "Cultivated area by county"). These data series encompass all 41 counties of Romania and the Municipality of Bucharest (though Bucharest has very limited agricultural area, thus data for it are sparse). Using these two indicators, we computed the crop yield for each county and year, defined as output per unit area (tonnes per hectare - t/ha) for the given crop. Yield is a direct measure of land productivity and provides a comparable metric across regions and time.

To facilitate comparison between the pre-EU accession period (1990–2006) and the post-accession period (2007–2023), we aggregated the annual yield data into two sub-periods. For each county and each crop, we calculated the following summary statistics over the years 1990–2006 (17 years) and 2007–2023 (17 years): Average yield (Mean) – an indicator of overall productivity level in that period; Median yield – a measure of central tendency less influenced by outlier years, useful for skewed distributions (for instance, years with extreme drought or bumper harvest); Maximum and minimum yield – the highest and lowest annual yield recorded, highlighting best-case and worst-case outcomes experienced by each county in each period; Standard deviation (Std. Dev.) – $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(x_i - \mu)^2}$ measuring the year-to-year variability in yields as an indicator of consistency (a lower standard deviation implies more stable outputs, whereas higher values indicate large fluctuations due to weather, or other factors); Growth percentage – the relative change in average yield from the first period to the second, computed as *(Average 2007–2023)/(Average 1990–2006) * 100%*. This indicates how much yields improved or declined in the later period compared to the earlier period. For convenience, we express this as a percentage (e.g., 150% implies a 50% increase in average yield in the post-2007 era relative to the pre-2007 era). All data processing and calculations were conducted using a combination of spreadsheet analysis and statistical software. The resulting dataset provides a comprehensive picture of how wheat and sunflower productivity has evolved over time in each county. We present the findings through descriptive statistics and illustrative charts. It should be noted that Bucharest and a few very small counties had missing or negligible data for certain years (especially in the early 1990s for Bucharest, which has almost no arable land). In computing national or regional averages, such cases were either excluded or treated as zeros where appropriate, but this has minimal impact on overall results due to their tiny share in national agriculture. The insights gained can inform more detailed future studies that might incorporate multiple inputs (land, labor, capital) and advanced efficiency analyses (such as econometric models or DEA) [5, 6] to further investigate the drivers behind the observed productivity trends.

RESULTS AND DISCUSSIONS

The comparative analysis reveals that Romania's wheat and sunflower yields increased substantially in the 2007–2023 period compared to 1990–2006 (Figure 1).

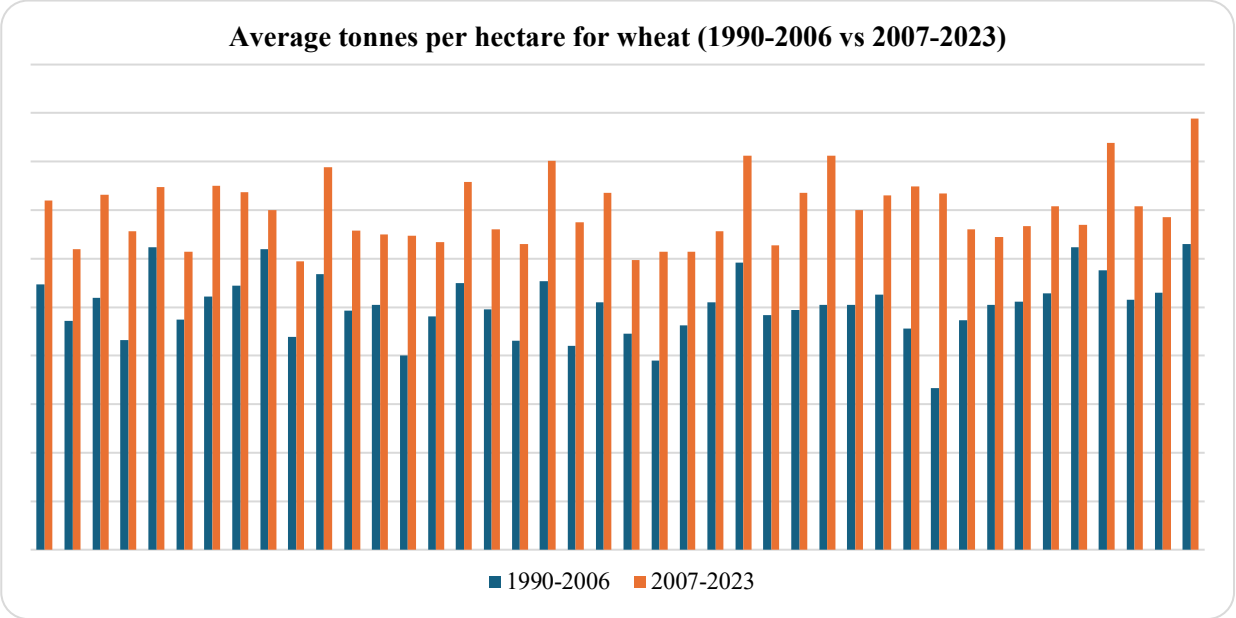


Fig. 1. Comparative analysis for wheat yield between 1990-2006 and 2007-2023
Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

At the national level, the average wheat yield rose from approximately 2.5 t/ha (1990–2006 average across counties) to about 3.5 t/ha in 2007–2023, which is roughly a 40% increase in output per land unit. Similarly, sunflower yields registered an even larger relative jump, from around 1.2 t/ha in the first period to 1.9 t/ha in the second, equating to about a 58% gain.

These improvements reflect the general positive trajectory of Romanian agriculture post-EU accession, aided by better access to inputs and technologies. They align with broader trends reported in regional studies, which note significant yield growth for major crops in Eastern Europe after the mid-2000s [10]. Counties in the fertile plains of the south and west consistently outperform those in the north-east and mountainous center. For wheat, the highest average outputs in 2007–2023 are concentrated in counties like Timiș, Teleorman, Dolj, Călărași, and Ialomița, each recording multi-year mean yields around 3.5–4.0 t/ha or higher. For instance, Timiș a western county with large, mechanized farms – achieved an average wheat yield of 3.8 t/ha in 2007–2023, up from 2.7 t/ha in 1990–2006 (an increase of 41%). Likewise, Călărași, a Danube plain county known for its quality soils and high investment, saw wheat yields rise from 2.9 t/ha to 4.0 t/ha between the two periods; however, Călărași also had years of very poor performance, reflecting vulnerability to weather extremes. In contrast, counties such as Botoșani, Vaslui, and Mehedinți, which historically lagged in wheat yields – improved from roughly 2.0–2.5 t/ha to 3.0–3.3 t/ha averages, narrowing the gap but still falling short of the top performers. The lowest wheat productivity in the 2007–2023 period was observed in Vâlcea (from 3.1 to 3.3) and Covasna (from 3.1 to 3.5 t/ha), both of which, despite improvements, remain about 20–25% below the national mean. Notably, even traditionally low-yield areas experienced significant absolute gains; for example, Harghita's wheat yield grew by 35% in the second period compared to the first (from 2.2 to 2.9 t/ha), indicative of a general uplift across all regions.

For sunflower, the spatial pattern of productivity is somewhat different but still marked by south–east vs. north–west disparities.

The South Muntenia and South-East regions show good outputs in 2007–2023, with counties like Călărași averaging around 2.2 t/ha up to 1.4 t/ha (1990-2006) of sunflower yield. Timiș achieved an impressive 2.4 t/ha average in 2007–2023, up from around 1.3 t/ha previously (+76%), benefiting from large-scale farms and sunflower's adaptation to its climate.

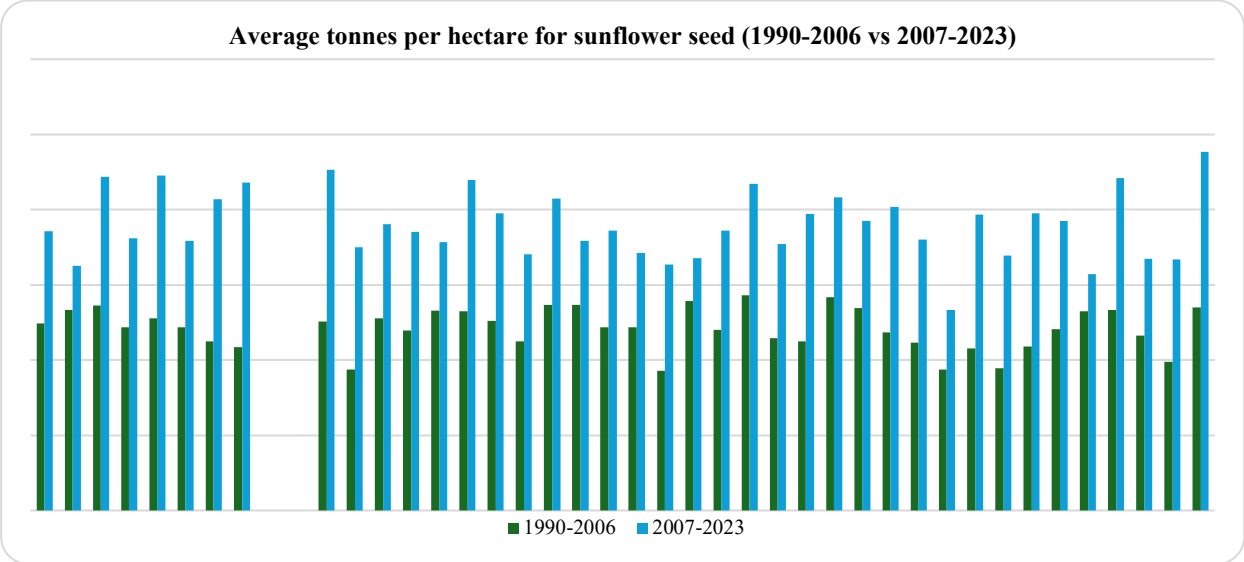


Fig. 2. Comparative analysis for sunflower seed yield between 1990-2006 and 2007-2023
Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A

On the other hand, several counties which are less traditional for sunflower cultivation remain on the lower end; for instance, Vâlcea, Bistrița-Năsăud, and Tulcea had second-period averages near 1.6 t/ha. These lower yields can be attributed to cooler climate and smaller farm sizes in such areas, as well as the possibility that sunflower is grown on more marginal plots there. Nevertheless, even these counties improved relative to their past: Tulcea increased its sunflower yield from 0.9 t/ha to 1.6 t/ha average (+77%), reflecting the diffusion of better sunflower hybrids and practices nationwide. It is worth highlighting the case of Vaslui in eastern Romania: although it had a modest sunflower yield (1.1 t/ha) in 1990–2006, by the second period Vaslui reached 1.7 t/ha on average (+51%), and an exceptional year (2018) it recorded the highest sunflower yield in the country at 3.92 t/ha. This suggests that with favorable weather and improved techniques, even traditionally lagging areas can momentarily match the top producers.

Alongside changes in average productivity, the consistency of yields over time is a critical aspect of agricultural performance. Our analysis indicates a general increase in yield variability in 2007–2023 compared to 1990–2006. Standard deviations of annual yields were higher in the latter period for the majority of counties and for both crops. For wheat, the nationwide average standard deviation across counties rose from about 0.7 t/ha in 1990–2006 to about 0.9 t/ha in 2007–2023 (a 31% increase), while for sunflower the increase was even more pronounced (from 0.3 t/ha to 0.6 t/ha on average, indicating a variability that has almost doubled). This heightened volatility is largely attributable to climatic fluctuations. For example, as mentioned, Călărași county's wheat yield varied from a disastrous 1.2 t/ha in 2007 to an excellent 5.8 t/ha in 2018 – a range far wider than anything seen in the 1990s.Such findings align with other observations that climate factors have become increasingly pivotal in agricultural outcomes [18].

Interestingly, some high-productivity counties also demonstrate relatively stable performance, while others are quite irregular. Timiș, for instance, not only boasted high wheat productivity but also a moderate variability (wheat yield std.var. of 0.9 t/ha in 2007–2023), partly due to its better infrastructure and perhaps localized irrigation and risk management. On the other hand, Ialomița and Călărași, despite similar high averages, showed greater variability (wheat yield std.var. of 1.4 t/ha in 2007–2023) reflecting their exposure to drought risk in the mostly rain-fed southern plains. In the case of sunflower, Caraș-Severin counties emerged as an example of consistency but not necessarily with improvement: it achieved respectable yields (1.7 t/ha averages in 2007–2023) with relatively lower year-to-year fluctuation

(benefiting from a more temperate and reliable rainfall pattern) wheat yield std.var. of 0.3 t/ha. These patterns suggest that geographical and climatic factors play a significant role in yield stability – western and central counties with moderate climates tend to have steadier outputs, whereas the eastern and southern counties, though capable of very high yields, also face sharp downsides in bad years.

The relative improvements from the first to second period also carry implications for regional disparities. The percentage growth in yields was not necessarily higher for those counties that started with lower baseline productivity. Thus, not following the form of catch-up effect. There are exemptions, for example, many counties in the Moldavia (NE) region saw wheat yield increases on the order of +50% to +66%, outpacing gains in some already high-yielding counties which grew only by +40% to +50%. Although apparently the gap between the traditionally highest and lowest yielding counties narrowed slightly in proportional terms e.g. in 1990–2006, the top wheat-producing county (by average yield) had roughly 1.6 times the yield of the lowest-producing county; by 2007–2023 this ratio fell to about 1.5. If we longitudinally analyze the standard deviation between the counties, the disparities grew from 0.32 t/ha to 0.34 t/ha for the average yields. A convergence is observed for sunflower: the highest county average was about 1.5 times higher than the lowest in the first period, growing to about 1.7 times in the second period, when we longitudinally analyze the standard deviation between the counties, the disparities grew from 0.13 t/ha to 0.22 t/ha for the average yields. This indicates that underperforming areas have not benefited significantly from the post 2007 advancements.

In summary, our findings paint a picture of overall progress in Romanian wheat and sunflower productivity between 1990–2006 and 2007–2023, coupled with persistent but not necessarily moderating regional disparities, and an increase in yield volatility. The improvements testify to successful adoption of better agricultural technologies and the positive impact of agricultural policies in the post-EU accession period. The remaining disparities and high variability, on the other hand, highlight the influence of structural and natural factors that have yet to be fully addressed – including the need for greater land consolidation, improved irrigation and water management (to buffer against drought), and enhanced support for regions with difficult agro-ecological conditions.

There has been a clear and substantial improvement in land productivity for both wheat (Figure 3) and sunflower seed (Figure 4) in the post-2007 period. The average wheat yield is roughly 40% higher, and the average sunflower yield about 60% higher, than in the pre-2007 era. This growth reflects successful developments in the agricultural sector, including the uptake of improved crop varieties, better farm management, and the influence of EU agricultural support.

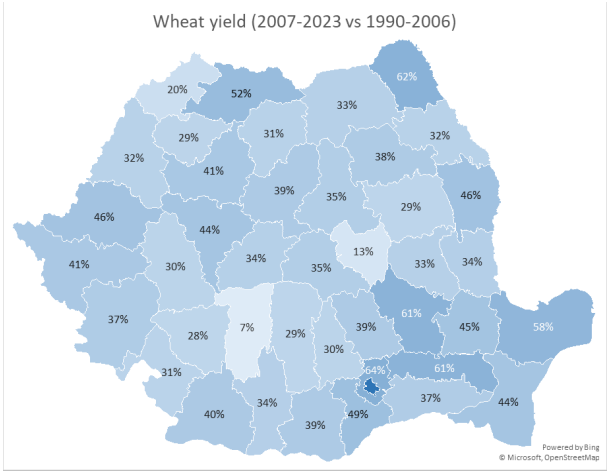


Fig. 3. Wheat increase in yield (t/ha) from 1990-2006 to 2007-2023

Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

It underscores that Romanian agriculture has made positive strides in the last two decades toward realizing more of its production potential.

Despite overall gains, regional yield disparities persist.

The traditional grain belts (Western and Southern counties) remain at the top in terms of productivity, while northern and upland counties continue to produce less per hectare on average.

There is some evidence of convergence, as lower-ranked counties often had higher relative

growth rates, but an absolute gap in output endures. These disparities suggest that inherent advantages (such as soil quality and terrain) and historical differences (such as farm structure and capital availability) are still strongly influencing outcomes. The post-2007 period has seen greater variability in annual yields. This finding is consistent with more frequent extreme weather events (droughts in particular) associated with climate change, as well as possibly market and policy-induced volatility (e.g., price swings affecting input use). Higher variability means higher risk for farmers, as a bumper year may be followed by a very poor year. From a food security and farm income perspective, this is a concern.

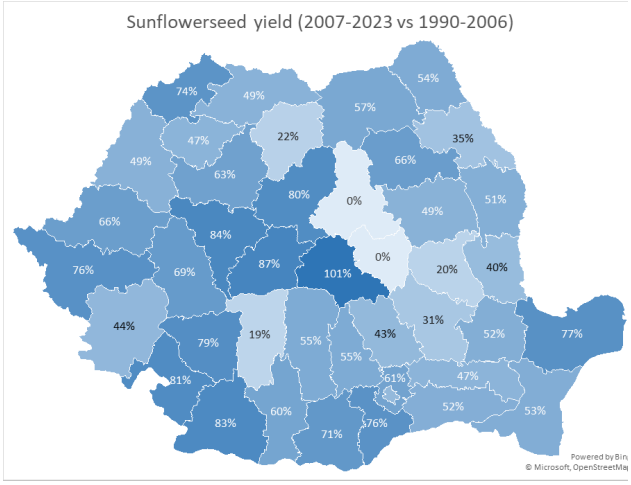


Fig. 4. Sunflower seed increase in yield (t/ha) from 1990-2006 to 2007-2023
Source: Authors' processed, analyzed and computed data from [21] dataset: AGR108A & AGR109A.

The fact that some high-yield regions also experience the biggest swings suggests a need for improved risk mitigation (such as irrigation, crop insurance, and drought-resistant crop varieties) in those areas.
The timing of the yield improvements strongly indicates that policy changes around EU accession played a facilitating role. Access to CAP funds for equipment modernization, better extension services, and integration into European markets likely contributed to yield growth. However, structural issues rooted in the 1990s transition (land fragmentation, demographic challenges in rural areas, etc.) continue to limit the performance of certain regions. In counties with many small subsistence farms, adoption of new technologies can be slower, and investment per hectare is lower, which in turn keeps yields below potential. This dichotomy points to the importance of structural reforms (e.g., encouraging cooperative farming or land consolidation) alongside direct productivity-enhancing measures. The findings highlight that region-specific strategies are warranted. High-performing counties demonstrate what is achievable under current conditions – for example, yields above 4 t/ha for wheat and 2.5 t/ha for sunflower have been attained in multiple counties in favorable years. Transferring the knowledge and resources that enabled those successes to lower-performing counties could raise the national baseline. At the same time, infrastructure development, could stabilize outputs and protect gains.
We must acknowledge that although we qualitatively linked yield variability to climate events, we did not explicitly model the impact of weather or climate change. Year-to-year yield fluctuations due to rainfall and temperature anomalies were evident, but a dedicated analysis (e.g., regression of yields on weather variables) would help quantify these effects. Given the trends of more frequent droughts in Romania, integrating climate data would strengthen the assessment of risk and the need for adaptation measures. We treated the pre- and post-2007 periods as a binary comparison primarily due to EU accession. However, many other changes occurred in these intervals – for instance, market liberalization in the 1990s, fluctuations in global commodity prices, and domestic policy shifts (such as subsidies and credit programs in certain years).
Strengthening the participation of the rural population in decision-making processes can play a crucial role in accelerating agricultural modernization and ensuring that local needs and conditions are properly addressed [7].

CONCLUSIONS

The comparative analysis of Romania's county-level data on wheat and sunflower yields for 1990–2006 versus 2007–2023 leads to several important conclusions.

We concentrated on two major crops for brevity and clarity. However, Romanian agriculture has a diverse crop mix. It is possible that some counties prioritized one crop over another between periods (for instance, expanding sunflower area at the expense of maize, etc.). Such changes in cropping patterns could affect comparative productivity. A more comprehensive study could examine multiple crops or an aggregate productivity index. Moreover, factors like crop rotation, fallow land, or changes in cultivated area (we analyzed yields, which already account for area, but total production trends are also relevant for food security) were not explored in depth. Also, the INS data, while the most authoritative source, may contain inconsistencies, especially in the early 1990s when statistical systems were just re-establishing. Additionally, Bucharest and a few small counties had incomplete data, which we largely excluded from analysis; researchers focusing on those areas might need to supplement with local sources if available. Also, we considered county aggregates – but within each county, there is farm-level heterogeneity. Micro-data at the farm level (if accessible) could reveal, for example, if gains are broad-based or concentrated among larger commercial farms.

In conclusion, Romania's experience from 1990 to 2023 in wheat and sunflower production reflects a broader story of transition: initial difficulties, followed by significant progress, yet with challenges that evolve rather than vanish. Productivity has improved and become more aligned with European norms, but ensuring sustainable and equitable growth remains a key task. Policymakers should capitalize on the positive trends by reinforcing what worked (investment in technology and human capital) and addressing the weaknesses (fragmentation, climate vulnerability). As Romania continues to modernize its agriculture, lessons from the past periods will be invaluable in shaping interventions that boost yields further while also enhancing resilience and reducing regional inequities. Engaging rural communities not only fosters greater adoption of innovative practices but also contributes to building more resilient and inclusive agricultural systems. As Romania moves forward, integrating these social dimensions with technical and structural reforms will be essential for achieving a more productive, sustainable, and equitable agricultural sector.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

READING IN THE SMART VILLAGE: HOW TECHNOLOGY CAN TRANSFORM ACCESS TO CULTURE IN RURAL COMMUNITIES

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Abstract

In the context of digitalization and the transition to industry 5.0, where AI technology will mainly intertwine with robotics, the Romanian village will have to respond to these new challenges by preparing the young generations in accordance with technological requirements. The success of this response will be given by an adequate education of the young generation in the appropriate management of traditional and digital elements. The objective proposed in this article was to provide an analysis of the impact of digitalization on the reading process of the young generations in rural areas. Based on quantitative investigations, using the survey method, we took into account the interaction between the digital environment, students, books and the reading process. Based on the analysis of 145 respondents, we observed that although the trend of digitalization is increasingly gaining momentum, even in rural areas, students tend to prefer printed books, while other activities such as: discussions and information are preferred in digital format. In this sense, we mainly concluded that reading is a driver of individual and collective progress. In a constantly changing world, the ability to learn and adapt is essential, and reading remains the most accessible and effective way to acquire new knowledge and intellectual perspectives.

Key words**:** *reading, culture, digitalization, rural environment, smart village*

INTRODUCTION

In the era of accelerated digitalization, when access to technology is becoming increasingly widespread, traditional reading on paper is beginning to be complemented or even replaced by electronic format. In the Romanian village, a space where tradition and modernity often intertwine, this phenomenon takes a special form. Although reading has long been associated with the school library or the personal collections of the inhabitants, modern technologies, such as e-readers, reading applications and digital platforms, open new horizons for access to knowledge.

This transformation, however, comes with specific challenges, but also with opportunities. On the one hand, through digitization, access to (literature, textbooks, specialized books and cultural publications) is greatly simplified, reducing many barriers (geographic and economic). On the other hand, the Romanian village still faces limitations related to digital infrastructure, internet access and the digital skills of its inhabitants. However, educational initiatives and programs promoting digital reading play an important role in reducing these gaps and bringing rural communities closer to new technological trends. Thus, the digitization of reading in the Romanian village is not just an adaptation to a global trend, but also an opportunity to connect people to a wider world of knowledge, while maintaining respect for local values and traditions. It is a process that redefines not only

the way people access information, but also the role of reading in the life of rural communities. Omar et al. (2023) conducted a quantitative descriptive and correlational study used on 231 fourth grade students from selected public schools in the eastern part of Malaysia. The authors apply a set of questionnaires developed and tested on four research variables: (a) knowledge, (b) motivation, (c) attitude and (d) technology readiness [8]. The results showed that knowledge on the use of digital technology was the prominent indicator describing the degree of technology readiness among the study population. The authors propose solutions to increase the implementation of digital technology for students in rural schools to create a meaningful learning ecosystem and launch strategic planning on the digitalization effort.

Rahman et al. (2022) investigated the process of digitization of education in rural areas. They conducted "a qualitative research with phenomenological methods". Their data collection methods used were interviews and observations. They used data analysis methods consisting of data preparation, data coding, application of data coding results in the themes that were analysed, as well as data interpretation. They concluded that "the four subjects, namely subjects M, H, BL and YMJ located in rural areas, had a good development of education digitization, but there were obstacles from several factors, namely the poor infrastructure factor, the availability of limited facilities and the lack of training for teachers who carry out their teaching activities in rural areas"[10]. They conclude that the constraint on the training factor (minimum knowledge of digitization) of the teacher is directly influenced by the age of the educators, most of whom are at least 40 years old.

Mamabolo et al. (2023) analysed the transition to smart villages, aiming to find out the challenges "for the use of digital library services" related to rural areas [5]. In the study conducted, the authors look for a set of categories, which they will later use in classifying and organizing data. The authors obtained interesting results, concluding that it is necessary to establish digital libraries in rural areas. As shown in numerous works, "library authorities are challenged to adapt digital ways of providing information, librarians provide digital content in libraries to be used on users' laptops and other gadgets" [5]. A main conclusion reached by the authors is that this digitization trend forces a digital transformation of libraries "to successfully maintain libraries as sources of information" [5]. Thus, it is necessary to adopt certain transformation measures, and of course, where possible, to update information policies.

Soekamto et al., (2022) aimed to develop the professional skills of village craftspeople with an emphasis on digital literacy. In this regard, they aim to quantify the level of "digital literacy and existing competence of rural teachers in Indonesia and the Middle East" [11] by assessing the level of digital literacy training of rural teachers "for their professional development in these regions" [11]. Their research is based on a quantitative method (survey) whose data were processed and statistically analysed using SPSS. The research report highlighted "the challenges faced by digitalization in rural areas and the differences in the provision of digital literacy training in Indonesia and the Middle East". In this study, the authors identify certain limitations factors that hinder the integration of digital literacy in underdeveloped areas, these limitations would be: (lack of adequate digital infrastructure).

Preda and Toma (2021) consider that the development of rural education is a strategic objective in Romania, especially due to current challenges such as: decreasing number of students, poverty, lack of infrastructure, etc. Thus, the pressure on the sector was even greater during the pandemic period, when the rural education infrastructure was not prepared to cope with the demands [9]. They aimed to analyse the quality of education in rural areas with a case study in Argeș County, through a survey among 107 teachers from 7 middle schools and 1 high school, located in five rural villages. The results highlighted the needs of rural teachers to ensure a good education, the needs of students to learn, the measures that need to be implemented in terms of programs, teaching methods and learning techniques [9].

Tomuletiu and Moraru (2010) presented the results of research conducted in 61 Romanian

villages whose objective is ”to capture the specific characteristics of rural educational forms and institutions”. In the presented work, it was shown that rural development depends on factors such as: the experience and degree of education of local educational personnel; the logistics of local educational institutions; “the specific search methods used by each institution; interferences with the city community (rural-urban interrelation)” [14].
The educational training, as explained by Tița et al. (2018) of people working within a company is essential for the economic and social performance of the enterprise [13].
Moreover, this background potential positively affects both the student's career and the image of the affiliated university. Reading in rural areas is an important topic, having a significant impact on the personal, educational and cultural development of residents of rural areas. The analysis of cultural activities in rural areas involves identifying those responsible, the factors involved and the links between them.
In this context, the purpose of the research was to study how the young generations from the rural areas prefer access to books and reading, and how they disseminate the knowledge using digital solutions.

MATERIALS AND METHODS

The research was carried out in cultural units in the South Muntenia region, and is based on the analysis of book reading activity in the period 2024.
The research considered the interaction between students, books and the reading process and was based on quantitative investigation, from which we chose the survey method. Thus, questionnaires were developed aiming to identify the reading ability of primary school students, the influence of digitalization of reading, as well as the use of digital devices in the reading process.
Data collection for this paper was done through questionnaires distributed electronically to 145 respondents, using digital means at five rural schools (Lunguleț u, Serdanu, Tărtășești, Slobozia Moară, Gherhani).
Frequencies and correlations were analyzed using statistical processing applications, such as SPSS.

RESULTS AND DISCUSSIONS

The Smart Village concept integrates digital technology to improve life in rural areas, including access to education and culture. Reading in Smart Villages can become more accessible and interactive through innovative digital solutions.
Technology has the potential to revolutionize access to culture in rural communities, offering new opportunities for learning, participation and the preservation of cultural heritage.
Reading is the basis of the development of society, being an important pillar in the development of the new and the traditional in the Romanian village. It also plays a crucial role in the transition to a smart village, primarily by being a powerful tool for education, and not only that, but also for awareness, innovation and emancipation of the community. In a smart village, where tradition takes on digital forms, traditional books are preserved, reading through printed books is aided by digital resources, online educational materials and access to relevant information for sustainable development.

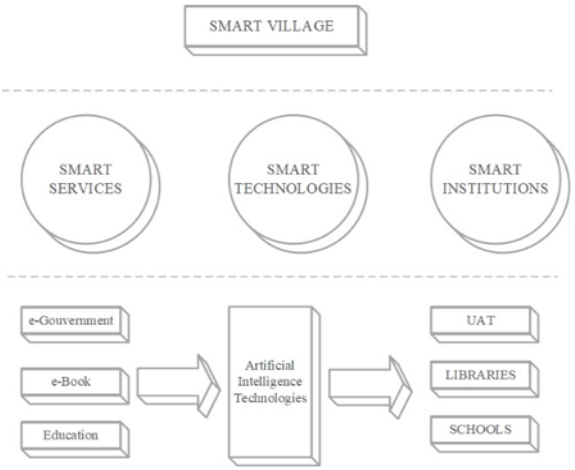


Fig.1. Reading in the Smart Village
Source: Own determinations.

Industry 4.0 brings automation, artificial intelligence and digitalization to all areas, including agriculture, education and rural development. In a Smart Village, reading

becomes essential for adapting to new technologies, supporting innovation, education and economic progress (Fig. 1).

The transition from Industry 4.0 to Industry 5.0 brings fundamental changes in the way technology is used in everyday life.

While Industry 4.0 focused on automation, artificial intelligence and data, Industry 5.0 emphasizes collaboration between people and technology, sustainability and personalization. In this context, reading becomes an essential tool for adapting to new requirements, especially in Smart Villages.

Digitizing reading in rural education represents both a huge opportunity and a significant challenge.

In many rural communities, access to traditional educational resources, such as libraries or up-to-date textbooks, is limited. Digitization can reduce these disparities by providing students with access to e-books, interactive educational platforms, and online teaching materials, eliminating geographical and economic barriers.

This digital age makes room for you in all the processes of our lives.

The Romanian village, it does not escape being updated either, the UATs in rural areas, must accept this transition.

Observing the trend of the future citizens of the village, starting from primary education to the last form of education available to the rural environment.

Basically, children represent the future of a nation, and education complemented by reading leads to an evolution of the Romanian village and of course to a well-being of the Romanian peasant.

The proposed objective of this article is to observe the impact on the way of providing and consuming reading among tomorrow's generations of rural areas.

It was identified both a positive aspect, in the appreciation of the patterns of the traditional book, but possibly also a rate of development of the digital sector that does not allow reading in electronic format (Table 1).

Perhaps at the level of school units, both the subordinate libraries and the computer laboratories should allow access to manuscripts presented in electronic format. At the same time, procedures and methods should be developed where necessary to offer young people the opportunity to discover useful information through reading.

Table 1. Access to digital resources

Response	%	%	%
	8 - 10	10 - 12	12 - 15
At Schoo	8.00	1.96	4.35
Home	76.00	76.47	57.97
Both Variants	16.00	19.61	31.88
In Other Parts	0.00	1.96	5.80
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations.

Although the trend towards excessive digitization has increasingly taken place in our lives, the choice of reading in a classic format is appreciated by most students. In this sense, we can think that at younger ages, such as the 8-10 year-old sample, they use digital technology mainly for communication, information and spending their free time other than reading.

Table 2 shows that the evolution of the use of digital devices for reading decreases by age group from the youngest (8-10) years to the oldest (12-15) years.

Table 2. Electronic or traditional reading

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Printed Book	72.00	54.90	42.03
Digital Reading	24.00	19.61	14.49
Both Forms	4.00	25.49	43.48
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations.

The evolution of the number of books read by students in rural areas depends on factors such as: school requirements, culture and education acquired in the family, access to literature, guidance towards literature.

The data from Table 3 present the increase in book reading among students which is a positive aspect.

According to the data obtained in the presented study, book reading in the last year is more pronounced in the younger groups (8-10) years. They chose to read, in the vast majority, more than two books in the last year.

We observe here a trend of reduced reading among students in the final grades of gymnasium, they preferred to read only one, maximum two books in the previous year. This situation may also be due to the fact that they allocate more time to preparing for access to a higher education institution. Another possible cause is the allocation of free time to digital relaxation methods.

Of course, analysing the composition of readings for the little ones, we realize that they are shorter. That is why they can read more than two books in approximately the same time that students in the final grades of middle school will read one book.

Comparing the fact that the vast majority of students have read one book or more (over 80% of students between 8 and 10 years old), the data from Table 3 show that in the same age category students indicated that over 70% preferred a printed book, we can think that there is a possibility that the printed textbook is still in the readers' preferences.

Table 3. Number of books read

Response	%	%	%
	8 - 10	10 - 12	12 - 15
None	12.00	5.88	26.09
A Book	24.00	29.41	31.88
Two Or More	64.00	64.71	42.03
TOTAL	**100**	**100**	**100**

Source: Own determinations.

In the midst of the digital age where businesses that are not online do not exist, the sources of purchasing a book are multiple, both in urban and rural areas. Although many rural areas are often deprived of physical access to bookstores, students find support in the main sponsors (parents and grandparents) in the educational institution, as well as in local libraries. However, most often books are often discovered and purchased online and received through the shipping solutions of each literature supplier.

The study conducted among students shows that the library is at the top of the preferences for getting books for reading among the little ones. In this regard, the causes can be multiple, such as: lack of finances for a new book, the desired reading is already in the library, lack of access to new titles and publications...etc. Students approaching middle school, show a high desire to purchase a book from the bookstore, where they can still choose from a limited number of titles. Within this category, we can observe an increase in interest in the use of digitization in purchasing books.

Comparing by age range, the most interested in using the virtual environment to purchase a book are students who have already entered middle school. If in the 8-10 age range only 20% of respondents prefer digital means, in the 12-15 age range the percentage of those who prefer to purchase a book online increases to over 30% (Table 4).

Table 4. Book acquisition

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Internet	20.00	21.57	30.43
Bookstore	12.00	29.41	11.59
Library	32.00	25.49	13.04
From other source	36.00	23.53	44.93
TOTAL	**100**	**100**	**100**

Source: Own determinations.

The main service used by the phenomenon of digitalization of services is information. In this sense, the use of digital services for information in the acquisition of books facilitates processes such as selection, comparison and acquisition.

Among students enrolled in rural schools, there is an increasing trend with a peak in the 10-12 age range for students who do not use digital information services, as presented in Table 5. At the same time, the trend in the use of digital technologies is increased among students aged 12-15 (almost 60%). The use of digital services is related to aspects such as digital literacy, the availability of equipment and online connectivity services and, very importantly, the availability for reading.

Comparing the data from Table 3, from the 8-10 year old group, we observe that over 60% of those surveyed have read more than one book, and according to the data in Table 5, half have turned to digital services for information on readings (title, author, pricing policy, publisher, delivery time, format, physical or ebook).

Table 5. Use of digital services for information

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Yes	48.00	27.45	56.52
No	4.00	11.76	7.25
Sometimes	48.00	60.78	36.23
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations.

Banciu et al. (2013) stated that in a modern and dynamic world, where information is updated every second, every person, regardless of age and occupation, it is compulsory to learn and improve your knowledge continuously. In the era of new information and communication technologies, the Internet has revolutionized almost all areas of social and professional life, including education, upbringing and culture. Education via the Internet represents a new way of learning for the student but also a new way of teaching for the teacher [3].

Discussion forums are online platforms where users can communicate, share information, and debate various topics. They are organized into specific categories and topics, allowing the exchange of ideas and experiences between members.

Examples Goodreads – international community for book reviews and recommendations, LitNet, Softpedia Books – forums dedicated to literature. According to Allen & Seaman (2005) online reading and learning is increasingly popular in education, as administrators consider it an effective method of increasing enrollment at a relatively low cost [1].

A classic custom in rural areas and only, is to share opinions and impressions with friends about the readings read, the quality of the topics and the authors. The era of digitalization brings new communication options, in which readers from other branches of the Romanian village, but also urban readers, can be involved. Asked if they prefer discussions on the internet, those interviewed in the vast majority (over 50%) denied using forums to discuss reading topics (Table 6). Taking into account that in the 8-10 year age range, the percentage of reading was higher, those in this category read one or more books (Table 3) we can see that they are also the ones who use forums to discuss impressions about the books read.

Table 6. Internet discussion forums

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Yes	48.00	37.25	13.04
No	52.00	62.75	86.96
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations

In the book Education through E-Learning (Banciu et al.(2020), it was mentioned that the beneficiaries of education are no longer the same as those in the 20th century, and the institutions providing education are fighting a huge battle to bring up a generation that no longer exists, trying to preserve methods and practices that were effective in the past but are proving ineffective today [2].

Compared to some cities, printed books in rural areas are more accessible in dedicated institutions (bookstores, libraries) and less accessible when it comes to book fairs. However, purchasing books at a book fair is a special experience, combining access to the latest titles, attractive discounts and the opportunity to interact directly with authors and publishers.

Analyzing the data from Table 7, we observe that the categories that tend to have access to literature from institutions such as the library and bookstore are between 10 and 15 years old. That is, we can say that once the middle school period is over, students access these resources more, comparing by age category.

Table 7. Where to find books for reading

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Internet	40	56.86	40.58
Bookstore	20	7.84	17.39
Library	36	31.37	39.13
Book Fair	4	3.92	2.90
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations.

These institutions, which have a classic character in rural development, are competing with the virtual space, which is also easily making its way into the Romanian village. Thus, the tendency to purchase books on the internet is over 40% in each age category.

Access to digital infrastructure (digital tools and services) in the Romanian village is a key challenge for sustainable rural development, primarily for reducing the gap between urban and rural areas. In many villages, access to resources (internet and digital technologies) is often limited or below average for good functioning, which can lead to inequalities in key areas (education, health, business environment and public administration).

An article published on EDUPEDU mentioned that " in 2021, approximately 237,000 students in Romania did not have access to the internet, and 287,000 did not have the necessary equipment for online school" [4]. Most of these students come from rural areas, where digital infrastructure is less developed.

the data published by the National Institute of Statistics from 2021, showed that only 19.45% of school laboratories are located in rural areas [7]. Also, six out of ten rural schools do not have school libraries, thus limiting students' access to essential educational resources.

On the other hand, there are over 140 communes in Romania implementing over 220 "smart village" initiatives. These include schools with distance learning systems, digitalized town halls, and smart solutions for public transport and waste collection.

Table 8. Access to digital media and services

Response	%	%	%
	8 - 10	10 - 12	12 - 15
Yes	48.00	37.25	13.04
No	52.00	62.75	86.96
TOTAL	**100.00**	**100.00**	**100.00**

Source: Own determinations.

Marin et al (2022) affirmed that assisting rural enterprises to better connect, integrate and cooperate with urban businesses are the new challenges facing the inhabitants of Romanian villages [6].

Stoyanova-Toneva (2021) mentions that cultural heritage, to the extent that it is preserved, in symbiosis with the history of each region, has the potential to become a successful tool for the social and economic development of rural communities [12].

Reading in the Romanian village also faces challenges related to access, digitalization and socio-economic changes. However, the transition to smart villages, combining the traditional with the digital, must support the new generations in the village through innovative solutions, such as digital libraries, interactive reading clubs, and education through technology, can transform reading into an essential tool for the development of rural communities.

CONCLUSIONS

A student's life experience, according to the study conducted, is directly proportional to the reading requirements related to age. Thus, we can conclude that as a student progresses to middle school, the reading requirements increase and students turn to modern purchasing solutions to acquire the necessary titles;

Students who are looking for books and want to turn to digital solutions, have predominantly used access to their own digital resources. The resources provided by school units are the least targeted, possibly due to lack of access to computer rooms;

Reading is a pillar of the development of a smart village, providing residents with the necessary tools to learn, adapt and thrive in a constantly changing world. By promoting reading and access to information, rural communities can become more resilient, more innovative and more connected to global trends; Investment in education and reading resources is essential to transform villages into smart and sustainable communities;

Reading is a central element in the transition from Industry 4.0 to Industry 5.0, providing rural communities with access to essential information about new technologies, sustainability and human-machine collaboration. Through digitalization and access to quality knowledge, smart villages can become more prosperous, more innovative and better connected to the future;

While there are notable efforts to improve access to digital resources in Romanian villages, significant challenges related to infrastructure and facilities persist. Continued investments in digitalization and education are

essential to reduce the digital gap between rural and urban areas.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

READING IN RURAL SPACE BETWEEN CLASSIC AND DIGITAL TRANSFORMATION

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Abstract

In the context of the era of digitalization and the new industrial revolution – Industry 4.0 – the Romanian village is facing a historic opportunity: the transition to the smart village. This process involves the integration of modern technology into rural infrastructure to improve the lives of residents, streamline public services and stimulate sustainable development. In this regard, the purpose of this research was to assess to what extent students value reading after school hours. This paper was structured in four parts, namely: a part in which it was analysed the situation of reading providers, the second part in which it was analysed the type of reading requested by students and (printed or digital book), as well as the category of topics of the requested readings, and the third part in which there were studied the reasons that stimulate students to consume readings after school hours. The last part was dedicated to the conclusions obtained.

Key words: *reading, culture, printed book, digital book, rural environment, smart village.*

INTRODUCTION

Reading has, over time, been an essential pillar in the intellectual, cultural and moral development of the individual, representing a bridge between generations, cultures and eras. In rural areas, this activity has also undergone significant transformations, evolving from traditional forms, based on printed books, to new digital reading methods, influenced by the rapid technological advances of the last period. Thus, reading in rural areas is today at the intersection of classic and modern, between traditional and digital, gradually adapting to the needs and possibilities of new generations. Traditionally, reading in villages was closely linked to the school library, small communal libraries or personal collections passed down from generation to generation. The physical book was a concrete, tangible presence, which stimulated not only the intellect, but also a certain affective relationship with reading. Collective reading, storytelling evenings or even sporadic literary meetings contributed to keeping this habit alive, even in conditions of limited access to diversified cultural resources. Nowadays, however, the digital transformation has started to make its presence felt more and more in rural areas. Access to the internet, the proliferation of mobile devices, the emergence of online reading platforms and virtual libraries offer new opportunities for access to information, but also new challenges. Digitalization has democratized reading to a certain extent, offering the possibility for anyone to read anytime and anywhere, provided that the necessary infrastructure exists. However, this process also comes with risks: a decrease in interest in deep reading, the replacement of literary reading with rapid

information consumption or difficulties in digital literacy for some categories of the population.

Therefore, the objective of this article is to analyze how students in rural Romania value reading outside of class and what motivations or obstacles they encounter in forming a constant reading habit.

It is important to understand not only the changes produced, but also their implications for education, culture and community identity, in a constantly changing world.

The rapid rise of digital technologies has inaugurated a transformative era for the preservation and dissemination of classical literary heritage, presenting both unprecedented opportunities and formidable challenges.

The digitization of reading has generated many challenges over time. Peras et al. (2023) made a comparison between electronic reading (e-reading) and reading on paper. They aimed to evaluate "the current state of reading consumption in classic format compared to digital reading consumption among students aged 6 to 18" [8]. They extended the research by analyzing the learning style of these students by evaluating the impact of certain factors such as: "(gender, socioeconomic status and school location) in explaining the differences between the two learning modes" [8].

Thus, they used quantitative or mixed methods to compare digital reading with reading on paper. The results of the study show that there are "no significant differences in the comprehension of the texts read between the two learning modes, while others suggest the inferiority of the screen, thus favoring reading on paper". The research conducted is exiting, so they also analyze the learning style of students in the target group, evaluating the impact of certain factors "such as: (gender, socioeconomic status and school location) in explaining the differences between the two learning modes". The authors use quantitative methods, even mixed ones, to compare digital reading with reading on paper. The results obtained show that "there are no significant differences in the comprehension of the texts read between the learning modes, while others suggest the inferiority of the screen, thus favoring reading

on paper". The authors show that certain predictive factors at the individual level, "such as previous text comprehension skills and reading habits", are essential and play a crucial role in increasing reading performance in different teaching modes. At the same time, certain factors at the family level, "such as the number of books at home, and factors at the school level, such as the use of ICT resources", influence both the comprehension of text on paper and digital. The authors showed that, "gender differences are evident in attitudes and performance towards different reading modes" According to Peras et al. (2023), "comparing electronic and paper-based reading modes reveals a complex interplay of individual and contextual factors that influence text comprehension and attitudes" [8].

Nikolayevna (2024) explored "the nuanced dynamics of digitization in the field of classical literature, focusing on three critical aspects: accessibility, perception, and interpretation by the new generation of readers" [6]. Using mixed methods, Nikolayevna integrated "quantitative surveys and qualitative interviews to comprehensively explore digital interaction with classical texts among a diverse demographic of readers". The results highlight a "significant improvement in the accessibility of classical works through digital platforms, albeit marked by disparities in genre representation and the fidelity of digital reproductions" [6]. Furthermore, the research reveals a "complex landscape of reader perception, with digital formats promoting a new paradigm of interaction characterized by convenience and interactive exploration, but sometimes hampered by technological limitations and the loss of tactile interaction". The study reveals a "notable shift in the interpretation of classical texts, as digital media facilitate collaborative and dynamic interpretive practices among the new generation, diverging from traditional solitary reading experiences". These insights underscore the essential role of "digital literacy in shaping the interaction with and understanding of classical literature in the digital age" [6].

The study published by Spjeldnæs et al (2022) extends ”beyond empirical findings to reflect on broader implications for educators, librarians, and digital platform developers, advocating for strategic improvements to digital literary ecosystems to enrich the reader’s experience” [11]. The digitization of classical literary heritage “represents a crucial moment, offering both challenges and opportunities for revitalizing the legacy of classical texts for future generations, requiring a concerted effort to harmonize technological advances with the pedagogical and cultural stewardship of our literary past” [11].

The study conducted by Hu et al. (2023) showed that the introduction of digital technology will greatly enrich the resources of rural education, promote equity in education and cultivate students' innovative ability [4]. The education system "is not without challenges” [4], so the authors pointed out that there are some deficiencies such as the lack of ”digital educational resources, the cognitive deficiency of digital education, the homogenization of digital education programs and the insufficient digital literacy of teachers” [4]. In order to meet these challenges, the authors propose ”to fully utilize the advantages of digital technology in rural education, it is necessary to formulate comprehensive support policies, improve infrastructure construction, strengthen teacher training and promote the popularization of digital literacy, so as to achieve the sustainable development of the digital transformation of rural education” [4].

The fourth industrial revolution (industry 4.0) and the trend of digital transformation ”have created many changes, brought many values, and also raised many challenges in the formulation and improvement of policies on culture in general and policies for the development of reading culture in particular”. The research proposed by Son (2024) through the analysis of secondary data, “especially the current policies on the development of reading culture, analytical research assesses the compatibility between current policies and the requirements of cultural development, guiding people towards the creation of a learning society in the context of the fourth industrial revolution” [10].

The author proposed ”a set of approaches and solutions to the policy implications for promoting a reading culture, development towards the creation of a learning society in the context of the fourth industrial revolution and the trend of digital transformation” [10].

In this context, the study assesses to what extent students value reading after school hours.

MATERIALS AND METHODS

The transition from the traditional village to the smart village involves a long-term process through which all the elements of the classic must find their counterpart in the digital world. Our research focuses on the valorisation of reading by students in rural Romania. In this research, we followed the way in which students read in their free time, reading between classic and digital as an element of supporting the transition to the smart village, as well as the motivational elements to direct students towards reading. In this sense, we conducted a study in schools in 3 villages in Dâmbovița County, where with the agreement of the school we formed 3 groups, namely students between 8-10 years old, 10 – 12 years old and 12 – 15 years old. With the agreement of the parents, the children answered the questions in the questionnaire and we managed to gather over 100 respondents.

Frequencies and correlations were interpreted and analysed using statistical processing applications, such as SPSS, and finally the main conclusions were formulated.

RESULTS AND DISCUSSIONS

Generically, the rural environment can be defined as the set of territories and localities outside cities, characterized by low population density, the predominance of agricultural activities and a traditional lifestyle.

Bogos et al. (2023) affirmed that "for Romania, rural areas are of particular importance, partly because a significant percentage of the country's population lives in villages, but also because rural areas are the place where ancient traditions and customs are preserved, which

provides a clear image of the identity of the Romanian people"[2].

A real challenge for rural students is the developing infrastructure that supports restrictions on access to information. Thus, Popescu et al. (2022) consider that "rural schools have smaller facilities and infrastructure due to reduced funding, teachers have limited opportunities for professional development, bookstores and libraries are missing in many cases, and schools are located far from cultural centers" [9].

In the era of accelerated digitalization, in which industry 4.0 represents the trend of evolution, reading is in full transition between traditional and modern. In rural areas, this transition is felt in a special way, where printed books still have an important place, but the increasing access to technology brings new opportunities for digital reading. The proposed theme aims to highlight how students and rural communities navigate between classic reading and new digital forms, as well as the impact of these changes on reading habits.

Reading is an essential component in the intellectual and personal development of students. In rural areas, the habit of reading in leisure time is influenced by several factors, such as access to books, family support or available educational resources. In this article, we aimed to analyse to what extent students in Romanian villages value reading outside of class and what motivations or obstacles they encounter in forming a constant reading habit.

In order to have a complete picture of access to reading in rural areas, we will analyse some statistical data regarding the infrastructure that provides access to reading in rural areas. In this regard, data published by edupedu.ro show that in the period 2021–2022, the number of school libraries in rural areas decreased from 7,119 (nationally) to 6,022, due to the fact that over 1,000 libraries closed. In 2022, 60% of rural schools did not have a functional library at all.

From the data presented in Table 1, it appears that of the schools that had a library, (39%) had an endowment below the minimum level (few titles and a small number of copies).

According to Table 1, even in 2023, the situation did not improve much, even though investment funds were still accessed (on average 6 out of 10 rural schools did not provide an adequate reading space, and the library, if it existed, was most often non-functional and with old collections).

Table 1. Situation of reading providers in the period 2021 – 2024

Indicator	2021	2022	2023
Households with internet	69.7 %	82.1 %	85.7 %
Internet users	89.7 %	~92 %	92.5 %
Daily users	69.2 %	—	~70 %
Rural schools without a functional library	–	60 %	60 %
Schools with poorly equipped libraries	–	39 %	39 %
Closed libraries (rural schools)	–	-1,097 (2021 vs. 2022)	–

Source: Processed based on data provided by NIS [5].

Children in rural areas often spend their free time on:

• household activities - where 30–35% of children aged 8–14 in rural areas spend at least 1–2 hours [3];

• using computer applications and internet access - in 2023, ~80% of rural households had a connection [5];

• reading activities, where (according to worldvision.ro/), only 15–20% of children read in their free time.

In the Romanian village, reading has traditionally been supported by village libraries, schools, churches and by the important role of the teacher and priest in promoting written culture. However, in recent decades, as stated on the website https://worldvision.ro/ “reading in rural areas has faced a significant decline, due to population migration, lack of modern infrastructure and reduced access to updated cultural resources” [12].

As shown in Figure 1, reading at the village level is provided through bookstores (mainly through those of schools) but also through book fairs. The beneficiaries of these services, the students, are practically the bridge of transition between the classic village and the smart village. This transition to the smart village is channelled through efforts to digitize

libraries, provide an internet access infrastructure, digital educational programs and even promote digital culture.

Patnaik et al. (2020) emphasizes that the main dimensions of a smart village are "culture, education, health, sanitation, information connectivity, electrification, establishment of cottage and small-scale industries", consequently "the whole world is striving today for a "Sustainable Development" agenda that would include smart villages" [7].

Figure 1 presents reading in a period of transition to smart village in the rural areas in our conception.

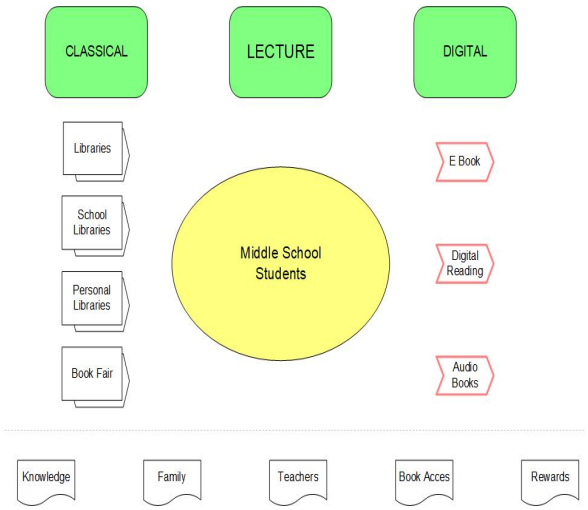


Fig. 1. Reading in transition to the smart village
Source: own-determination.

From the study conducted on rural students, as presented in Table 2, the inclination towards reading in their free time is more appreciated by students who are in primary school with a share of over 60%.

This trend is decreasing by age group, middle school students and those who are at the end of middle school (10-12 years and 12-15 years) are less attracted to reading in their free time, reaching a share of approximately 25%.

Table 2. Student reading in free time 2023 - 2024

Answer	%	%	%
	8 - 10	10 - 12	12 - 15
Yes	64.00	56.86	24.64
No	16.00	13.73	21.74
Partial	20.00	29.41	53.62
TOTAL	**100.00**	**100.00**	**100.00**

Source: own-determination.

Most children have easier access to old physical books from family or school than to high-performance digital devices. Although we are going through an era of knowledge and digitalization, rural students mostly read printed books. Printed books are easier to understand and use for young students (8–10 years old), teachers and parents often encourage the classic form for homework, assessments or mandatory reading. As the data from our study, structured in Table 3, show, by age group, printed reading is more appreciated by primary school students with a share of over 70%. Thus, as students move towards middle school and even further towards the last stage of pre-university education, they tend to embrace both forms, both printed and digital.

Table 3. Reading type preference, 2024

Answer	%	%	%
	8 - 10	10 - 12	12 - 15
Printed book	72.00	54.90	42.03
Digital reading	24.00	19.61	14.49
Both forms	4.00	25.49	43.48
Total	**100.00**	**100.00**	**10.00**

Source: own-determination.

The type of reading preferred by rural children reflects not only their access to educational resources, but also their level of personal and academic development. In general, children up to 15 years old in rural areas prefer printed books, especially in the first years of school. As they grow older, more and more of them also start to use digital reading, although access to technology remains, in some cases, limited.

Reading, regardless of its form, has a profound impact on children's development. Through reading, they enrich their vocabulary, develop their imagination, critical thinking and ability to express themselves. In addition, constant contact with new stories and ideas stimulates their curiosity and desire to learn.

For children in rural areas, promoting both forms of reading can contribute to reducing educational gaps compared to those in urban areas. Access to digital reading, especially through schools and libraries, represents a chance for inclusion and adaptation to the demands of the modern world. Therefore,

reading is not only a means of spending free time, but an essential key for the harmonious development of children in rural areas.
The type of reading sought is important for the development of students in rural areas, but also for the provision of reading materials.
In Table 4, it is shown that not only are printed books preferred, but also that interest in fields such as science decreases with age, the most interested being children between the ages of 10 and 12 (20%). At the same time, the field of geography is a less sought-after field by primary school students, occupying over 21% of the reading space of middle school students. Although often closely related, fiction and science do not always determine the same interest. An interesting aspect is that reading with fiction topics is often more sought after by students who leave middle school (almost 40%).

Table 4. Preferred reading type in the period 2023 - 2024

Answer	%	%	%
	8 – 10	10 - 12	12 - 15
Scientifically	20.00	15.69	0.00
Travel	20.00	27.45	17.39
Geography	16.00	27.45	21.74
Fiction books/stories	32.00	21.57	37.68
Other	12.00	7.84	23.19
TOTAL	**100.00**	**100.00**	**100.00**

Source: own-determination.

In an increasingly digitalized world, artificial intelligence can play an important role in supporting the education of children in rural areas.
One of the most promising uses of this technology is the personalized recommendation of readings, adapted to the age, level of understanding and interests of students.
The fact that statistics reveal that rural areas where access to libraries, specialized teachers or educational counseling is often limited makes the use of AI particularly valuable in rural areas.
Through intelligent platforms, AI can analyze a child's previous readings, school results or even questionnaire answers to suggest suitable books.
Thus, every student has the chance to discover reading as an enjoyable activity, not imposed, which can increase motivation for learning and personal development. In addition, AI can provide translations, explanations and audio readings, facilitating the understanding of the text even for children with learning difficulties.
The use of AI systems in education should not replace the role of the teacher, but complement it. In rural areas, such tools can become a real support for students, teachers and parents, reducing inequalities and giving each child the chance to evolve at their own pace.
AI can transform reading from an obligation into a personalized and accessible adventure for all.
Analysing the behaviour of students in rural areas, artificial intelligence systems are most often used by students who are in their final year of middle school (approximately 57%) (Table 5).
Primary school students quite frequently use artificial intelligence applications as an intelligent search engine.
Structuring according to various criteria and presenting them in a clear report, understandable to young children, makes 48% of those surveyed use these applications frequently.

Table 5. Use of AI systems for reading recommendations in the period 2023 - 2024

Answer	%	%	%
	8 - 10	10 - 12	12 - 15
Yes	48.00	27.45	56.52
No	4.00	11.76	7.25
Sometimes	48.00	60.78	36.23
TOTAL	**100.00**	**100.00**	**100.00**

Source: own-determination.

Dissemination of the subject of reading in rural areas is done mainly through storytelling with close people. The transition to an intelligent architecture of the Romanian village requires the efficiency of work through digitization. Basically, we can say that we are moving towards village 4.0.

In the study, we wanted to find out what is the tendency of students to disseminate information after reading a book. Thus, we could observe that there is a tendency to decrease the desire to express themselves online. The most active are those who are between primary and secondary school (approximately 50%). This tendency decreases with age, reaching almost 14% in the case of students who are moving towards high school education. discussions about reading topics

Table 6 presents the use of reading appreciation forums by age group.

Table 6. Use of reading appreciation forums in 2023 - 2024

Answer	%	%	%
	8 – 10	10 - 12	12 - 15
Yes	48.00	37.25	13.04
No	52.00	62.75	86.96
TOTAL	**100.00**	**100.00**	**100.00**

Source: own-determination.

Analysing the factors that predominate in motivating students to read books in their free time, we can say that they vary between the student's desire to learn and the support provided by the family and teachers. In households where parents or older siblings encourage reading, children are more motivated to read at home. Also, the involvement of teachers, who recommend suitable books and create a friendly environment for reading, has a direct impact on students' habits.

Another essential element is access to attractive books. In some villages, libraries are poor or non-existent, which significantly limits students' options. However, educational projects, book donations and digital readings can reduce this gap. Last but not least, personal motivation, curiosity and the pleasure of discovering stories play a major role in the formation of a young reader.

The analysis carried out observed that family support plays a determining role, especially in the case of primary school students. Approximately 50% of respondents aged between 8 and 10 claim that the family is the main supporter of reading after school hours. Among students aged between 10 and 12, family support was also found to be somewhat better shaped by the desire for knowledge (approximately 34%). The influence of the family is, however, lower in the case of students aged between 12 and 15 (38.5%). In this interval, a slight increase in the desire for knowledge was observed.

Regarding teacher support, through various educational methods (reading circles, public appreciation in front of the class, letters to imaginary authors, etc.), it has a fairly small value in the total of factors that determine book consumption, reaching a weight of only 11.5% in the case of students aged between 12 and 15. Access to books is a factor with also low motivation, it is emphasized by only 12% of students aged between 10 and 12. In this sense, it is necessary to alternate digital reading with that in printed format, Acad. Banciu et al. (2012) proposed a system of digital libraries, defining the digital library "as an organization, which can be virtual, that collects, manages and preserves comprehensively, in the long term, rich digital content and offers its user communities specialized functionalities for that content, of measurable quality and in accordance with codified policies" [1].

As we can see, certain rewards for reading are not considered by respondents to be a strong motivational factor, approximately 5% of students aged between 10 and 12 believe that a reward can motivate them to read literature after school hours.

Table 7 shows the main factors which influence the consumption of reading after school hours in the rural areas.

Table 7. Factors determining the consumption of reading after school hours by children in rural areas 2023 - 2024

Answer	%	%	%
	8 - 10	10 - 12	12 - 15
The desire for knowledge	32.00	34.00	37.00
Family influence	48.00	42.00	38.50
Teacher support	10.00	7.00	11.50
Access to the book	7.00	12.00	10.00
Rewards	2.00	5.00	0.00
Another	1.00	0.00	3.00
TOTAL	**100.00**	**100.00**	**100.00**

Source: own-determination.

CONCLUSIONS

Internet access in rural areas has steadily increased: from 69.7% in 2021 to 80.3% in 2023, indicating a significant expansion of connectivity at the school level.

• The rate of internet use is very high, suggesting an increased potential for access to digital educational resources.

• However, access to physical reading resources remains very limited: 60% of schools do not have a library, and those that do exist are poorly equipped.

• This duality – high digital connectivity but physical infrastructure – highlights the need for hybrid solutions: promoting digital reading (ebooks, educational platforms), together with investments in school libraries and physical materials

Statistically, as children grow older, the exclusive interest in reading (printed or digital book) decreases. This may reflect both better technological adaptation and a diversification of reading sources among adolescents;

The type of reading preferred by rural children is closely linked mainly to the available resources and the level of personal and educational development. Encouraging reading (printed or digital) is essential to support school performance and to form more autonomous, informed and confident children.

Reading after school hours in rural areas is encouraged by curiosity, support from family and teachers, access to appropriate books and awareness of the value of reading. With the right conditions and encouragement, reading can become a natural part of the lives of rural children, contributing to their harmonious development.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PERCEPTION OF DECISION MAKERS ON DEVELOPMENT OF RURAL TOURISM IN LOCALITIES ALONG BORCEA BRANCH OF THE DANUBE RIVER, CĂLĂRAȘI COUNTY, ROMANIA. CASE STUDY.

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Abstract

Rural tourism is a component of economic and social development but also of rural civilization. The issue of rural area is extremely complex and its economic and social development has not yet been sufficiently addressed, in fact lacking a unitary concept on how the rural area of our country can be included in an evolutionary process. The tourism potential of Călărași county is given by the multitude of natural and anthropogenic tourism resources it possesses. The county location along the Danube and Borcea branch represents one of its main assets, which is why we set out to survey the perception of decision-makers in the localities located along Borcea branch of the Danube in Călărași county, in order to highlight the unused potential of the area. The research recorded the opinions and attitudes of 118 respondents, decision-makers in the localities located on the banks of Borcea Branch, Călărași county, regarding the development of rural tourism in this area. The questionnaire, with a number of 12 questions, 11 questions with multiple answer options and one open question, also included 4 filter questions. Starting from the consideration that in the development of the objectives and strategy for the rural tourism sector in the localities bordering Borcea Branch, Călărași county, the opinion and involvement of decision-makers from these localities is important, we surveyed and interviewed people who can play an important role in this regard. We note that 64% of the respondents, especially those who work in the city halls but also some of the managers, want to get involved in the development of rural tourism in the localities bordering Borcea Branch of the Danube. Also, 86% of the respondents believe that rural tourism could be a factor in the economic and social development of rural localities, by creating new jobs, stimulating the consumption of agri-food products and increasing revenues to local budgets.

Key words**:** *Borcea branch of the Danube River, sustainable development, questionnaire, strategy, rural tourism*

INTRODUCTION

Rural tourism is the form of tourism practiced in rural area, with destinations that belong to this space and have a functional structure of accommodation and heterogeneous services. This activity is organized and coordinated by the population belonging to rural society, which has a strong connection with nature and the environment [4].

Rural tourism has been practiced in Romania for a long time in an unorganized way, resulting from the need of tourists to find an accessible and more comfortable accommodation than in the case of campsites or chalets, during their holidays [8, 6]. After 1989, the need to organize these accommodation spaces was manifested, by approving, registering and classifying them. Organized rural tourism first appeared in the Rucăr-Bran area, then ANTREC (National Association of Rural, Ecological and Cultural Tourism) was established [2]. With the establishment of this organization, farms were approved in all counties and competition emerged, based on the natural tourist resources specific to each area, on the attractions offered to tourists. As a result of these transformations and the trend of modernization and improvement of rural tourist activities, rural tourism has occupied and occupies an important place in the tourist offer in our country, representing for many of us an attractive alternative for spending holidays and vacations [1].

The objectives, principles and requirements of sustainable development are found in forms of tourism such as ecotourism and rural tourism. These forms of tourism pursue both economic development and environment protection [9].

The specialized literature also presents arguments that show the favorability of rural tourism activities precisely through the factors that influence the emergence and development of this form of tourism: increased pollution of the urban environment, worsening health problems, the picturesqueness and uniqueness of rural settlements, the diverse and exceptional offer of mountain areas, increased nostalgia for birthplaces, increased complexity of work, reduced working week, sharp decrease in purchasing power, affordable prices for all categories of consumers, accessibility in consuming fresh food, the existence of ethno-folkloric-cultural traditions, the trend of population aging [8, 5, 9]. As an alternative to Romania sustainable development, rural tourism is considered a product-price-consumption aggregate, which gives the country multiple opportunities after the accession process, through which it benefits from all the functioning mechanisms of the European Union [7].

Starting from the saying 'man sanctifies the place', in rural tourism too it can be said that man is the one who can add value to places, natural resources and anthopian resources, but also to historical resources, whether material or informative – stories, legends, stories inherited by word of mouth from our ancestors [7, 14].

The general objective of the research is closely linked to the purpose of the paper, namely, the perception and awareness of decision-makers regarding the development of the rural tourism potential of Călărași county, as a county bordering Borcea Branch of the Danube. Although nature has been generous to this county, endowing it with wonderful natural tourist resources, which, if used rationally, could be like a magnet for tourists, there is still no viable strategy that, when implemented, would lead to the development of this sector.

MATERIALS AND METHODS

The quantitative field research was carried out in the period June-July 2025, based on a non-standardized questionnaire, applied face-to-face, at the subjects workplace.

The research recorded the opinions and attitudes of 118 respondents, decision-makers in the localities located on the banks of Borcea branch, Călărași county, regarding the development of rural tourism in this area, namely:

- assessments of the importance of rural tourism for community development and the profile of the rural tourist
- forms of rural tourism that could be developed and practiced in the area
- the main reasons that would determine tourists to visit their locality
- the tourist assets of the locality and the perception of their involvement in the development of rural tourism
- assessments of the way to promote existing tourist facilities in the locality, etc.

The questionnaire, with a total of 12 questions, 11 multiple-choice questions and one open-ended question, also included 4 filter questions that targeted the respondent's age group, decision-making structure, education levels and residence area.

We also used **interviews** to collect additional information. For information collecting, interviews were generally preferable to questionnaires because they allowed for direct interaction, detailed questioning and unlimited discussions. The main issues were identified immediately (sometimes through "body language") through several questions. In an interview, not all questions need to be determined in advance (as is done in a questionnaire). It was an interview in the true sense of the word, sometimes unscheduled, which generally lasted 30 – 40 minutes.

The data obtained were processed, ensuring the confidentiality of the information, and the results of the processing are available to the research participants.

The results obtained as a result of the interpretation of this data set led to the emergence of a set of conclusions.

Starting from the consideration that in the development of the objectives and strategy for the rural tourism sector in the localities bordering Borcea branch, Călărași county, the opinion and involvement of decision-makers from these localities is important, we questioned and interviewed people who can play an important role in this regard, as presented in Table 1.

We also took into account the fact that rural tourism development initiatives must be approached in a public-private partnership, which is why, along with political decision-makers, we also questioned people who have a say in the community, namely, managers from different fields of activity, directors of educational institutions, cultural centers, etc., doctors, priests, police officers and pensioners respected in the community.

Table 1. Categories of respondents depending on workplace

Specification	No.respondents	%
Mayor	6	5.1
Vice-mayor	11	9.3
Local counsellor	23	19.5
Teaching staff	15	12.7
Manager/Administrator LTD CO/SC/II/ANP	20	16.9
Director of public institutions	16	13.7
Doctor	5	4.2
Priest	6	5.1
Local policemen	5	4.2
Others	11	9.3
TOTAL	**118**	**100**

Source: Processing information in questionnaire applied to decision makers [10].

As mentioned in Figure 1, 50% of respondents fall into the age category 31-50, active people, from all the categories mentioned in Table 1, who can contribute to the development of rural tourism in the community in which they operate.

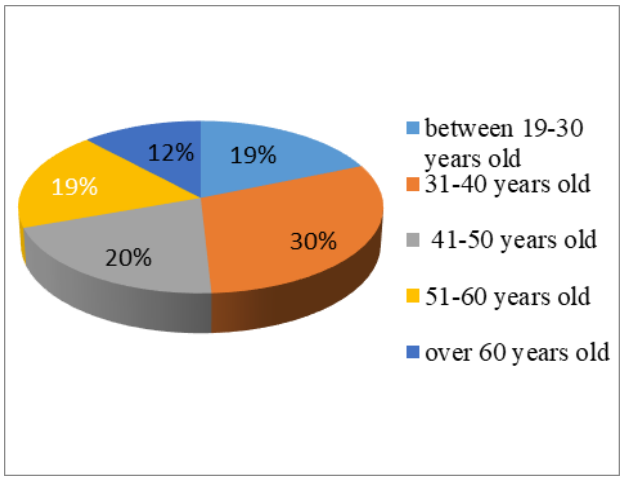


Fig. 1. Structure of respondents by age category
Source: Processing information in questionnaire appliedto decision makers [10].

We also included in the sample 12% of people over 60, some retired, but who, through the respect gained in the community, can influence the decision of young people and, at the same time, have a lot of information about the natural and anthropogenic objectives in the area.

In rural communities, educated people are respected and can influence decision-making power. Based on this consideration, we included in the study sample only people who are at least high school graduates. From Figure 2, we find that 67% of the respondents have higher education.

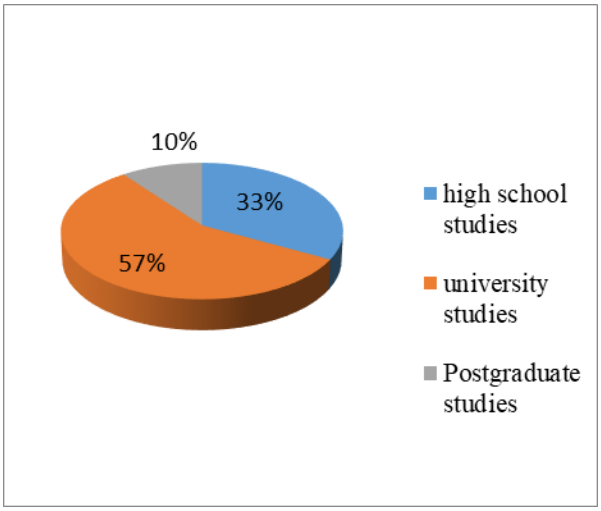


Fig. 2. Structure of respondents accordign to study level
Source: Processing information in questionnaire applied to decision makers [10].

Although they work in the rural area, 22% of respondents live in urban area and commute daily; this is the case for some teaching staff, doctors, policemen, managers/administrators.

RESULTS AND DISCUSSIONS

Borcea branch is part of the Danube Plain, being positioned near the national road DN3B, which connects Călărași town and Fetești town [12]. Right in front of Călărași town, Borcea branch splits into two watercourses: Borcea branch and Bala branch, which are to reunite near Unirea locality, following the route until leaving the county in a single watercourse: Borcea branch [3]. The rural localities that border the county in the South and which also benefit from the natural wealth of Borcea branch are: Modelu commune with the villages

of Radu Negru, Modelu, Stoenești and Tonea; Roseți commune consisting only of Roseți village; Dichiseni commune with Coslogeni, Dichiseni and Satnoieni villages, Unirea commune consisting of Oltina and Unirea villages, Jegalia commune consisting of Iezeru, Jegalia and Gâldău villages and Borcea commune consisting of Borcea and Pietroiu villages [13].

The natural resources of rural tourism are truly fascinating because nature offers us the most wonderful things to enjoy, and the people of the rural area are true treasures because they have the ability to enjoy the smallest things, the beauty of nature and can share wonderful stories about the rural space.

Natural resources are represented by both the flora and fauna of the area, as well as the people of the places, crafts, traditions and customs transmitted from generation to generation [12, 11].

Regarding the respondents' assessment of the importance of tourism on a personal level, as mentioned in Figure 3.76% rate it as very important and important. However, there are also 9% of respondents who consider tourism to be little important to them.

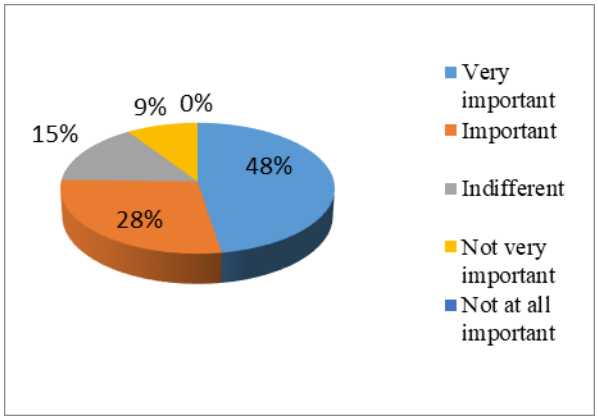


Fig. 3. Structure of responses on assessment of tourism importance
Source: Precessing information in questionnaire applied to decision makers [10].

As it is mentioned in Figure 4, 83 of the respondents (70%) are not very satisfied or not at all satisfied with the way tourism is carried out in Călărași county, most of them mentioning the accommodation infrastructure, road infrastructure, public catering services among the reasons for these dissatisfactions. However, there is also a percentage of 22% of the respondents who declare themselves quite satisfied and even very satisfied with the tourism infrastructure of Călărași county.

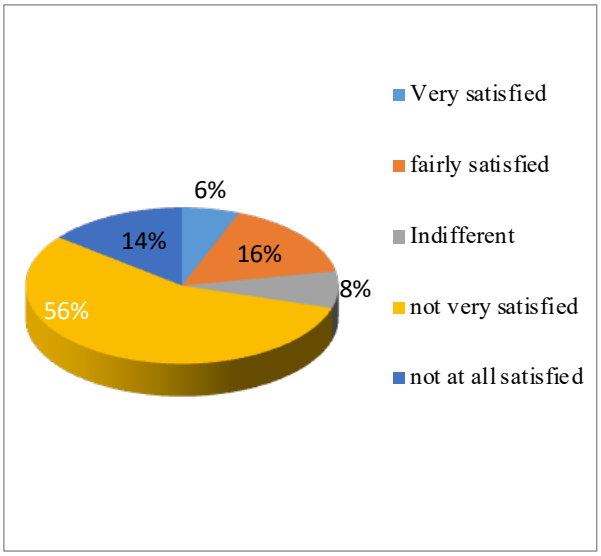


Fig. 4. Structure of responses on assessment of turism in Călărași county
Source: Precessinf information in questionnaire applied to decision makers [10].

In Table 2, we quantified the responses regarding the types of tourism that can be practiced in Borcea branch localities. In first place, as expected given the fact that they are localities with access to water but also with a special hunting background on the other side of Borcea branch is **hunting and fishing tourism**, followed by **rest and recreation tourism, visits to cultural-historical sites, agrotourism and ecotourism.**

In the category ‚others', respondents mentioned the traditional cuisine of the area. In order to verify the accuracy of the responses, we asked respondents for their opinion on the reasons that would determine tourists to visit their locality. The answers, presented in Table 3, correlated with the answers regarding the types of tourism that can be practiced in the localities along Borcea branch, demonstrated stability and seriousness on the part of the respondents, who, in the first places among the reasons for the visit, mention hunting and fishing, the natural and unpolluted landscape, rest and recreation in the rural area without the daily hustle and bustle of the town. As it can be seen from the information contained in Table 4.,

regarding the statements regarding the ingredients of a successful trip/vacation, respondents appreciated in a percentage of over 90%, the quality of food services, the destination location, the entertainment and recreation facilities, and the accommodation services. 17.8% of respondents mentioned the quality of the surroundings and the proximity of the location to the center of the accommodation. Some of the respondents mentioned that these very ingredients that they particularly appreciate in a successful trip cannot be brought to the forefront by the poor infrastructure of the facilities made available to tourists who would like to spend a vacation in their locality.

Table 2. Respondents' perception on categories of turism that can be developed and practiced in locality

Category of tourism	**No. of respondents**	**%**
a.events tourism	89	75.4
b hunting and fishing tourism	115	97.5
c.visits to tourist (cultural-hisotircal) sites	111	94.1
d.religious tourism	67	56.7
e. rural tourism, agritourism, ecotourism	109	92.4
f. sportive, nautical tourism	78	66.1
g.entertainment tourism (beach, campsite)	87	73.7
h.Rest and relaxation tourism	113	95.7
i.hiking	32	19.4
j.others	13	11.0

Source: Processing information in questionnaire applied to decision makers [10].

Table 3. Respondents' perception on main reasons that determine tourist to visit locality

Main reasons that determine tourists to visit locality	No. respondents	%
a. landscape, natural beauty, unpolluted natural area	113	95.7
b. will to know, curiosity	87	73.7
c. water sports practicing, beach	78	66.1
d.hiking practicing	32	19.4
e. huntign and fishing	114	96.6
f. study visits, pilgrimage	68	57.6
h. rest, relaxation	113	95.7
i. anthropic tourist sites.	109	92.4
j.others	13	11.0

Source: Processing information in questionnaire applied to decision makers [10].

Table 4. Respondents' perception n ingredients of a successful trip

Ingredients of a successful trip	No. respondents	%
a.Quality of accommodation services	105	88.9
b.Quality of destination location	109	92.4
c.Qaulity of catering services	114	96.6
d.Diversity of relaxation facilities	107	90.7
e.Diversity of entertainment facilities	111	94.1
f.easy to reach destination	75	63.5
g.others	21	17.8

Source: Processing information in questionnaire applied to decision makers [10].

Table 5. Respondents' perception on main assets that determine tourist to visit locality

Atuuri	No. respondents	%
a.Hospitable atmosphere	118	100
b.Entertainment and leasure facilities	107	90.7
c. Access to Borcea branch	118	100
d.Local gastronomy	64	54.2
e.Unique natural landscape	113	95.7
f.Cultural and religious sites	101	85.6
g.Local traditions	87	73.7

Source: Processing information in questionnaire applied to decision makers [10].

Table 6. Respondents' perception on influence of information sources on selecting rural tourist destination

Influence of information sources on selecting rural tourist destination	No. respondents	%
a.Promotion on town hall website	98	83.1
b.Promotion of Călărași County Association of Agritourism, Rural and Ecological Tourism	87	73.7
c.Catalogues, leaflets, tourist guides	76	64.4
d.Tourist recommendations	90	76.3
e. Tour operators recoomendations	67	56.8
f.Advertisments in newspapers, magazines, radio, TV	101	85.6
g.Other means on Internet	103	87.2

Source: Processing information in questionnaire applied to decision makers [10].

At the risk of disturbing by returning to the same aspects captured in the previous questions but with the desire to make the respondents realize the unused potential of rural tourism in their locality as well as the desire to verify the accuracy of the responses, we requested the respondents' opinion on the most important assets that their locality can highlight through rural tourism. The responses, presented in Table 5, correlated with the responses regarding the types of tourism and the reasons of tourists to visit the localities bordering Borcea branch, demonstrated balance and seriousness on the part of the respondents, who, on the first places among the assets of their locality regarding the development of rural tourism, mention in percentage 100% the hospitable atmosphere with which the guests would be received and the access to Borcea branch which facilitates hunting and fishing, water sports, the beach, the natural and unpolluted landscape, rest and recreation in the rural space but also the local traditions that would pleasantly surprise the tourists.

86% of respondents believe that rural tourism could be a factor in the economic and social development of rural localities, by creating new jobs, stimulating the consumption of agri-food products and increasing revenues to local budgets.

18% of respondents, especially mayors and vice-mayors, mention that rural tourism is quite promoted in their locality, through the information provided on the locality website, but when asked why tourists do not come to the area, they do not have many answers. However, 82% of respondents are aware that neither the area is promoted enough nor the tourist infrastructure is adequate. From the information presented in Table 6, it results that, in a percentage of over 80% of respondents, they consider that the main means of promotion, respectively, sources of information for tourists could be the town hall website, the media and the internet, followed by the recommendation of other tourists or promotion on the website of Călărași County Association of Agritourism, Rural and Ecological Tourism.

Regarding the profile of the rural tourist, they mentioned: People with less money, people with children who want to get to know animals and plants closely, people who love nature, people passionate about fishing and hunting, weekend tourists who want to relax. We note that 64% of respondents, especially those who work in town halls but also some managers, want to get involved in the development of rural tourism in the localities along Borcea branch.

As main priorities for the development of rural tourism, they mentioned:

- Developing and implementing a strategy to increase the visibility of reception units and attractions in the area.
- Attracting European funds to improve the physical and reception infrastructure.
- Developing a common image (county brand) that represents a delimited identity aspect for tourism consumers.
- Creating a local network for organizing and promoting tourism.
- Identifying and capitalizing on existing tourist attractions (physical - monuments, buildings or intangible - events, customs) in these localities.

CONCLUSIONS

The natural and anthropogenic resources of the county give it a high tourist potential. Its riverbank on the Danube and the branches into which it splits (Borcea Branch and Bala Branch) create picturesque landscapes and offer a natural setting favorable to fishing and hunting. The presence of these flowing waters on the territory of the county must be properly exploited and highlighted. In order to introduce these natural resources into tourist circuits, expenses are necessary for arranging and cleaning the banks to give them a pleasant and attractive appearance, so that tourists want to return to these places. Natural tourist resources alone are not enough to attract tourists, their exploitation and care making them real attractions for them. There are many natural and anthropogenic resources that can be exploited through tourism, but at this moment their organization into packages and their promotion as tourist packages is in its initial phase.

The tourism industry is constantly changing. Tourist needs and expectations are increasing and the competitiveness of the economic actors involved is also on an upward trajectory.

The association of actors involved in tourism clusters can represent an option that increases the quality of services of the actors involved and offers complex service packages that satisfy different needs (whether it is entertainment, cultural activities, etc.). Also, the existence of a concern at the European Union level regarding the development of financing lines dedicated to clusters could represent an opportunity at the territorial level if this form of intervention is chosen for the development of rural tourism.

Regarding the development of the banks of the Danube and Borcea branch and of the flowing and standing waters in Călărași county, this is deficient, given that there are no modern tourist infrastructures such as aquaparks, tourist ports, etc., but only small, rudimentarily developed beaches in the riverside towns.

Among the reasons for not using this significant tourism potential are the lack of strategic investors in the field of tourism, the lack of clear legislation in the field of public-private partnership, the restrictions imposed by environment legislation. From the point of view of tourism activity, the region must also face additional challenges, such as climate and demographic changes. Increasing temperatures will reduce the tourist season, and opportunities for sports and recreational activities will simultaneously decrease, the summer season will register a higher demand, with negative effects on the environment and with exceeding the tourist support capacity of certain areas. The influence of climate change on tourism should not be treated in isolation since major changes in tourist demand can have strong effects on the economic and social policy in the respective areas (for example: on the demand for labor, transport infrastructure).

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

A STUDY ON STRATEGY DETERMINATION IN THE EGG POULTRY SECTOR IN TÜRKIYE THROUGH SWOT AND SOR ANALYSIS

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Abstract

In this study the current status of the egg poultry sector in Türkiye was examined, taking Afyonkarahisar, Manisa, and Konya, where production is most intensive, and Antalya, Burdur, and Isparta as examples. Research data were obtained through face-to-face interviews conducted with 68 egg-producing enterprises selected using the stratified random sampling method. Within the scope of the SWOT analysis, the strengths and weaknesses of the sector, along with opportunities and threats, were identified, and these findings were further evaluated from a strategic perspective through the SOR (Strategic Orientation) analysis. The research findings indicate that increasing domestic raw material production and reducing dependency on imports are essential for lowering feed costs. Furthermore, to ensure continuity in the egg market and maintain price stability, it is crucial to develop technological infrastructure that allows eggs to be preserved for longer periods in liquid or dried forms. Extending the shelf life of eggs and encouraging a shift toward high-value-added products will enhance competitiveness in both domestic and international markets, thereby contributing to the sustainability of the sector.

Key words**:** *egg poultry sector, SWOT analysis, SOR analysis*

INTRODUCTION

Today, a significant portion of the world's population lacks sufficient protein consumption. According to Food and Agriculture Organisation (FAO) data, more than two billion people experience difficulties in accessing protein and micronutrients, while three billion people cannot maintain a healthy and balanced diet due to insufficient protein intake [3]. When the global supply of animal protein is examined, it is observed that approximately 30–40% comes from meat, 20% from milk and dairy products, 15–17% from fish and seafood, and 7–10% from eggs [4].

Eggs, with their rich nutritional content and low cost, are an economically accessible source of protein. In a wide range of uses, from breakfasts to confectionery and gastronomy, they are consumed not only by low-income groups but also by middle- and high-income groups [1, 2].

According to FAO data, global egg production was 51.3 million tons in 2000, and by 2023 it had increased by 77%, reaching 91.1 million tons. In the same period, egg exports increased by 127%, while imports rose by 167%. This situation reveals that eggs have become an increasingly strategic product not only in domestic consumption but also in international trade. A similar trend is observed in Türkiye. While egg production in 2000 was 844 thousand tons, in 2023, it increased by 52% to approximately 1.3 million tons. The value of egg exports rose from 3.6 million dollars to 403 million dollars in the same period, demonstrating Türkiye's competitiveness in the sector and its role in the global market.

Isik and Gul (2024) affirmed that egg price has seasonal fluctuations depending on offer/demand ratio in Türkiye [6].

When previous studies on SWOT analysis are examined, Sav [9] in his study on the effects of policies implemented on Türkiye's vegetable seed foreign trade with SWOT and SOR analysis, concluded that the seed sector should be supported to modernise. İşler and Ören [7], in their studies, determined that Burdur province has a leading position in livestock farming, particularly in cattle breeding (dairy

farming). Uysal [11] in their study on determining strategies with SWOT and SOR analysis in the pulse sector of Mersin province, identified that the most important problem faced by producers was the instability in supply and prices. Taş [10], in her study, determined that changes in natural structure directly affect agricultural areas. This study reveals that the increase in egg production and trade carries not only an economic dimension but also a strategic dimension in terms of global food security and the sustainable supply of animal protein. In this context, the strengths and weaknesses of the egg poultry market, as well as opportunities and threats, were determined by using the SWOT analysis method. The outputs obtained from the SWOT analysis were then evaluated through the SOR (Strategic Orientation Round) method, to contribute to the development of the egg poultry sector.

MATERIALS AND METHODS

The primary material of the study was obtained through face-to-face interviews with 68 enterprises selected by the stratified random sampling method from the provinces where egg poultry farming is intensively carried out in Türkiye, namely Afyonkarahisar, Konya, Manisa, Antalya, Burdur, and Isparta.

The survey form covers topics such as establishment investment costs, enterprises' input costs, fluctuations in egg prices, the situation of egg prices compared to meat and milk prices during crisis periods, the adequacy of enterprise sizes, the impact of obtaining feed raw materials through imports on costs, disease risks observed in poultry farming (such as Newcastle disease and avian influenza), and the economic role of eggs in meeting human protein needs. The data obtained from the research were subjected to SWOT analysis to reveal the strengths and weaknesses of the sector as well as its opportunities and threats. The results of the SWOT analysis were evaluated with the help of the SOR (Strategic Orientation) analysis matrix, and applicable strategic goals for the sector were developed. SWOT analysis is a strategic analysis method that allows a comprehensive assessment of the current status of a sector, an enterprise, or a specific activity, considering market conditions and competitors' positions. Through this method, enterprises can see their current situation more clearly and effectively carry out strategic planning for the future. In SWOT analysis, internal factors represent the strengths and weaknesses of the enterprise, while external factors indicate the opportunities and threats in the environment (Table 1) [5]. SOR Analysis refers to the process of strategy development using the outputs obtained from the SWOT analysis [8]. SOR stands for Strategic Orientation. To develop a strategy with this analytical approach, the results of the SWOT analysis need to be used as the primary input (Table 2).

Table 1. SWOT analysis matrix

Strengths	**Opportunities**
The strong points of the enterprise are specified.	Opportunities in the external environment that may provide advantages to the enterprise have been indicated.
Weaknesses	**Threats**
The aspects of the enterprise that need improvement are identified.	Threats in the external environment that the enterprise may encounter are explained.

Source: [5].

Table 2. SOR analysis matrix

Score	**What It Indicates**	**What Can Be Done**
Total score (calculated separately for Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T))	Indicates the importance level of S, W, O, T factors	Based on the most significant opportunities and threats from external factors, 2 or 3 strategies can be developed for optimal benefit
Scores for each combination	Shows the effect of strengths or weaknesses in addressing opportunities or threats	Strategic objectives are determined for the combinations that yield the highest scores.
Total score for each combination	Provides an overall assessment	Determines the type of strategy: • High S-O: Offensive strategy; opportunities are strong • High S-T: Defensive strategy; strengths can be used against threats • High W-O: Weaknesses need to be addressed to take advantage of opportunities • High W-T: Threats are severe; solutions are challenging

Source: [12].

RESULTS AND DISCUSSIONS

As a result of the field study, the analysis of the data obtained from the sample region determined the strengths, weaknesses, opportunities, and threats of the egg production sector (Table 3). Examination of the data on the 68 firms interviewed revealed the sector's strengths and weaknesses as well as the opportunities and threats it faces.

Table 3. SWOT analysis of firms in the egg poultry sector

Strengths	Weaknesses
S1. Being the most economical source of protein needed by people (31 firms)	**W1.** High enterprise-level input (feed) costs (29 firms)
S2. Egg prices do not increase as much as meat and milk prices during crises, remaining the cheapest animal protein source (26 firms)	**W2.** High establishment and investment costs of the enterprise (27 firms)
S3. Short production period compared to other animal groups and high production potential (6 firms)	**W3.** Enterprise sustainability is affected by the price instability of eggs (6 firms)
S4. Poultry has a better feed conversion rate compared to other farm animal groups (3 firms)	**W4.** Insufficient size of enterprises (4 firms)
S5. High yield per unit area within animal production in the poultry sector (2 firms)	**W5.** Cost fluctuations due to the main feed ingredients being largely imported (2 firms)
Opportunities	**Threats**
O1. Increasing orientation toward cheap protein sources (30 firms)	**T1.** Continuous increase in feed prices (46 firms)
O2. Türkiye's geostrategic proximity to the world's largest importing countries and the absence of egg production in Middle Eastern markets (15 firms)	**T2.** Risk of diseases (such as Newcastle and avian influenza) and their variants (8 firms)
O3. Rising interest in protein-focused diets for healthy nutrition (12 firms)	**T3.** Dependence on imported breeding material and feed ingredients (6 firms)
O4. Increased demand for protein to maintain immunity during the COVID-19 pandemic (8 firms)	**T4.** Difficulties in finding qualified personnel (5 firms)
O5. Demand across all income levels due to cheap, healthy, and high-quality animal protein (3 firms)	**T5.** Lack of interest from the younger population in the business (3 firms)

Source: Own calculation.

According to the analysis, 31 firms stated that the sector's strongest aspect is "its economic source for meeting human protein needs." In contrast, 29 firms indicated that the sector's greatest weakness is "the high input costs in the egg production sector." Regarding opportunities, 30 firms viewed the sector's "orientation toward cheap protein sources" as a chance for growth, while 46 firms expressed that the "continuous increase in feed prices" represents the main threat facing the sector.

After the SWOT analysis, a SOR matrix was created to make strategic decisions for the sector and to determine a roadmap. In preparing the SOR matrix, the factors included in the SWOT analysis were rated by the participating firms on a scale from 0 (least important) to 3 (most important). Based on the obtained scores, the matrix was divided into four main areas: "attack" (strengths × opportunities), "quick escape" (weaknesses × opportunities), "defence" (strengths × threats), and "crisis" (weaknesses × threats). In the study, the "quick escape" area was identified with the highest value of 220 points, and accordingly, the strategic roadmap was formed by leveraging opportunities to transform weaknesses into strengths (Table 4).

Table 4. SOR analysis results of companies in the egg poultry sector

		Opportunities					Threats					TOTAL
		O1	O2	O3	O4	O5	T1	T2	T3	T4	T5	
Strengths	S1	15	10	6	11	13	15	5	7	9	4	95
	S2	14	9	4	11	12	15	6	5	10	3	89
	S3	10	5	5	8	10	11	7	5	7	4	72
	S4	8	7	4	9	9	9	4	4	8	6	68
	S5	7	5	4	7	8	7	4	3	4	5	54
Weaknesses	W1	15	9	5	13	13	14	7	7	8	4	95
	W2	12	10	5	8	12	13	5	7	8	5	85
	W3	12	8	5	10	12	11	5	5	9	5	82
	W4	9	6	3	8	7	9	3	5	7	5	62
	W5	10	6	4	8	10	11	5	5	6	4	69
Scoring		112	75	45	93	106	115	51	53	76	45	771

Source: Own calculation.

Strategic Objectives in Egg Poultry Farming in Türkiye: An Assessment Based on SOR Analysis

The egg poultry sector in Türkiye has experienced significant development in recent years. While production and consumption data indicate that the sector has gained momentum, specific structural weaknesses at the sectoral level continue to exist. In this context, it is necessary to develop strategic approaches to address these weaknesses in order to utilise existing opportunities effectively. The results of the SOR (Strategic Orientation) analysis indicate that two primary strategic objectives emerge as crucial for the sustainable development of the sector. Strategic Objective

1: The high cost of basic inputs in the sector (Z1:15) and the high production costs faced by producers wishing to invest in the poultry industry (Z2:12) are among the main barriers limiting the development of the sector. In this context, providing input subsidies to producers and supporting new investors will increase consumers' tendency towards affordable and accessible protein sources (F1:112). Thus, the egg sector's potential to provide the protein needed by people will be preserved in an economically sustainable manner (G1:15).
Strategic Goal 2: The instability of egg prices (Z3:12) and the heavy dependence of primary raw materials for poultry feed on imports (Z5:10) have been identified as other significant structural weaknesses of the sector. Implementing measures to ensure price stability and increasing production capacity for raw material supply will sustain consumer demand for eggs, which are an affordable, healthy, and high-quality source of animal protein (F5:106). This approach will prevent egg prices from rising as sharply as meat and milk prices during potential economic crises, thereby preserving eggs' position as the most economical source of animal protein (G2:12).

CONCLUSIONS

Türkiye, due to its geographical location, has significant advantages in egg production; however, it remains vulnerable, particularly in connection with developments in Middle Eastern countries, Russia, and Ukraine. Among the sector's main issues are the heavy reliance on imported raw materials for feed—the primary input determining production costs—and the price instability of eggs resulting from problems in exports. In this context, policymakers need to reduce dependence on imported raw materials and encourage domestic production to mitigate feed costs. Additionally, to address fluctuations in egg prices and disruptions in the supply chain, the use of technological automation infrastructure in enterprises—which can extend the shelf life of eggs and convert them into higher-value products—should be promoted. These measures will help ensure the continuous availability of eggs in the market and contribute to price stability both domestically and internationally.

ACKNOWLEDGEMENTS

This paper was a part of Mehmet IŞIK's PhD. Thesis.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC ANALYSIS OF EGG-PRODUCING ENTERPRISES IN TÜRKIYE

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Abstract

This study aims to examine the economic structure and performance of egg-producing poultry farms in Türkiye. A total of 68 farms operating in the provinces of Afyonkarahisar, Konya, Manisa, Antalya, Burdur, and Isparta were evaluated in five groups according to flock size; the data cover the 2022 production season. The majority of farm owners have a high school or higher education level, and their experience plays a determining role in profitability and production management. As farm scale increases, the adoption of modern production systems (88.24% enriched cages), the rate of organisation (77.9%), and profitability also increase. Feed costs constitute the most significant portion of production expenses (67.05%), with an average unit egg cost of 1.27 TRY and a selling price of 1.55 TRY. Small farms still face limitations in cost management and access to financial resources. The findings indicate that economies of scale, modern production systems, and effective cost management are critical for profitability. To achieve sustainable profitability, strategies such as improving feed efficiency, encouraging organisation, expanding modern cage systems, and facilitating financial access are recommended.

Key words**:** *egg production, economic analysis, production cost, Turkiye*

INTRODUCTION

Poultry farming has historically been an important component of Turkish agriculture. Historical records indicate that the Ottoman Empire was among the entities exporting eggs. However, over time, the sector lagged behind developed countries due to insufficient adaptation to technological and industrial advancements [17].

The more and more increased demand for eggs and meat due to the high protein content as needed by consumers [7] has led to significant industrialisation in Turkish poultry farming which began during the planned development period of the 1960s, with the importation of hybrid parent stocks authorised in 1963. From the 1970s onwards, the increase in private sector investments contributed substantially to the sector's development [14].

With the advancement of modern agricultural techniques and the transition from extensive to intensive farming methods, the importance of enterprises suitable for industrial agriculture has increased. In this context, egg production stands out as a sector in which modern techniques can be more easily applied, climatic factors can be controlled, and production sustainability can be ensured.

Today, egg poultry farming has become a sector that continuously improves in terms of production, efficiency, and exports, thereby making a significant contribution to the Turkish economy [12][5]. Nevertheless, high production costs, the elevated prices of key inputs, and seasonal price fluctuations remain significant challenges limiting the sector's development [11].

Studies on the economic structure of egg production enterprises indicate that feed costs constitute a significant proportion of total expenses. Research has shown that large-scale enterprises have advantages over smaller ones in both production efficiency and profitability [6][14][3]. High input costs, in particular, restrict the economic performance of small- and medium-sized enterprises [8][16]. Some studies report that enterprises starting with pullets incur higher costs and achieve lower

gross profits [10], whereas even large enterprises, despite more rational operations, may fail to reach optimal factor utilisation [13]. These findings highlight the critical role of enterprise size and cost management in determining profitability in the egg poultry sector.

This study aims to analyse the economic structure of egg-producing enterprises in Türkiye, compare their performance, and provide insights that can guide investors, producers, and policymakers.

MATERIALS AND METHODS

The primary material of the study consisted of face-to-face survey data, for the 2022 production period, collected from farms operating in Afyonkarahisar, Konya, Manisa, Antalya, Burdur, and Isparta, which together account for 32.92% of Türkiye's layer poultry production. Farm records were obtained from the relevant Provincial Directorates of Agriculture and Forestry, and the Central Union of Egg Producers, while secondary data were sourced from FAO, TURKSTAT (TÜİK) [18], and the existing literature.

Since it was not possible to reach all farms comprising the target population, Stratified Sampling was employed, with strata allocation determined using the Neyman method. The sample size was calculated as 68 farms, based on a 99% confidence level and a 5% margin of error. The farms were categorised into five groups according to the number of laying hens they possessed (Table 1).

Table 1. Distribution of sampled enterprises

Group (Number of Laying Hens)	n
Group I (1–25,000)	13
Group II (25,001–75,000)	11
Group III (75,001–150,000)	12
Group IV (150,001–250,000)	8
Group V (250,001 and above)	24
Total	68

Source: Own calculation.

In the data analysis, Absolute Profit, Relative Profit, Gross Profit, and Gross Production Value were calculated. In addition, the production and feed performance indicators of the enterprises, as well as their socio-economic characteristics (such as education level, work experience, credit utilisation, and organisational membership), were evaluated.

RESULTS AND DISCUSSIONS

Among the enterprise owners, 11.76% had primary education, 14.71% had secondary education, 38.24% had a high school diploma, 13.24% had an associate degree, and 22.06% held a bachelor's degree. This indicates that all enterprise owners possessed at least one diploma (Table 2). The relatively high level of education provides a significant advantage in terms of adopting modern production techniques and keeping up with sectoral developments.

Similarly, Doğan [8] in Konya and Turhan [16] in Akçakoca reported that the majority of enterprise owners, in their studies, were diploma holders. Therefore, the educational level of producers in the sector is generally high.

In conclusion, enterprises with higher educational levels are likely to make more informed decisions, be more open to innovations, and maintain a stronger position in terms of sustainability.

Table 2. Educational levels of farm owners

Educational Level	Farm Scale					Total	Percentage (%)
	I	II	III	IV	V		
Primary School	4	2	2	0	0	8	11.76
Middle School	5	1	2	1	1	10	14.71
High School	3	6	4	3	10	26	38.24
Associate Degree	1	1	2	0	5	9	13.24
Bachelor's Degree	0	1	2	4	8	15	22.06
Total	13	11	12	8	24	68	100.00

Source: Own calculation.

When evaluating the work experience of the enterprise owners included in the study, the majority possess long-standing experience. Specifically, 44.12% of the owners have 31 years or more, 27.94% have 21–30 years, 14.71% have 11–20 years, and 13.24% have 1–10 years of experience (Table 3). This indicates that experience is prevalent in the management of enterprises operating in the sector. Similar findings have also been reported in the literature. For instance, Sarıözkan [14] determined that a large proportion of owners in enterprises located in Afyonkarahisar had 11

years or more of experience. In light of these findings, it can be suggested that the experience of enterprise owners in the egg poultry sector may have positive effects on business management and production performance.

When examining the reasons why farm owners engage in egg poultry farming, it was found that 52.94% pursued it for profit, 13.24% as a secondary occupation, and 33.82% due to the lack of alternative employment opportunities (Table 4). Similar findings have been reported in the literature. For instance, Doğan [8], in his study conducted in Konya, indicated that the majority of farm owners produced either as part of a family business or for profit. In contrast, Sarıözkan [14], in a study carried out in Afyonkarahisar, observed that a significant portion of enterprises engaged in egg poultry farming due to secondary income needs or limited alternatives. These findings suggest that egg poultry farming is influenced both by the potential for economic gain and by the scarcity of alternative employment opportunities, providing an important indicator for understanding sectoral preferences.

Table 3. Work experience of farm owners (years)

Experience (years)	Farm scale										Total	
	I		II		III		IV		V			
	N	%	N	%	N	%	N	%	N	%	N	%
1-10	2	15.38	1	9.09	2	16.67	1	12.50	3	12.50	9	13.24
11-20	1	7.69	2	18.18	2	16.67	3	37.50	2	8.33	10	14.71
21-30	4	30.77	4	36.36	3	25.00	1	12.50	7	29.17	19	27.94
31 and over	6	46.15	4	36.36	5	41.67	3	37.50	12	50.00	30	44.12
Total	13	100.00	11	100.00	12	100.00	8	100.00	24	100.00	68	100.00

Source: Own calculation.

Table 4. Reasons for engaging in egg production

Reason for engaging in egg production	I		II		III		IV		V		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Profitability	5	38.46	6	54.55	8	66.67	3	37.50	14	58.33	36	52.94
Secondary job	2	15.38	1	9.09	1	8.33	2	25.00	3	12.50	9	13.24
Lack of alternative job opportunities	6	46.15	4	36.36	3	25.00	3	37.50	7	29.17	23	33.82
Total	13	100.00	11	100.00	12	100.00	8	100.00	24	100.00	68	100.00

Source: Own calculation.

The majority of the 68 enterprises included in the study (77.9%) were found to be members of agricultural producer organisations. The highest rate of organisation membership was observed in group III and group V enterprises at 91.67% (Table 5). Similar studies also indicate that the sector is considerably organised [8][14]. This finding suggests that egg-producing poultry enterprises have the potential to enhance knowledge sharing, marketing, and production processes through organisational participation.

The findings regarding credit usage during the establishment phase of the enterprises indicated a relationship between scale size and financing preferences. The credit utilisation rates of small-scale enterprises in Groups I and II were 30.77% and 36.36%, respectively, whereas this rate increased to 58.33% and 62.50% in Groups III and V. In Group IV, the credit utilisation rate was determined to be 37.50%. Overall, 48.53% of the 68 enterprises surveyed used credit at the establishment stage, while 51.47% did not (Table 6). This suggests that larger-scale enterprises tend to meet their initial financing needs through credit, highlighting the effect of scale size on access to financial resources.

In the examined enterprises, the majority of egg production (88.24%) was carried out in enriched cage systems, while the remaining 11.76% was produced using conventional cage systems (Table 7). This indicates that most enterprises prefer production systems based on

modern technology and are taking steps to improve both production efficiency and animal welfare. Although the use of conventional cages is relatively higher in small-scale enterprises, the overall trend favours modern systems.

Table 5. Organisation membership status of enterprises

Enterprise scale	Organisation membership status				Total	
	Yes	%	No	%	N	%
I	7	53.85	6	46.15	13	100.00
II	10	90.91	1	9.09	11	100.00
III	11	91.67	1	8.33	12	100.00
IV	3	37.50	5	62.50	8	100.00
V	22	91.67	2	8.33	24	100.00
Total	53	77.94	15	22.06	68	100.00

Source: Own calculation.

Table 6. Organisation membership status of enterprises

Enterprise scale	Use of establishment credit				Total	
	Yes	%	No	%	N	%
I	4	30.77	9	69.23	13	100.00
II	4	36.36	7	63.64	11	100.00
III	7	58.33	5	41.67	12	100.00
IV	3	37.50	5	62.50	8	100.00
V	15	62.50	9	37.50	24	100.00
Total	33	48.53	35	51.47	68	100.00

Source: Own calculation.

Table 7. Rearing systems applied in enterprises

Enterprise scale	Rearing system				Total	
	Cage	%	Enriched cage	%	N	%
I	1	7.69	12	92.31	13	100.00
II	0	0.00	11	100.00	11	100.00
III	0	0.00	12	100.00	12	100.00
IV	2	25.00	6	75.00	8	100.00
V	5	20.83	19	79.17	24	100.00
Total	**8**	11.76	**60**	88.24	**68**	100.00

Source: Own calculation.

The majority of the workforce in the enterprises consisted of men (60.78%), while women accounted for a lower proportion (39.22%). The proportion of men varied between 50.96% and 68.53% across the enterprise groups (Table 8). This finding is consistent with similar studies in the literature and indicates that male labour still predominates in egg production enterprises [2][8].

47.06% of the surveyed enterprises implemented mandatory moulting, while 52.94% did not. Among the enterprise groups, this rate was highest in group III (66.67%) and lowest in group I (7.69%) (Table 9). Enterprises resort to moulting to reduce costs and increase profit margins during periods when the prices of pullets and chicks are high. Similarly, Sarıözkan [14] reported that 35% of enterprises in Afyonkarahisar practised moulting. These findings indicate that enterprise scale and economic conditions influence the implementation of moulting practices.

Table 8. Number and proportion of the workforce in enterprises

Enterprise scale	Male		Female		Total	
	N	%	N	%	N	%
I	142	59.41	97	40.59	239	100.00
II	141	59.49	96	40.51	237	100.00
III	135	68.53	62	31.47	197	100.00
IV	53	50.96	51	49.04	104	100.00
V	183	61.20	116	38.80	299	100.00
Total	654	60.78	422	39.22	1076	100.00

Source: Own calculation.

Table 9. Status of mandatory moulting in enterprises

Enterprise scale	Mandatory moulting				Total	
	Yes	%	No	%	N	%
I	1	7.69	12	92.31	13	100.00
II	4	36.36	7	63.64	11	100.00
III	8	66.67	4	33.33	12	100.00
IV	4	50.00	4	50.00	8	100.00
V	15	62.50	9	37.50	24	100.00
Total	32	47.06	36	52.94	**68**	100.00

Source: Own calculation.

Cost components in egg poultry farming

In the examined farms, total production costs were determined as 112,013,000 TRY, of which 85.34% were variable costs and 14.66% were fixed costs. Among these expenses, feed costs accounted for the largest share at 67.05%, followed by marketing costs at 10.14%, pul (day-old chick) depreciation at 8.45%, and tray (packaging) costs at 4.17%. When analysed by group, feed costs ranged from 65.42% in group I to 67.31% in Group V. Marketing, plant depreciation, and packaging costs also held significant shares within total costs (Table 10). Similar studies have shown that feed costs constitute the most significant portion of total production costs [1][14][8][13][6]. These findings indicate that managing feed costs is the most critical factor in reducing expenses in egg production. In conclusion, feed, marketing, fuel, and packaging expenses are of primary importance in farm cost management.

Table 10. Production costs and their distribution in the examined enterprises

Cost Items	I	II	III	IV	V	Average
Total Feed Cost	5,088,148	15,987,396	34,532,832	49,313,994	168,994,349	75,099,670
Temporary Labour Cost	1,443	16,039	12,510	21,341	46,505	24,002
Veterinary & Health Cost	192,482	480,368	810,016	1,145,499	3,324,076	1,565,416
Tray (Packaging) Cost	238,376	941,681	2,011,443	3,032,105	10,662,781	4,672,916
Electricity Cost	94,327	259,289	429,968	671,765	1,948,477	902,583
Marketing Cost	598,914	2,510,679	5,580,090	7,714,816	25,354,168	11,361,514
Moulting Period Cost	5,600	274,044	832,745	956,895	4,084,480	1,746,514
Repair & Maintenance (Equipment & Machinery)	47,258	66,825	92,177	115,979	252,917	139,021
Other Expenses (Cleaning, Fire Safety, etc.)	30,368	70,833	67,090	58,399	139,879	85,343
A- Total Variable Costs	**6,296,915**	**20,607,154**	**44,368,871**	**63,030,793**	**214,807,632**	**95,596,979**
General Administrative Expenses (3% of A)	188,907	618,215	1,331,066	1,890,924	6,444,229	2,867,909
Permanent Labor	252,923	504,709	786,750	1,212,375	2,773,700	1,390,421
Pul Depreciation	702,107	1,977,115	4,094,059	6,429,648	21,337,582	9,463,875
Pul Capital Interest	26,696	94,160	207,031	324,556	1,090,776	480,033
Depreciation (Building, Equipment & Machinery)	302,051	644,218	1,295,517	1,491,600	4,515,467	2,159,754
Capital Interest (Building, Equipment & Machinery)	7,551	16,105	32,388	37,290	112,887	53,994
B- Total Fixed Costs	**1,480,236**	**3,854,522**	**7,746,811**	**11,386,393**	**36,274,641**	**16,415,986**
Total Production Cost (A + B)	**7,777,150**	**24,461,675**	**52,115,681**	**74,417,187**	**251,082,272**	**112,012,965**
	Share (%)					
Total Feed Cost	65.42	65.36	66.26	66.27	67.31	67.05
Temporary Labour Cost	0.02	0.07	0.02	0.03	0.02	0.02
Veterinary & Health Cost	2.47	1.96	1.55	1.54	1.32	1.40
Tray (Packaging) Cost	3.07	3.85	3.86	4.07	4.25	4.17
Electricity Cost	1.21	1.06	0.83	0.90	0.78	0.81
Marketing Cost	7.70	10.26	10.71	10.37	10.10	10.14
Moulting Period Cost	0.07	1.12	1.60	1.29	1.63	1.56
Repair & Maintenance	0.61	0.27	0.18	0.16	0.10	0.12
Other Expenses	0.39	0.29	0.13	0.08	0.06	0.08
A- Total Variable Costs	**80.97**	**84.24**	**85.14**	**84.70**	**85.55**	**85.34**
General Administrative Expenses	2.43	2.53	2.55	2.54	2.57	2.56
Permanent Labor	3.25	2.06	1.51	1.63	1.10	1.24
Pul Depreciation	9.03	8.08	7.86	8.64	8.50	8.45
Pul Capital Interest	0.34	0.38	0.40	0.44	0.43	0.43
Depreciation (Building, Equipment & Machinery)	3.88	2.63	2.49	2.00	1.80	1.93
Capital Interest (Building, Equipment & Machinery)	0.10	0.07	0.06	0.05	0.04	0.05
B- Total Fixed Costs	**19.03**	**15.76**	**14.86**	**15.30**	**14.45**	**14.66**
Total Production Cost (A + B)	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Own calculation *1 USD = 16.62 TRY for 2022 year

Annual performance results of egg-laying poultry farms

In the examined farms, the gross production value increased with the scale of the enterprise, achieving an average of 135.95 million TRY.

The majority of the income (97.33%) was obtained from egg sales, while the shares of culled chickens and manure sales were 1.95% and 0.73%, respectively (Table 11). These findings indicate that as the farm size increases, revenues from egg sales rise, and marketing-related problems decrease. Similarly, Şahin and Yıldırım [15], Bayaner [4], Durrani [9], and Demircan et al. [6] also reported that the majority of gross production value was derived from egg sales.

Table 11. Sales revenues of the examined enterprises

Revenue components	I	II	III	IV	V	Average
A - Egg Sales Revenue	6,902,803	24,306,935	55,547,630	90,529,701	316,677,838	132,312,165
B - Cull Chicken Sales Revenue	107,257	525,023	1,193,599	1,920,017	5,964,476	2,647,064
C - Fertiliser Sales Revenue	44,255	208,450	449,442	667,641	2,234,091	988,542
Gross Production Value (GPV) (A+B+C)	**7,054,315**	**25,040,408**	**57,190,671**	**93,117,359**	**324,876,405**	**135,947,771**
Share (%)						
A - Egg Sales Revenue	97.85	97.07	97.13	97.22	97.48	97.33
B - Cull Chicken Sales Revenue	1.52	2.10	2.09	2.06	1.84	1.95
C - Fertiliser Sales Revenue	0.63	0.83	0.79	0.72	0.69	0.73
Gross Production Value (GPV) (A+B+C)	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Own calculation.

According to Table 12, the average gross profit per enterprise was calculated as 40,350,792 TRY, the net profit as 23,934,806 TRY, and the relative profit as 1.21. The gross and net profit per chicken were 140 TRY and 83 TRY, respectively. The gross and net profits of the first group of enterprises were significantly lower than those of the other groups, while the fifth group exhibited the highest profit levels. This observation indicates that profitability increased with production scale. Therefore, egg production was economically profitable for all enterprises except those in the first group. At this point, enterprise size and efficient management emerge as the primary factors determining profitability in the sector.

Table 12. Organisation membership status of enterprises

Indicators (TRY per enterprise)	I	II	III	IV	V	Average
A – Gross Production Value (GPV)	7,054,315	25,040,408	57,190,671	93,117,359	324,876,405	135,947,771
B – Total Variable Costs (TRY/Year)	6,296,915	20,607,154	44,368,871	63,030,793	214,807,632	95,596,979
C – Total Production Costs	7,777,150	24,461,675	52,115,681	74,417,187	251,082,272	112,012,965
Gross Profit (A–B)	757,401	4,433,254	12,821,800	30,086,566	110,068,773	40,350,792
Net Profit (A–C)	-722,835	578,732	5,074,990	18,700,173	73,794,133	23,934,806
Relative Profit (A/C)	0.91	1.02	1.10	1.25	1.29	1.21
Indicators (TRY per chicken)						
A – Gross Production Value (GPV)	415	440	460	486	495	471
B – Total Variable Costs (TRY/Year)	371	362	357	329	327	331
C – Total Production Costs	458	430	419	389	382	388
Gross Profit (A–B)	45	78	103	157	168	140
Net Profit (A–C)	-43	10	41	98	112	83
Relative Profit (A/C)	0.91	1.02	1.10	1.25	1.29	1.21

Source: Own calculation.

Egg production costs in the examined enterprises

In the examined enterprises, the unit cost of egg production was calculated by dividing the total production expenses, after subtracting secondary incomes, by the total number of eggs produced. On average, 85,120,409 eggs were produced per enterprise, with total production costs of 112,012,965 TRY, and total secondary income of 3,635,606 TRY. Accordingly, the cost per egg was determined as 1.27 TRY (Table 13).

In the study conducted by Doğan [8], the unit cost of eggs was found to be 0.21 TRY. The

primary reason for the difference between that study and the current one is the 439% increase in inflation during the 2017–2022 period, which significantly raised production costs. This finding is consistent with studies that take temporal cost variations into account.

In light of production costs, the average selling prices per egg were determined as 1.55 TRY in the enterprises, 1.65 TRY in public markets, and 1.76 TRY in retail stores (Table 13). Accordingly, the profit margin per egg was 0.28 TRY on average at the enterprise level, 0.38 TRY in public markets, and 0.49 TRY in retail stores (Table 13). These findings indicate the impact of different marketing channels on pricing and profitability and show that production costs can be balanced with sales strategies.

Table 13. Unit egg production cost in the examined farms

Indicators	I	II	III	IV	V	Average
A-Total Production Cost (TRY)	**7,777,150**	**24,461,675**	**52,115,681**	**74,417,187**	**251,082,272**	**112,012,965**
k-Cull Chicken Sales Revenue (TRY)	107,257	525,023	1,193,599	1,920,017	5,964,476	2,647,064
m-Manure Sales Revenue (TRY)	44,255	208,450	449,442	667,641	2,234,091	988,542
B-Total Secondary Revenue (k+m) (TRY)	**151,512**	**733,473**	**1,643,041**	**2,587,659**	**8,198,567**	**3,635,606**
C-Egg Production (units/year)	4,747,960	16,453,925	35,933,777	56,142,450	194,380,259	85,120,409
D-Egg Cost (TRY/unit) [(A-B)/C]	**1.61**	**1.44**	**1.40**	**1.28**	**1.25**	**1.27**
E-Selling Price (TRY/unit)	1.45	1.48	1.55	1.61	1.63	1.55
H-Profit Margin (TRY/unit) (E-D)	**-0.15**	**0.04**	**0.14**	**0.33**	**0.38**	**0.28**

Source: Own calculation

CONCLUSIONS

The poultry egg production enterprises examined in this study are generally managed by owners with a high level of education and extensive industry experience. As the scale of the enterprises increases, management experience, use of modern production systems, and profitability levels also rise. The analyses indicate that a significant portion of production costs originates from feed expenses, directly impacting enterprise profitability.

Furthermore, the widespread use of enriched cage systems and the fact that a large proportion of enterprises are members of agricultural organisations highlight the sector's high potential for technological adoption and knowledge sharing.

Economic analyses demonstrate that economies of scale in egg production enhance profitability and that positive profit margins are achievable when production costs are balanced with sales prices.

However, cost management and access to financial resources remain limited in small-scale enterprises.

Based on these findings, the following recommendations are proposed:

(i) Feed Management and Cost Control: Given the high share of feed expenses in total production costs, adopting practices that improve feed efficiency and implementing cost-effective procurement strategies are recommended.

(ii) Organisation and Knowledge Sharing: Encouraging membership in agricultural producer organisations can enhance enterprise capacity in terms of production efficiency, marketing, and application of modern technologies.

(iii) Promotion of Modern Production Systems: Encouraging the use of enriched cage systems instead of conventional cages in small-scale enterprises can improve both animal welfare and production efficiency.

(iv) Access to Financial Resources: Facilitating access to credit and financial instruments for small-scale enterprises can reduce initial investment costs and contribute to achieving economies of scale.

(v) Diversification of Marketing Channels: Utilising diverse sales channels may positively influence product pricing and profit margins; therefore, enterprises are encouraged to diversify their marketing strategies.

In conclusion, the egg production sector has the potential to achieve sustainable profitability under the leadership of educated and experienced producers, through economies

of scale, modern production systems, and effective cost management.

ACKNOWLEDGEMENTS

This paper was a part of Mehmet IŞIK's PhD. Thesis.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

A PRODUCTION AND ECONOMIC ANALYSIS OF SUNFLOWER: CURRENT SITUATION IN SERBIA AND BULGARIA

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Abstract

The aim of this research is an economic and financial analysis of sunflower production in Serbia and Bulgaria. The authors analyse the cultivated areas, production value, and yield of sunflower in both countries during the period from 2014 to 2023. The analysis also includes producer prices and the role of sunflower in foreign trade exchange in Bulgaria and Serbia during the same period. The applied methods involve descriptive statistics, analysis and synthesis, desk-research, and the comparative research method. The research is based on the fact that both countries have very similar climatic and geographical characteristics, water resources, as well as access to high-quality hybrids and other necessary agrotechnical measures for sunflower production. The difference lies in the financial support for production, given that Bulgaria is entitled to incentives from the EU budget, while Serbia does not have the right to use this financial support. The authors conclude that, despite the similarities and differences between the two countries, successful and profitable sunflower production can be achieved by combining several measures to improve production, as stated in the paper. These measures can help improve the efficiency and yield of sunflower, while minimizing risks and optimizing resources.

Key words: *sunflower, production, yield, prices, foreign trade exchange, Serbia, Bulgaria*

INTRODUCTION

In recent years, agriculture in Serbia and Bulgaria has been facing similar challenges. The main issue is climate change which has been recognized by the European Union as a global limiting factor for agricultural production in the long-term strategic document "The European Green Deal" [7]. In order to prevent climate change from significantly endangering agricultural production, numerous authors underline the significance of insurance as an important strategy for risk management in agriculture [20, 21, 27]. For instance, economic losses caused by natural disasters [3] ranged from 420 to 520 billion euros globally from 1980 to 2020, and in 2022 alone these losses amounted to 251 billion euros, of which only 44% were insured [20].

In addition, in the last few years, the share of agriculture in both Serbia and Bulgaria has been decreasing in gross domestic product (GDP), gross value added (GVA), and in total employment. Some authors [15] believe that the primary cause of the mentioned indicators in Bulgaria is the production of low value-added products. The situation is similar in Serbia, where agricultural producers pay insufficient attention to processing and improving the quality of agricultural products, while adhering to ecological standards, quality standards and food safety regulations [22]. In modern agricultural production, it is essential to follow ecological standards [14] and implement digital technologies that optimize production, reduce costs, and thus enhance profitability and efficiency in production, as well as product competitiveness in the market [1, 12].

As a consequence of climate change, drought has become an increasingly prevalent limiting factor for the production of most crops, although sunflower is considered to be relatively resistant to this risk [35, 36]. Therefore, irrigation represents a necessary agrotechnical measure [9]. However, it is insufficiently implemented in Serbia. According to the results of the latest Census of

Agriculture, during the 2022/2023 production year, only 27.5% of the total number of agricultural households had irrigation systems, and just 8.3% of the total agricultural land was irrigated [25]. This was attributed to the lack of financial resources for investments in production, which is a major problem for most family farms [26]. Family farms account for the majority (99%) of agricultural entities in Serbia. Despite this issue, a group of authors [4] concluded in their research that drought had a significant impact on the decrease in sunflower yield in Serbia from 2015 to 2023. However, they also found that agricultural producers achieved a positive financial result in sunflower production. It is clear that this result was significantly affected by selling prices which, alongside yield and input costs, have an impact on the production profitability [33].

Bulgaria was the largest producer of sunflower seeds in the European Union in 2022, according to the Eurostat data. The same source states that in the same year Bulgaria produced 2.117 million tonnes of sunflower seeds, which accounts for the quarter (23%) of the total production in the European Union. In addition to Bulgaria, leaders in the production of sunflower seeds in the EU are Romania, which produced 2.079 million tonnes in 2022, and France, which produced 1.779 million tonnes in 2022 [6]. According to the data of the Bulgarian Industrial Association, Bulgaria is also one of the global leaders in the export of sunflower seeds [10]. This country ranked second in the world in 2021 with exports valued at 730 million dollars, and its main export markets were Germany and Turkey [2]. Bulgaria ranks third in the world according to sunflower oil exports. In 2021, the revenue from these exports amounted to 700 million dollars. Sunflower oil is mainly exported to Spain, Italy, Turkey and Greece [2]. The area designated for agriculture in Bulgaria is about 47% of the territory of the country. The utilized agricultural area for sunflower production for the last five years varied from 789604 ha in 2029 to 985591 ha in 2022. [17].

It is believed that areas under sunflower cultivation have reached their maximum, and that in the future the efforts should be directed at improving agrotechnics and increasing the average yield and quality [36].

Sunflower, maize and rape are also important for producing biomass for renewable energy [11]. Sunflower, along with soybeans, is the most prevalent oil crop in Serbia [16]. Sunflower production in Serbia started in the 1930s. Sunflower was planted on 1,907 ha in 1935, and by 1938 it expanded to 23,000 ha. The significant contribution to the development of sunflower production in Serbia was made by the Institute of Field and Vegetable Crops, founded in Novi Sad in 1938 [29]. Over the past decades, the technology of hybrid production, i.e. sunflower breeding, has changed in line with the changing climatic conditions and problems related to plant diseases and pests [32].

Sunflower production in Serbia is most concentrated in the Autonomous Province of Vojvodina, where the majority of oil mills and processing capacities are located [5], According to the results of the latest Census of Agriculture, conducted in 2023, 78,049 of agricultural households, or 15% of the total number of agricultural households (508,325), were engaged in the production of industrial crops. Out of this number of households, 52,760, or as much as 68% of the total number of agricultural households engaged in this production, were located in the region of Vojvodina. In 2023 sunflower was sown on 235,904.97 ha, or 47% of the total area (479,755.53 ha) sown by industrial crops in the same year [24]. Considering that sunflower production is mainly located on family farms, most authors agree that its long-term stability depends on buyers, who influence profitability and, consequently, sustainability of this production through the level of purchase prices, as seen from the perspective of direct producers. Connecting primary agricultural production with processing industry is important for ensuring the placement and stability of primary production, but also for securing the continuity of raw material supply [30].

The research is based on the fact that Bulgaria and Serbia have very similar climatic and geographical characteristics, as well as water resources, which result in similar conditions

for agricultural production. Climatic similarities allow for similar agricultural practices and common challenges in water and soil management. On the other hand, despite some similarities in the support provided to agricultural producers in Serbia and Bulgaria, the main difference is that Bulgaria, as an EU member, has greater opportunities for the financial and infrastructural support through EU funds. Although in the process of joining the EU, Serbia still relies only on domestic subsidies and a slower implementation of European standards.

Therefore, the aim of this paper is to observe the current state of sunflower production in the area of Bulgaria and Serbia by monitoring the cultivated areas, production values and yield levels of this important oil crop. The conducted research also included the analysis of foreign trade exchange, as well as the differences in the sunflower producer price between these two countries. This is important for several reasons. First, understanding the differences in sunflower production between these two countries can help assess their economic strengths and weaknesses. This is important for the development of agricultural policies, i.e. subsidy and investment policies. The comparison can help determine the most efficient ways to enhance yield and decrease production costs. In addition, if one country is more efficient or competitive regarding production, this can affect the understanding of the market and negotiations with other countries. The analysis of these differences can lead to better recommendations for sustainable agriculture. Finally, by learning from each other, both countries can improve production efficiency, reduce negative environmental effects and position themselves better in the global sunflower market.

MATERIALS AND METHODS

For the research in this paper, the authors used data from the Statistical Office of the Republic of Serbia, and the MAF database, Department "Agrostatistics" in Bulgaria. Data from the statistical database of the Food and Agriculture Organization of the United Nations (FAO) were used for the analysis of the state of the global sunflower production, both total and by continent. The research period covered ten years (2014-2023). The data were processed using descriptive statistics indicators, such as arithmetic means, standard deviation for measuring the average deviation from the arithmetic mean, and the coefficient of variation for calculating the stability of occurrences. The paper also uses the analysis and synthesis methods, desk research, and the comparative research method.

When it comes to foreign trade exchange, data from the FAO statistics, Trade Statistics for International Business Development (TRADE MAP), the Ministry of Agriculture and Food of Bulgaria, as well as www.statista.com, were used. The same statistical databases were also used for the analysis of producer prices.

The research results are presented using tables and graphs. In the analysis and interpretation of the research results, the authors used scientific and expert papers by authors from Serbia, Bulgaria and other countries, who focus on the same or similar topics in their scientific work.

RESULTS AND DISCUSSIONS

Sunflower production in the world

Sunflower is one of the most important oil crops in the world.

The largest producers of sunflower are Ukraine, the Russian Federation, Argentina, China, Romania, Bulgaria, Turkey, Hungary, France and the United States of America.

The complex military and economic situation in Ukraine has affected sunflower production over the past three years, although sunflower production has been intensively developing in the country since 2004.

In the period from 2004 to 2020 the gross domestic yield increased by 3.1 times [28], and in 2012 Ukraine produced 25% of the total global sunflower seed production [13].

Between 2014 and 2023, sunflower was produced on an average of about 27 million hectares worldwide.

More than a half of sunflower production, or more precisely, just under 70% is realized in Europe [23].

Regarding the representation of areas under sunflower cultivation, Europe is followed by

Asia with around 12%, America with around 9%, Africa with about 8%, and finally Oceania where sunflower is grown on a much smaller area (Table 1).

The areas under sunflower cultivation and its production vary from one year to another, depending on the changes in climatic conditions, agrotechnical and other measures in production, as well as market demands.

Table 1. Distribution of areas harvested to sunflower seed worldwide by continent during the 2014-2023 period (units in ha)

Continents	Average in the 2014-2023 period	Structure (world=100%)
Africa	2,276,498	8.37
America	2,571,202	9.45
Asia	3,461,758	12.72
Europe	18,880,934	69.39
Oceania	17,819	0.07
World (total)	27,208,211	100.00

Source: Authors' calculations based on the FAO database, 2024 [8].

Europe leads in the average annual global sunflower production with 73%, or 36,939,644.8 tonnes. It is followed by Asia (12.51%), America (9.73%), Africa (4.73%) and Oceania (0.04%) (Table 2).

Table 2. Average sunflower production worldwide by continent during the 2014-2023 period (units in tonnes)

Continents	Average in the 2014-2023 period	Structure (world=100%)
Africa	2,393,062.20	4.73
America	4,923,322.8	9.73
Asia	6,331,121.8	12.51
Europe	36,939,644.8	72.99
Oceania	21,096.8	0.04
World (total)	50,608,248.42	100.00

Source: Authors' calculations based on the FAO database, 2024 [8].

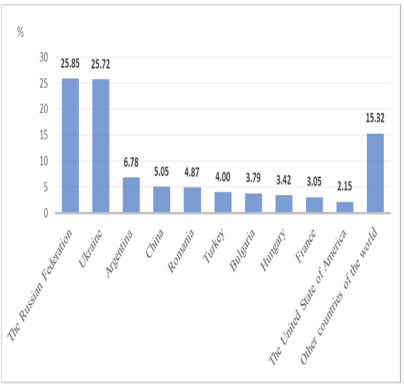
At the global level, the average sunflower yield amounts to 1.85 t/ha, being the highest in Europe with 1.95 t/ha and the lowest in Africa with 1.05 t/ha (Table 3).

Table 3. Average sunflower seed yields worldwide by continent during the 2014–2023 period (units in t/ha)

	Africa	America	Asia	Europe	Oceania	World (total)
Average in the 2014-2023 period	1.05	1.91	1.84	1.95	1.16	1.85

Source: Authors' calculations based on the FAO database, 2024 [8].

The largest global sunflower producers are the Russian Federation, Ukraine, Argentina, China and Romania. Figure 1 shows the ten largest global sunflower producers and their percentage share in the total production.



World	50,608,248
The Russian Federation	13,081,950
Ukraine	13,018,784
Argentina	3,430,608
China	2,557,261
Romania	2,464,059
Turkey	2,023,293
Bulgaria	1,918,204
Hungary	1,730,112
France	1,546,060
The United State of America	1,086,336
Other countries of the world	7,751,581

Fig. 1. The world's largest sunflower producers for the 2014-2023 period (units in tonnes)
Source: Authors' calculations based on the FAO database, 2024 [8].

Ukraine and the Russian Federation account for a large part of the global sunflower production, while Serbia accounts for 1.21% of sunflower production in the world.

Analysis of sunflower production in Serbia and Bulgaria

The average area devoted to sunflower cultivation amounted to 214,531 ha in the territory of Serbia. The smallest area was sown in 2015 (166,192 ha), while the largest was in 2023 (240,520 ha). Compared 2014, taken as the base year, the area under sunflower cultivation rose steadily until 2023, with a coefficient of variation of 12.15%. In Bulgaria, the production area under sunflower cultivation is considerably larger. The average sunflower sown area amounted to 842,031 ha for the research period, which is approximately four times more than in Serbia. The smallest area was recorded in 2017 (788,656 ha), while the largest was registered in 2022 (916,959 ha). Compared to 2014, the area increased, followed by a slight decline from 2018 to 2021, after which the area continued to increase again. The coefficient of variation is 4.63% (Table 4). It can be stated that, for the research period, the value of the sunflower sown area was relatively more stable in the territory of Serbia than in Bulgaria.

Table 4. Annual changes in areas devoted to sunflower cultivation in Serbia and Bulgaria during the 2014–2023 period (units in ha)

Research year	Serbia	Base Index (2014=100)	Bulgaria	Base Index (2014=100)
2014	175,366	100.00	843,644	100.00
2015	166,192	94.77	810,841	96.11
2016	200,299	114.22	817,511	96.90
2017	219,338	125.07	898,844	106.54
2018	239,148	136.37	788,656	93.48
2019	219,404	125.11	815,561	96.67
2020	221,149	126.11	821,922	97.43
2021	212,736	121.31	836,469	99.15
2022	251,155	143.22	916,959	108.69
2023	240,520	137.15	869,907	103.11
Arithmetic mean	214,531	-	842,031	-
Coefficient of variation (%)	12.15	-	4.63	-

Source: Authors' calculations based on the data from MAF [17].

The total average realized production for the research period amounts to 614,483 tonnes with the coefficient of variation of 14.73% for the territory of Serbia. In Bulgaria, this production amounts to 1,564,871 tonnes, while the coefficient of variation is 44.83% (Table 5). Similarly to the production area, production in Serbia is significantly more stable than in Bulgaria.

Table 5. Statistical indicators of sunflower production in Serbia and Bulgaria during the 2014–2023 period (units in tonnes)

Research year	Serbia	Base Index (2014=100)	Bulgaria	Base Index (2014=100)
2014	509,250	100.00	2,010,668	100.00
2015	437,084	85.83	1,699,228	84.51
2016	621,127	121.97	183,767	9.14
2017	540590	106.15	2,056,987	102.30
2018	733,706	144.08	192,704	9.58
2019	729,079	143.17	1,914,072	95.20
2020	636,688	125.02	1,720,299	85.56
2021	607,574	119.31	1,989,068	98.93
2022	643,459	126.35	2,117,319	105.30
2023	686,268	134.76	1,764,594	87.76
Arithmetic mean	614,483	-	1,564,871	-
Coefficient of variation (%)	14.73	-	44.83	-

Source*:* Source: Authors' calculations based on the data from MAF [17].

The average sunflower yield is 2.88 t/ha in Serbia, and 2.26 t/ha in Bulgaria. The coefficient of variation of the yield is 8.33% in Serbia, while it is 5.99% in Bulgaria (Table 6). Variations in the yield are slightly greater in Serbia than in Bulgaria.

In their studies a group of authors [19] found the "predicted sunflower yield in Serbia in years: 2022 (3.09 t/ha); 2023 (3.12 t/ha)". However, based on the data presented in Table 6, it can be concluded that this was not realized. The reasons for this lie in the fact that the cited authors expected that sunflower would be produced on larger areas in the specified years ("predicted sunflower production in Serbia in years: 2022 (736,632 t); 2023 (772,270 t)" (Ibid, p. 1269). In addition, the reasons can certainly be found in the insufficient application of full agrotechnics, due to the lack of financial resources for investing in the development of agricultural production.

Table 6. Statistical indicators of sunflower yields in Serbia and Bulgaria during the 2014–2023 (period units in tonnes/ha)

Research year	Serbia	Base Index (2014=100)	Bulgaria	Base Index (2014=100)
2014	2.90	100.00	2.38	100.00
2015	2.60	89.66	2.09	87.82
2016	3.10	106.90	2.25	94.54
2017	2.50	86.21	2.29	96.22
2018	3.10	106.90	2.44	102.52
2019	3.30	113.79	2.35	98.74
2020	2.90	100.00	2.09	87.82
2021	2.90	100.00	2.38	100.00
2022	2.60	89.66	2.31	97.06
2023	2.90	100.00	2.03	85.29
Arithmetic mean	2.88	-	2.26	-
Coefficient of variation (%)	8.33	-	5.99	-

Source: Authors' calculations based on the data from MAF [17].

While large areas can enable greater overall production, smaller plots allow for more precise and easier control of conditions which directly affect yield. A higher yield is the result of good adjustment of all production factors – selection of the variety, soil treatment and the cultivated plant treatment, as well as efficient resource management.

Foreign trade exchange

The greatest importers of sunflower from Serbia are Bosnia and Herzegovina, Hungary, the Russian Federation, Ukraine, and Germany. Serbia exports 1% of the world exports for this product, and its ranking in the world exports is 16. The average distance of the importing countries is 663 km and the export concentration is 0.34 (Figure 2). On the other hand, Serbia imports sunflower mainly from France, Turkey, Bulgaria, Hungary and Bosnia and Herzegovina. Serbia's imports represent 0.4% of the world imports for this product, and its ranking in the world imports is 37. The average distance of the supplying countries is 1,274 km and the market

concentration is 0.35 (calculations based on [34]).

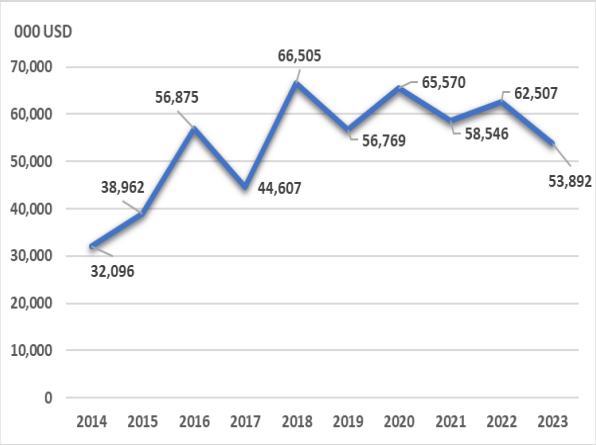


Fig. 2. Value of sunflower seeds exported from Serbia (in thousand USD)
Source: Authors' design based on the data from FAO [8].

Sunflower exports from Bulgaria vary significantly over the years depending on the harvest, market conditions and international demand. Bulgaria is among the world leaders in sunflower seed exports and ranks second for 2021 with sales of more than $730 million, according to an analysis by the Bulgarian Industrial Association [2]. Its main markets are Germany and Turkey.
The country **also ranks third in the world in sunflower oil exports with revenues of $700 million in 2021**. The country's sunflower oil is mainly exported to Spain, Italy, Turkey and Greece. Liberalized grain imports from Ukraine threaten the country's export competitiveness, BIA said. The value of sunflower seeds exported from Bulgaria is shown in Figure 3. The organizational, structural and regulatory changes imposed on Bulgaria as part of its EU membership on the one hand, and the economic environment in Bulgaria on the other, influence the development of all branches of plant growing in Bulgaria. These factors determine the changes in the number of farms, the areas sown, the average yields and the production obtained. With the accession of Bulgaria to the EU, new factors appear which the sub-sector must consider, such as the possibility of access to the single European market; elimination of customs barriers; anti-competitive protection of trade with third parties; aid under the Single Area Payment Scheme and national surcharges; specific food safety requirements, product quality standards, and ecological regulations. Some of these factors positively influence the development of this sector in the country, others set specific requirements. Oil crops show continuous growth in their development. This particularly applies to sunflower and canola. After the accession of Bulgaria to the EU, sunflower areas have generally remained at a high level. In the structure of cultivated areas, sunflower has accounted for 13-15% in the last 5 years. The number of sunflower areas shows a steady upward trend (one of the factors for this are secure foreign markets, mainly in Turkey and the EU). Sunflower cultivation areas are considered to have reached their maximum and future efforts should be directed at improving agricultural techniques, increasing average yields and enhancing quality [18].

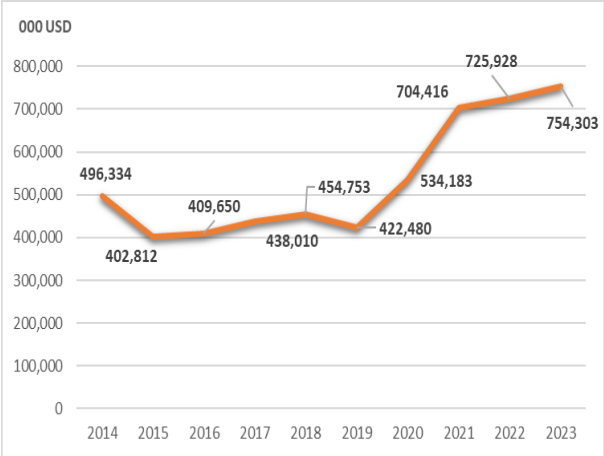


Fig. 3. Value of sunflower seeds exported from Bulgaria (in thousand USD)
Source: Authors design based on the data from FAO [8] and Statista [31]

When it comes to import, Bulgaria imports sunflower mainly Romania, Ukraine, Moldova, France and Hungary. Bulgaria's imports represent 6.8% of the world imports for this product, and its ranking in the world imports is 4. The average distance of the supplying countries is 750 km and the market concentration is 0.32 (calculations based on [34]).
Sunflower exports from Bulgaria are higher than those from Serbia because Bulgaria has a

larger sunflower cultivation area and more favourable geographical and climate conditions for this type of agricultural production. As the EU member country, Bulgaria has different **agricultural policies** and access to subsidies and agricultural support which are not available in Serbia. These subsidies can result in greater sunflower production and export. On the other hand, Bulgaria has a more developed export infrastructure and better access to the European market, where there is a high demand for sunflower. This includes ports and transport networks that facilitate access to European markets. As a result, sunflower exports from Bulgaria are more competitive than exports from Serbia.

The average producer price in Serbia was 344.0 USD per tonne, while the average price in Bulgaria was slightly higher at 443.5 USD per tonne (Table 7).

Table 7. Annual value, producer price, 2014-2023 (USD/tonne)

Research period	*Serbia*	*Bulgaria*
2014	302.5	405.6
2015	337.0	395.4
2016	275.7	394.2
2017	308.3	362.8
2018	269.0	343.4
2019	267.8	336.3
2020	314.5	422.5
2021	521.0	603.3
2022	518.1	619.0
2023	326.2	445.0
Average price	**344.0**	**443.5**

Source: FAO [8].

A higher production price of sunflower in Bulgaria compared to Serbia is conditioned by specific economic, agricultural and market factors which indicate the following: - ***Difference in production costs:*** Bulgaria may have greater labour, fuel, fertilizer, pesticide or other input costs required for sunflower production. These costs can be higher due to various economic factors, such as wages, energy costs or material import; - ***Different agricultural policies***: Bulgaria and Serbia have different agricultural subsidies, incentives and taxes which affect the total production costs; - ***Difference in yields***: Difference in climate, soil or technologies used in sunflower production affect yield and production efficiency. Since this research has shown that Bulgaria has lower sunflower yields than Serbia, this can increase production costs; - ***Differences in market conditions:*** There is a higher market demand for sunflower in Bulgaria, which also increases the market price. Also, if there is a specific need for certain sunflower types in Bulgaria (e.g., for industries requiring specific quality), production can be more expensive; - ***Currency and economic factors:*** Differences in currencies and economies of the two countries also affect the production price. A higher cost for importing inputs due to a weaker currency or other economic factors could increase the production price.

Measures for improving sunflower production

Improvement of sunflower production (increase of yield and enhancement of quality) requires the implementation of modern agrotechnical measures and use of new/innovative technologies which can increase the yield and seed quality. Some of the possible measures are the following:

Selecting the appropriate variety, one that is resistant to diseases, to drought caused by pronounced climate changes, and to specific soil conditions, can significantly contribute to higher yields. In addition, it is important to use high-quality seeds. Innovative hybrids, which are resistant to diseases and pests, can significantly increase yield.

Proper timing of planting: sunflowers grow best when planted in spring when soil temperatures are stable.

Soil preparation, fertilization and regular irrigation: Thorough soil preparation is crucial. Sunflowers grow best on well-drained, fertile soils. Before planting, check the soil's pH value and, if necessary, adjust it by adding lime or other treatments. Introducing crop rotation can improve soil quality and decrease the risk of diseases. Sunflowers are plants that love both sunlight and water. Regular irrigation during dry periods can significantly improve yield, especially during the flowering and seed formation phases.

Weed, disease and pest control: Regular monitoring and controlling of weeds, diseases and pests are crucial for preserving plant health. The use of herbicides and pesticides

must be in accordance with recommendations and legislation. Biological treatments and integrated protection from pests can be efficient alternatives to chemical treatments.

Optimal timing of harvesting: Sunflowers must be harvested at the right moment, when the seeds reach maturity. This ensures high oil quality and decreases the risk of losing seeds due to dropping from the plant.

Application of precision agriculture: Technologies such as GPS, drones and sensors allow precise monitoring of field conditions, which enables better risk management and optimization of all production phases.

Training and education: Continuous education of farmers about new technologies, plant protection methods, as well as market trends can contribute to higher yields and increased income from production. Investing in farmer education and their training on new methods, technologies and innovations in agriculture can be the key to long-term improvements in sunflower production.

Using subsidies and other support measures for agricultural producers. Combining all these measures can improve the efficiency and yield of sunflower, while minimizing risks and optimizing resources.

CONCLUSIONS

Based on the above mentioned in the research (2014-2023), the following can be concluded:

-The total area under sunflower cultivation in the world amounts to 27,208,211 ha. The production of 50,608,248.42 tonnes with the average yield of 1.85 t/ha is realized on this area. The largest areas are located in Europe and amount to 18,880,934 ha, which accounts for approximately 70% of the total sunflower production in the world;

-The largest global sunflower producers are the Russian Federation, Ukraine, Argentina, China, etc. Bulgaria ranks seventh in this list, while Serbia is far below the leading global producers in terms of sunflower production;

-In Serbia, sunflowers are grown on 214,531 ha. The average annual production is 614,483 tonnes, with the average yield of 2.88 t/ha. In Bulgaria, sunflowers are produced on 842,031 ha, with the production of 1,564,871 tonnes and the average yield of 2.26 t/ha.

-The largest amount of sunflower from Serbia is exported to Bosnia and Herzegovina, Hungary, the Russian Federation, Ukraine and Germany, while the largest quantities of sunflower from Bulgaria are exported to Germany and Turkey.

-The producer price of sunflower fluctuates over the years and depends on the exchange rate, import tariffs, weather conditions, as well as supply and demand. The average price of sunflower in Bulgaria is 443.5 USD per tonne, while it is 344.0 USD per tonne in Serbia.

-The long-term stability of sunflower production is greatly dependent on buyers, since they directly affect profitability and, consequently, sustainability of this production through purchase prices.

The growth and stability of production can also be achieved by improving production and introducing innovations, along with the continuous support and assistance from the government, ranging from production and subsidies to helping with the placement of products on the global market.

This applies to both countries that were the subject of research in this paper, without exception.

ACKNOWLEDGEMENTS

The paper is a part of research financed by the MSTDI RS, agreed in decision no. 451-03-136/2025-03/200009 from 04.02.2025.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF THE DEGREE OF SUFFICIENCY WITH SUNFLOWER PRODUCTION IN THE REPUBLIC OF MOLDOVA

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Abstract

The paper purpose is to analyze the degree of assurance with sunflower production in the Republic of Moldova on the basis of the statistical data from the National Bureau of Statistics. The methods used to process the data are: analysis, synthesis, comparison and monographic. In the period of the years 2016-2023, the surface of sunflower increased approximately 1.7 times, reaching 391,9 thousand hectares in 2023 in the households of all categories. The gross harvest of sunflower in all categories of producers increased respectively by 12.0; 53.9 and 20.9% in 2023 compared to 2016, 2020 and 2022.In 2021, it was obtained the highest seed production. The good results are due to well-trained specialists, but also on the strength of the fact that the degree of insurance with agricultural machinery in the agricultural companies is at a high level. The high value of the net profit generated from the sunflower production determines the local producers to increase the areas of this crop. The increase of the sunflower oil volume intended for export denotes the fact that Moldova has reached a high level of competitiveness even at the international level. The Ministry of Agriculture and Food Industry made the decision to grant a license on import of the sunflower seeds to the enterprises that process this type of production for ensuring the continuity of the activity of the oil companies in the country.

Key words**:** *export, sunflower, oil, agricultural producers, food security*

INTRODUCTION

In the Republic of Moldova, sunflower production is sufficient to meet domestic consumption, thus ensuring national food security.According to the information presented by the National Bureau of Statistics of the Republic of Moldova, sunflower production is satisfactory, ensuring the necessary quantity for domestic consumption, thus ensuring the possibility of exporting excess production. This situation created on the local sunflower production market allows ensuring economic stability. At the same time, the relevant bodies in Moldova emphasize the local processing of sunflower seeds, thus, entrepreneurs contribute to the production of added value, in this case, we refer to the production of sunflower oil and its export, but not the seeds. However, the agricultural sector faces challenges such as rising agricultural input costs and price volatility on the international market, which can impact both production and profitability.

The authors Tcaci et al. (2021) mentioned that all the activities from the economic field bears costs for the human, the material and the financial resources [13].

Another challenge is climate change, which significantly affects sunflower production in the Republic of Moldova, influencing both yields and crop quality. Prolonged droughts and extreme temperatures during the vegetative period hinder plant development and limit seed formation, reducing production, especially in the southern and central regions of the country. For example, in years of severe drought, average yields per hectare can drop below 1 ton compared to 2-2.5 tons in favorable conditions. Additionally, uneven and torrential rainfall leads to soil erosion and reduces the moisture reserves available to plants. Global warming has extended the growing season, which may encourage pest infestations and the spread of diseases such as downy mildew and gray mold, directly affecting seed quality and oil content. Climate change has also contributed to a decline in the

average oil content of seeds, which in drought years can fall below 38%, compared to the standard of 44% [4].

Another significant factor is excessive monoculture, which depletes the soil and infests it with specific diseases and pests such as downy mildew or sunflower moths. This agricultural practice reduces soil fertility and crop efficiency, requiring additional investments in fertilizers and phytosanitary treatments.

To overcome these challenges, it is essential to implement modern agricultural practices, diversify crops, promote optimal crop rotation, and develop irrigation systems to ensure production stability. In the absence of modern irrigation systems and adaptive technologies, producers are exposed to major fluctuations in both production and income.

An important role for the sustainable development of the country belongs to its population. Therefore, the government pays a great attention to the level of the food security and nutriment.

As the level of self-sufficiency with production is one of the indicators that describes the level of the food security of the country.FAO attaches special importance to this indicator as a factor of stability, which reduces the vulnerability to fluctuations in the domestic and the international agricultural markets.

The Food and Agriculture Organization of the United Nations (FAO) emphasizes that "the raising the level of nutrition and living conditions of the population, improving the yield of production and the effectiveness of the distribution of all food and agricultural products, improving the condition of rural populations and contributing to the development of the world economy" [7].

From the food production and marketing to the nutrition education legislation, promoting the nutrition standards in the business practices, FAO is concerned with the entire food chain, from the cultivation of raw materials to family distribution. Within all these concerns, the organization aims for development based on equitable growth and the support of policies focused on the needs of peoples in general and vulnerable populations, from a nutritional point of view.

FAO provides services for the food and nutrition assessment to help the governments to determine the effective measures in time. Also, it is responsible for analysis of the consumption structure and the supply of foods, in detection of the problems and for the purpose to establish all the priorities, in identifying the vulnerable categories that call for the emergency measures [7].

Currently, FAO (2016) defines the food security as the situation in which "all people have physical, social and economic access, at all times, to sufficient, safe and nutritious food that meets their dietary requirements and preferences for an active life and healthy". In the mid-90s of the 20th century, the term nutrition was added to the concept of food security, this means the use of the food by the organism of the human. Initial, the syntagma "food and nutrition security" was used, showing the increasing importance given to nutrition and the fact that food is not only sufficient, but also safe and nutritious [7].

FAO also uses other notions to express the complex concept of the food security. Thus, there are notions such as adequate nutrition, individual food security, family food security and national food security.

The adequate nutrition is assessed over three-time intervals:

- in the short term, the sufficient nutrition is ensured if the amount of energy consumed corresponds to the needs of energy of the person, that can vary depending on the weight, gender, age, state of health, physical and intellectual effort;
- in the medium term, the appropriate nutrition can be provided if there is no protein-caloric lack of proper nutrition;
- in the long term, nutrition can be ensured if there is no chronic caloric malnutrition [7].

The individual food security is the individual's ability to have access to safe and nutritionally sufficient food that ensures a healthy life.

The family food security is necessary to ensure the individual one, but it is not sufficient because the available food is not distributed among the family members according to each one's energy needs.

The food security of the country corresponds to its ability to ensure the family food security

and the individual food security not giving up other strategic goals.
According to Scerbacov(2016), food security is evaluated at the world (global),regional, national, family and individual level [12].
To establish the national food security level over a certain period of time, usually a year, the food energy availability per person is calculated. Food security of a country should not be confused with the notion of food self-sufficiency. Food self-sufficiency also includes the availability of food energy, which must be ensured from domestic production. In some countries, food security is ensured despite the fact that the level of food self-sufficiency is low. This is the situation for countries with the extremely limited agricultural resources, such as the oil-producing ones in the Middle East. They are making intense efforts to increase their degree of the food self-sufficiency, thus reducing their high import of food and the dependence on the world agricultural market [8].
In this context, the purpose of the paper is to analyze the level of self-sufficiency with sunflower production as an indicator proposed by FAO for determination of the level of the national food security.

MATERIALS AND METHODS

The entire analysis elaborated by the author is made by using the data of the National Bureau of Statistics of the Republic of Moldova. The works of the scientists of the country were analyzed, as well as those of the foreign scientists.
Method of analysis, synthesis and comparison were applied for interpreting the obtained results.
Fixed basis index was used to comparatively assess the values of each studied indicator in the last year of study versus the first year of the period.
Sunflower trade balance (TB) was determined making the difference between the export value and import value, as shown by the formula:
TB = E - I
where:
E = Export value
I = Import value.
Self-consumption rate (SCR) was calculated using the formula:

SCR = 100 *(P - E)/ P .....(1)
where:
P = production
E- Export.

Self-sufficiency rate (SSR) was calculated using the formula:

SSR = 100* P/DC.....(2)

where:
P = production
DC = Domestic Consumption.

RESULTS AND DISCUSSIONS

The sunflower is an economically and agronomically important crop. It has a fully mechanized technology, achieves high productions and is easily and profitably capitalized.

Sunflower cultivated area

Figure 1 presents the cultivated area with sunflower, 2016-2023.

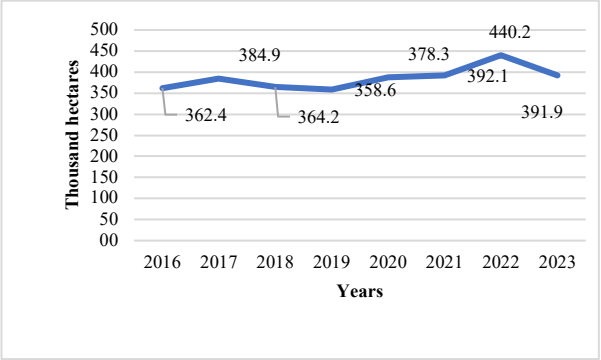


Fig. 1. The sunflower sown areas in all categories of producers (thousand hectares)
Source: [4].

According to the data presented in Figure 1, we can conclude that the sunflower areas in the Republic of Moldova decreased in 2023 compared to 2022 by 11%, the main cause being drought.
It should be noted that sunflower cultivation is quite profitable, provided that technologies are followed. This fact can serve as one of the main reasons for the increase in sunflower cultivated

areas. But unfortunately, the producers do not respect the crop rotation. Thus, before the analyzed period, the sunflower crop was cultivated on the same surface at an interval of 6-7 years, at the current stage the interval has been reduced to 4 years. This fact has a negative consequence, reducing the quality of the soil.

In the opinion of the expert RijaIu. cited by [2], until 2021 year, the Republic of Moldova exported mostly sunflower seeds, i.e. raw material with a lower level of profitability, and much less sunflower oil which ensures added value [2].

Currently, the sunflower oil that is cold pressed and that contains a large amount of oleic acid registers a high demand in the market. In addition, sunflower groats is introduced into the animal feed ration.

Sunflower seed yield

Figure 2 shows the yield level of sunflower seeds by year.

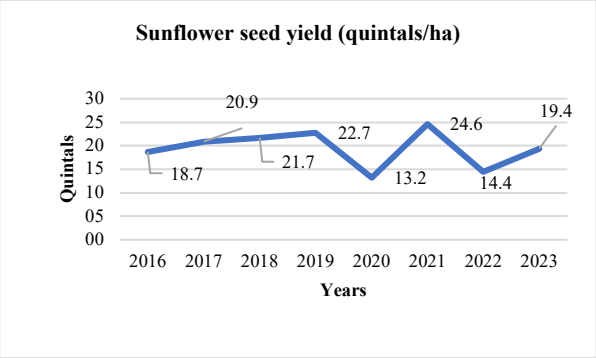


Fig. 2. Yield per hectare of sunflower in all categories of producers (quintals/ha)
Source: [4].

Yield level varied depending on various factors such as: the hybrid performance potential, fertilization degree and climate conditions.

The expert Iu.Rija said that in the case of introducing fertilizers in a smaller amount, the average yield of the sunflower crops will decrease, which will reduce the profit of the enterprises and as a result, the production costs will not be covered [3].

In the last two years, the price of the mineral fertilizers has increased significantly. The share of these types of fertilizers in the total costs is quite high, constituting approximately 30%. The agricultural producers introduce these fertilizers to achieve higher productivity of field crops. For some types of fertilizers, the price has increased in the limits between 1.8-2.5 times [3].

Sunflower seed production

The dynamics of sunflower seed production is shown in (Fig. 3). The trend is in general similar with the yield tendency in the studied period.

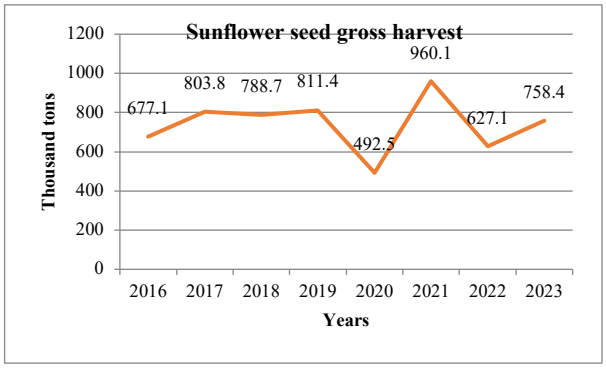


Fig. 3. Gross harvest of sunflower in all categories of producers (Thousand tons)
Source: [4].

The data presented in Figure 3 confirm that 2021 was the most favorable year for sunflower cultivation. In that year, sunflower production reached a volume of 960 thousand tons. Also, an increase in the sunflower harvest was achieved in 2023. If we compare the harvest received in 2023 with 2016, 2020 and 2022, we observe an increase of 12.0, 53.9 and 20.9%.The highest value of this indicator was reached in the year 2021 in value of 960.1 thousand tonnes.

The level of training of the specialists and the provision of the domestic producers with agricultural techniques are the main factors that favored this remarkable result.

On the telegraph.md site, A. Slusari mentioned that in August and September of 2023 year a large number of local producers were forced to sell their sunflower seed production at a maximum price of 5 lei per kilogram. Both the Trans-Oil and other large processing enterprises informed the local producers that if they did not accept the proposed price, the sunflower seed production would be imported from Ukraine[14].There is a monopoly in the production and processing of the sunflower seeds, with a 100% market share. The situation is worrying both for the authorities and for the

agricultural producers, as it has a negative impact on the industry and the entire economy. The Ministery of Agriculture and Food Industry V. Bolea, specified that the possession of the absolute control by the same processing enterprise creates barriers in this branch and consequently will result in the decrease of prices for the enterprises producing sunflower seeds. Thus, discussions took place between the representatives of the ministry and the agricultural producers with the aim of establishing a series of measures that would allow ensuring the fair competition in this absolutely necessary industry [5]. The processing of the sunflower production will allow the creation of new jobs.

Sunflower seed resources and uses according to sunflower balance

Sunflower resources and uses

Table 1 shows the sunflower seed resources and Table 2 the uses in 2022.

Seed resources are not enough to cover the processing capacity of the manufacturing plants into sunflower oil.

Table 1. Sunflower seed resources in 2022 (Thousands tons)

Product	Resource			
	Production	Import	Variation of inventory	Total resources
Sunflower	627.1	105.1	30.1	762.3

Source: [10].

Table 2. Uses of sunflower production, thousands of tons, year 2022

Specification	2022
Export	434.2
Seeds	2.7
Feed	3.2
Processing for non-food purposes	312.7
Losses	5.9
Personal consumption of the population	3.6
Total uses	**762.3**

Source: [10].

The Ministry of Agriculture and Food Industry has decided to grant the sunflower seed import license to several processing enterprises in order to maintain the operation process of the oil factories in our country. The decision was taken due to the liquidation of sunflower seed inventory, and the aim being to avoid the price increases for the oil production on the local markets. On the information Portal Agricol.md, A. Slusari mentioned that 70 thousand tons of sunflower seeds are needed. Ukraine is the base country from which the required quantity of sunflower will be imported [1].

Sunflower export

Analyzing the volume of EU sunflower seed imports by country, we deduce that the Republic of Moldova is in 4th place, being surpassed by Ukraine, Argentina and Russia. For example, in the period 2023-2024, the EU sunflower seed import share from the Republic of Moldova was 52.8% [4, 9].

In value terms, the quantity of sunflower seeds exported to the EU market in 2023 and 2024 is more than 190 thousand tons, approximately 50% more than in the period 2022-2023.

The Republic of Moldova sells sunflower seeds abroad to such countries as Romania, Bulgaria, Turkey, Spain.According to the expert Iu. Rija, our country's tendency to export to the EU is positively appreciated because the reorientation to this market has brought with it a number of advantages. In the previous years it was exported to the CIS countries. The dynamic increase in demand from the EU states indicates an intensification of partnership relations in the foreign trade [6].

In the information portal NOI.MD it is mentioned that the production volume of the sunflower oil which is exported indicates that the Republic of Moldova has many competitive advantages at the international level. The oil which is obtained by the national enterprises is of a high quality [11].

Table 3. Sunflower seeds exported quantity, 2019-2022 (Tons)

Year	Exported amount (Tons)
2019	577.5
2020	381.4
2021	302.7
2022	336.3
2022/2019 %	58.2

Source: [17].

Table 3 shows the data of the exported quantity of sunflower seeds in the period 2019-2022 by the Republic of Moldova. The information reflect a decrease year by year of the exported

quantities of sunflowers seeds by 41.8%from 577.5 tons in 2019 to 336.2 tons in the year 2022.

Zaharco S. considers that among the problems of the producers are: poorly developed infrastructure, limited accessto some technologies and finance, not applicableexport promotion tools [16].

Sunflower trade balance

Based on the data from The Observatory of Economic Complexity, OEC [14],it was determined sunflower seed trade balance in the period 2016-2023 (Table 4).

As export values are higher than import values in each year of the analyzed period, the sunflower is a positive one, reflecting that the Republic of Moldova is a net exporting country.

Table 4. Sunflower seed trade balance, 2016-2023, Republic of Moldova (USD Million)

	Export Value	Import value	Trade balance
2016	279	20.7	+258.3
2017	298	21.2	+276.8
2018	221	26.9	+194.1
2019	235	23.6	+211.4
2020	168	27.9	+140.1
2021	192	37.2	+154.8
2022	351	91.9	+259.6
2023	160	43.4	+116.6
2023/2016 %	57.3	209.0	-

Source: Own calculation based on the data from The Observatory of Economic Complexity, OEC [15].

Self-consumption rate with sunflower seeds

Table 5. Self-consumption rate of sunflowers seeds, 2019-2022 (%)

Year	Production	Export	SCR (%)
2019	811.4	577.5	28.8
2020	492.5	381.4	22.5
2021	960.1	302.7	68.5
2022	677.1	434.2	35.9
2022/2019 %	83.4	75.2	+7.1 pp

Source: Own calculations based on the data from [4] and [17].

The self-consumption rate in the Republic of Moldova is low with values below 100%(Table 5).

The degree of self-sufficiency rate with sunflower seeds

The dynamics of the self-sufficiency rate in the Republic of Moldova with sunflower seeds is presented in Figure 4. The data show that this rate is much higher than 100in the entire analyzed period, and its surplus is exported.

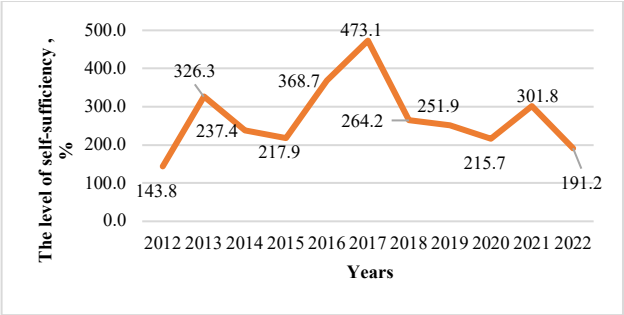


Fig. 4. The level of self-sufficiency with sunflower production, 2012- 2022(%)
Source: Own calculations.

CONCLUSIONS

The sunflower occupies the 4th place among oil crops, followed by the production of palm, soy and rapeseed. In our country, the areas occupied by cultivated with sunflower production increases year by year, achieving 391.9 thousand hectares in 2023 year.

These results are due to the qualified specialist that were trained in this field, as well as applying agricultural techniques. The resulting indicator, namely the net profit, leads producers to opt for this crop.

A major problem is the fact that the practice of planting different crops sequentially on the same plot of land is not respected, because the interval at which the sunflowers are cultivated has reduced to 4 years currently from 6-7 years in 2000, and as a result it leads to the soil degradation.

The increase in the amount of sunflower oil exported highlights the fact that our country has reached a higher level of external competitiveness. The oil obtained by our processing plants is of high quality, this qualifier being assigned by the consumers abroad

At present, the uninterrupted production process of oil processing enterprises is possible due to the involvement of specialists from the Ministry of Agriculture and Food Industry, who decided to grant a license for the import of

sunflower seeds. This decision will help to avoid further increases in oil prices on the domestic market.

Moldova holds the leading position in the export of sunflower seeds, reaching 52,8% in total EU exports in 2022 and 2024 years.

The sunflower seeds are exported to Romania, Bulgaria, Turkey, Spain. In the past years, it was mainly sold to the CIS states. Due to the increase in production quantities requested by the EU countries, the commercial relations are intensifying and the Republic of Moldova will exploit advantages from these actions.

The price of mineral fertilizers has essentially increased during the last two years. The weight of these fertilizers in the total costs is high, being around 30%.

The purpose of introducing their fertilizers is to obtain a higher yield per hectare. The price of fertilizers has increased by 1,8-3 times.

If the fertilizers are introduced less than the technological norms provide, the yield per hectare will decrease and as a result the production costs will not be able to be exceeded by the collected revenues.

Unfortunately, there is a monopoly situation on the domestic market both in the production and processing of sunflower seeds. This situation alarms both the authorities and the producers, because it negatively influences the results obtained in the industry, but also of the economy as a whole.

Since the level of self-supply of the Republic of Moldova exceeds 100%, we can conclude that we are over insured with sunflower production in the analyzed period, and the surplus quantity is exported.

ACKNOWLEDGEMENTS

This research work was carried out within the research subprogram CADDCRMCE/ 020408.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF HUMAN RESOURCES IN RURAL ROMANIA: TRENDS AND SOCIO-ECONOMIC IMPLICATIONS

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Abstract

The paper analyzes the dynamics of human resources in rural Romania from 2021 to 2023, highlighting major trends and associated socio-economic implications. Key aspects examined include the evolution of the resident population, household structures, labor force, access to the internet, and adult participation in education, focusing on differences between urban and rural areas. The findings indicate a general decline in the total population; however, the rural population experienced a modest increase, suggesting internal migration from urban areas is likely due to the COVID-19 pandemic. The structure of rural households remained relatively stable, with a slight increase in the average number of members in certain social categories. Research results showed that employment rates and active participation in the labor market in rural areas have decreased. In contrast, the unemployment rate remained relatively high, amidst economic challenges and a lack of job opportunities for the population. Access to the internet has significantly increased in rural areas, partially narrowing the gap compared to urban areas. Participation in non-formal and informal education was higher in urban areas than in rural ones, reflecting the unequal access of the population to educational opportunities. From a socio-economic perspective, the study suggests the need for public policies that address regional disparities, support job creation, and facilitate access to education and digital infrastructure in rural areas. Implementing concrete measures is essential to reduce the gaps between rural and urban areas and to stimulate sustainable development in rural Romania.

Key words**:** *human resources, rural areas, Romania.*

INTRODUCTION

The transformations that have shaped the European rural landscape in recent decades—driven by demographic shifts, technological advancements, and socio-economic restructuring—have brought to the forefront the strategic importance of human resources in fostering sustainable development in these areas. In Romania, rural communities face persistent structural challenges, such as population ageing, limited access to essential services, and weak integration into the labor market. In the context of the COVID-19 pandemic, specific dynamics, such as reverse migration from urban to rural areas, have intensified, highlighting the need for an in-depth analysis of human resources in these regions [8]. Demographic changes in rural Romania, characterized by ageing populations and depopulation, significantly impact the economic viability of households and the ability of communities to sustain long-term development [1].

An essential element in assessing the sustainability of rural areas lies in the population's capacity to engage in economic activities actively, adapt to digital transformation processes, and access lifelong learning and training opportunities. Although recent years have seen improvements in infrastructure and policy frameworks, rural populations remain vulnerable to poverty, educational inequalities, and underemployment. Recent studies show that rural regions in Central and Eastern Europe, including Romania, continue to exhibit significant disparities compared to urban areas in terms of income and participation in lifelong learning or access to digital tools [3].

These realities highlight the importance of conducting a rigorous analysis of the current trends in rural human resources, focusing on population dynamics, household structures, labor market participation, and digital inclusion. A data-driven understanding of these processes is crucial for designing effective public policies to narrow the gap

between rural and urban areas. Promoting sustainable development in Romanian villages requires an awareness of existing inequalities and the implementation of concrete measures to strengthen human capital in disadvantaged regions [16]. The progress achieved in the field of rural public policies highlights that the sustainable development of Romanian villages fundamentally depends on investments in human capital and social infrastructure. Such interventions are essential for reducing economic and social disparities between urban and rural areas, ensuring equitable access to education, healthcare services, and labor market opportunities. Without strategic and coherent support, rural communities risk remaining in a state of stagnation or decline, unable to capitalize on local resources and existing human potential [13]. Although progress has been made in attracting European funding, the effectiveness of implementation has often been undermined by the lack of coordination between material investments and the development of rural population skills. Stimulating employment in rural areas requires an integrated development vision, in which financial resources are complemented by educational and social interventions [12]. The unequal access to digital resources and essential services between urban and rural regions directly influences the ability of communities to respond to economic and social shocks, such as those generated by the pandemic or broader financial instability. Rural areas with underdeveloped infrastructure are more exposed to social and economic exclusion risks. At the same time, the lack of digital skills significantly limits people's capacity to engage in online education, remote work, or modern entrepreneurial initiatives. In this context, digitalization becomes not merely a technological tool, but a catalyst for social cohesion and territorial inclusion [4].

The digitalization process has become a strategic component in revitalizing rural areas in Romania, offering increased opportunities for the population's economic and social integration. Recent studies emphasize that adopting digital technologies in Romanian villages is essential for reducing the rural-urban gap, particularly in the context of sustainable development. Digitalization streamlines agricultural and administrative activities and strengthens human capital by facilitating access to education and vocational training [2].

The transition towards a green economy entails technological changes and a profound reconfiguration of the labor market, with significant implications for rural regions where employment is already fragile and heavily reliant on traditional sectors [9].

The decline in the active population and the outmigration of young people from rural areas directly affect the ability of agricultural regions to maintain a balance between production and workforce renewal, highlighting the urgent need for revitalizing local human resources [10].

The adaptability of Romanian agriculture to climate change depends directly on the level of preparedness and engagement of the rural labor force.

Limited access to education and vocational training in rural areas represents a significant barrier to sustainable development, undermining the capacity of communities to meet the demands of a modern and competitive economy [4].

Promoting non-agricultural entrepreneurship in rural environments is a key instrument for enhancing the ability of local communities to create employment, innovate in the use of regional resources, and alleviate pressure on the traditional agricultural sector. The establishment of diversified rural businesses not only stimulates local economic development but also contributes to the social transformation of these areas by attracting young people, reducing migration, and revitalizing local human capital [14].

Rural communities' resilience is closely linked to their capacity to adopt sustainable practices, modern technologies, and climate risk management strategies. In the current context of ecological transition, strengthening the pool of skilled human resources in rural areas is a fundamental prerequisite for safeguarding food security and maintaining socio-economic balance [11].

Recent demographic developments, combined with persistently high unemployment rates and

accelerated technological transformations, reflect a complex reality in which Romania's rural areas are increasingly vulnerable to socio-economic exclusion—unless they are supported by coherent public policies and targeted investments in human capital and digital infrastructure [15].

In this context, the paper aimed to study the dynamics of human resources in rural areas of Romania from 2021 to 2023, for identifying the major tendencies and associated socio-economic implications regarding: resident population, household structures, labor force, access to the internet, and adult participation in education, emphasizing differences between urban and rural areas.

MATERIALS AND METHODS

This study is based on official statistical data from the National Institute of Statistics (NIS) in Romania for period 2021–2023. The analysis is focused on key indicators reflecting the dynamics of human resources in rural areas, such as the evolution of the resident population, household structures, labor force, internet access, and adult participation in education. The theoretical documentation was conducted by reviewing open-access scientific articles from internationally recognized databases, including Research Gate, Clarivate Analytics, SCOPUS, and Google Scholar. The collected data were statistically processed and analyzed, and the results were graphically represented to highlight trends and differences between rural and urban areas. Conclusions were validated by comparing the findings with specialized literature, ensuring the scientific consistency of the analytical approach.

RESULTS AND DISCUSSIONS

The analysis of Romania's resident population evolution during the 2021–2023 period reveals a series of significant demographic transformations, with direct implications for the country's social and economic structures. Available data indicate contrasting trends between urban and rural areas, outlining a complex picture of population redistribution. At the same time, notable regional differences emerge, suggesting that demographic processes are influenced by specific local factors such as economic attractiveness, infrastructure, and internal migration.

According to the National Institute of Statistics (NIS, 2024a) [5], between 2021 and 2023, Romania's total population experienced a slight yet demographically significant decline, decreasing from approximately 19.23 million people in 2021 to 19.05 million in 2023. This reduction of around 180,000 inhabitants reflects the general trends of demographic decline observed in many European countries, where birth rates are falling, and external migration remains high. Although the numerical decrease may appear moderate at first glance, it carries important structural implications for labor market sustainability, the balance of social systems, and national economic dynamism.

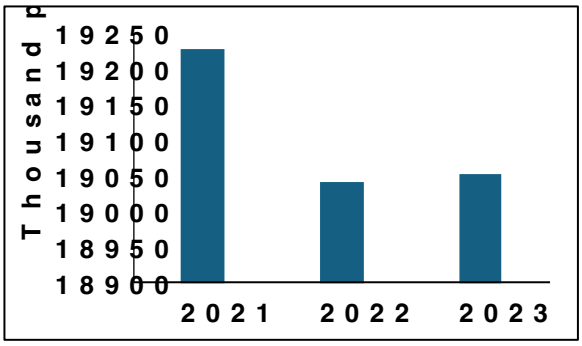


Fig. 1. Demographics of Romania's Resident Population,
Source: Authors, by using NIS (2024a) [5].

As illustrated in Figure 2, a particularly relevant demographic trend during the analyzed period is the divergent population dynamics by area of residence.

The urban population experienced a significant decline, decreasing by approximately 375,000 people, from 10.32 million in 2021 to 9.94 million in 2023. In contrast, the rural population increased from 8.91 million to 9.11 million over the same period, amounting to a gain of roughly 200,000 individuals. This territorial demographic redistribution can be interpreted as a complex response to the health, social, and economic context generated by the COVID-19 pandemic. Restrictions imposed in urban areas, combined with the expansion of remote work and a growing desire for a

lifestyle closer to nature, prompted a portion of the population to relocate to rural or peri-urban zones. Additionally, the perception of rural quality of life has improved, particularly as access to internet connectivity and basic infrastructure has significantly advanced in recent years.

From a socio-economic perspective, this shift may signal the beginning of a functional relocation of the active population, combining the benefits of rural living with the opportunities offered by remote work and personal development outside urban agglomerations. This reversal of trends between urban and rural areas can be interpreted through several structural and contextual factors. First, internal migration appears to have played a key role.

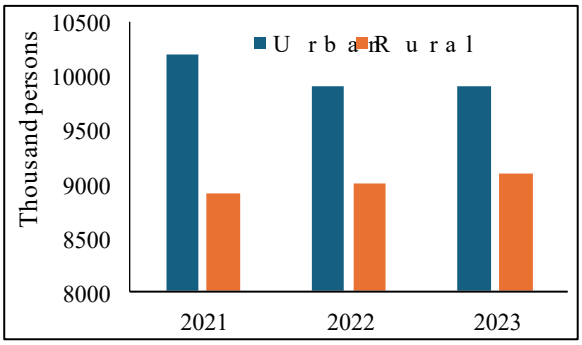


Fig. 2. Urban vs. Rural Population – Romania (million people)
Source: Authors, by using NIS 2024a [5].

Demographic data, correlated with post-pandemic behavioral changes, indicate a growing preference among the population for less crowded areas, perceived as safer, quieter, and more financially accessible. This phenomenon has also been supported by increased labor flexibility, particularly through the expansion of remote work, which has enabled professional relocation without the constraint of physical presence in urban environments.

A second major contributing factor is the development of rural infrastructure. Increased investment in transportation networks, public utilities, and digital connectivity has improved the quality of life in rural areas, thereby narrowing the historical gap between the two types of residence. In this context, rural localities near major cities or metropolitan areas are increasingly attractive to the active population. Demographic factors also contribute to explaining this trend. Despite ongoing socio-economic challenges in rural areas, birth rates remain relatively higher than in urban zones. This aspect may partially support the observed increase in the resident rural population. These combined factors point to a gradual reconfiguration of population geography in Romania, with potential implications for regional development policies and medium- to long-term territorial planning.

As Table 1 shows, the regional analysis highlights significant variations in urban-rural dynamics across Romania's development regions between 2021 and 2023.

Table 1. Resident Population in Romania by Region, 2021-2023

Region	2021	2022	2023
North-West	2,538,826	2,523,601	2,531,913
Centre	2,304,136	2,273,401	2,280,856
North-East	3,172,915	3,221,997	3,224,213
South-East	2,356,667	2,361,692	2,353,162
South-Muntenia	2,871,136	2,854,893	2,841,139
South-West Oltenia	1,892,961	1,869,602	1,861,680

Source: Authors, by using NIS 2024a [5].

In the North-West region, a decline in the urban population from 1.32 million to 1.27 million is observed, alongside an increase in the rural population from 1.22 million to 1.26 million, suggesting a clear relocation trend toward rural areas. This shift is likely influenced by the growing economic attractiveness of rural zones or by the pressures associated with urban living. In the Centre region, while the urban population decreased slightly (from 1.31 to 1.27 million), the rural population increased marginally (from 0.99 to 1.01 million), indicating a relatively stable demographic profile. The North-East region displays a distinct dynamic, with the rural population rising from 1.84 million to 1.92 million. In contrast, the urban population registered only a minor decrease, maintaining a more favorable demographic balance compared to other regions. In the South-East, the urban population declined from 1.25 to 1.21 million, accompanied by a growth in the

rural population from 1.11 to 1.14 million. This trend may result from internal migration to peripheral or semi-rural localities near urban centers. In the South-Muntenia region, urban and rural populations recorded slight declines—urban from 1.13 to 1.10 million and rural from 1.74 to 1.74 million—indicating a general stagnation in demographic structure. The South-West Oltenia region is the only one where both residential areas experienced simultaneous population decline, with the urban population dropping from 0.86 to 0.85 million and the rural population from 1.03 to 1.02 million. This evolution may reflect deeper structural issues such as economic stagnation, external migration, or pronounced population ageing.

According to data from the National Institute of Statistics (INS, 2024b) [6], the average number of members per household in rural areas remained relatively stable from 2021 to 2023, fluctuating slightly from 2.705 to 2.714, as shown in Table 2. This slight increase may reflect processes such as the temporary return of family members from the diaspora, internal migration from urban to rural areas, and the persistence of extended family structures in rural communities.

In households with salaried members, the average household size is more significant in rural areas (3.136 in 2023) compared to urban areas (2.674), suggesting a more frequent cohabitation of multiple generations under the same roof. The average household size for self-employed individuals engaged in non-agricultural activities is among the highest, 3.52 members per household in rural areas versus 3.32 in urban areas. This may be associated with local economic resilience, where independent activities such as crafts or small family-run businesses help sustain extended household structures.

Farmer households recorded a slight decrease in average size, from 3.168 in 2020 to 3.138 in 2023. This trend may reflect the modernization of agriculture, a reduced reliance on family labor, or the migration of younger generations toward other economic sectors or urban areas. Nevertheless, these households remain among the largest in terms of membership, underscoring the role of agriculture in supporting extended rural families. In households where unemployment predominates, the average size is significantly higher in rural areas (3.628 in 2023) compared to urban ones (3.076), indicating an adaptive strategy of extended cohabitation under economic uncertainty and limited employment opportunities.

In the case of pensioners, a gradual decline in the average number of household members is observed in rural areas, from 2.104 in 2020 to 2.072 in 2023, against the backdrop of an aging population and the outmigration of younger residents. Nevertheless, rural pensioner households remain larger than their urban counterparts, reflecting the continued prevalence of traditional family living models where multiple age groups share the same household.

Table 2. Average Persons/Household by Social Category and Area of Residence, 2021–2023

Social Category	Area of Residence	2021	2022	2023
Total	Total	2.533	2.510	2.499
	Urban	2.425	2.392	2.328
	Rural	2.671	2.664	2.714
Employees	Total	2.834	2.842	2.840
	Urban	2.706	2.712	2.674
	Rural	3.095	3.101	3.136
Self-employed in non-Agri activities	Total	3.203	3.235	3.451
	Urban	3.170	3.118	3.320
	Rural	3.219	3.298	3.520
Farmers	Total	3.213	3.159	3.138
	Urban	3.423	2.917	3.203
	Rural	3.195	3.177	3.133
Unemployed	Total	3.174	3.372	3.345
	Urban	3.075	3.273	3.076
	Rural	3.270	3.486	3.628
Pensioners	Total	1.996	1.937	1.916
	Urban	1.922	1.860	1.787
	Rural	2.080	2.026	2.072

Source: Authors, by using NIS 2024b [6].

According to data provided by the National Institute of Statistics (NIS, 2024b) and analyzed for 2021–2023, the structure of Romania's resident population reflects a slight but consistent decline in both the male and female segments. The male population decreased from approximately 9.40 million in 2021 to 9.25 million in 2023, indicating a reduction in the economically active demographic. At the same time, the female population declined from 9.83 million to 9.81

million, a more moderate but demographically relevant decrease. Although subtle, these changes reflect a downward demographic trend that equally affects both sexes and signals potential future pressures on the labor market, intergenerational balance, and the functioning of social protection systems.

The analysis of household connectivity, as shown in Table 3, highlights a clear upward trend in home internet access in Romania between 2020 and 2023, both in urban and rural areas. Nationally, the share of connected households increased from 78.2% in 2020 to 85.7% in 2023, marking a significant milestone in the digitalization process of Romanian society. This development was accelerated, at least in part, by the pandemic context, which pushed many essential activities, such as education, employment, and commercial services, into the online environment.

Table 3. Share of Households with Internet Access at Home, by Area of Residence, 2021-2023

Area of Residence	2021 (%)	2022 (%)	2023 (%)
Total	80.8	82.1	85.7
Urban	86.9	88.6	89.8
Rural	73.1	73.7	80.3

Source: Authors, by using NIS 2024c [7].

Nonetheless, disparities between urban and rural areas remain significant. In urban areas, the household internet connection rate reached 89.8% in 2023, compared to 84.8% in 2020, reflecting an almost complete penetration of internet services in the urban environment. This high level of access is supported by advanced telecommunications infrastructure, a dense network of service providers, and increased demand driven by the digitalization of urban life. In rural areas, internet connectivity has improved significantly but still lags the urban level. In 2023, 80.3% of rural households had internet access, compared to only 69.7% in 2020. This notable increase suggests the impact of policies aimed at expanding digital infrastructure and a growing awareness of the importance of connectivity for access to education, administrative services, and economic opportunities. However, the rural-urban gap persists, underlining the need for sustained interventions to reduce digital inequalities, particularly in disadvantaged regions.

CONCLUSIONS

The analysis of human resource dynamics in rural Romania for the 2021–2023 reveals a complex set of demographic and socio-economic processes that shape a nuanced picture of the profound transformations occurring within contemporary Romanian society. Overall, the total population registered a declining trend, reflecting a broader demographic downturn marked by low birth rates and persistent external migration. This phenomenon has significant implications for the labor market, the sustainability of social systems, and the country's economic development potential.

A distinctive feature of this period is the divergent dynamics between urban and rural areas. While cities experienced a notable decrease in population, rural regions saw a moderate increase, suggesting a trend of internal relocation and a revaluation of rural living, considering new lifestyle models, particularly in the post-pandemic context. This reversal of trends between urban and rural settings reflects residential motivations and a broader reshaping of living infrastructure, community values, and access to resources.

At the regional level, population distribution followed different trajectories, reflecting each area's economic, social, and geographical specificities. Some regions, such as the Northeast and Northwest, recorded increased rural populations, while others, like South-West Oltenia, experienced a uniform demographic decline. These differences underline the importance of territorially customized approaches in the design of public policies.

The gender structure shows a slight but steady decline in both male and female population categories, indicating a generalized reduction in the active demographic base and requiring increased attention to intergenerational balance.

At the same time, the analysis by social category highlights significant disparities between rural and urban areas. Rural

households are generally larger than their urban counterparts, and in particular social groups, such as the unemployed, farmers, or self-employed workers, household size reflects either economic adaptations or traditional cultural and family patterns. These findings reveal social resilience and specific cohabitation models in rural settings, directly impacting social, fiscal, or housing support policies.

Another essential aspect is internet access. Although connectivity has steadily increased in both environments, the digital divide between rural and urban areas persists. This gap affects access to education, employment, public services, and development opportunities, reinforcing existing inequalities. Technological progress must be accompanied by targeted investments in rural digital infrastructure and the development of digital skills among the population.

In conclusion, human resources in Romania's rural areas are undergoing a complex transformation, shaped by the interaction of demographic, economic, and technological factors. The sustainable development of these communities cannot be achieved without an integrated approach that includes coherent interventions in education, employment, infrastructure, and digitalization. Enhancing rural human capital must become a central pillar of regional and national development strategies to ensure real territorial cohesion and a socially and economically fair Romania.

ACKNOWLEDGEMENTS

This paper was supported by Dunărea de Jos, University of Galați, Doctoral School of Fundamental and Engineering Sciences, field of Engineering and Management in Agriculture and Rural Development.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE ROLE OF SOCIAL NETWORKS IN PROMOTING LOCAL GASTRONOMIC EXPERIENCES IN ROMANIAN TOURISM

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Abstract

This research aims to analyze how social networks contribute to the promotion of local gastronomy in the context of contemporary Romanian tourism. In a period when tourists are no longer looking for just destinations, but authentic and culturally relevant experiences, gastronomy is becoming a central element in the process of selecting and valorizing the places visited. Social networks play an increasingly important role in this process, providing not only inspiration, but also direct influence in decision-making regarding culinary and tourist consumption. A quantitative methodology, implemented through the use of a structured questionnaire, was employed to support the analytical approach. Its goal was to record the respondents' sociodemographic traits as well as their attitudes and behaviors regarding food consumption in tourist settings and the impact of social networks. The research instrument was applied online and was completed by a number of 137 people. The results obtained show that the vast majority of respondents prefer authentic traditional food during the holidays and appreciate local restaurants, agrotourism guesthouses and regional street food. Regarding the digital environment, Booking, Facebook, Instagram and Tripadvisor are the most frequently used platforms for tourist inspiration, and the types of content considered to have the greatest impact are stories about local producers and reviews from other tourists. Over 78% of respondents say that they have chosen a restaurant or guesthouse based on the visual or narrative content found on social networks, which confirms the direct influence of the digital environment on tourist consumption behavior. The conclusions led us to the idea that the research conducted confirms that social networks represent an essential channel in promoting local gastronomy, not only from a commercial perspective, but also as a vector of cultural identity. The consumer public is increasingly attracted to authenticity, stories, the relationship between the product and the place of origin, and social networks facilitate precisely this closeness. From this perspective, tourist communication must be strategically rethought, so as to combine visual professionalism with narrative sincerity, and local gastronomy becomes an integral part of the image and attractiveness of each destination.

Key words: *social networks, tourism, gastronomy, influencers, authenticity*

INTRODUCTION

The digital transformations of the last decades have profoundly reshaped the dynamics of the tourism industry, creating an interactive ecosystem, centered on the active participation of consumers. Digital promotion has thus become a key element of the communication strategies of destinations, gradually replacing traditional channels with interactive, customizable and globally accessible digital media [16, 18]. In this new context, gastronomic tourism is emerging as one of the most dynamic forms of experiential tourism, capable of creating emotional connections between tourists and local culture through food. [10, 20].

The rise of social media platforms such as Instagram, TikTok, YouTube and Facebook has radically reconfigured the way food destinations are promoted, with these platforms enabling not only the rapid dissemination of visual content but also the creation of authentic narratives around the culinary identity of the places visited [5, 27, 30]. According to recent research, user-generated content has a much greater impact on travel decisions than conventional advertising

materials, due to perceived authenticity and the trust relationships developed between users [15, 33].

In this context, digital marketing in tourism takes on a deeply relational dimension, oriented towards stimulating emotional involvement and creating memorable experiences [3, 32]. Gastronomic tourism, by its multisensory and narrative nature, lends itself ideally to promotion in the online environment, where the story of a local dish or a meal in a picturesque village becomes a tool for attraction and loyalty [21, 29].

A central component of this digital ecology is represented by social media influencers, who have become trusted vectors in promoting tourist destinations and local gastronomic products. Influencers are distinguished by their ability to create attractive content, build communities of followers and significantly influence consumption behaviors and travel intentions [17, 28, 31]. Unlike traditional celebrities, digital influencers base their social capital on authentic interactions and a high level of engagement with their audiences [1, 9].

More than just a source of visual inspiration, social media has become a channel for local gastronomic branding, helping to build and strengthen the image of regions through traditional dishes [12, 30]. Place branding strategies can integrate culinary storytelling into digital campaigns to differentiate rural destinations and combat the effects of over-tourism in urban centers [4].

At the same time, gastronomic experiences promoted online contribute to the consolidation of tourist memory, as local food is perceived as an essential component of cultural authenticity [19]. Unique culinary experiences, photographed and shared online, become symbols of the destination and contribute to attracting new visitors [2, 6]. The Fear of Missing Out phenomenon, supported by social media, fuels the desire to reproduce experiences seen online, especially in the gastronomic field, where "foodstagramming" is becoming a common social behavior [14, 24]. At the same time, the use of influencers in tourism promotion campaigns has proven to be an effective form of open innovation for the HoReCa sector, offering quick and efficient access to diverse target audiences [7, 8, 16].

Because social media gives small farmers, farms, and traditional restaurants more prominence, promoting local cuisine there helps the local economy in addition to boosting tourism [13, 25]. This sustainable and participatory tourism model supports cultural heritage and promotes social cohesion [11, 23, 26].

The accelerated development of gastronomic tourism increasingly requires an integrated vision, in which digitalization is correlated with sustainability, cultural identity and the participation of local communities. In the post-pandemic era, tourists are looking not only for safe and attractive destinations, but also for authentic, personalized and visible experiences in real time on digital platforms. From this perspective, local gastronomy becomes not only an object of consumption, but also an educational tool and a form of intangible heritage promoted through technology. Digital platforms offer the ideal space for local stories to be told visually, emotionally and creatively, with a direct impact on the travel decision. The integration of new technologies, such as artificial intelligence, augmented reality or virtual tours, brings innovative perspectives on how gastronomy can be experienced and promoted. At the same time, the dialogue between tourism and local gastronomy is becoming a form of cultural diplomacy, in which each destination expresses its identity through taste, aesthetics and story [22].

Therefore, social networks, digital marketing and influencers form an integrated and dynamic ecosystem, which is becoming increasingly important in the context of the development of contemporary gastronomic tourism. These tools do not work in isolation, but are interconnected in a complex way, influencing consumer perceptions, generating the desire to explore and facilitating the decision-making process of the modern tourist. Social networks allow the rapid and amplified circulation of visual and narrative content, creating emotion, anticipation and attachment to a specific destination or culinary experience. Digital marketing, through personalized targeting techniques, storytelling and sensory

branding, manages to transform apparently common elements of local gastronomy into differentiating and attractive attributes at an international level. At the same time, influencers act as cultural mediators and credible promoters, facilitating the public's access to authentic experiences and validating through their own example the authenticity of the products and services promoted.

By promoting authentic local experiences and valorizing elements of culinary identity, these communication channels contribute significantly to the strategic repositioning of tourist destinations. They not only promote, but also generate content with symbolic and affective value, capable of creating a deep relationship between tourists and the cultural space visited. Thus, gastronomy is no longer perceived as a simple functional component of a vacation, but becomes a form of cultural expression and a bridge between visitors and local communities. In this sense, the intelligent and coherent use of social networks and digital marketing can transform gastronomy from a secondary element into a central identity vector, with an impact on the image, competitiveness and sustainability of tourist destinations.

MATERIALS AND METHODS

To analyze the role of social networks in promoting local gastronomic experiences in Romanian tourism, we opted for a mixed methodological approach, with an emphasis on the quantitative component, by applying a sociological questionnaire, considering that this method is the most appropriate in understanding the behaviors, attitudes and perceptions of Romanian consumers and tourists in relation to the influence of the digital environment on culinary choices in a tourist context.

The main purpose of applying this questionnaire was to identify: how often and in what way social network users allow themselves to be influenced in choosing local gastronomic experiences; which platforms are perceived as the most relevant in promoting culinary tourism; which types of content are considered attractive for tourists interested in gastronomy.

The questionnaire was structured into five thematic sections, with a total of 12 questions, both closed and open:

1. Basic demographic data, with questions related to age, gender, level of education and recent travel experience in Romania;
2. Tourist consumption behaviors, with questions regarding respondents' preferences in choosing restaurants and the importance given to local food;
3. Use of social networks, with questions regarding the platforms used, frequency and types of content that influence gastronomic consumption decisions;
4. Influence of the online environment, with questions regarding the role of influencers, perception of the impact of social media in promoting gastronomy;
5. Personal perceptions and experiences, with questions regarding culinary preferences and experiences related to traditional Romanian food.

The questions were formulated in a way that allowed for both quantitative analysis and qualitative interpretations for the open-ended questions.

The questionnaire was designed to be administered online, via Google Forms and Facebook, and distributed to social media users. The target group included people over 18 years old, from different regions of the country, who had traveled at least once in the last 12 months and had contact with gastronomic experiences during their holidays. The sample was non-probabilistic, self-selective, and the number of respondents was 137 people.

The collected data were processed using Microsoft Excel and Google Sheets, and the analysis included: descriptive statistics, comparative graphs for questions related to social networks and preferred platforms; simple correlations between variables such as: age - platform used, gender - type of preferred content, tourist experience - social media influence; qualitative analysis of open-ended responses, to identify themes, key phrases and possible relevant case studies.

To support the interpretations obtained through the survey, the research was complemented by a documentary analysis based on the specialized literature on gastronomic tourism and digital marketing, international studies on the influence of social networks on consumer behavior in tourism, scientific articles and case studies published in tourism, marketing and sociology journals.

RESULTS AND DISCUSSIONS

The application of the questionnaire and the collection of responses allowed us to cover the real needs of understanding the dynamics between new communication technologies and emerging tourist behaviors, especially regarding the consumption of local gastronomic experiences. We consider the subject to be all the more relevant as social networks have become, in recent years, a key tool in influencing travel decisions, from choosing a destination to selecting restaurants or authentic culinary products. Using a questionnaire as a research method has the advantage of obtaining direct and structured data, which allows a quantitative analysis of public trends and preferences, while also ensuring an updated perspective on the role of digital content in valorizing the Romanian gastronomic heritage.

It was designed to capture both the socio-demographic profile of the respondents and their behaviors, perceptions and preferences related to tourism and gastronomic consumption. Its structure was divided into several sections, starting with general questions on age, gender and level of education, followed by aspects related to the frequency of domestic travel and the importance given to local gastronomy. Special attention was paid to how social networks influence tourists' culinary choices, so a significant part of the questionnaire included questions on preferred digital platforms, types of content followed (photos, reviews, stories about local producers, etc.), as well as direct experiences related to choosing a restaurant or guesthouse following exposure to online content.

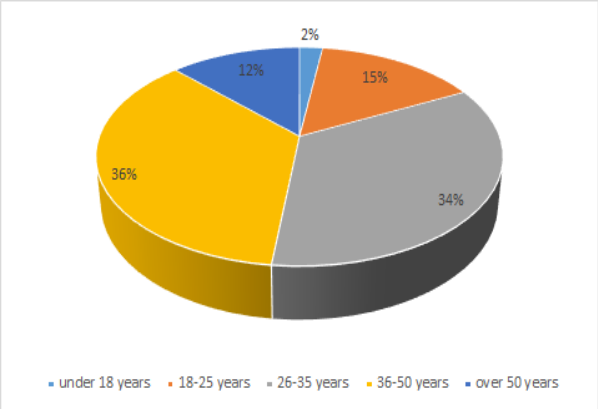


Fig. 1. Structure of respondents, by age
Source: own processing.

The structure of respondents by age highlights a balanced distribution, but with significant accents among active adults. The largest category is represented by respondents aged between 36 and 50 (36%), followed by the 26–35 group (34%). This concentration around adult segments reflects an economically active population, with access to technology and a high predisposition towards travel and consumption of personalized experiences, including gastronomic ones. The 18–25 age group is also well represented, indicating a significant involvement of young people in the culinary tourism phenomenon, influenced by online trends and the increased consumption of digital content. The age categories under 18 and over 50 have lower shares, either due to lower interest in answering questions, but also to a more limited exposure to social networks.

We thus find that the most active audience in the digital environment is also the most receptive to gastronomic experiences in a tourist context.

Of the total respondents, 63% were women and 37% were men (Fig.1).

The structure of the respondents, by level of education, highlights a predominance of people with higher education, which indicates a high educational profile of the research participants, this being due to the fact that this questionnaire was distributed through social networks within the Faculty of Management and Rural Development Bucharest. This structure is relevant in a context in which tourist consumption, especially that oriented towards authentic gastronomic experiences, is frequently associated with a higher level of

education, cultural openness and capacity to appreciate local values.

This aspect offers an analytical advantage, as this segment is more active in digital environments, more receptive to online promotional messages and more prone to informed choices in culinary and tourism terms.

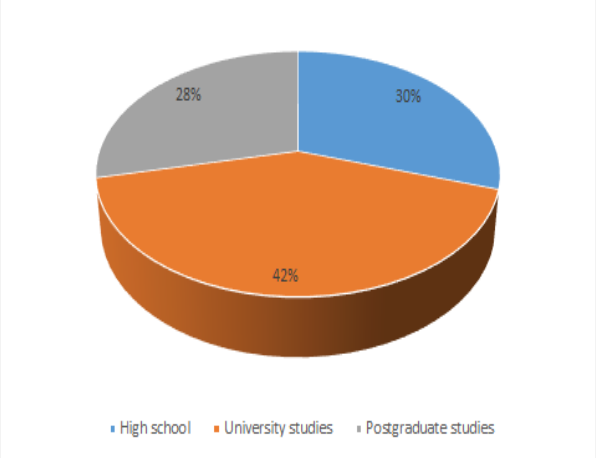


Fig. 2. Structure of respondents, by level of education
Source: own processing.

The distribution by educational level supports the idea that promoting local gastronomy through social networks is effective among an informed public, capable of valuing authenticity, sustainability and cultural identity (Fig. 2).

From question no. 4: *Have you traveled to Romania in the last 12 months as a tourist?* it resulted that the majority of respondents (73%) traveled in the last year, confirming their interest in tourism and offering us the possibility of conducting an analysis of the influence of local gastronomy.

The analysis of the questions in Category II, Tourist behavior and gastronomic preferences, provided us with information on how culinary experiences influence travel decisions.

Respondents' perception of the role of local gastronomy in the context of tourist travel is an important indicator for understanding the potential that the culinary component has in valorizing destinations in Romania.

Thus, from the answers provided to question no. 5: *How important is local food to you when traveling? (1 = not at all important, 5 = very important)* it resulted that the majority of respondents attach high importance to local food, which confirms that gastronomy is not just an adjacent element, but a determining factor in shaping the tourist experience (Fig. 3). This trend highlights a paradigm shift in the behavior of the modern tourism consumer, who seeks authenticity, tradition and cultural connection through food.

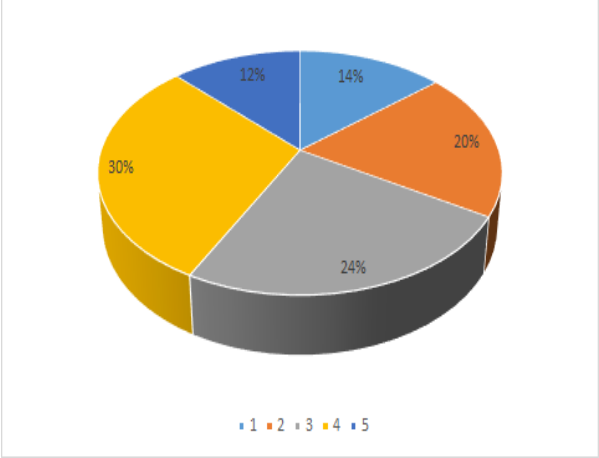


Fig. 3. Importance of local gastronomy for respondents
Source: own processing.

Moreover, this increased appreciation of local gastronomy can be interpreted as a strategic opportunity for Romanian tourism actors to capitalize on the local culinary identity, through storytelling, branding and digital promotion, which can become a competitive vector in attracting and retaining tourists.

The answers provided to question no. 6: *What type of restaurants do you prefer on vacation? (choose a maximum of two)*, highlighted the fact that Romanian tourists show a strong attraction for traditional gastronomy and authentic experiences. The most frequently chosen options are traditional Romanian restaurants and local street food, both indicating a desire to reconnect with regional specifics and local dishes.

The increased interest in agrotourism guesthouses and international diversity completes this picture, demonstrating that the contemporary tourist is open to new experiences, but particularly appreciates local culinary identity. Fast food, although present, is marginal in the respondents' choices, which reinforces the idea that holidays are a context in which culinary authenticity takes

precedence over standardized solutions (Table 1).

Table 1. Respondents' preferences regarding restaurant category

Restaurant category	No. respondents
Traditional Romanian Restaurants	73
Fast Food	31
International Restaurants	49
Local Street Food	67
Agritourism Guesthouses	44

Source: own processing.

In Section III, questions were asked about the social networks used by respondents.

The answers provided to question no. 7: *Which social networks do you use most often for tourist inspiration? (choose a maximum of two)* demonstrate that there is a diversity of digital channels used for inspiration and information in the tourist context, with a clear dominance of platforms focused on utility and reviews. The most frequently mentioned is Booking (63 respondents), followed by Facebook (46), Instagram (45) and Tripadvisor (42), which leads us to the conclusion that there is a combination of functional platforms that support practical decisions (accommodation, reviews), and visual and social platforms that offer emotional and aesthetic inspiration (images, personal recommendations) (Table 2).

Table 2. Respondents' preferences regarding the tourism-related social networks used

Network	No. respondents
Instagram	45
TikTok	39
Facebook	46
You Tube	36
Tripadvisor	42
Booking	63

Source: own processing.

The significant presence of Instagram and TikTok confirms the increasingly important role of visual content and influencers in shaping tourist choices, especially among younger generations.

YouTube remains a valuable channel through its extended narrative format. We believe that promoting local gastronomy in tourism should combine inspirational visual content with useful information and trusted reviews, to meet both the emotional and pragmatic needs of digital tourists.

The answers provided to question no. 8: *Have you ever chosen a restaurant or a guesthouse based on what you saw on social networks?* show that 78% of respondents did so, which highlights the major impact of social networks on tourism and gastronomic consumption decisions.

This significant proportion confirms that digital platforms are not only sources of inspiration, but also true instruments of influence and conversion in the real choices of users, shaping a new type of behavior: the informed and visually stimulated tourist, who acts based on recommendations from the online environment.

The answers provided to question no. 9: *What type of content influences you the most when choosing a gastronomic experience? (choose a maximum of two)* provided us with information regarding the forms of content that most influence tourists' gastronomic choices.

The most appreciated type of content is the story about local producers, with 71 mentions, signaling a trend towards authenticity, transparency and the valorization of the short food chain and reflecting the desire of respondents to understand the origin of products and the culinary identity of the place visited, not just to consume. In second place are tourist reviews and comments (59 respondents), confirming that decisions are influenced by the experiences of other visitors, perceived as more credible and closer to reality.

Food photos (52 respondents) and culinary videos (43 respondents) are also strongly represented, highlighting the power of visual content in triggering the desire to explore a gastronomic experience.

At the same time, recommendations from influencers (42 respondents) are appreciated, but not dominant (Table 3).

Table 3. Respondents' preferences regarding the tourism-related social networks used

Content Category	No. respondents
Food Photos	52
Recipe or Dining Videos	43
Influencer Recommendations	42
Tourist Reviews/Comments	59
Stories About Local Producers	71

Source: own processing.

Moreover, from question no. 10: Have you followed Romanian influencers who promote local culinary tourism? it resulted that only 28% of respondents follow influencers.

The last 2 questions aimed to measure respondents' perceptions regarding their culinary and recreational preferences, forming part of the last section of the questionnaire.

Thus, the answers given to question no. 11: *How much do you think social networks contribute to the promotion of Romanian gastronomy?* (1 = not at all, 5 = very much) highlighted the fact that there is a predominantly positive perception of respondents regarding the role of social networks in promoting local gastronomy in Romania (Fig. 4). Most survey participants considered that these platforms contribute to the visibility and appreciation of traditional dishes, thus confirming the importance of the digital environment as a tool for cultural and tourist valorization. This generalized opinion supports the idea that social networks are not only entertainment channels, but effective means of educating, influencing and connecting the public with local culinary identity.

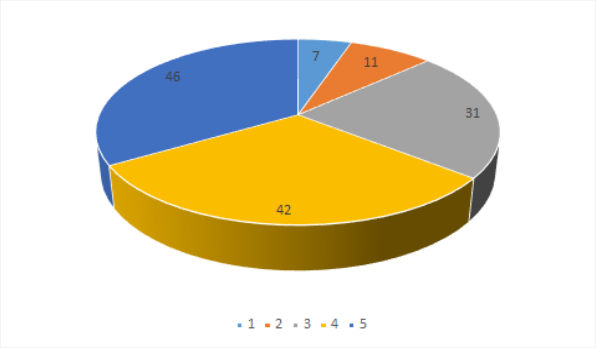


Fig. 4. Respondents' perception of the contribution of social networks to the promotion of local gastronomy in Romania
Source: own processing.

The answers provided to question no. 12: *On your holidays, do you prefer authentic local food or modern dishes?* demonstrate the fact that there are preferences for culinary authenticity, with most respondents opting for traditional local food to the detriment of modern reinterpreted dishes, which shows that Romanian tourists value local specificity and want their gastronomic experiences on holiday to reflect the cultural identity of the region visited (Fig. 5).

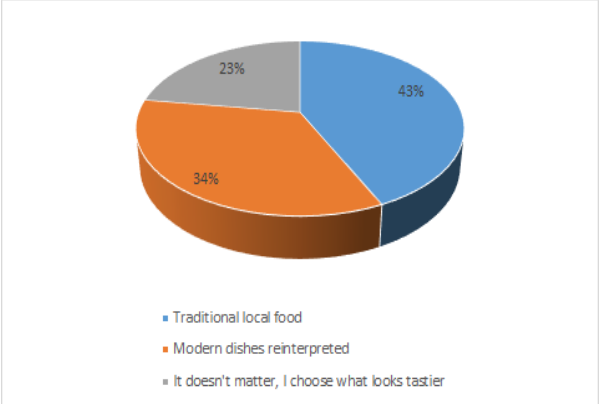


Fig. 5. Respondents' preferences regarding the restaurant category
Source: own processing.

This orientation towards authenticity proves that traditional gastronomy can become a strategic element in the development of Romanian tourism.

CONCLUSIONS

The present study analyzes an increasingly relevant area for contemporary tourism: the role of social networks in the valorization and promotion of local gastronomy. In a context in which travel is no longer motivated exclusively by classic tourist attractions, but by authentic multisensory experiences, gastronomy becomes a strategic element of differentiation, with the potential to consolidate cultural identity and stimulate the sustainable development of destinations.

Social networks have significantly changed the way tourists are informed, choose and evaluate tourist and gastronomic services. They offer an accessible and dynamic platform for interaction, influence and storytelling, facilitating the connection of consumers with

local products, culinary traditions and regional producers. Thus, local gastronomy is no longer just an act of consumption, but a narrative experience, loaded with cultural and affective significance, transmitted and amplified through the digital environment.

This research highlights the fact that the current tourist audience is increasingly receptive to this type of content, and consumption decisions are often influenced by the online presence of destinations and local actors. This trend highlights the need for a strategic and professional approach to communicating gastronomy through social media, focused not only on visual promotion, but also on authenticity, traceability and emotional connection.

We believe that exploring the relationship between social networks and gastronomic tourism represents a current and pertinent research approach, with theoretical but especially applied implications, being a direction that deserves further in-depth study, both through qualitative and quantitative studies, in order to support the sustainable development of local tourism and to consolidate Romania's positioning as an emerging gastronomic destination in the European landscape.

Given the results obtained, several essential strategic directions are outlined for capitalizing on the potential of social networks in promoting local Romanian gastronomy, targeting both institutional and private actors in tourism, as well as local communities, influencers and digital content creators.

We believe that a professionalization of gastronomic communication in the digital environment is necessary, so that beyond occasional posts or commercial images, the current audience is receptive to narrative, visually well-structured and authentic content, which manages to convey a story, either about a traditional dish or about the cultural context in which it is prepared and consumed. Therefore, restaurants, guesthouses, local producers and tourism promotion authorities should invest in digital content that not only informs, but also creates an emotional connection with the user.

Moreover, collaborating with local or regional influencers involved in promoting tourism and gastronomy can bring added visibility and credibility to local culinary brands, and when choosing these partners, it's critical to consider the audience's demographics, the message's consistency, and—most importantly—the genuineness of the influencer-sponsored space relationship. Promoting traditional recipes, lesser-known places and the people behind the products can generate a positive impact on public perception. In addition, we think that local cuisine should be incorporated into destination narratives as a component of the area's tourism identity. Food should not be seen as a separate component, but as part of a complex tourist experience, which includes landscapes, people, traditions and local customs. Through intelligent use of social networks, these stories can be amplified and disseminated to a wider audience, contributing to the differentiation of the destination in a competitive landscape.

In addition, a direction with high potential is the development of participatory campaigns, which involve not only tourists, but also local communities, from traditional producers to chefs, artisans or local storytellers. This type of initiative strengthens the relationship between locals and tourists, supports the local economy and contributes to the preservation of intangible cultural heritage.

Last but not least, we believe that it is essential that small entrepreneurs in rural and gastronomic tourism benefit from support in digital training. The use of social platforms, the creation of relevant visual content and efficient online interaction with potential customers must become basic skills, accessible to all. This type of education can reduce the visibility gaps between developed and peripheral areas, stimulating inclusion and diversification of the Romanian tourism offer.

In this way, an integrated and sustainable vision of Romanian gastronomic tourism can be outlined, in which social networks are not just a promotion channel, but a strategic tool for cultural connection, local development and regeneration of interest in the authentic values of the local culinary space.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC RESILIENCE AS A VECTOR OF COMPETITIVENESS IN THE EU ANALYSIS AND LESSONS FROM THE POST-CRISIS AND POST-SHOCK PERIOD

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Abstract

This research aims to comparatively analyze the economic resilience of the European Union member states, in the context of successive economic shocks, by constructing composite scores that synthesize the adaptation and recovery capacity of each economy. The main goal was to highlight the structural and dynamic differences between economies, in terms of internal stability and response to crises, thus providing an integrated tool for evaluating and substantiating public policies. The objectives pursued included: (1) measuring structural resilience in the pre-crisis period, 2015–2019, (2) assessing post-shock resilience in the period 2020–2024, (3) comparing performances through standardized scores and (4) identifying the determinants of economic resilience in the EU. To achieve these objectives, a quantitative methodology was used, based on the aggregation and standardization of four main indicators: GDP per capita, unemployment rate, annual inflation (HICP) and total exports, with data from official sources (Eurostat) for all 27 EU Member States. The results show clear differences between economies, both in terms of structural fundamentals and post-crisis adjustment capacity. Germany, Ireland and the Netherlands stand out with high overall scores, while Greece, Spain and Estonia are at the bottom of the ranking, indicating persistent vulnerabilities or recent heightened pressures. Romania is in a middle position, with a balanced profile, but with clear needs for institutional consolidation and macroeconomic stability. The proposed scores provide a synthetic picture of resilience and can contribute to guiding development strategies and the efficient allocation of European resources.

Key words: *resilience, competitiveness, economy, post-crisis, E.U.*

INTRODUCTION

In the context of accelerated transformations of the global economy, the capacity of states to cope with external shocks is becoming not only a condition of stability, but also a strategic competitive advantage. Recent crises, the COVID-19 pandemic, supply chain disruptions, the energy crisis triggered by the Russian-Ukrainian conflict, global inflation, have profoundly tested the economic resilience of the European Union, exposing imbalances, but also differentiated adaptation capacities among member states [2, 24]. In this sense, resilience is no longer conceived exclusively as a capacity to return to the previous equilibrium, but as an active process of economic, institutional and structural reconfiguration [1, 16].

The specialized literature emphasizes the fact that resilience is a multidimensional construct, which includes components of shock resistance, rapid recovery capacity and the ability to structural transformation in the face of new challenges [5, 21, 26]. Recent studies emphasize the role of economic governance, the quality of institutions, human capital, the degree of economic diversification and trade integration as determinants of adaptability [4]. In the EU, initiatives such as the "Next Generation EU" and the "Recovery and Resilience Facility" reflect the effort to create systemic mechanisms for absorbing and adapting to crises [7, 18, 23]. To measure this capacity, empirical research often uses

indicators such as real GDP, unemployment rate, inflation, exports or the level of public debt, which are then integrated into synthetic resilience scores [6, 19, 22, 25]. These can be constructed through standardized aggregation methods, factor analysis or dimensional reduction (PCA), providing a comparative picture of how countries position themselves in relation to external shocks [3].

The present study aims to comparatively analyse the capacity of EU Member States to cope with successive shocks in the period 2020–2023 and, complementary, to assess long-term structural resilience for the period 2015–2023. The research is built on a unified statistical database, which includes key indicators of macroeconomic performance, trade openness and external vulnerability. By standardising them and constructing two composite scores, one post-crisis and one structural, we will be able to classify EU countries according to their resilience profile and identify the common features of the most adaptable economies. Furthermore, the analysis will be complemented by the exploration of correlation relationships and clustering, in order to capture regional adaptation patterns and distinguish between convergent and divergent models. Thus, the research contributes to the current literature by providing an applied analytical framework, based on real data and modern quantitative methods, which can support both academic analysis and the formulation of future-oriented economic policies.

MATERIALS AND METHODS

In order to assess the economic resilience of the European Union Member States to successive shocks in the period 2015–2023, the research was based on the construction of a multidimensional database, which integrates economic, trade and structural indicators essential for understanding the adaptation capacity of economies. The data were collected exclusively from official sources, in particular from the Eurostat database, thus guaranteeing international comparability and reliability of the sources.

The selection of the analyzed states was made according to the complete availability of data for the period 2015–2024. Only the 27 European Union Member States that have complete time series for the indicators considered relevant were included, excluding those states that presented significant gaps or methodological breaks, in order to maintain the statistical coherence of the analysis.

The methodology was structured in two stages: the first consisted of descriptive statistical analysis of each indicator: mean, standard deviation, minimum and maximum values, quartiles, in order to capture distributions, dispersion and possible anomalies or regional variations, as well as to understand the general directions of evolution of European economies in the context of recent instability. In the second stage, we constructed composite economic resilience scores, on two distinct temporal dimensions: (1) structural resilience in the period 2015–2019, defined as economic sustainability under conditions of stability, and (2) post-shock resilience in the period 2020–2024, which captures the capacity to adapt to shocks generated by the COVID-19 pandemic, the energy crisis and inflationary volatility. For each period, we selected four representative indicators: GDP per capita (as a proxy for economic development), unemployment rate (as an indicator of institutional capacity), inflation (as a measure of price stability) and exports (as an expression of external positioning).

To bring the indicators onto a common scale [0,1], we used the Min–Max normalization method:

$$X^* = (X - X_{min}) / (X_{max} - X_{min}), \text{ in care:}$$

X^*: normalized value of a raw indicator
X: raw value of the indicator for a given country and year.
Xmin: the lowest value of that indicator in the entire set of countries and years.
Xmax: the highest value of that indicator in the same set.
$X^* \in [0,1]$: the rescaled indicator – where 0 means minimum performance and 1 maximum performance in that domain.

For indicators with a negative meaning (unemployment, inflation), the formula was inverted as follows:

X = 1 - (X - Xmin) / (Xmax - Xmin)* [17, 20]

The composite scores were calculated as simple arithmetic means of the normalized indicators for each country:

Structural score = (GDP + Exports* + Unemployment* + Inflation*)/4 (for the years 2015–2019)*

Post-shock score = (GDP + Exports* + Unemployment* + Inflation*)/4 (for the years 2020–2024)*

Finally, the overall resilience score was obtained as the average of the two scores:

Overall score = (Structural score + Post-shock score)/2

This approach allows not only comparison between countries, but also monitoring the evolution over time of the economic response capacity and the potential for structural transformation within the European Union.

RESULTS AND DISCUSSIONS

This paper provides an analytical framework based on four essential pillars to examine the economic resilience of European Union Member States in the event of consecutive shocks between 2015 and 2024. This multimodal method enables an integrated examination of the potential of European economies to withstand, adapt, and change in the face of crises. The first pillar, economic capacity, reflects the structural potential of an economy, being assessed through indicators such as real GDP per capita, labor productivity and export dynamics. The second pillar targets external vulnerability, expressed through the degree of dependence on energy imports and the balance of trade balance. The third pillar focuses on institutional and fiscal capacity, analyzing indicators such as public debt, unemployment rate and macroeconomic stability. Finally, the capacity for adaptation and transformation reflects the potential for innovation and digitalization, being measured through productivity and specific indicators of structural modernization.

Table 1. GDP evolution in EU countries in the period 2015-2024 (Index, 2015=100)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	105.45	107.69	110.13	112.87	114.85	107.59	112.75	118.70	117.57	116.19
Belgium	105.81	107.07	108.65	110.69	113.40	107.96	114.66	119.55	120.98	122.22
Bulgaria	106.78	110.01	113.03	115.91	120.30	116.43	125.49	130.56	133.02	136.76
Croatia	99.24	102.67	106.04	109.12	112.51	103.15	116.18	124.65	128.79	133.85
Cyprus	92.00	98.05	103.69	110.19	116.67	112.91	125.77	134.83	138.55	143.33
Czechia	108.33	111.13	116.88	120.18	124.47	117.87	122.62	126.11	126.04	127.45
Denmark	106.22	109.48	112.83	114.93	116.89	114.81	123.29	125.19	128.31	133.03
Estonia	119.45	123.14	130.08	134.89	139.92	135.88	145.61	145.69	141.29	140.92
Finland	99.83	102.40	105.78	107.04	108.49	105.78	108.62	109.44	108.41	108.26
France	105.58	106.48	108.70	110.49	112.73	104.34	111.52	114.39	115.46	116.81
Germany	108.69	111.18	114.20	115.48	116.62	111.84	115.95	117.54	117.22	116.94
Greece	81.19	81.17	82.36	84.06	85.98	78.07	84.83	89.70	91.79	93.88
Hungary	110.96	113.67	118.35	124.99	131.33	125.64	134.71	140.46	139.28	139.99
Ireland	140.97	142.69	157.03	168.88	177.39	190.09	220.99	240.04	226.76	229.53
Italy	96.62	97.82	99.39	100.21	100.64	91.71	99.90	104.72	105.47	106.23
Latvia	119.61	122.66	126.83	132.29	133.19	128.57	137.49	139.98	143.97	143.33
Lithuania	123.23	126.52	132.35	138.86	145.36	145.42	154.70	158.62	159.17	163.58
Luxembourg	111.22	116.75	118.29	120.20	123.50	122.87	131.39	129.95	129.05	130.38
Malta	131.85	137.23	155.03	166.17	172.96	167.15	189.38	197.47	210.89	223.48
Netherlands	104.54	107.08	110.06	112.54	115.13	110.68	117.62	123.51	123.61	124.82
Poland	116.75	120.29	126.49	134.39	140.54	137.68	147.22	154.96	155.34	159.88
Portugal	95.57	97.48	100.71	103.68	106.53	97.79	103.22	110.43	113.32	115.50
Romania	114.69	117.97	127.64	135.45	140.76	135.59	143.11	148.78	152.36	153.60
Slovakia	113.32	115.53	118.85	123.68	126.49	123.22	130.25	130.82	133.65	136.41
Slovenia	101.98	105.07	110.51	115.35	119.39	114.51	124.12	127.47	130.16	132.24
Spain	100.50	103.43	106.43	108.98	111.12	98.96	105.57	112.10	115.10	118.72
Sweden	110.98	113.59	115.66	117.86	120.87	118.44	125.47	127.31	127.16	128.40

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

Each pillar is treated both from a cross-sectional perspective, through comparison between states, and longitudinally, based on the evolution over time of the associated indicators.

Economic capacity is the foundation of any form of systemic resilience. It reflects the level of structural development, productive potential and the capacity of an economy to absorb and adapt to external or internal shocks. In the context of the European Union, this dimension becomes especially essential in the post-pandemic period, marked by energy transitions, digital transformations and geopolitical tensions.

The data in Table 1 shows the dynamics of real GDP per capita (standardized values) in the 27 Member States of the European Union, in the period 2015–2024. A constant upward trajectory is noted for most economies, especially in Central and Eastern Europe (Romania, Poland, Hungary), but also in performing states in the euro area (Ireland, Malta, Estonia). The year 2020 marks a negative inflection, confirming the severe economic impact of the COVID-19 pandemic, with decreases of over 5–10 points on average, but followed by an accelerated recovery in 2021–2022.

Table 2. Descriptive statistics on economic capacity – GDP

Year	count	Mean Index, 2015=100	std	Min Index, 2015=100	25%	50%	75%	Max Index, 2015=100
2015	27	108.57	12.17	81.19	101.24	106.78	114.01	140.97
2016	27	111.42	12.60	81.17	104.25	110.01	117.36	142.69
2017	27	116.15	15.65	82.36	107.54	113.03	122.67	157.03
2018	27	120.35	18.14	84.06	110.34	115.48	128.64	168.88
2019	27	124.00	19.71	85.98	113.06	119.39	132.26	177.39
2020	27	119.44	22.80	78.07	106.69	114.81	127.10	190.09
2021	27	128.61	27.37	84.83	113.71	124.12	136.10	220.99
2022	27	133.44	29.59	89.70	118.12	127.31	140.22	240.04
2023	27	134.55	28.79	91.79	117.40	128.79	140.28	226.76
2024	27	136.88	30.35	93.88	117.83	132.24	142.13	229.53

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

Table 2 summarizing the descriptive statistics of real GDP per capita captures a dual dynamic present within the European Union: a general trend of increasing economic capacity, but also an accentuation of differences between Member States. These developments reflect not only the effects of the accumulation of European policies in favor of recovery, but also the uneven degree of structural readiness of the states to capitalize on post-crisis opportunities. On one side, the average and median of standardized GDP reflect systemic development, backed by the 2020-2023 reforms, the digital transition, and the large inflow of capital through European funding. On the other hand, the increase in the dispersion of values between countries indicates that this progress has not been uniform. States with flexible economic structures, efficient administrations and investment capacity oriented towards innovation have managed to accelerate their economic convergence, while others have registered relative stagnation. This polarization is a direct effect of uneven resilience: external shocks, such as the pandemic or the energy crisis, have hit European economies with varying intensity, and government responses and the absorption capacity of European funds have led to different recovery trajectories. As a result, the differences between performing and vulnerable economies have deepened, affecting the internal cohesion of the Union and justifying the need for a multidimensional analysis of resilience.

In this context, descriptive statistics should not be seen as a simple description of levels, but as an x-ray of the capacity of each economy to transform resources and policies into sustainable adaptation. They thus provide a fundamental starting point for interpreting regional differences and for formulating differentiated policies to strengthen economic resilience in Europe. The external vulnerability of an economy reflects the degree to which it is exposed to global shocks, especially in terms of energy, one of the most sensitive components of the trade balance. Table 3

shows the evolution of the value of energy imports (in million euro) for all European Union Member States, during the period 2015–2023, while Table 4 summarizes descriptive statistics for each year.

Table 3. Evolution of energy imports in EU countries during 2015-2024 (Million euro)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023
Austria	11,978.91	12,855.65	13,575.58	13,410.92	15,722.32	11,879.75	10,832.93	14,712.21	11,996.78
Belgium	42,344.42	41,358.44	43,458.18	45,661.87	46,802.54	40,546.43	42,633.35	43,380.42	42,891.78
Bulgaria	6,633.10	6,640.60	7,024.96	6,162.43	6,584.83	5,526.12	5,498.79	6,808.01	5,817.89
Croatia	3,207.06	3,431.67	3,889.70	3,727.16	3,859.81	3,698.83	3,887.71	4,402.34	4,345.98
Cyprus	1,235.80	1,312.50	1,330.44	1,306.84	1,309.83	1,139.48	1,157.09	1,262.67	1,260.58
Czechia	11,526.70	11,394.20	12,613.26	12,158.90	12,947.13	11,045.15	12,477.30	12,470.59	11,129.11
Denmark	8,179.69	7,826.62	6,468.81	6,466.27	7,526.08	7,763.21	6,698.08	7,341.93	10,488.24
Estonia	1,125.70	1,223.70	1,264.11	1,356.90	1,237.05	1,385.29	1,335.66	1,105.63	896.71
Finland	10,931.40	11,839.60	11,448.70	11,684.10	11,447.30	10,770.20	9,020.85	10,048.80	8,997.80
France	80,305.11	79,334.23	82,108.22	80,281.42	82,060.42	67,576.15	69,541.87	76,844.54	71,115.44
Germany	143,156.80	141,527.50	152,998.67	129,959.46	133,837.87	116,426.74	122,188.12	127,950.59	109,463.96
Greece	17,684.30	18,923.30	19,864.22	20,135.03	19,541.01	19,281.94	20,271.07	19,620.30	18,667.43
Hungary	9,253.20	9,617.60	11,357.70	10,600.40	12,702.30	9,979.00	9,823.40	10,730.40	9,986.60
Ireland	7,773.04	6,248.00	6,027.93	6,135.74	6,267.84	6,173.87	6,828.24	7,088.76	6,559.83
Italy	83,122.40	85,219.80	88,908.15	85,813.35	86,095.16	74,827.50	82,209.49	86,172.07	77,474.58
Latvia	2,157.90	2,069.30	2,036.63	2,089.91	1,979.06	1,670.11	1,674.47	1,619.65	1,563.20
Lithuania	7,164.80	7,169.10	7,192.84	6,861.77	7,128.74	6,248.04	6,147.03	7,015.22	7,021.38
Luxembourg	1,886.59	1,860.89	1,920.43	1,989.17	2,022.94	1,703.25	1,813.68	1,595.79	1,518.25
Malta	1,359.50	1,345.00	1,645.16	1,734.21	1,795.11	1,606.30	1,448.29	1,585.08	1,668.00
Netherlands	104,242.20	107,119.11	94,386.91	97,203.97	98,054.09	88,514.41	91,779.25	99,777.56	96,487.99
Poland	25,865.40	27,447.10	30,686.50	33,475.22	33,370.87	30,841.41	31,895.88	33,944.74	33,431.92
Portugal	13,321.20	13,139.20	14,497.12	13,103.56	12,472.21	10,754.43	10,622.61	11,046.41	9,822.95
Romania	5,563.10	6,686.30	6,792.64	7,215.73	8,262.73	7,102.92	8,293.67	8,413.11	7,897.43
Slovakia	7,720.30	7,675.50	8,329.80	7,796.60	8,766.10	7,190.70	7,784.90	8,410.50	7,545.50
Slovenia	2,635.50	2,914.50	3,025.39	3,042.31	3,117.90	2,669.58	2,561.28	2,951.30	2,868.51
Spain	66,997.20	66,383.30	71,161.60	70,081.60	68,908.00	57,821.80	62,198.59	68,377.02	63,679.22
Sweden	15,310.60	16,737.10	16,032.80	16,115.00	13,908.13	14,573.73	14,049.88	14,515.71	14,053.81

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

Overall, there is a significant increase in the average value of energy imports until 2019, followed by a sharp decline in 2020, as a direct effect of pandemic restrictions that reduced global demand and affected international prices. This decline was, however, temporary: in 2021–2022, energy imports return to an upward trend, driven by the energy crisis generated by the war in Ukraine, the volatility of gas and oil prices, and the reopening of European economies.

Table 4. Descriptive statistics on external vulnerability - Energy imports

Year	count	Mean (million euros)	std	Min (million euros)	25%	50%	75%	Max (million euros)
2015	27	25,654.89	36,924.01	1,125.70	4,385.08	9,253.20	21,774.85	143,156.80
2016	27	25,899.99	36,946.27	1,223.70	4,839.83	9,617.60	23,185.20	141,527.50
2017	27	26,668.39	37,954.39	1,264.11	4,958.82	11,357.70	25,275.36	152,998.67
2018	27	25,761.85	35,122.74	1,306.84	4,931.45	10,600.40	26,805.13	129,959.46
2019	27	26,212.12	35,619.36	1,237.05	5,063.82	11,447.30	26,455.94	133,837.87
2020	27	22,915.42	30,882.57	1,139.48	4,612.48	9,979.00	25,061.68	116,426.74
2021	27	23,876.80	32,671.25	1,157.09	4,693.25	9,020.85	26,083.47	122,188.12
2022	27	25,525.60	34,785.45	1,105.63	5,605.18	10,048.80	26,782.52	127,950.59
2023	27	23,653.74	31,465.15	896.71	5,081.93	9,822.95	26,049.67	109,463.96

Source: own processing [8, 9, 10, 11, 12, 13,14, 15].

However, the differences between countries are significant. Germany, with a volume of energy imports consistently above EUR 100 billion, remains the most exposed economy, and its variations have a systemic impact at European level. In contrast, countries such as Estonia, Cyprus or Malta present low values in absolute terms, but may be relatively more vulnerable when imports are reported in relation to the size of the economy or population. Another aspect is the stability of some economies in the face of energy shocks. For example, Romania and Poland are recording a gradual but controlled increase in

imports, which indicates a certain internal production capacity in diversifying sources. In contrast, countries such as Italy or France, although they have implemented energy transition strategies, continue to depend on imports to a high extent, which keeps them in an area of strategic risk. The high standard deviations in Table 4 indicate a high dispersion in the level of imports between countries, reflecting different economic structures and unequal levels of energy autonomy. This dispersion is accentuated in crisis years, confirming that external shocks amplify pre-existing imbalances.

Therefore, in the context of a European Union aiming for energy independence, the current level of dependence on energy imports represents a critical vulnerability. This dimension of resilience must be understood not only in economic terms, but also in geostrategic terms, and energy transition and source diversification policies must be calibrated according to these data.

The institutional capacity of an economy is not only expressed in the stability of the public budget, but especially in the efficiency with which it can absorb and counteract the effects of economic and social shocks. In this context, three key indicators – the unemployment rate, inflation and the level of public debt – provide a relevant picture of internal stability and the room for manoeuvre for anti-crisis policies.

Table 5. Evolution of the unemployment rate in EU countries in the period 2015-2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	6.1	6.5	5.9	5.2	4.8	6.0	6.2	4.8	5.1	5.2
Belgium	8.7	7.9	7.2	6.0	5.5	5.8	6.3	5.6	5.5	5.7
Bulgaria	10.1	8.6	7.2	6.2	5.2	6.1	5.2	4.2	4.3	4.2
Croatia	16.2	13.0	11.1	8.3	6.6	7.4	7.5	6.8	6.1	5.0
Cyprus	15.0	13.0	11.1	8.4	7.2	7.6	7.2	6.3	5.8	4.9
Czechia	5.1	4.0	2.9	2.2	2.0	2.6	2.8	2.2	2.6	2.6
Denmark	6.3	6.0	5.8	5.1	5.0	5.6	5.1	4.5	5.1	6.2
Estonia	6.4	6.8	5.8	5.4	4.5	6.9	6.2	5.6	6.4	7.6
Finland	9.4	8.9	8.7	7.5	6.8	7.7	7.7	6.8	7.2	8.4
France	10.3	10.1	9.4	9.0	8.4	8.0	7.9	7.3	7.3	7.4
Germany	4.4	3.9	3.6	3.2	3.0	3.7	3.7	3.2	3.1	3.4
Greece	25.0	23.9	21.8	19.7	17.9	17.6	14.7	12.5	11.1	10.1
Hungary	6.6	5.0	4.0	3.6	3.3	4.1	4.0	3.6	4.1	4.5
Ireland	9.9	8.4	6.7	5.8	5.0	5.9	6.2	4.5	4.3	4.3
Italy	12.0	11.7	11.3	10.6	9.9	9.3	9.5	8.1	7.7	6.5
Latvia	9.9	9.7	8.7	7.4	6.3	8.1	7.6	6.9	6.5	6.9
Lithuania	9.1	7.9	7.1	6.2	6.3	8.5	7.1	6.0	6.9	7.1
Luxembourg	6.7	6.3	5.5	5.6	5.6	6.8	5.3	4.6	5.2	6.4
Malta	5.4	4.7	4.0	4.0	4.1	4.9	3.8	3.5	3.5	3.1
Netherlands	7.9	7.0	5.9	4.9	4.4	4.9	4.2	3.5	3.6	3.7
Poland	7.7	6.3	5.0	3.9	3.3	3.2	3.4	2.9	2.8	2.9
Portugal	13.0	11.5	9.2	7.2	6.6	7.1	6.7	6.2	6.5	6.5
Romania	8.4	7.2	6.1	5.3	4.9	6.1	5.6	5.6	5.6	5.4
Slovakia	11.5	9.6	8.1	6.5	5.7	6.7	6.8	6.1	5.8	5.3
Slovenia	9.0	8.0	6.6	5.1	4.4	5.0	4.8	4.0	3.7	3.7
Spain	22.1	19.6	17.2	15.3	14.1	15.5	14.9	13.0	12.2	11.4
Sweden	7.5	7.1	6.8	6.5	6.9	8.5	8.9	7.5	7.7	8.4

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

The data presented in Table 5 and summarized in Table 6 reveal a steady decline in unemployment in the EU during 2015–2019, followed by a slight increase in 2020, associated with the COVID-19 crisis. However, the rapid recovery after the pandemic is observable, reflecting the efficiency of the support measures applied in most Member States (wage subsidies, flexible work programs, European funds). Countries such as Poland, the Czech Republic and Malta managed to maintain unemployment rates below 4% even during the crisis, which indicates a structural resilience of the labor market, supported by dynamic economies and proactive policies. In contrast, the southern European countries (Greece, Spain, Italy) remained with significantly higher unemployment rates throughout the period. In the case of Greece, for example, the persistent level of unemployment reflects not only the effects of successive crises, but also deep

structural rigidities of the labor market and the reduced capacity for fiscal reform. Thus, weak institutional capacity accentuates social vulnerabilities, amplifying regional disparities.

Table 6. Descriptive statistics on institutional capacity – unemployment rate

Year	count	Mean %	std	Min %	25%	50%	75%	Max %
2015	27	9.99	4.86	4.40	6.65	9.00	10.90	25.00
2016	27	8.99	4.46	3.90	6.40	7.90	9.90	23.90
2017	27	7.88	4.07	2.90	5.80	6.80	8.95	21.80
2018	27	6.82	3.64	2.20	5.10	6.00	7.45	19.70
2019	27	6.21	3.32	2.00	4.45	5.50	6.70	17.90
2020	27	7.02	3.23	2.60	5.30	6.70	7.85	17.60
2021	27	6.64	2.89	2.80	4.95	6.20	7.55	14.90
2022	27	5.77	2.53	2.20	4.10	5.60	6.80	13.00
2023	27	5.77	2.26	2.60	4.20	5.60	6.70	12.20
2024	27	5.81	2.17	2.60	4.25	5.40	7.00	11.40

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

Annual inflation, as measured by the Harmonized Index of Consumer Prices (HICP), was relatively stable between 2015 and 2020, but increased between 2021 and 2023, according to the data. This dynamic is caused by several factors: disruptions in global supply chains, rising energy costs, wage pressures and imbalances between supply and demand in the post-pandemic context.

Table 7. Evolution of annual inflation change in EU countries in the period 2015-2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	100	100.97	103.22	105.41	106.98	108.47	111.46	121.07	130.40	134.21
Belgium	100	101.77	104.03	106.44	107.77	108.23	111.71	123.26	126.07	131.52
Bulgaria	100	98.68	99.85	102.48	104.99	106.27	109.30	123.52	134.15	137.63
Croatia	100	99.37	100.67	102.23	103.04	103.06	105.82	117.11	126.94	132.04
Cyprus	100	98.78	99.45	100.23	100.78	99.67	101.92	110.17	114.50	117.09
Czechia	100	100.70	103.10	105.10	107.80	111.40	115.10	132.10	147.90	151.90
Denmark	100	100.00	101.10	101.80	102.50	102.90	104.90	113.80	117.60	119.10
Estonia	100	100.80	104.48	108.05	110.50	109.80	114.72	137.03	149.52	155.10
Finland	100	100.39	101.23	102.42	103.58	103.98	106.12	113.74	118.67	119.83
France	100	100.31	101.47	103.60	104.95	105.50	107.68	114.04	120.50	123.29
Germany	100	100.40	102.10	104.00	105.50	105.80	109.20	118.70	125.90	129.00
Greece	100	100.02	101.15	101.94	102.46	101.17	101.75	111.21	115.84	119.31
Hungary	100	100.45	102.84	105.84	109.46	113.15	119.04	137.22	160.59	166.56
Ireland	100	99.80	100.10	100.80	101.70	101.20	103.60	112.00	117.80	119.40
Italy	100	99.90	101.30	102.50	103.20	103.00	105.00	114.20	120.90	122.30
Latvia	100	100.10	103.00	105.63	108.53	108.62	112.14	131.47	143.38	145.32
Lithuania	100	100.68	104.42	107.07	109.47	110.63	115.75	137.57	149.52	150.79
Luxembourg	100	100.04	102.15	104.21	105.93	105.93	109.61	118.55	122.02	124.77
Malta	100	100.90	102.18	103.95	105.54	106.37	107.12	113.69	120.01	122.94
Netherlands	100	100.11	101.40	103.02	105.78	106.96	109.98	122.78	127.81	131.92
Poland	100	99.80	101.40	102.60	104.80	108.60	114.30	129.40	143.50	148.70
Portugal	100	100.64	102.20	103.40	103.71	103.58	104.55	113.03	118.98	122.15
Romania	100	98.93	100.00	104.08	108.15	110.67	115.21	129.06	141.64	149.91
Slovakia	100	99.52	100.90	103.46	106.33	108.47	111.53	125.05	138.79	143.17
Slovenia	100	99.85	101.40	103.36	105.11	104.82	106.97	116.94	125.38	127.87
Spain	100	99.66	101.69	103.46	104.26	103.91	107.04	115.95	119.89	123.33
Sweden	100	101.14	103.02	105.12	106.93	107.63	110.49	119.39	126.44	128.98

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

It is observed that countries such as Hungary, Lithuania and Estonia have recorded record levels of inflation, exceeding 150% compared to the base year (2015), which reflects a combination of factors: high dependence on imported energy, rigidities in the fiscal structure and delayed reactions of central banks. In contrast, more stable economies, such as France, Denmark or Finland, have managed to maintain a firmer control over

inflation, which denotes a more solid institutional capacity to manage price shocks.

Table 8. Descriptive statistics on institutional capacity – annual inflation change

Year	count	Mean %	std	Min %	25%	50%	75%	Max %
2015	27	100.00	0.00	100.00	100.00	100.00	100.00	100.00
2016	27	100.14	0.72	98.68	99.80	100.10	100.66	101.77
2017	27	101.85	1.34	99.45	101.13	101.47	102.92	104.48
2018	27	103.79	1.85	100.23	102.49	103.46	105.11	108.05
2019	27	105.55	2.51	100.78	103.65	105.50	107.38	110.50
2020	27	106.29	3.40	99.67	103.75	106.27	108.54	113.15
2021	27	109.33	4.51	101.75	105.97	109.30	111.93	119.04
2022	27	121.19	8.49	110.17	113.92	118.70	127.06	137.57
2023	27	129.80	12.59	114.50	119.95	126.07	140.22	160.59
2024	27	133.26	13.50	117.09	122.62	129.00	144.25	166.56

Source: own processing [8, 9, 10, 11, 12, 13, 14,15].

Inflation is not only a monetary indicator, but also an expression of confidence in public policies. The large differences between countries confirm that financial sustainability is closely linked to administrative efficiency, the quality of governance and the capacity to intervene quickly.

The combination of the evolution of unemployment and inflation shows an uneven macroeconomic resilience within the EU. Although all states have benefited from the support of common European mechanisms, only some have managed to maintain a balance between price stability and employment. Institutional capacity, therefore, is not just a budget issue, but reflects a complex network of factors – fiscal policies, administrative efficiency, labor market flexibility and institutional robustness.

The ability of an economy to adapt and transform in times of crisis is essential for maintaining competitiveness and for sustainable recovery, and the dynamics of total exports, presented in Table 9 and summarized through descriptive statistics in Table 10, provide a clear benchmark on how European economies reacted to external and internal shocks between 2015 and 2024.

Table 9. Situation of exports to EU countries in the period 2015-2024 (million euros)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	137,756.80	137,409.90	148,756.40	156,428.80	159,588.50	148,288.00	171,541.20	201,398.40	207,254.50	197,652.30
Belgium	357,771.80	359,757.30	380,590.40	396,270.00	399,841.10	369,963.60	466,867.60	595,727.90	525,287.60	495,054.00
Bulgaria	22,877.60	24,021.80	27,779.90	28,495.90	29,788.70	27,966.90	34,822.30	47,508.80	44,377.30	43,063.00
Croatia	11,663.30	12,489.50	14,201.40	14,750.50	15,350.00	15,022.60	18,520.80	24,284.20	23,089.70	23,998.30
Cyprus	2,960.80	2,680.60	2,904.40	4,251.70	3,079.00	2,696.90	3,367.70	4,296.30	4,638.90	4,085.40
Czechia	142,364.10	146,979.00	161,213.90	171,260.20	177,903.00	167,597.40	191,571.00	230,242.70	236,444.80	242,964.60
Denmark	86,060.30	86,136.70	90,756.30	92,913.30	99,237.20	95,027.50	106,533.20	125,216.60	120,370.30	123,136.10
Estonia	11,575.30	11,896.90	12,877.60	14,422.40	14,382.10	14,273.80	18,253.00	21,734.30	18,161.40	17,400.00
Finland	53,951.30	52,321.30	60,239.20	64,235.80	65,615.50	57,874.50	69,471.30	81,884.70	76,362.00	72,208.10
France	456,514.70	453,075.80	473,814.80	492,964.10	509,948.20	427,236.20	494,948.80	589,710.20	602,223.50	590,802.40
Germany	1,195,822.00	1,205,489.00	1,281,865.00	1,320,732.00	1,330,414.00	1,209,208.00	1,376,196.00	1,593,593.00	1,574,517.00	1,553,790.00
Greece	25,753.70	25,445.80	28,863.00	33,472.40	33,864.50	30,800.70	39,971.50	55,762.20	51,017.40	49,937.50
Hungary	88,846.10	92,073.20	100,752.40	105,572.80	110,578.60	105,428.50	119,912.10	144,218.00	149,234.00	145,251.70
Ireland	111,259.10	118,230.30	121,759.70	139,637.10	151,515.60	157,828.30	161,204.90	203,431.80	192,695.30	223,077.00
Italy	412,291.30	417,268.90	449,129.00	465,325.40	480,352.10	436,717.80	520,771.10	626,169.40	625,949.70	623,508.70
Latvia	11,079.90	11,111.70	12,351.00	13,703.30	14,034.70	14,266.10	17,650.50	22,954.80	20,954.50	19,068.90
Lithuania	22,903.90	22,607.00	26,410.50	28,271.00	29,623.50	28,648.20	34,474.90	44,312.60	39,759.90	36,680.80
Luxembourg	15,460.40	14,259.80	13,972.90	13,883.40	14,673.10	12,113.30	14,208.40	16,506.20	15,898.90	14,985.20
Malta	2,355.00	2,879.20	2,524.50	2,704.50	2,839.20	2,479.40	2,593.00	3,101.60	3,206.00	3,495.70
Netherlands	514,309.10	515,934.60	577,087.10	615,600.70	633,056.90	590,233.20	711,069.80	917,539.90	865,966.70	851,959.90
Poland	179,532.60	184,171.30	207,385.40	223,213.10	238,178.40	239,213.70	288,180.60	342,893.90	352,925.70	351,155.90
Portugal	49,634.00	50,038.80	55,018.00	57,850.00	59,902.80	53,757.40	63,618.50	78,402.70	77,340.10	79,222.10
Romania	54,620.20	57,392.40	62,615.60	67,424.50	68,667.10	61,775.60	73,923.00	91,972.80	93,069.90	92,691.00
Slovakia	67,764.50	69,606.50	73,790.10	79,136.90	79,962.00	75,586.20	87,868.10	103,042.80	108,711.90	106,845.10
Slovenia	28,792.60	29,742.40	34,007.20	37,423.00	40,147.20	39,246.80	48,544.40	66,410.60	67,578.50	73,074.30
Spain	254,599.40	262,041.30	283,094.60	293,458.80	298,337.00	269,521.00	321,434.90	394,896.90	390,840.00	392,122.80
Sweden	126,258.20	125,901.10	135,356.90	140,551.80	143,421.10	136,108.20	160,337.10	187,838.70	182,728.40	180,963.20

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

Between 2015 and 2019, EU Member States' exports grew steadily, supported by the stability of the single market, trade openness and logistical and digital progress. This trend reflects the deep integration of European economies into global value chains and the development of export industries (automotive, chemicals, medical devices, processed food).

The COVID-19 crisis in 2020 caused a significant contraction, visible in the reduction in the average value of exports at EU level. However, the recovery was rapid and significant starting in 2021, and in 2022–2023, an acceleration of exports is observed in most countries, demonstrating that the economic structure was flexible enough to respond to sudden changes in global demand. Countries such as Germany, the Netherlands, Italy and Ireland recovered faster and with record volumes, reflecting not only the size of these economies, but also their ability to quickly reposition production and international logistics. Smaller economies, such as Slovenia, Lithuania or Romania, have also recorded increases in exports, demonstrating a high degree of adaptability and efficient specialization. For example, Romania managed to double its export volume between 2015 and 2023, a performance due to the expansion of the industrial network, the digitalization of the customs infrastructure and the strategic reorientation towards Western European markets.

However, not all economies followed the same trajectory. Countries such as Cyprus, Malta or Luxembourg had smaller volumes and more volatile developments, due both to the dependence on undeclared services in exports and to geographical and structural constraints. Also, the high dispersion of the values (highlighted by the large standard deviations in Table 10) underlines the existence of structural differences in competitiveness between states. This variation shows us that the capacity to adapt is not evenly distributed within the Union, and the success in the return of exports depends on a combination of factors: the degree of industrialization, access to international markets, the level of digitalization and active policies to support internationalization.

Table 10. Descriptive statistics on adaptation and transformation capacity - exports

Year	count	Mean (million euros)	std	Min (million euros)	25%	50%	75%	Max (million euros)
2015	27	164,621.42	253,076.67	2,355.00	22,890.75	67,764.50	160,948.35	1,195,822.40
2016	27	166,331.92	254,698.44	2,680.60	23,314.40	69,606.50	165,575.15	1,205,488.80
2017	27	179,226.55	271,957.94	2,524.50	27,095.20	73,790.10	184,299.65	1,281,864.60
2018	27	187,924.21	281,368.22	2,704.50	28,383.45	79,136.90	197,236.65	1,320,732.40
2019	27	192,751.89	284,951.72	2,839.20	29,706.10	79,962.00	208,040.70	1,330,414.00
2020	27	177,365.91	258,358.59	2,479.40	28,307.55	75,586.20	203,405.55	1,209,207.70
2021	27	208,068.71	298,992.94	2,593.00	34,648.60	87,868.10	239,875.80	1,376,195.50
2022	27	252,409.33	355,277.30	3,101.60	45,910.70	103,042.80	286,568.30	1,593,593.00
2023	27	247,059.41	347,487.33	3,206.00	42,068.60	108,711.90	294,685.25	1,574,517.10
2024	27	244,747.91	342,143.27	3,495.70	39,871.90	106,845.10	297,060.25	1,553,789.50

Source: own processing [8, 9, 10, 11, 12, 13, 14, 15].

On the other hand, exports do not only reflect current economic performance, but also the systemic capacity for transformation. Thus, countries that have demonstrated a rapid resumption of exports following crises, while maintaining or diversifying their product and market portfolio, are those that can be considered resilient in the full sense of the term. This dimension completes the overall picture of economic resilience and justifies the inclusion of exports in composite resilience scores.

We have therefore considered that in a European economic context marked by uncertainties and successive shocks, the simple analysis of individual economic indicators is no longer sufficient to comprehensively assess the capacity of states to resist and adapt. From this perspective, the construction of composite economic resilience scores allows for the synthesis of national performances by aggregating essential indicators such as GDP per capita, unemployment rate, inflation and exports, each standardized and weighted

according to its economic meaning. The purpose of these scores is not only to provide a hierarchy between economies, but also to highlight structural fundamentals and the capacity for transformation in times of crisis. The two-stage approach – 2015–2019 and 2020–2024 – reflects two essential dimensions of resilience: the first period captures structural resilience, i.e. institutional robustness and stability under normal conditions, while the second period reflects the response of economies to major shocks, including the pandemic, the energy crisis and accelerated inflation. Thus, the resulting scores provide a balanced picture of economic performance and post-crisis adaptability, constituting a useful analytical tool for both research and policy formulation.

Table 10. Economic resilience scores in the EU

Country	Structural score 2015-2019	Postdoc score 2020-2024	Global resilience score
Germany	0.717	0.709	0.713
Ireland	0.690	0.707	0.698
Malta	0.582	0.634	0.608
Netherlands	0.553	0.571	0.562
Poland	0.568	0.496	0.532
Denmark	0.520	0.501	0.511
France	0.484	0.478	0.481
Cyprus	0.467	0.494	0.480
Slovenia	0.446	0.479	0.463
Italy	0.457	0.456	0.456
Bulgaria	0.480	0.421	0.450
Luxembourg	0.450	0.446	0.448
Czechia	0.465	0.416	0.441
Romania	0.497	0.384	0.441
Belgium	0.399	0.471	0.435
Slovakia	0.457	0.378	0.417
Finland	0.431	0.404	0.417
Austria	0.411	0.413	0.412
Croatia	0.412	0.406	0.409
Portugal	0.376	0.426	0.401
Sweden	0.413	0.388	0.401
Hungary	0.429	0.328	0.379
Latvia	0.396	0.332	0.364
Lithuania	0.390	0.332	0.361
Estonia	0.374	0.312	0.343
Spain	0.337	0.308	0.322
Greece	0.191	0.252	0.222

Source: own processing [8, 9, 10,11, 12, 13, 14, 15].

The synthetic resilience scores highlight clear differences between EU Member States in terms of their capacity to sustain long-term economic performance (structural resilience), but also in their ability to respond effectively to multiple recent shocks, such as the COVID-19 pandemic, the energy crisis and post-2020 inflation (post-shock resilience).

Germany ranks first in the overall resilience score rankings, with a structural score of 0.717 and a post-shock score of 0.709, reflecting long-term macroeconomic stability, institutional stability and a sustainable recovery of exports after the crisis. Ireland is close behind, with a balanced performance between stable fundamentals (0.690) and a broadly similar resilience capacity (0.707), supported by technological orientation and integration into global value chains. Malta, although a small economy, impresses with an overall score of 0.608, demonstrating efficiency in public policies and rapid adaptability in the recent period. At the opposite end, Greece has the lowest overall resilience score (0.222), with an extremely low structural score (0.191), signaling persistent fragility in terms of unemployment, inflation and overall economic performance. Spain and Estonia complete this category, with overall scores of 0.322 and 0.343 respectively, reflecting difficulties in adjustment and high volatility in the post-shock period. In the case

of Estonia, high inflation and labor market pressures have contributed significantly to the decline in the post-shock score, despite a good performance in previous years.

Romania occupies an intermediate position in the economic resilience ranking, with a balanced overall score, resulting from a combination of relatively stable structural fundamentals and a moderate capacity to adapt to recent shocks. Between 2015 and 2019, Romania recorded a sustained growth in GDP per capita and a steady expansion of exports, signs of an economy in the process of convergence with the European average. However, the unemployment rate remained slightly above the EU average, and inflation, although controlled, was consistently above Western European levels, affecting the structural resilience score. However, Romania has registered a visible convergence in relation to the European Union average, consolidating this score that allowed for a partial absorption of subsequent shocks. After 2020, a relatively rapid economic recovery was achieved, supported by accelerated digitalization, public investment and increased external demand. Exports continued to grow, and the labor market showed signs of resilience, with a relatively stable unemployment rate. However, high inflation in the period 2021–2023 exerted pressure on consumption and competitiveness. Thus, the post-shock score reflects an economy capable of reacting, but vulnerable to external volatility and persistent structural imbalances. Overall, Romania is part of the group of economies with resilient potential, but in need of institutional consolidation and macroeconomic stability to increase its long-term adaptive capacity.

The resilience score ranking confirms that overall economic performance is not only the result of the level of development, but also of structural adaptability, institutional efficiency and the quality of the crisis response. The differences between countries indicate the need for a tailored approach in public policies, especially for the states in southern and eastern Europe that have lagged behind in terms of stability and economic transformation.

CONCLUSIONS

The objective of this research was to compare economic resilience among the member states of the European Union, by constructing composite scores structured on two essential dimensions: structural resilience (2015–2019) and post-shock resilience (2020–2024). This approach allowed the assessment of both the stable economic background in the medium term and the effective capacity to react and adapt to successive crises: pandemic, energy crisis, accelerated inflation and geopolitical tensions.

The results obtained highlight a significant diversity of the adaptive capacity among the EU states. Large and advanced economies, such as Germany, Ireland or the Netherlands, are distinguished by high overall scores, which reflects a combination of solid economic fundamentals, stable institutional capacity and effective responses to shocks. In contrast, countries such as Greece, Spain or Estonia show lower resilience, caused either by historical structural weaknesses or by recent pressures on public budgets, the labour market or inflation.

Romania occupies an intermediate position, with a balanced evolution between structural consolidation and moderate economic recovery. Its performance shows a positive direction, but also the need for further strengthening of fiscal policies, institutional infrastructure and the capacity to absorb external shocks.

Overall, the statistically validated composite scores confirm that resilience is not a static attribute, but a result of the interaction between economic development, institutional coherence and the capacity to adjust to rapid changes. These conclusions can inform both national development strategies and common European policies focused on reducing vulnerabilities and strengthening economic convergence within the Union.

Moreover, we can outline several action directions with application relevance for these policies. First, for countries with low structural scores, it is essential to strengthen resilience through targeted investments in infrastructure, education and digitalization, especially in

vulnerable regions, to support internal convergence and long-term development. Second, post-crisis inflation has significantly affected post-shock resilience scores, which requires the adoption of more flexible fiscal and monetary measures, as well as instruments to protect consumers and small businesses from energy price volatility.

At the same time, employment policies need to be adapted to support mobility and reskilling, especially in economies experiencing structural rigidities and persistent unemployment. Export dynamics have proven to be a key determinant of resilience, suggesting the need for strategic diversification of the trade portfolio and the stimulation of high value-added sectors. Finally, the composite scores developed in this paper can be used as diagnostic tools in public policy-making, providing a synthetic picture of the capacity of economies to manage and overcome shocks. They can serve as an analytical basis for reform planning and the efficient allocation of European funds under the Recovery and Resilience Mechanism.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PROTECTIONISM, INTERVENTIONISM, GLOBALISATION AND ECONOMIC REGIONALISM: THE IMPACT OF CUSTOMS TARIFFS ON AGRI-FOOD TRADE. COMPARATIVE ANALYSIS BETWEEN EU, MERCOSUR AND ASEAN

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Abstract

This research aims to comparatively analyse the impact of customs tariffs on international agri-food trade, integrating the concepts of protectionism, interventionism, globalization and economic regionalism. The study focuses on five key economies: the European Union, Argentina, Brazil, Vietnam and Thailand, representative of three major trading blocs – the EU, MERCOSUR and ASEAN. The main objective is to identify differences in tariff policies and assess how they influence market access, the volume of trade flows and the efficiency of preferential agreements. The research aims to: (1) analyze the level of MFN tariffs (both simple and weighted) by agri-food product categories; (2) compare the degree of trade openness between regions; (3) assess the relationship between applied tariffs and import and export volumes; and (4) construct a synthetic indicator of tariff protectionism, based on the distribution of tariffs by percentage intervals. The methodology is quantitative and comparative in nature, based on official data from 2022, published in 2024 by the World Trade Organization (WTO), the European Commission, ITC and UNCTAD. The composite indicator developed allows for a coherent and comparable quantification of tariff protectionism within the five economies, complementing the classic descriptive analysis. The results highlight significant structural differences: the European Union applies a selective tariff liberalization strategy in agriculture, while Argentina and Thailand demonstrate extensive protectionism in sensitive sectors. Vietnam adopts a dual model, combining interventionism with openness to multilateral trade partnerships. Brazil falls into an intermediate zone, with relatively protectionist policies, but compatible with regional dynamics. The composite score confirms these guidelines, providing a rough quantitative hierarchy. Therefore, in an international context dominated by the reassessment of trade strategies, including the recent decision of the United States to increase tariffs on strategic imports, the study demonstrates that tariffs remain relevant geopolitical instruments, with a direct impact on the structure of trade chains. The main conclusion is that preferential trade agreements can significantly reduce real tariff barriers, contributing to the stabilization and efficiency of global agri-food exchanges in an increasingly fragmented trade climate.

Key words: *custom tarrifs, trade, agri-food sector, EU, MERCOSUR, ASEAN*

INTRODUCTION

International agri-food trade is not only an essential economic dimension for the trade balances of states, but also a strategic factor for global food security. In a landscape marked by geopolitical tensions, supply crises and pressures on sustainability, trade policies are gaining increasing importance in shaping regional and global balances. In this context, customs tariffs constitute one of the most direct and visible forms of economic intervention, with the ability to encourage or limit cross-border trade [18].

Protectionism, understood as a measure to defend domestic production through tariff and non-tariff barriers, often intersects with economic interventionism, through which states act on the market for strategic, social or food security purposes [19]. At the opposite pole, globalization promotes trade liberalization and economic integration, while economic regionalism appears as an intermediate form, through which countries cooperate within trading blocs to defend their

interests, but also to stimulate intraregional trade [24, 25].

The importance of a comparative analysis between the European Union, MERCOSUR and ASEAN derives precisely from the different ways in which these blocs apply the aforementioned paradigms. The EU is characterized by a common tariff framework, regulated by the Common Agricultural Policy and supported by numerous multilateral and preferential trade agreements [3, 6, 12, 15]. In contrast, MERCOSUR – dominated by major agricultural exporters such as Brazil and Argentina – maintains a high degree of tariff protectionism, aiming to protect local value chains and strengthen economic autonomy [4]. ASEAN, through actors such as Vietnam and Thailand, adopts a mixed model: accelerated trade opening, combined with selective intervention measures in sensitive agri-food sectors [2].

In this context, the analysis of the impact of customs tariffs on agri-food trade becomes essential for understanding regional and global trade dynamics, as well as the constant tension between openness and protection. The specialized literature highlights the complexity of the relationship between tariff policies and the performance of agri-food exports, especially in vulnerable sectors such as meat, sugar or dairy. Several studies, notably those undertaken by the Joint Research Centre of the European Commission, suggest that free trade agreements may offer major advantages to European agriculture provided they are accompanied with protection and transition measures matched to regional specificities [8, 9, 17, 21].

The commercial ties between the EU and MERCOSUR, defined by an association agreement agreed but not yet implemented, aim to gradually liberalize customs tariffs on a wide variety of agri-food items. Despite the potential for more commerce, the pact raises worries about sustainability and competitiveness for European companies [7, 10]. In the case of ASEAN, trade agreements with the EU – such as the EVFTA (EU–Vietnam) or the treaty with Thailand – have shown that tariff reductions stimulate agri-food exports, in particular for rice, fish and tropical fruits [5, 23], but also pose challenges related to compliance with European sanitary and phytosanitary standards [8].

Thus, customs tariffs prove to be not only economic instruments, but also political and strategic means through which states and regional blocs project their position in global supply chains. In this context, the proposed comparative analysis contributes to understanding the fragile balance between protection, liberalization, regional autonomy and global integration [1, 13, 20].

MATERIALS AND METHODS

The research aimed to comparatively analyse the impact of customs tariffs on international agri-food trade, focusing on the trade policies of five representative economies: the European Union, Argentina, Brazil, Vietnam and Thailand. The selection of these countries reflects their membership in three relevant trading blocs (EU, MERCOSUR and ASEAN) and allows for a regional assessment of tariff strategies and trade openness.

Tariff and trade data were extracted from official reports WTO – World Tariff Profiles 2024, Access2Markets (European Commission), as well as from sources such as UNCTAD, ITC Trade Map and FAO [11, 14, 16, 22, 26, 27].

The research method is quantitative, based on comparative analysis, descriptive interpretation and construction of synthetic indices. The analysed tables include average MFN tariffs (simple and weighted), the value of agri-food imports and exports, tariffs applied by partners and the distribution of tariffs by percentage intervals.

To assess the degree of tariff protectionism, we built an aggregate protectionism indicator, which is calculated by assigning a progressive score to each tariff interval (e.g. 0% = 0 points, 0–5% = 1 point, 5–10% = 2 points, etc.) and then by multiplying the score by the respective frequency. The final value represents the sum of the weighted results.

The formula applied is the following:

$$\text{Score} = \Sigma\,(\text{Score}_i \times \text{Frequency}_i),$$
$$\text{for } i = 1...n$$

The result obtained ranges from 0 (completely liberal) to 7 (hyper-protectionist), and the scores obtained for the five economies allow a robust quantitative comparison between national tariff profiles.
The method was complemented by an analysis of the correlation between the level of MFN tariffs and the volume of imports, supported by economic interpretations and assessments of the efficiency of preferential trade agreements.

RESULTS AND DISCUSSIONS

For this analysis, the year 2022 was used as a time reference, as it represents the most recent year for which consolidated, and internationally comparable tariff data are available in official sources. Although the reports were published in 2024, they reflect the tariff structure applied in 2022, in accordance with the methodology of the World Trade Organization and other multilateral institutions. This approach is frequently used in international economic research, given the natural lags between the time of application of tariff policies and the time of official publication of data.
The selection of countries was made for comparative purposes, including three major trading regions: the European Union, MERCOSUR (through its main representatives, Argentina and Brazil) and ASEAN (through Vietnam and Thailand). They reflect different trade models: the EU – with a common and liberalized tariff policy, MERCOSUR, with an agri-food protectionist orientation, and ASEAN, with a combination of openness and selective protection. The choice of these economies ensures structural diversity, geopolitical relevance and access to harmonized official data, which provides the premises for a methodologically rigorous comparison.

Table 1. Average MFN customs tariffs applied to agri-food and non-agri-food products in 2022

Country / Region	Average MFN tariff total (%) (%)	Average MFN tariff agro (%)	Average MFN tariff Non-agro (%)	Total weighted average rate (%)
Argentina	13.4	10.3	13.9	10.3
Brazil	11.2	8.1	11.7	6.7
EU	5	10.8	4.1	2.7
Thailand	9.8	27	7.1	6.3
Vietnam	9.4	17.1	8.1	5.1

Source: own processing [28].

MFN (most-favoured-nation) tariffs remain a fundamental indicator of a country's degree of trade openness. A comparative analysis of the average values applied in 2022 by five relevant economies, representing the three major trading blocs (EU, MERCOSUR and ASEAN), reveals significant differences between tariff policies, in particular between the agri-food and non-agricultural sectors. The European Union, although applying an average general MFN tariff of 5%, maintains a significantly higher level in the agri-food sector (10.8%), compared to the non-agricultural sector (4.1%). This structure reflects the protection granted to sensitive agricultural products under the Common Agricultural Policy, in parallel with a marked openness in industrial trade. In contrast, the MERCOSUR countries, Argentina and Brazil, present a more protectionist general tariff regime, with average total MFN tariffs of 13.4% and 11.2% respectively, and the difference between the agri- and non-agricultural sectors is relatively small, indicating a uniform approach to protecting domestic production. In the case of the ASEAN countries analyzed, an interesting polarization is noted: Vietnam applies moderate tariffs in both sectors (17.1% agro, 8.1% non-agro), while Thailand applies an agri-food tariff of 27%, the highest in the sample, signaling a pronounced food protectionism. At the same time, weighted tariffs, which reflect the real impact of tariffs on trade, are much lower than nominal tariffs, especially in the EU (2.7%) and Brazil (6.7%),

suggesting the existence of preferential trade agreements and the effective application of reduced tariffs for a significant part of trade.
The tariff structure of these regions therefore confirms their general trade orientations: the EU as a liberalized but selective actor in agriculture, MERCOSUR as a balanced protectionist bloc, and ASEAN as a dual zone – with industrial openness and active agri-food protectionism, especially in Thailand. This tariff configuration has direct implications for trade competitiveness and strategic positioning within international agreements.

Table 2. Total imports and comparative sectoral structure in the EU, MERCOSUR and ASEAN in 2022

Country / Region	Total imports (USD bn)	Agri imports (USD bn)	Non-agri imports (USD bn)	GDP (USD bn)
Argentina	80.60	5.00	75.60	632.79
Brazil	272.30	13.10	259.20	1,950.00
EU	2,806.30	174.10	2,632.20	16,600.00
Thailand	302.20	16.90	285.30	495.65
Vietnam	352.40	32.80	319.60	410.32

Source: own processing [28].

The structure and size of imports reflect the degree of trade integration and external economic dependence of an economy. In 2022, the comparative analysis of the value of total and agri-food imports, in relation to GDP, provides relevant indications on the trade position and strategic priorities of the five economies analyzed.
The European Union (EU) is distinguished by a total import volume of 2,806 billion USD, of which 174.1 billion come from the agri-food sector, which represents approximately 6.2% of total imports. Compared to EU GDP (16,600 billion USD), agri-food imports are only 1%, indicating a relatively low dependence, supported by its own agricultural production capacity and the integration of the internal market. At the same time, the structure of non-agricultural imports, worth 2,632 billion USD, confirms the trade openness in the industrial and technological sectors.
In contrast, MERCOSUR economies, such as Argentina and Brazil, have a more modest share of agri-food imports: USD 5 billion and USD 13.1 billion respectively. In comparison to GDP, these numbers are modest (below 1%), indicating both agricultural self-sufficiency and restrictive trade policies in the agri-food industry. Brazil, with a GDP of USD 1,950 billion, is nevertheless notable for a total volume of imports of USD 272 billion, a moderate level compared to the size of its economy.
In the case of ASEAN countries, the structure is noticeably different. Vietnam, with a GDP of only USD 410 billion, imports products worth USD 352 billion (86% of GDP), of which USD 32.8 billion comes from the agri-food sector. This high proportion highlights a strong trade openness and a significant dependence on external supplies, particularly for agro-industrial raw materials. Thailand presents a similar profile, with agri-food imports of USD 16.9 billion (compared to a GDP of 495 billion), but with a more stable balance between trade and domestic production.
Therefore, the analysis of the value of imports relative to GDP reveals contrasting trade patterns: the EU, a balance between self-sufficiency and openness, MERCOSUR, agri-food autonomy and protectionism, ASEAN, deep trade integration and dependence on external chains. These structural differences explain, in part, the distinct approaches to negotiating trade agreements and managing customs tariffs.
Based on this distribution of import values, it is appropriate to test the relationship between the level of customs tariffs and the volume of trade. A frequently tested economic hypothesis is that reducing customs tariffs stimulates imports – hence, a negative correlation between MFN tariffs and the value of imports. The data analysed partially support this hypothesis: the European Union, with the lowest tariffs (especially for non-agricultural

goods), records the highest volume of total imports (2,806 billion USD). In contrast, Brazil and Argentina, with significantly higher tariffs, import only 272 billion USD and 80 billion USD respectively.

However, in the case of ASEAN, important nuances emerge: Vietnam, although maintaining agricultural tariffs of 17.1%, has total imports of over 350 billion USD. This paradox is explained by the country's role in re-exporting, integration into global chains and the existence of preferential trade agreements (e.g. EVFTA), which reduce the effective tariff applied. Thus, the tariff-import relationship is also influenced by other structural factors, and a simple numerical correlation must be contextualized economically and geopolitically.

On the other hand, the weighted average tariff more accurately reflects the real tariff policy, as it takes into account the structure of imports and the effective application of preferences. In this respect, the EU stands out again with a very low level (2.7%), while Brazil (6.7%) and Thailand (6.3%) maintain a more consistent real tariff burden.

An additional indicator used in the analysis is the ratio between imports and GDP, which provides a measure of trade openness. Thus, Vietnam registers an extremely high rate (imports of 86% of GDP), which reflects a deep trade integration. At the opposite pole, Argentina imports at a value of only 13% of GDP, signaling a low dependence on international flows, in line with its agro-export profile and restrictive tariff regime.

Therefore, customs tariffs influence competitiveness and the degree of trade openness, but cannot be interpreted in isolation from preferential agreements, domestic production capacity and the geo-economic status of each country.

Table 3. Volume of agri-food exports and preferential tariffs applied in bilateral trade

Exporting country	Main partner (agro)	Agro exports (million USD)	Simple tariff applied (%)	Weighted tariff applied (%)	Tariff preferences (yes/no)
Argentina	EU	7,166.00	15.80	5.40	Yes
Brazil	EU	20,528.00	15.20	5.30	Yes
EU	UK	46,789.00	14.20	13.60	Yes
Thailand	Japan	3,892.00	14.80	13.00	Yes
Vietnam	EU	3,634.00	12.30	2.80	Yes

Source: own processing [28].

Agri-food exports represent a strategic dimension of external competitiveness, and the tariff regime applied by trading partners directly influences the performance of the agri-export sector. The data analyzed for 2022 indicate significant differences between the five economies, both in the volume of agri-food exports and in the level of tariffs applied by the main destinations of these trade flows.

Brazil is the largest agri-food exporter among the nations evaluated, with a volume of 20.5 billion USD shipped to the European Union. Although the EU's basic tariff is 15.2%, the weighted tariff reduces to 5.3%, indicating preferential access afforded through trade agreements and sectoral exclusions. The same trend is visible in the case of Argentina, whose agricultural exports to the EU are valued at 7.1 billion USD, and the effective tariff borne is only 5.4%, despite a nominal value of 15.8%.

The European Union, as an exporter, sends agri-food products mainly to the United Kingdom, with a volume of 46.8 billion USD. Unlike the other countries, the difference between the simple tariff (14.2%) and the weighted tariff (13.6%) is small, which may suggest either a stable export structure or a limited application of the post-Brexit tariff preferences. However, the maintenance of a preferential tariff with the UK confirms the persistence of a privileged trade relationship.

In the ASEAN space, Thailand exports agri-food products worth 3.9 billion USD to Japan, and Vietnam exports 3.6 billion USD to the EU. In both cases, a significant difference is observed between the simple and weighted tariff (e.g. Vietnam – 12.3% vs. 2.8%),

reflecting the efficiency of free trade agreements such as EVFTA and AJEPA, respectively. This gap confirms the fact that preferential regimes have a direct impact in reducing trade costs and, implicitly, in stimulating exports.

Therefore, the combined analysis of the value of exports and the applied tariff regime demonstrates that the presence of tariff preferences is a determining factor for the competitiveness of agro-exporters. The greater the difference between the simple and the weighted tariff, the clearer the effect of the trade facilities granted under bilateral or multilateral agreements. In their absence, exporters would be exposed to a much higher degree of protectionism from trading partners.

The consistent difference between the simple and the weighted tariff applied highlights the efficiency of preferential trade regimes. In Vietnam, the decline from 12.3% to 2.8% clearly shows the benefits afforded by the Free Trade Agreement with the European Union, which permits the use of decreased tariffs for a wide variety of agri-food items. Similarly, Brazil and Argentina benefit from a significant reduction in the effective tariff borne in relations with the EU (from over 15% to almost 5%), a sign of the application of trade facilities despite the absence of a full EU–MERCOSUR agreement. These differences confirm that large exports are supported by the real reduction in tariff barriers, rather than the nominal level of duties.

The European Union, although applying high average MFN tariffs on agri-food imports (10.8%), itself benefits from significant preferential access to its partners' markets. For example, in relation to the United Kingdom, the weighted tariff applied is 13.6%, with only a slight reduction compared to the simple tariff (14.2%), which may reflect a stable export structure, but also a limited reduction in post-Brexit barriers. In contrast, ASEAN countries, especially Vietnam, benefit from significantly higher tariff access, which supports the claim that mutual market opening is essential for strengthening agri-food trade flows. The existence of a relationship between export volume and the presence of tariff preferences is supported by the data analysed. All five economies apply preferential regimes, and in all cases the weighted tariff is substantially lower than the simple tariff. This demonstrates that trade agreements, especially for emerging economies, represent an essential platform for integration into international trade networks and for increasing the value of agri-food exports.

Table 4. Agri-food tariff structure by product categories in the EU, MERCOSUR and ASEAN

Country/ Region	Meat MFN Tariff (%)	Dairy MFN Tariff (%)	Fruits and Vegetables MFN Tariff (%)	Cereals MFN Tariff (%)	Coffee, Tea, Cocoa MFN Tariff (%)	Total Imports agro (USD billion)
Argentina	34.5	35	30.9	34.4	34.5	5
Brazil	34.9	35	29.4	33.5	33.6	13.1
EU	11.5	11.5	4.5	1.9	3.1	174.1
Thailand	41.9	50.5	28.9	24.5	29.4	16.9
Vietnam	10.9	11.3	8.3	11.3	35.1	32.8

Source: own processing [28].

MFN tariffs applied at sectoral level provide a more detailed picture of each economy's trade protection priorities. A comparative analysis of the five major agri-food product groups reveals marked differences in tariff policies, reflecting distinct strategic orientations and domestic sensitivities. In the case of the European Union, MFN tariffs range between 1.9% (cereals) and 11.5% (meat and dairy), generally remaining below 12%. This tariff structure denotes a relatively liberal trade regime, but with moderate protection around animal products, considered sensitive for the internal market and the common agricultural policy. The low tariffs for coffee, tea and cocoa

(3.1%) correspond to the EU's status as a large net importer of non-domestic tropical products. In contrast, MERCOSUR (Argentina and Brazil) applies extremely high and relatively uniform MFN tariffs across all five groups – over 29% in each case, with peaks of over 35% for meat and dairy. This approach indicates a consolidated and generalized protectionism in agriculture, aimed at defending domestic production and controlling the agro-industrial value chain. These tariffs also partly explain the relatively low volume of agri-food imports (5 billion USD Argentina, 13.1 billion USD Brazil), reflecting the region's agricultural self-sufficiency.

The ASEAN countries present an interesting divergence. Thailand applies very high tariffs on dairy products (50.5%), meat (41.9%) and tropical products (29.4%), demonstrating an aggressive policy of protection of local agriculture. However, Thailand's agri-food imports are significant (USD 16.9 billion), which demonstrates both the need for supply for industrial processing, but also the application of preferential agreements that reduce the real tariff impact.

Vietnam applies significantly lower tariffs on meat, dairy, fruit and cereals (8–11%), but maintains a high tariff on coffee, tea and cocoa (35.1%), in order to stimulate domestic processing and value-added exports. The high volume of imports (32.8 billion USD) suggests an active integration into international agribusiness trade networks, despite selective protection.

Therefore, the analysis by category highlights distinct trade strategies: EU moderate protection, oriented towards animal products; MERCOSUR generalized protection, self-sufficiency; ASEAN extreme protection in strategic sectors (e.g. dairy, meat).

This tariff arrangement has a direct impact on the typology of trade exchanges and the positioning of each region in the global agrifood system.

Table 5. Distribution of agri-food MFN tariffs by percentage range in selected economies

Country / Region	0% (duty-free) (%)	0–5% (%)	5–10% (%)	10–15% (%)	15–25% (%)	25–50% (%)	50–100% (%)	>100% (%)	NAV / Undefined (%)
Argentina	5	10.2	13.8	14.1	12.7	23.6	16.6	0	4
Brazil	10.9	9.1	53.5	21.1	4.3	1	0.1	0	0
EU	31.1	11.1	18.5	14	10.6	8.6	2.2	0.3	32
Thailand	13.4	11.4	8.3	0	10.5	46.1	8.5	1.8	11.7
Vietnam	15.5	17.8	14.7	10.3	17	22.7	1.8	0.3	0

Source: own processing [28].

The frequency distribution of MFN tariffs applied to agri-food products highlights not only the average level of customs taxation, but also the degree of dispersion and severity of the tariff regime. The comparative analysis of the five economies provides a detailed picture of the trade policies applied in the agri-food sector, highlighting the differences between protectionist and liberalized models. The European Union stands out for its relatively balanced structure: 31.1% of agri-food tariff lines benefit from a "duty-free" regime, while only 2.2% are taxed in the range of 50–100% and 0.3% above 100%. This distribution reflects a predominantly liberal tariff policy, focused on opening up agri-food trade, but with residual protection around sensitive products (sugar, red meat, dairy products). The presence of a significant percentage of "undefined" tariff lines (32%), however, indicates the complexity of the regulations and the existence of tariff exceptions or quotas. In contrast, Thailand is distinguished by an extremely protectionist tariff regime: 46.1% of agri-food tariffs are in the range of 25–50%, 8.5% between 50–100% and 1.8% above 100%. Only 13.4% of the positions benefit from zero tariffs. This tariff structure is a clear signal of the policy of defending the national agricultural sector, especially in the face of competition from developed economies. Argentina and Brazil, as members of

MERCOSUR, also apply a restrictive tariff policy, although in different ways. Argentina has a relatively balanced distribution, with large shares in the ranges of 25–50% (23.6%) and 50–100% (16.6%), which demonstrates generalized protectionism. Brazil concentrates 53.5% of tariff positions in the 5–10% range, but maintains a low component in highly protected areas, signaling a more uniform but less aggressive tariff policy than in the case of Thailand.

Vietnam adopts a mixed strategy: 15.5% of tariffs are zero, but 22.7% fall within the 25–50% range, reflecting a selective protection policy based on domestic agricultural and industrial development priorities.

The data analyzed support the idea that the degree of tariff protectionism in the agri-food sector varies significantly between the economies analyzed. Countries such as Thailand and Argentina apply a high proportion of tariffs in the >25% range, reflecting an explicitly protectionist agricultural policy aimed at supporting domestic producers and limiting foreign competition. On the other hand, the European Union has a significantly more liberalized tariff structure: a third of agri-food products are imported duty-free, and only a small part is subject to prohibitive tariffs. This policy favors trade and integrates the EU into global supply chains, provided that rigorous technical and sanitary standards are respected. In conclusion, the distribution of tariffs by range not only quantifies trade protection, but also highlights the model of agricultural development and trade openness adopted by each economy. High tariffs are not always synonymous with effective protection, but signal strategic choices regarding food security and domestic control over the agri-food market.

Table 6. Composite score of agri-food tariff protectionism

Country	Tariff Protectionism Score
Argentina	3.485
Brazil	2.022
EU	1.908
Thailand	3.641
Vietnam	2.725

Source: own processing.

The tariff frequency analysis allows for a synthetic assessment of the degree of protectionism in agriculture. Countries with a high proportion of tariffs above 25%, notably Thailand and Argentina, adopt clearly protectionist trade policies, designed to discourage foreign competition and support domestic production.

The EU, in contrast, applies a high share of tariff exemptions (31.1%) and maintains high tariffs only for a minority of products, reflecting a liberal but selective approach based on standards rather than taxes.

Brazil and Vietnam have hybrid regimes: moderate protectionism and concentration in intermediate tariff bands.

This assessment supports the idea that the degree of tariff protectionism is not only a matter of arithmetic average, but also of the structural distribution of customs policy across product segments and percentage bands.

To assess the degree of tariff protectionism beyond the simple average of tariffs, we constructed a composite index, which aggregates the distribution of MFN tariffs by percentage range, assigning a rising score to each tariff class. This methodology provides a synthetic measure of the level of trade protection, highlighting not only the severity of tariffs, but also their frequency within the customs policy. The results confirm the structural differences observed previously, namely that Thailand registers the highest protectionism score (3.641), due to the very high concentration of tariffs in the ranges 25–50% and 50–100%. This tariff profile denotes a clear strategy of protecting local agriculture and a restricted access for imported agri-food products. Argentina (3.485) also applies a protectionist tariff policy, with high shares in the ranges 15–50%, and a notable presence of very high tariffs (50–100%). Vietnam (2,725) and Brazil (2,022) occupy intermediate positions. Vietnam selectively protects certain sectors, while Brazil concentrates tariffs in the 5–10% and 10–15% ranges, indicating moderate but stable protection. The European Union, with a score of 1,908, turns out to be the most liberal of the economies analyzed, with a high proportion of 0% tariffs and a low frequency of very high ones. This score

confirms the EU's approach oriented towards tariff liberalization, but with specific exceptions for sensitive products.

Therefore, the composite tariff score provides a reliable quantitative measure of tariff policy and supports the general conclusion that Thailand and Argentina have the most protectionist agri-food policies, while the EU remains open in terms of tariffs, complementing market control through other mechanisms (e.g. quality standards, sanitary requirements).

In recent years, customs tariffs have been revalued not only as instruments of economic protection, but also as geopolitical instruments of influence and strategic pressure. The most recent example is the decision by the United States in 2024 to significantly increase tariffs on key imports from China, including in the technology, automotive and, in some cases, agri-food sectors. These measures were officially motivated by economic security considerations, but they have generated trade chain reactions, especially in Asia and Latin America.

In this context, international trade in agri-food products is once again becoming a field of manifestation of global political and commercial interests. The reorientation of trade flows, caused by increased tariff barriers, favors the consolidation of bilateral or regional relations, to the detriment of open global exchanges. Thus, countries such as Vietnam, Brazil or Argentina can become indirect beneficiaries of this reconfiguration, if they know how to capitalize on the new trade windows and adapt their tariff policies intelligently.

On the other hand, the volatility of tariff regimes directly affects the stability of international agri-food chains. In a sector already exposed to climate and food security risks, the sudden introduction of punitive tariffs undermines trade predictability, especially for developing countries. This is why multilateral trade agreements and stable preferential regimes take on additional strategic value.

Recent US tariff decisions amplify protectionist trends globally and highlight the need for countries to strengthen their trade resilience through balanced tariff policies, regional integration and export market diversification. The results of this research, which highlight differences between regional tariff models and the efficiency of trade preferences, thus gain increased relevance in a tense and unpredictable international climate.

CONCLUSIONS

In a profoundly changed global trade landscape, marked by the reconfiguration of international economic relations and the sharp return of strategic protectionism, customs tariffs are reaffirming their role as an essential instrument of economic and geopolitical policy. The United States' decision to increase tariffs on strategic imports and to privilege selective trade partnerships has accelerated a fragmentation of the global trading system, in which economic security, self-sufficiency and resilience of chains are becoming dominant priorities.

In this context, the comparative analysis of tariff regimes applied in agri-food trade by the European Union, Brazil, Argentina, Vietnam and Thailand provides a picture not only of distinct trade strategies, but also of the ways in which states and economic blocs respond to new systemic pressures. The research results show that unilateral trade liberalization is no longer a viable option, but must be replaced by calibrated policies, based on selective protection, conditional openness and strengthened regional integration.

Preferential trade agreements remain relevant, but their effectiveness depends on the ability of states to simultaneously respond to requirements related to standards, sustainability, traceability and food safety. Economic regionalism is becoming a strategic anchor, capable of ensuring stability and coherence in an increasingly unstable global trading system.

In an increasingly fragmented global trade climate, tariff policy recommendations must rationally combine strategic protection with conditional openness. The emphasis is shifting from pure liberalization to managing trade risks and strengthening regional partnerships, and customs tariffs are becoming an expression

of geopolitical positioning, not just domestic economic balance.

Under these conditions, customs tariffs must be seen not only as trade barriers, but as economic and geopolitical policy instruments through which states configure their resilience, food security and competitiveness. The use of synthetic indicators such as the composite tariff protectionism score becomes crucial for the formulation of agile and substantiated trade policies, in an international environment that is constantly reconfiguring.

This research therefore proposes not only a quantitative analysis of tariff regimes, but also a strategic framework for interpreting trade dynamics that can guide economic and institutional decisions in the global agri-food sector.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ASSESSING THE DEGREE OF INNOVATION IN THE EUROPEAN RURAL ENVIRONMENT THROUGH A MULTI-INDICATOR COMPARATIVE ANALYSIS

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Abstract

The present research aims to analyze the relationship between innovation and sustainable economic development in the rural areas of the European Union, in the context of the transition towards a knowledge-based economy and territorial balance. The main aim of the paper was to identify to what extent factors such as education, employment, logistics infrastructure and economic structure influence the innovation capacity of European rural regions. The methodology applied was based on a comparative quantitative analysis, using official statistical data for the period 2018–2023, extracted from Eurostat sources, and focusing on five relevant indicators: gross domestic product per capita, employment rate, share of the population with tertiary education, employment in industry and agriculture, and volume of road freight transport. The analysis included both comparisons between Member States and correlations between indicators, applied to annual series and multi-annual averages, in order to capture both recent dynamics and structural patterns. The research results show the existence of clear differences between the European Union Member States regarding the conditions that support rural innovation. Western and northern European countries are distinguished by high GDP per capita, high levels of tertiary education, dynamic labour markets and an efficient logistical infrastructure, which favour the rapid adoption of modern agricultural technologies. Southern and eastern countries present structural imbalances: a high employment rate in agriculture, a low level of skilled human capital and low economic performance, which limit the diffusion of innovations and maintain vulnerabilities. Correlational analysis confirms these findings and leads to the conclusion that rural innovation depends on a combination of economic performance, human capital and infrastructure, which requires differentiated policies to reduce the gaps. The overall conclusions indicate the need for integrated European strategies, able to capitalise on the advantages of developed regions and mitigate the structural deficits of those lagging behind, in order to ensure innovative convergence and the sustainability of European agriculture.

Key words: *innovation, rural environment, multi-indicators, economic development, E.U.*

INTRODUCTION

In recent decades, the European rural area has undergone a complex transformation process, in which the dynamics of globalization, demographic developments, climate change and digital transition have profoundly influenced its functions, structures and development prospects. If in the past the rural environment was perceived almost exclusively through the lens of agriculture, today it is recognized as a multifunctional space, in which economic, social and ecological activities interact in an increasingly complex way [2, 15]. In this context, innovation – in its multiple forms – has become an essential pillar for economic revitalization, territorial cohesion and the sustainability of rural development [23, 25].

The theme of innovation in the rural areas of the European Union is today at the heart of public policy and scientific research concerns, in response to multiple challenges: depopulation of rural areas, population aging, decline in economic competitiveness, vulnerability of infrastructure and regional inequalities [4, 16]. At the same time, these spaces are also sources of untapped potential:

natural resources, social capital, biodiversity, productive traditions and resilient local communities. In this framework, innovation is perceived not only as a technological process, but as a systemic transformation involving new forms of organization, digitalization, participatory governance and reconfiguration of relationships between local actors [1, 13, 24].

The European Union has explicitly recognised the central role of innovation in rural development through policies such as the Farm to Fork Strategy, the European Green Deal or the long-term vision for the EU's rural areas 2021–2040 [14, 17]. Also, initiatives such as Smart Villages, the European Funding from the Horizon Europe Program or the Innovation Partnership in Agriculture are tangible tools for fostering innovation in rural regions [18]. In addition, Pillar II of the revised Common Agricultural Policy include support measures for innovation, digitization, and collaboration among farmers, SMEs, and research facilities. Accordingly, the European Commission's 2024 report on rural finance highlights that innovation sits at the intersection of social cohesion, technological advancement, and participatory governance rather than being reduced to traditional economic measurements [11]. The long-term vision for rural areas highlights the objectives of transforming them into stronger, more connected, more resilient and prosperous communities, and financial instruments such as EAFRD, LEADER/CLLD and EIP-AGRI partnerships directly contribute to achieving these targets through projects aimed at digitalisation, economic diversification and social innovation [3]. Recent territorial analyses indicate that the gaps between western and northern regions, on the one hand, and southern and eastern regions, on the other, are not only explained by differences in GDP, infrastructure or human capital, but also by the level of integration of public policies and the degree of community participation [21]. Thus, Member States that have developed holistic national strategies and have used European funds (CAP, ERDF, ESF, EMFAF) in a complementary manner perform better in absorbing innovations and strengthening rural resilience, compared to countries where policies remain fragmented and sectoral.

Therefore, rural innovation should be understood as the result of the interaction between economic performance, human capital, logistical infrastructure, digitalisation and social capital, and reducing territorial disparities requires differentiated policies, sensitive to local specificities, but also strategic coordination of European and national funds [20]. Such an integrated approach not only supports innovative convergence, but also contributes to the long-term sustainability of European agriculture and rural economies.

However, the literature and European reports show that territorial differences in the innovation capacity of rural regions are still significant [5, 12, 19, 22]. Western and northern European regions benefit from high-performance infrastructure, consolidated innovation ecosystems and access to skilled human capital, while rural regions in the eastern and southern EU often face structural constraints that limit the absorption and generation of innovation. In addition, there is a lack of integrated data and analyses that correlate the level of innovation with indicators such as education, employment, economic structure or transport infrastructure – essential factors in shaping a clear picture of rural development.

Therefore, the present research aims to contribute to this analytical effort, starting from the following central question: What are the relevant correlations between innovation and sustainable economic development in the rural environment of the European Union in the period 2018–2023?

From a theoretical point of view, the research is anchored in the concept of systemic innovation, which goes beyond the classical understanding of innovation as a technological result and proposes an integrative vision, in which the interaction between institutions, knowledge, practices and economic and social structures generates sustainable transitions. In recent literature, rural innovation is conceptualized in close connection with the notions of human capital, social capital and multiscalar governance, highlighting the role of local communities, partnerships and

knowledge networks in stimulating development. Thus, sustainable rural development becomes not only a matter of material investments, but also of collective learning capacity and institutional adaptability.
In addition to the scientific purpose, the present research also has a practical stake: supporting the formulation of differentiated public policies for the European rural environment, based on clear empirical evidence whose results can contribute to: identifying rural regions with high innovation potential, but economically underperforming; supporting investments in education and infrastructure as accelerators of sustainable transition; strengthening the arguments for an integrated approach to innovation in rural development policies post-2027.
The research topic aligns with a major challenge for the European Union: how can innovation be stimulated in territories characterized by economic fragility, structural dependence and geographical exclusion, without reproducing the urban-industrial development model? The answer requires not only complex statistical analyses, but also a rethinking of dominant paradigms, in favor of an inclusive, territorial and sustainable vision of development.
Thus, the present paper aims to contribute to this endeavor through a solid empirical analysis, offering a comparative and updated picture of the role of innovation in shaping the present and future of the rural environment in the European Union.

MATERIALS AND METHODS

The study, which used a quantitative-comparative methodology, sought to examine the connection between the level of innovation and sustainable economic growth in EU rural regions between 2018 and 2023. To capture both temporal dynamics and structural patterns, the analysis is cross-sectional and multi-annual, utilizing both yearly series and multi-annual averages. The European Union's member states, seen at the national level, serve as the analytical unit.
The data were collected exclusively from the official Eurostat database, which guarantees comparability and statistical accuracy. The annual values available for the period 2018–2023 were used, an interval chosen because it provides a recent framework, but sufficiently extensive to capture both the effects of the crisis generated by the COVID-19 pandemic, and the economic recovery trends. The statistics are national averages based on Eurostat's established territorial typologies and classifications, with the EU Member States serving as the territorial units of reference.
In the absence of direct measures of innovation in rural areas (such as research and development expenditure or the number of patents, which are not available at an updated level), proxy indicators were selected, with demonstrated relevance in the specialized literature:
Gross domestic product per capita, as a measure of economic performance and resources available for innovative investments
Employment rate, as an indicator of the integration of human resources and the capacity of the labor market to absorb innovative activities.
The share of the population with tertiary education, for the purpose of locating highly qualified human capital, which is essential for the development and dissemination of innovations.
The share of the population employed in agriculture and industry, as a measure of the rural economic structure, between dependence on traditional sectors and diversification towards innovative activities.
The volume of road freight transport, as a way of measuring the logistics infrastructure and economic connectivity, crucial factors for the dissemination of innovations.
These indicators provide a complex picture of the structural conditions that can favor or limit innovation in the European rural space.
The statistical analysis was carried out in several stages:
Descriptive analysis consisting of calculating means, extremes and standard deviations, to highlight differences between countries.
Multinational comparative analysis that was the basis for identifying groups of countries with similar profiles based on the five indicators.

Correlation analysis by applying the Pearson coefficient for normally distributed variables and Spearman for asymmetric distributions, with the interpretation of the results according to statistical significance ($p < 0.05$) and the intensity of the relationship.

The analysis is subject to inherent limitations. First, the lack of direct indicators of rural innovation (research and development spending, patents, organizational innovations) reduces the degree of precision of the assessment. Second, the use of national averages can mask intra-state disparities (between rural and urban regions or between peripheral and central areas). Despite these limitations, the selection of indicators is validated by the scientific literature, and the proposed methodology allows for a coherent comparative analysis, highlighting the structural differences between states and the conditions that determine the degree of innovation in the European rural environment.

RESULTS AND DISCUSSIONS

In order to emphasize the variations among Member States, the research examined the link between innovation and sustainable economic growth in rural regions of the European Union using a set of similar metrics
and allowing the identification of rural development models associated with innovation.

Table 1. Evolution of GDP/capita in the European Union member states during 2018-2023 (euro/capita)

Country	2019	2020	2021	2022	2023
Austria	115,685.86	111,280.91	116,626.55	130,648.94	:
Belgium	23,389.00	23,004.00	25,565.77	29,018.73	30,586.00
Bulgaria	3,435.71	3,657.05	4,176.46	4,591.78	5,074.81
Croatia	21,275.52	19,126.08	22,206.12	25,925.24	30,015.00
Czechia	41,720.11	40,770.16	44,967.84	51,514.97	58,764.68
Denmark	45,566.48	45,945.05	48,513.34	49,356.38	52,031.97
Estonia	3,880.48	3,686.51	4,166.91	4,769.25	4,904.53
Finland	42,271.04	41,786.89	44,133.19	48,416.41	49,743.78
France	478,315.00	467,997.00	506,212.00	530,692.00	554,375.00
Germany	387,890.00	382,752.00	403,943.00	439,946.00	:
Greece	43,553.22	39,033.44	42,632.43	48,996.00	:
Hungary	17,537.03	16,559.81	18,116.00	19,884.93	22,396.00
Ireland	165,549.16	175,102.25	209,299.79	244,614.70	229,939.00
Italy	127,088.11	118,061.44	129,013.00	138,275.52	:
Latvia	4,684.71	4,947.58	5,518.07	6,194.79	:
Lithuania	2,348.71	2,407.59	2,662.82	3,155.71	3,343.90
Netherlands	4,232.38	4,238.89	4,556.11	5,119.00	4,834.00
Poland	151,640.46	152,282.00	164,440.67	186,497.77	:
Portugal	:	:	56,018.00	61,058.35	66,739.00
Romania	68,308.51	67,301.39	72,934.69	82,979.79	94,813.00
Slovakia	37,787.45	37,541.29	40,082.64	42,940.20	49,800.00
Slovenia	23,134.98	22,359.78	24,656.99	27,030.46	29,936.33
Spain	29,251.70	26,412.20	29,550.60	32,770.00	:
Sweden	26,497.02	26,190.73	29,826.25	30,693.91	28,653.14

Source: own processing [6].

This approach attempted to capture both recent dynamics and structural trends, and the statistical interpretation is complemented by comparative elements, useful for formulating relevant conclusions from a territorial and strategic perspective.

Comparing the Member States of the European Union, we can see the existence of persistent economic disparities between the west and north of the continent, on the one hand, and the east and south of Europe, on the other. Countries with consolidated economies, characterized by diversified productive sectors and developed infrastructures, consistently record higher levels of GDP per capita (Table 1). These countries have superior financial and institutional resources to support innovation in rural areas, through investments in digitalization, advanced agricultural technologies and related services. However, the GDP per capita of the economies of Central and Eastern Europe and several Baltic republics is far lower. This gap reflects both dependence on low-productivity sectors and delays in the process of European economic convergence. In these cases, innovation in rural areas is often limited by insufficient financial resources, poor logistical infrastructure and a higher share of traditional occupations.

GDP per capita thus remains a sensitive indicator of the capacity of states to transform economic growth into innovative and sustainable development of rural areas.

Table 2. Population employed in industry and agriculture in the European Union member states in the period 2018–2023 (Thousands)

Country	2019	2020	2021	2022	2023
Austria	1,457.9	1,430.5	1,457.9	1,495	:
Belgium	312	309	315.55	321.67	322
Bulgaria	337.9	339.47	332.4	268.09	:
Croatia	691	744.16	760.12	772.62	785
Czechia	1,112.12	1,083.6	1,092.29	1,107.03	1,116.73
Denmark	472.45	467.53	478.84	492.97	496.96
Estonia	112.08	108.85	109.72	112.86	114.01
Finland	530.54	516.69	523.97	532.51	537.73
France	6,809	6,817	6,950	7,470	7,548
Germany	5,629.29	5,576	5,573	5,618	:
Greece	1,279.52	1,251.19	1,309.9	1,331	:
Hungary	625.78	619.33	617.12	618.38	618
Ireland	1,230.47	1,210.41	1,286.49	1,375.95	1,429.42
Italy	1,970.7	1,935.9	1,943	1,966.5	:
Latvia	190.71	193.35	189.13	190.9	:
Lithuania	102.17	100.61	100.66	106.98	101.54
Netherlands	51.3	50.4	50.5	53	:
Poland	5,693	5,681.1	5,811.6	5,836.6	:
Portugal	:	:	1,392	1,424.06	:
Romania	3,661.61	3,548.06	3,582.19	3,588.6	3,539
Slovakia	1,084.8	1,065.77	1,058.46	1,082.26	1,078.64
Slovenia	544.8	539.58	544.55	558.28	564.06
Spain	504.6	484.2	497.8	512	:
Sweden	335	334.8	335.2	346.2	357.4

Source: own processing [7].

A common feature is the increase in disparities between countries: although all have recorded an upward trend in the medium term, growth rates have consolidated the initial differences, which suggests a persistent fragmentation of economic convergence within the Union.

This dynamic reveals that GDP/capita, although sensitive to external shocks, remains closely associated with the degree of innovation and modernization of rural economies, being supported in particular by investments in human capital, infrastructure and diversification of the productive structure (Table 1).

Countries with high shares of the population employed in industry and agriculture reflect rural economies where traditional activities continue to absorb a significant part of the workforce. In these countries, agriculture and related industries remain the main pillars of employment, which can mean both an anchoring in productive structures with low added value and an opportunity for modernization through mechanization and technology. In Poland and Romania, for example, a high share of the population employed in agriculture is associated with fragmented holdings and traditional practices, which limits the diffusion of innovations (Table 2). However, this human potential can become an advantage when public policies stimulate the transition to smart agriculture and green industrial processes. In countries where the share of employment in industry and agriculture is low, such as the Netherlands, Belgium or the Baltic countries, the economic structure indicates a stronger orientation towards services and innovative sectors with high added value.

Table 3. Employment rate in the European Union Member States (2018–2023) (%)

Country	2020	2021	2022	2023	2024
Austria	75.3	74.8	76.6	76.6	76.4
Belgium	64	63	64.2	65.9	68
Bulgaria	64.4	64.1	66.8	63.8	63.4
Croatia	58.2	62.6	64.5	63.7	67.3
Czechia	75	75.2	76.3	75.6	76.2
Denmark	73.2	74.9	75.7	75	76.2
Estonia	71.3	72.1	75.2	75.7	73.8
Finland	70.5	71.2	72.5	73.4	73.7
Germany	:	77.8	:	79.2	79.3
Greece	56.8	57.1	59.8	62.1	63.8
Hungary	66.3	68.5	70	70.6	69.6
Ireland	66.6	68.7	72.2	73	73.1
Italy	57.6	58.7	60.7	61.4	62.6
Latvia	70.5	67.5	69.6	71.2	70.6
Lithuania	64.6	64.9	69.4	67.5	67.2
Netherlands	77.7	80.9	82.3	83.1	84.4
Poland	66.7	67.7	68.4	69.2	69.6
Portugal	68.9	69.6	71.5	72.1	72.1
Romania	70.1	60.5	61.5	60.7	60.7
Slovakia	66	66.9	68.8	70.6	70.9
Slovenia	70	70.1	71.6	71.3	71.7
Spain	63.6	65.2	65.9	66.6	67.5
Sweden	74.6	75	77	77	77.7

Source: own processing [8].

This reduces dependence on traditional agriculture and allows for a faster integration of digital and sustainable technologies in rural areas. In these economies, agriculture often becomes a niche activity, highly technological and competitive in international markets.

The impact on innovation in agriculture is clear: where the share of employment in agriculture remains high, the pressure to modernize is strong, but financial and educational constraints delay change. In economies where this share is low, agriculture plays a smaller role in labor absorption, but benefits from more consistent investment and an institutional and logistical infrastructure that favors rapid innovation.

Countries with high employment rates, such as the Netherlands, Germany, Sweden, Austria or the Czech Republic, demonstrate a functioning labour market and a constant capacity to integrate available human resources into economic activities. This has direct consequences for innovation in rural areas: the active population is involved not only in traditional sectors, but also in industrial activities and services related to agriculture, which stimulates diversification and the adoption of modern technologies. For example, a high employment rate facilitates the formation of agricultural and agro-industrial clusters, supports farmer associations and favours the rapid transfer of innovations to agricultural holdings. At the same time, the involvement of the workforce in sectors with higher added value contributes to the stability of rural incomes and to reducing vulnerability to external shocks. (Table 3).

In countries such as Belgium, Romania, Croatia, Italy and Greece, where the employment rate remains low, the consequences are multiple. The fragmented labour market generates high pressure on the agricultural sector, which becomes an occupational refuge for the rural population. Traditional methods with little technological advancement continue to dominate agriculture in the lack of varied economic options. The result is low productivity and limited innovation potential. In addition, low labour market participation leads to the migration of young and skilled workers, which amplifies the shortage of innovative human capital in rural areas.

The employment rate thus has a direct impact on agricultural modernisation processes. A strong and inclusive labour market favours investments in mechanisation, digitalisation and green solutions, as there are both financial resources and skills to use these technologies. Conversely, a low employment rate perpetuates dependence on manual labour, reduces the attractiveness of investments in agriculture and delays the transition to sustainable and innovative production models (Table 3).

Tertiary education represents the strongest source of differentiation between European Union countries in terms of innovation potential in rural areas. Countries with high levels of qualified population, such as Ireland, Finland, Belgium or Sweden, benefit from human capital capable of generating and disseminating innovative knowledge and technologies. These economies have managed to build efficient networks between academia, research centers and productive sectors, including agriculture (Table 4).

The direct consequence is the acceleration of the transition to smart, digitalized and sustainability-oriented agricultural models, in which the use of data, biotechnology and green energy is becoming increasingly common. In countries such as Romania, Italy, Hungary, Bulgaria or Croatia, where the share of the population with tertiary education is low, rural areas face major difficulties in attracting and retaining qualified human capital. These regions risk remaining trapped in a vicious circle of underdevelopment: the lack of specialists limits the modernization of agriculture, which reduces economic attractiveness and leads to the migration of young people to urban areas or to other Member States. The impact on agriculture is visible through the persistence of traditional practices, a low level of use of digital technologies and a slow pace of adaptation to the demands of global markets.

Table 4. Share of population with tertiary education (ISCED 5–8) in the European Union Member States in the period 2018–2023 (% of population 25–64 years old)

Country	2020	2021	2022	2023	2024
Austria	:	27.3	27.8	29.9	30.9
Belgium	38	40.2	41.9	40.6	41.9
Bulgaria	17.1	19.4	20.9	21.6	25.3
Croatia	:	19.2	20.5	20.5	21.7
Czechia	20.3	21.9	22.2	23	23.5
Denmark	29.8	31.4	31.2	29.6	32.4
Estonia	32.2	33.6	34.2	30	28
Finland	42.7	37.7	38.3	:	35.5
Germany	:	25.6	:	26.1	27.2
Greece	:	24.8	25.1	23.9	24
Hungary	17.2	18.3	19.3	19.9	20.8
Ireland	45.3	48.6	49.8	50.4	52.5
Italy	16.4	16.3	16.4	17.4	17.9
Latvia	28	28	30.3	32.4	31.3
Lithuania	26.9	25.1	26.4	28.2	26.6
Netherlands	24.3	29.8	27.9	26.8	30
Poland	23.7	23.9	24.7	27.9	28.7
Portugal	24.3	25.3	25.9	25.7	26.7
Romania	13.5	14.1	14.4	13	13.3
Slovakia	23.5	25.1	25.7	24.7	24.5
Slovenia	30.9	35.9	36	29.8	31
Spain	33.7	34.5	35.6	36.4	35.8
Sweden	35.3	37.6	41.6	40.4	40.5

Source: own processing [9].

The presence of skilled human capital in rural areas not only has a direct effect on agricultural productivity, but also generates indirect results by stimulating entrepreneurship, creating modern cooperatives and strengthening rural innovation ecosystems. Thus, differences between countries in terms of tertiary education translate into significant structural gaps in agricultural innovation capacity and in the pace of European convergence.

The countries with the highest volumes of road freight transport – Germany, France, Poland, Austria and Romania – are characterised by economies with a strong industrial and agricultural component, integrated into extensive logistics networks. These trade flows reflect both the infrastructural capacity and the intensity of rural economic activities. In rural areas, a high volume of road transport indicates not only the mobility of agricultural products, but also the existence of diversified value chains, which include processing, distribution and export. This connectivity facilitates the rapid diffusion of innovations, from agricultural production technologies to digital solutions for logistics management, strengthening the resilience and competitiveness of rural regions.

States with low volumes, such as Lithuania, the Netherlands, Estonia, Belgium and Latvia, illustrate two types of situations: either an economy more oriented towards services and high value-added sectors (the case of the Netherlands and Belgium), or limited infrastructural and economic capacity (the case of the Baltic countries) (Table 5).

Table 5. Volume of road freight transport in the European Union Member States in the period 2018–2023 (million tons)

Country	2020	2021	2022	2023	2024
Austria	173,436	186,991	181,321	167,090	152,413
Belgium	17,814	14,424	13,692	14,628	16,491
Bulgaria	19,013	23,550	30,793	24,382	11,577
Croatia	35,283	36,730	37,079	38,781	42,381
Cyprus	:	:	:	:	:
Czechia	106,087	118,490	103,578	95,249	91,308
Denmark	64,856	60,690	62,977	61,647	42,386
Estonia	10,152	14,134	13,834	12,349	9,374
Finland	117,699	131,408	:	:	67,176
France	541,998	582,553	555,224	547,002	524,755
Germany	666,831	676,910	665,232	627,874	539,351
Greece	164,449	106,195	148,600	120,159	98,399
Hungary	24,910	30,565	26,170	25,849	27,500
Ireland	79,691	85,268	88,357	90,081	89,149
Italy	113,495	128,829	125,028	128,160	101,005
Latvia	22,327	21,949	25,366	24,234	24,031
Lithuania	4,110	4,390	3,292	4,744	4,938
Netherlands	5,768	4,481	5,041	3,511	4,130
Poland	454,482	497,186	515,730	490,474	521,855
Portugal	54,769	59,086	57,915	50,094	46,841
Romania	120,237	137,623	144,806	147,130	126,507
Slovakia	51,520	43,178	45,531	44,370	54,475
Slovenia	28,693	32,958	34,428	35,692	37,819
Spain	81,324	88,203	89,627	83,887	68,849
Sweden	68,355	55,980	62,311	51,258	36,932

Source: own processing [10].

In these cases, although the dependence on road transport is lower, there is a risk that rural areas remain poorly connected to major trade flows, which reduces innovation opportunities and limits farmers' access to international markets.

The impact on agriculture is significant. In countries with high transport flows, farmers can more easily integrate modern technologies and benefit from economies of scale through rapid access to competitive markets and logistics networks. Conversely, in regions where road transport is reduced, the adoption of innovations is slowed down by isolation, high distribution costs and dependence on local markets. Thus, transport infrastructure appears as an essential element of rural innovation capacity, conditioning both the modernization of agriculture and the sustainable development of communities.

The integrated analysis of the five indicators reveals the existence of clear structural differences between European Union countries in terms of the conditions favourable to innovation in rural areas.

Western and Nordic countries, such as Germany, France, the Netherlands, Sweden, Finland and Ireland, have a profile that is conducive to innovation. They are distinguished by high GDP/capita, high employment rates, high levels of tertiary education and a low share of employment in traditional agriculture. At the same time, the logistics infrastructure and the volume of road freight transport are consistent, reflecting the connectivity of rural areas to European and

international value chains. In these countries, agriculture is rather intensive and technologically advanced, characterised by investments in mechanisation, digitalisation and ecological solutions. The impact on innovation is visible in the rapid adoption of precision farming practices, digital technologies and green transition processes.

A second group is represented by the southern and central European economies – Italy, Spain, Portugal, Croatia or Greece – which present an intermediate position. They have moderate GDP/capita, lower employment rates and a relatively low level of tertiary education, which limits the potential for innovation. Agriculture remains an important sector for rural employment, but the lack of highly qualified human capital and migration pressure affect the capacity for modernization. However, transport infrastructure and proximity to external markets contribute to maintaining favorable connectivity, which provides a basis for a gradual transition to innovative practices.

Central and Eastern European nations, such as Poland, Romania, Bulgaria, and Hungary, have a dual character: on the one hand, a sizable percentage of the labor force is employed in traditional industries and agriculture; on the other hand, there is accelerated economic growth and a sizable amount of road transportation. These characteristics show a significant innovation potential, but constrained by low levels of tertiary education and a still rigid occupational structure. In agriculture, this translates into the persistence of small and fragmented holdings, where the adoption of innovations is slow and dependent on the support of public policies and European funds. However, the pressure from global markets compels these nations to quicken their modernization process, which accounts for the latest efforts in the areas of modern cooperatives and agricultural digitalization.

The Baltic countries, Estonia, Latvia, Lithuania, occupy a particular position. Although they are distinguished by limited logistical connectivity and a low share of highly qualified human capital, they are gradually developing digital infrastructures and support networks for innovation, which could become a competitive advantage in the long term.

An emerging dimension of rural innovation is the adoption of precision agriculture technologies, but for which there is still not enough data reported at the country level. Recent estimates indicate that, for example, the European agricultural drone market is experiencing rapid expansion, set to grow from approximately USD 5.8 billion in 2024 to over USD 7.4 billion in 2025, with a compound annual growth rate of 28.6% until 2033 [11]. In line with the goals of the Green Deal and the shift to a knowledge-based economy, this dynamic validates the European Union's propensity to encourage the adoption of smart technology and assist the digital transformation of agriculture. Agricultural drones facilitate real-time monitoring of crops, differentiated application of inputs and optimization of production processes through the integration of artificial intelligence, which can increase the accuracy of agronomic diagnostics by up to 40%. In addition, their use contributes to reducing the consumption of pesticides and fertilizers, supporting sustainability and environmental protection objectives. However, the pace of adoption remains uneven across the Union, affected by fragmentation of flight and licensing regulations (implemented by EASA) and data protection concerns, which are causing reluctance among farmers – almost 40% of them expressing concerns about the unauthorized use of the information collected (Figure 1).

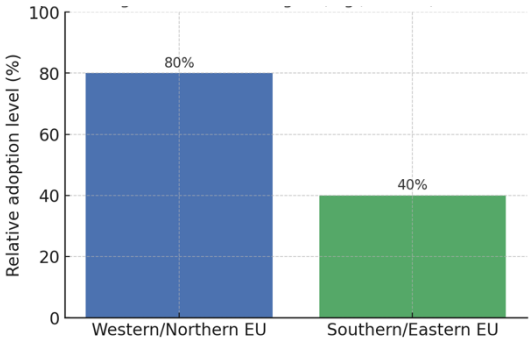


Fig. 1. Comparative Adoption of Agricultural Technologies in Rural Areas of the European Union
Source: own processing [11].

The comparative analysis shows that the degree of innovation in rural Europe is

conditioned by the combination of economic performance, labor market dynamics, education level, occupational structure and logistics infrastructure. Western and northern countries, characterized by high GDP, qualified human capital and high-performance digital infrastructure, adopt new technologies faster, which strengthens competitive advantages and the pace of innovative transformation. In contrast, southern and eastern countries, where employment in agriculture remains high, the level of tertiary education is low, and the logistics infrastructure is deficient, encounter significant barriers to the diffusion of innovations and risk perpetuating development gaps. Thus, the example of emerging technologies, such as agricultural drones, demonstrates that rural innovation reflects not only the general trends of the European market, but also territorial differences in innovative capacity, which underlines the need for differentiated policies to reduce disparities. After the comparative analysis of the five selected indicators, it became necessary to statistically test the relationships between them, in order to capture the structural links that define the degree of innovation. If the descriptive analysis highlighted the differences between the states and the general trajectories, the correlational analysis provides confirmation of the hypotheses regarding the association between economic performance, human capital, occupational structure and logistics infrastructure.

For this purpose, the Pearson and Spearman correlation coefficients were applied, based on the multiannual averages 2018–2023, for the 27 Member States of the European Union. This approach aimed not only to quantify the intensity of the relationships, but also to test the statistical significance ($p < 0.05$), which allows the differentiation between conjunctural associations and consistent links, with relevance for the innovation process.

The results are summarized in Table 6 which constitutes a matrix of correlations between the five indicators considered proxies for rural innovation: GDP/capita, employment rate, share of the population with tertiary education, employment structure in agriculture and industry, and volume of road freight transport. This table provides an integrated picture of how economic performance, human resources and infrastructure interrelate in supporting rural innovation (Table 6).

Table 6. Analysis of correlations between innovation indicators in rural areas in the European Union member states in the period 2018-2023 (multiannual averages)

Var_X	Var_Y	Pearson_r	Pearson_p	Spearman_r	Spearman_p
GDP_pc	Emp_ind_agri	0.802	0	0.867	0
GDP_pc	Emp_rate	0.217	0.32	0.09	0.683
GDP_pc	Tertiary_edu	0.012	0.958	-0.045	0.837
GDP_pc	Freight_vol	0.872	0	0.885	0
Emp_ind_agri	Emp_rate	-0.001	0.998	-0.152	0.488
Emp_ind_agri	Tertiary_edu	-0.326	0.129	-0.421	0.045
Emp_ind_agri	Freight_vol	0.919	0	0.858	0
Emp_rate	Tertiary_edu	0.325	0.131	0.423	0.044
Emp_rate	Freight_vol	0.19	0.385	0.015	0.946
Tertiary_edu	Freight_vol	-0.141	0.52	-0.163	0.457

Source: own processing.

The correlation analysis highlights several strong statistical relationships, with direct significance for understanding innovation in rural Europe. First, there is a very close association between GDP/capita and the volume of road freight transport ($r > 0.85$, $p < 0.001$), which shows that economic performance is inextricably linked to the degree of logistics connectivity, and rural regions well integrated into trade networks benefit from an increased capacity to diffuse innovations. A significant correlation is also

observed between the share of employment in agriculture and industry and the volume of road transport ($r > 0.90$, $p < 0.001$). This result shows that economies with a strong traditional structure generate intense, but not necessarily innovative, logistics flows, which may reflect both the potential for modernization and vulnerability to market fluctuations.

In social terms, the relationship between tertiary education and employment structure is negative and significant ($r = -0.42$, $p < 0.05$), which confirms the hypothesis that regions where agriculture and traditional industries absorb a high proportion of the workforce tend to be characterized by a low level of skilled human capital, which limits the capacity for innovation. Simultaneously, the positive correlation between employment rate and tertiary education ($r = 0.42$, $p < 0.05$) indicates that a more dynamic labor market is linked to a greater level of human capital, with a preference for digital and green technologies as well as agricultural modernization.

Other correlations, such as that between GDP and employment rate or GDP and tertiary education, were not significant, indicating that general economic performance does not automatically translate into rural innovation if it is not supported by adequate infrastructure and human capital. The results obtained confirm that rural innovation in the European Union depends on a complex combination of factors: logistical infrastructure and economic connectivity, occupational structure and education level. Public policies aimed at stimulating innovation in agriculture must therefore simultaneously target investments in human capital and infrastructure, alongside the structural transformation of rural economies.

CONCLUSIONS

The comparative analysis of the five indicators reveals that innovation in the rural areas of the European Union is not evenly distributed, but depends on the interaction between economic performance, human resources and logistical infrastructure. Western and northern countries have managed to build innovative rural ecosystems by integrating skilled human capital and by orienting agriculture towards modern technologies and sustainable processes. This development confirms that innovation is not an isolated process, but the result of a combination of economic, social and institutional factors.

Southern and eastern countries, especially those in Central and Eastern Europe, face persistent challenges: low levels of tertiary education, a high share of the population engaged in traditional agriculture and insufficiently developed logistical infrastructure. These characteristics limit the potential for diffusion of innovations and reduce the attractiveness of investments in agriculture. At the same time, the competitive pressure of European and international markets forces these countries to accelerate modernization, which can transform current vulnerabilities into opportunities in the medium term if supported by appropriate public policies.

From the perspective of European rural development policies, the results suggest the need for a differentiated approach. High-performing regions can be supported to become centers of excellence and diffusion of agricultural innovation, while regions with structural deficits require priority investments in education, vocational training, logistics infrastructure and digitalization. Only by reducing these gaps can real convergence between countries be ensured and European agriculture transformed into a competitive, sustainable and innovative sector on a continental scale.

The results of the comparative analysis highlight the need for differentiated policies, adapted to the structural specificities of the Member States. In the Western and Northern countries, where the rural environment is already highly technological and connected to complex value chains, policies should support the strengthening of innovative ecosystems by stimulating applied research, developing digital agriculture and accelerating the transition to climate neutrality. In these regions, the main objective is to create models of good practice and extend networks for the diffusion of innovations to other areas of the Union.

For the Southern and Central-Eastern countries, where agriculture continues to be a major employment sector, but qualified human capital and logistical infrastructure are insufficient, public policies should focus on vocational training and tertiary education adapted to rural needs. Expanding training programmes in smart farming, biotechnology and digital management can help to increase local innovation capacity. Simultaneously, investments in digital infrastructure and logistics are necessary to promote the adoption of contemporary technology and link rural regions into European economic processes.

The nations with the biggest gaps, particularly those in Eastern Europe and the Balkans, require focused assistance from the European Structural Funds and the Common Agricultural Policy to modernize small and medium-sized farms, encourage agricultural cooperatives, and establish collaborations between farmers, research facilities, and the private sector. These interventions could transform traditional productive structures into innovation actors and accelerate rural convergence at European level.

Therefore, rural innovation policies must combine financial, educational and institutional instruments to create a framework conducive to the modernisation of agriculture and the strengthening of economic sustainability. The structural differences identified between Member States show that a uniform approach is not effective; success depends on the application of flexible strategies adapted to the specificities of each rural economy.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE ROLE OF RURAL TOURISM IN DEVELOPMENT: THE AKÇAKOCA EXAMPLE, Türkiye

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Abstract

Akçakoca is a district in Türkiye known for its unspoiled natural landscapes, historical landmarks, and rich cultural heritage. For the past 50 years, it has played an important role in tourism and is strategically located at an equal distance from two of the country's largest cities. Alternative tourism is new opportunity for Akçakoca district besides mass tourism. The goal of this research study is to assess Akçakoca region potential to develop rural tourism. To achieve this, the perspectives of local residents engaged in rural tourism were examined. A quantitative research approach was adopted, and data were collected through face-to-face surveys. Using a convenience sampling method, responses from 175 participants were analyzed. The findings indicate that in order to enhance rural tourism in Akçakoca, greater emphasis should be placed on investment, promotion, and infrastructure. Expanding tourism activities throughout all four seasons, increasing local awareness, and distributing tourism revenues more evenly are seen as key steps toward sustainable regional development. Furthermore, collaboration among local authorities, tourism enterprises, and the community is essential for designing effective strategies. In this regard, encouraging greater participation of women and young people in tourism initiatives is expected to strengthen the positive impact of rural tourism on the local economy.

Key words: *rural tourism, local development, Akçakoca, Türkiye*

INTRODUCTION

In recent years, tourism perceptions have begun to change significantly due to economic, environmental and social developments in the world. For example, tourists who face situations such as the Covid-19 pandemic and climate change have begun to prefer different tourist products. In addition, it is seen that developed and developing regions that want to generate income from tourism throughout the year focus on different alternative tourism products In this regard, rural tourism, as one of the alternative forms of tourism which could be considered a prominent activity in the regions with high potential. This study aims to evaluate not only the potential resources for rural tourism development, but also the factors which have a positive and negative influence.
In this way, the intention is that the obtained results to bring a significant contribution to the literature on the topic.

Touristic Product

It is the totality of goods and services offered for consumption by tourists within the scope of tourism activities (Middleton, 1994) [25]. The tourist product is a multi-dimensional structure that brings together physical and abstract elements. It consists of components such as natural and cultural elements, accommodation, transportation, food and beverage, and entertainment (Cooper et al., 1998) [8]. Smith (2009) [35] defined the tourist product as a structure consisting of five components, which are attractions, access, facilities, image and price. Each of these components is among the factors that affect the tourist's travel decision. The tourist product may vary depending on the expectations and experiences of tourists. However, different destinations can offer tourist products tailored to their target audiences, thus gaining a competitive advantage (Kotler et al., 2014; Ritchie and Crough, 2003) [19, 33]. The marketing and management of tourist products is important for the tourism sector.

Touristic Product Features

The most important characteristics of the tourist product are heterogeneity, intangibility, inseparability, perishability and variability

(Kotler et al., 2014) [19]. These features are the basic elements that determine the dynamic structure of the tourism sector. The heterogeneous structure of tourist products means that each consumer has different expectations, making it difficult to provide a standard service (Holloway, 2004) [18]. The intangible nature of the tourist product ensures that it is experience-based and varies depending on the consumer's perception. This increases the importance of service quality and necessitates the provision of customer satisfaction (Buhalis, 2000) [7]. In addition, the perishability of tourist products indicates that the services produced cannot be stocked and must be provided on time (Middleton, 1994) [25].

Tourist Product Diversification

Tourist product diversification refers to the development of products for different types of tourism in order to increase the competitiveness of destinations (Buhalis, 2000) [7]. Alternative tourism types such as cultural, nature, health, gastronomy, rural and adventure tourism are evaluated within this scope (UNWTO, 2021) [38]. Diversification of tourism products is of great importance in ensuring the sustainability of tourism throughout the year and invigorating the regional economy (Hall & Williams, 2008) [17]. Alternative tourism types ensure that destinations are less affected by seasonal fluctuations and the tourist profile is expanded (Sharpley, 2002) [37]. In addition, tourist product diversification increases tourists' interest in destinations and supports sustainable tourism (Novelli, 2005) [29]. For example, thanks to gastronomy tourism, local cuisine is promoted, while cultural tourism preserves historical and artistic heritage (Richards, 2018) [34]. In addition, the development of areas such as health and wellness tourism helps to increase tourist activities, especially those requiring long-term accommodation, and to provide more economic gain to destinations (Smith & Puczkó, 2009) [35].

Rural Tourism

It is seen that the world tourism literature has been developed and that rural tourism has been expressed in various studies using different methods. These studies include concepts such as farm tourism, village tourism, highland tourism and ecotourism. The main reason for this diversity is that the boundaries of rural tourism cannot be determined with clear lines and vary depending on different diversity, cultural structures and natural environmental conditions. Rural tourism has been defined in various ways by scholars. While some describe it as a form of tourism closely connected to nature and committed to preserving ecological balance, others view it as an activity centered on experiencing local production processes or exploring traditional village life.

From a conceptual point of view, it is not easy to establish a general definition of rural tourism, as various authors have their own opinion on this aspect, whose study involves many disciplines depending on the geographic context. To create just only single definition largely accepted is a real challenge as affirmed (Nair et al., 2014; Lane, 1994, pp. 9–10) [26, 22].

In 1994, Lane [21] affirmed that: *"tourism that takes place in rural areas characterized by low population density and open spaces, typically consisting of small settlements with fewer than 10,000 inhabitants, where land is primarily used for farming, forestry, or natural purposes."* Also, he considers that rural tourism is closely linked to natural resources and cultural heritage of a region.

In 2019, Çetin [9] considered that *"rural tourism characterize villages or similar locations, involves natural and cultural attractions, specific services like: accommodation, food, beverages and infrastructure".*

A similar opinion had Sharpley and Roberts (2004) [36].

However, many researchers sustain that in the rural communities where tourism adopts and implements the principles of sustainability, it becomes a real factor destined to enhance economic and social development (Lane & Kastenholz, 2015) [23].

Rural tourism is an opportunity to create new jobs in villages, to valorize the production potential of the agricultural regions, to increase the income of the agriculturists and of other categories of rural residents (OECD, 2016)

[31]. In addition, in this way, the economic diversity could contribute to the development of the communities and regions. (Wilson et al., 2001) [39].

Expressing rural tourism with different terminologies has revealed that this tourism is multi-faceted and varies according to regional growth. This diversity, together with the significant unknown that strengthens both the economic and social dimensions of rural tourism, also makes it difficult to differentiate a common definition. Although a universally accepted definition of rural tourism has not yet been established, its primary objective is to promote tourism while safeguarding the natural and cultural assets of rural areas, supporting the development of local communities, and fostering a sustainable tourism model. In line with this purpose, the present research seeks to examine the role of rural tourism in regional development. Accordingly, the perspectives of residents in the Akçakoca district regarding rural tourism development were evaluated, and insights into the rural tourism potential of the region were also gathered.

MATERIALS AND METHODS

A quantitative research method was employed to achieve the objectives of the study. The research was designed as a two-stage process. In the first phase, data were collected from 175 voluntary participants through a survey. In the second phase, the study will be expanded by adopting a sampling method that takes into account the overall population size of the research universe. At this stage, participation will be sought from all individuals residing in Akçakoca who are engaged in or interested in rural tourism.

The survey technique was used to collect data in the study. After the literature review, the survey form used in the study of Ölmez and Girgin (2015) [30] was used in this study. This questionnaire was finalized after receiving the opinions of experts on the subject. The questionnaire consists of two main parts. The first section includes statements to determine the attitudes of local people towards rural tourism and includes a five-point Likert scale. The second part includes questions to determine the demographic characteristics of the participants.

In the study, a preliminary application was first carried out. The preliminary application was carried out on 20 people between December 01, 2024 and December 15, 2024. In this context, the reliability of the collected data was tested, and the Cronbach's alpha coefficient obtained from the preliminary application was calculated as 0.90. This result indicates a high level of internal consistency, as the overall Cronbach's alpha value exceeded the 0.70 threshold recommended by Nunnally (1967) [28]. Since the reliability level was deemed satisfactory, the data collection process was continued. In total, 200 questionnaires were distributed to participants, of which 175 were successfully returned and included in the analysis. Descriptive statistical techniques such as percentage and frequency were used to analyze the demographic data obtained. On the other hand, statistical analyses were conducted using Kruskal-Wallis and Mann Whitney U analysis techniques to understand whether demographic differences led to differences in the participants' views on rural tourism and development.

To evaluate the suitability of the data for normal distribution, firstly descriptive statistics were examined, then skewness and kurtosis values were analyzed. In order to determine the suitability for normal distribution, Kolmogorov-Smirnov and Shapiro-Wilk tests were applied, and histogram and Q-Q plot graphics were also examined. The analysis revealed that the data did not follow a normal distribution. Consequently, instead of parametric tests, nonparametric methods appropriate for the data distribution were employed. In this context, the Mann–Whitney U test and the Kruskal–Wallis H test were applied to examine whether participants' perceptions of rural tourism and rural development varied across demographic variables.

The Mann–Whitney U test was used for variables with two groups (e.g., gender and marital status), while the Kruskal–Wallis H test was applied to variables with three or more groups (e.g., age, education level, and income).

The results provided insights into whether perceptions of rural tourism differed significantly among demographic groups and contributed to the development of more targeted strategies for advancing rural tourism.

RESULTS AND DISCUSSIONS

Akçakoca is located at the western end of the Black Sea Region, the closest gate of Central Anatolia to the sea, and is a holiday resort where green and blue coexist between two major cities, Istanbul and Ankara. The region, which is 37 km away from Düzce province, is also the largest district of Düzce province. The district has 8 neighborhoods and 43 villages. Nearly 40% of the total land is covered with forests or open areas. The coastline is 30 km long and full of sandy beaches and natural beaches (Akçakoca District Governorship, 2015) [2]. According to the 2024 address-based population registration system results, the total population of the district is 41,223, of which 20,236 are male and 20,997 are female (Akçakoca District Population Directorate, 2025) [1]. In Akçakoca, hazelnut farming is the primary source of income for the people. There are hazelnut gardens in almost all villages. In addition to agriculture, animal husbandry, beekeeping, fishing and tourism are also used as alternative sources of income (Düzce Governorship Provincial Directorate of Culture and Tourism, 2010) [12].

Rural Tourism Trends in Akçakoca

Akçakoca district has special features concerning rural tourism, offering a large range of alternatives such as: ecotourism which is definitely linked to natural resources and the beauty of the landscapes, which are an important attraction (Düzce Governorship Provincial Directorate of Culture and Tourism, 2015) [13].

Akçakoca is the district that attracts the most tourists in the region due to its climate, completely unspoiled natural resources, environment, historical and cultural assets, local lifestyle, traditions, geographical location, proximity to main markets and suitability for coastal tourism (Altanlar, 2007: 85) [4].

Eco tourism area Aktaş waterfall, recreation areas, beaches, Fakıllı cave and Genoese castle, which can be easily reached within 10 minutes from Akçakoca center, are touristic areas worth seeing.

The Genoese Castle has been added to the UNESCO World Heritage temporary list. Akçakoca's rural tourism presence can be evaluated under 4 headings: rural areas, rural heritage, rural life and rural activity.

Among these titles, rural areas include mountains, lakes, rivers, forests and nature landscapes.

Within the rural heritage title, there are traditional architecture, industrial heritage, prehistoric heritage, castles, churches and villages.

Under the title of rural life, it includes handicrafts, local activities, culinary culture, agricultural tourism, traditional music.

Under the title of rural activities, it includes walking areas, fishing, horseback riding, cycling, hunting and water sports areas (Mesci and Öztürk, 2017:77-78) [24].

In the year 2025, Akçakoca district was visited by 57,720 tourists, of which 56,798 (94.80%) were domestic tourists and only 922 (5.20%) foreign visitors according to the data provided by Ministry of Culture and Tourism.

Also, in2025, the accommodation capacity of Akçakoca reached 1,006 rooms and 2,207 beds in total (Düzce Governorship Provincial Directorate of Culture and Tourism, 2025) [14].

Socio-economic characteristics of the participants at the interview

Table 1 presents the socio-economic characteristics of the interviewed individuals in this research.

56% of the participants are male and 44% are female. This distribution shows that the individuals participating in the study are relatively balanced in terms of gender. In terms of marital status, 54.3% of the participants are married and 45.7% are single. These data show that married individuals have more opinions on rural tourism, but single participants also have a significant proportion. When we look at the age distribution, the largest group consists of individuals between the ages of 36-50 with 37.7%, followed by young people between the

ages of 18-25 with 29.1%.While individuals between the ages of 26-35 represent a medium-sized group with 24.6%, participants between the ages of 50-65 constitute the smallest group with 8.6%. This distribution shows that the middle age group is decisive in the evaluation of rural tourism potential and that individuals between the ages of 36-50 are more involved in the process.

Table 1. Demographic characteristics of the participants

Variable	Category	N	%
Gender	Male	98	56.0%
	Female	77	44.0%
Marital Status	Married	95	54.3%
	Single	80	45.7%
Age	18-25 years old	51	29.1%
	26-35 years old	43	24.6%
	36-50 years old	66	37.7%
	50-65 years old	15	8.6%
Occupation	Housewife	6	3.4%
	Worker	19	10.9%
Average Income	Civil Servant	64	36.6%
	Other	86	49.1%
Graduation Status	30,000 TL and below	49	28.0%
	30,001-40,000 TL	27	15.4%
Occupation	40,001-50,000 TL	27	15.4%
	50,001 and above	72	41.1%
	High school and below	33	18.9%
Average Income	Undergraduate	92	52.6%
	Postgraduate	50	28.6%
Graduation Status	1-5 years	69	39.4%
	6-10 years	28	16.0%
	11-15 years	26	14.9%
	16-20 years	20	11.4%
	21 and above years	32	18.3%
Connection with the Tourism Industry	No	67	38.3%
	Yes	108	61.7%
Generating Income from Tourism	No	107	61.1%
	Yes	68	38.9%
Length of Life in Akçakoca	Less than 1 year	20	11.4%
	1-5 years	69	39.4%
	6-10 years	20	11.4%
	11-15 years	18	10.3%
	16 years and more	48	27.4%
Economic Activity	Farming/Animal Husbandry	24	13.7%
	Other	151	86.3%

Source: Created by the author.

When the occupational distribution of the participants is examined, it is seen that the largest group is included in the "*Other*" category with 49.1%. This category may include freelancers, entrepreneurs or different occupational groups related to tourism. Civil servants come next with 36.6%, workers are represented with 10.9% and housewives are represented with 3.4%. This distribution shows that views on rural tourism are evaluated from a broad professional perspective and how tourism can be associated with various business areas is gaining importance. When the income levels of the participants are examined, it is seen that 41.1% are in the monthly income group of 50,001 TL and above, 28% are in the income group of 30,000 TL and below, and the income groups of 30,001-40,000 TL and 40,001-50,000 TL each have 15.4% of the participants. These data reveal that the majority of individuals making evaluations about rural tourism are at middle and high income levels and that there is an economic potential to invest in rural tourism. When the education levels of the participants are examined, it is seen that 52.6% have a bachelor's degree, 28.6% have a postgraduate education, and 18.9% have a high school education or below. The high proportion of educated individuals among participants suggests that knowledge-based strategies can play an effective role in advancing rural tourism. Regarding professional experience, 39.4% of respondents reported having between one and five years of experience, while 18.3% indicated 21 years or more. This distribution highlights that both younger and more experienced individuals contribute to tourism development. Additionally, 61.7% of participants stated that they were directly involved in the tourism sector, whereas 38.3% reported having no direct connection to it. Although the rate of those who have a connection to the tourism sector is high, the rate of those who earn direct income from tourism remains lower at 38.9%. It is understood that the contribution of tourism income to the regional economy has not yet become fully widespread, but there is a development potential in this area.

An examination of participants' length of residence in Akçakoca shows that the largest group (39.4%) consists of individuals who have lived in the region for one to five years.

Meanwhile, 27.4% reported residing in the area for 16 years or longer, with the remaining groups distributed at lower rates. These findings indicate that rural tourism in Akçakoca involves both long-term residents and recently settled individuals who prefer rural lifestyles. In terms of economic activities, only 13.7% of participants reported working in farming or animal husbandry, while 86.3% were engaged in other sectors. This suggests that while agricultural production may serve a supportive role in rural tourism development, further consideration is needed on how to effectively integrate existing economic activities with tourism.

Findings Regarding the Research Area

In this section, the opinions of the participants regarding the rural tourism potential of the Akçakoca region, which was determined as the research area, and the benefits of this type of tourism to the region are analyzed. Within the scope of the research, participants' views on rural tourism were assessed through closed-ended questions, and the findings were used to evaluate both the current situation and the development potential of the region in terms of rural tourism.

General Findings Regarding the Regional Development of Rural Tourism

To assess the impact of rural tourism on regional development, a scale was developed consisting of 21 statements that measure its economic, social, and cultural contributions. This scale was adapted from previous studies in the field and tailored to reflect the specific characteristics and unique context of the Akçakoca region.

By examining the arithmetic means and standard deviations of the scale items, the study provided a detailed understanding of local residents' perceptions of rural tourism and its impacts.

Table 2. Participants' Views on Rural Tourism and Rural Development- Means and Standard Deviations

Substances	Avg.	Sd.
Rural tourism investments should be increased.	4.22	.872
When people living in our region sell the vegetables, fruits, sausage, cheese and dairy products they produce with their own means, both consumers and producers are satisfied.	4.14	.869
Rural tourism provides the opportunity to meet new people socially.	4.13	.844
Rural tourism contributes to the development of living conditions and the promotion of our culture.	4.11	.890
I believe that the place of women living in our region in society will be strengthened thanks to rural tourism.	4.06	.872
The number of places providing boarding house services in the region should be increased.	4.05	.901
Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which is not yet developed in the region.	4.01	.851
Rural tourism increases the income of local people.	4.00	.797
It makes me happy to take care of the garden with the people staying at the hostel, to grow various products and to taste the flavors such as jam, tarhana and poppy seeds from those products.	3.99	.980
Our local people will gain new job opportunities and additional income thanks to rural tourism.	3.98	.877
Rural tourism increases the income of local people.	3.94	.933
I think that it will be easier to promote my region's traditions, customs, food and drink and lifestyles through boarding houses.	3.91	.948
The fact that the natural environment in the region is intact facilitates rural tourism activities.	3.87	1.004
The rural tourism opportunities of the region are attractive.	3.80	.887
I think our region is an attractive place in terms of rural tourism activities.	3.78	.955
Harvest and other events held on certain dates of the year cause great interest in the region.	3.77	.967
The easy accessibility to Akçakoca district contributes to the increase in mobility for rural tourism.	3.71	1.134
I believe that our region is a tourism, culture, history and health center in every aspect.	3.70	1.017
Rural tourism enables tourism activities in our region to be spread over four seasons.	3.63	1.053
The tourist attractiveness of the region stems from its potential for rural tourism.	3.62	.987
Tourists visiting the region respect the historical and natural beauties and do not engage in harmful behavior.	3.50	.994

Source: Created by the author.

The results highlight the potential of rural tourism to serve as an effective tool for the regional development of Akçakoca (Table 2).

An analysis of participants' views on rural tourism and rural development indicates a general consensus that rural tourism represents an important opportunity for the region's advancement. The statement receiving the highest mean score, "*Rural tourism investments should be increased*" (M = 4.22), reflects the strong belief among respondents that greater investment is necessary to support the development of rural tourism. This is followed by the statement "*The sale of vegetables, fruits, sausage, cheese and dairy products produced by the people living in our*

region with their own means satisfies both the consumer and the producer" (4.14), which emphasizes the benefits that rural tourism provides to local producers and consumers.

Therefore, rural tourism is a creator of economic growth and also sustain the valorization of the local products. The relationship between the local producers and tourists as consumers offers the chance to meet each other and develop social contacts and establish cultural interactions, as conformed by the high average (4.13).

More than this, grace to the increased income of the local residents dealing with tourism, it is obvious that rural tourism is driver for better living conditions and promotion of the cultural heritage as demonstrated by the high value (M = 4.11).

The interviewed persons who participated in this research had the opinion that women living in the rural areas will be deeply involved in rural tourism in offering high quality accommodation and food services, cooking local delicious recipes and showing hospitality to better satisfy their guests. This is the result obtained for the opinion: "*I believe that the place of women living in our region in society will be strengthened thanks to rural tourism*" with a high average (4.06).

The interviewees' opinion was that "*The number of places providing boarding house services in the region should be increased*" as it is shown by the high average (4.05).

Therefore, the accommodation capacity in terms of rooms and beds, and also the boarding services should be improved.

The high average (4.01), concerning the promotion of the rural tourist attractions, localities, as attested by the affirmation that: "*Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which is not yet developed in the region*", reflects that promotional support in terms of informative flyers and brochures is pale at present.

Participants also expressed positive evaluations regarding the economic impacts of rural tourism on the region. "*Thanks to rural tourism, there is an increase in the income of the local people*" (4.00) and "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (3.98) the statements are noteworthy findings in this regard. Participants who believe that boarding house activities contribute positively to rural tourism said, "*Taking care of vineyards and gardens with the people staying at the boarding house, growing various products and tasting flavors such as jam, tarhana and poppy seeds from those products makes me happy*" they also showed a high level of agreement with the statement (3.99)."*I think that it will be easier to promote the traditions, customs, food and beverages and lifestyles of my region with the boarding house business, which is thought to contribute to the preservation of the traditional lifestyle*" the statement (3.91) is another remarkable finding.

An examination of the evaluations concerning the natural and historical appeal of the region shows that the statement "*The intactness of the natural environment in the region facilitates rural tourism activities*" received a relatively high mean score (M = 3.87). This finding shows that one of the most important elements in terms of rural tourism is the preservation of the natural environment. The statements "*The rural tourism opportunities of the region are attractive*" (M = 3.80) and "*I think our region is an attractive place in terms of rural tourism activities*" (M = 3.78) indicate a strong perception among participants that the region possesses considerable attractiveness and potential for rural tourism. In the evaluations made on the impact of the events organized in the region, it was stated that "*Harvest and other events held on certain dates of the year cause great interest in the region*." It is stated that traditional activities are an important attractiveness factor in terms of rural tourism with the statement (3.77). Evaluating the effect of ease of transportation on rural tourism, the statement "*Easy transportation to Akçakoca district contributes to the increase in mobility for rural tourism*" stands out with its average value of (3.71). In addition, the statement "*I believe that our region is a tourism, culture, history and health center in every aspect*" (3.70) indicates that the region has a multi-faceted tourism potential.

It is seen that there is a positive perception with the statement "*Rural tourism enables tourism activities in our region to spread to all four seasons*" (3.63) that rural tourism makes regional tourism active throughout the year. However, the relatively lower average of the statement "*The tourist attractiveness of the region stems from the potential for rural tourism*" (3.62) shows that the attractiveness of rural tourism to the region is not yet fully established. Regarding whether tourists are respectful to the environment, the statement "*Tourists visiting the region respect historical and natural beauties and do not engage in harmful behavior*" (3.50) has the lowest average value. This may indicate that there are some concerns about tourist sentiment towards the area.

When evaluated in general, the participants largely agree that rural tourism provides economic, social and cultural contributions to the region. It is emphasized that rural tourism should be developed further while preserving the natural structure and cultural values of the region. However, the findings also suggest that certain areas require further attention, particularly the expansion of accommodation facilities, the strengthening of promotional activities, and the enhancement of tourists' environmental awareness. Overall, the results indicate that while rural tourism has the potential to serve as a powerful instrument for regional development in Akçakoca, existing shortcomings must be addressed to fully realize this potential.

Findings on Inferential Statistics

Mann-Whitney U Test Results

The Mann–Whitney U test was conducted to examine whether participants' views on the development potential of rural tourism in Akçakoca differed by gender. The results revealed a significant difference, indicating that women expressed stronger agreement than men with the statement "*Easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" ($z = –2.918$, $p = 0.004$).

Similarly, a significant difference was observed between genders for the statement "*The intactness of the natural environment in the region facilitates rural tourism activities*" (z=-2.430, p=0.015). It was determined that women agreed with this statement at a higher level than men. In addition, in the analysis conducted for the statement "*I think our region is an attractive place in terms of rural tourism activities*", a statistically significant difference was found between the genders and it was determined that women agreed with this statement at a higher level than men (z=-2.609, p=0.009).

In addition, in the test conducted regarding the statement "*Our local people will gain new job opportunities and additional income thanks to rural tourism*", it was determined that women agreed with this statement more than men (z=-2.676, p=0.007). However, no significant difference was found between genders in the analysis of other statements (p>0.05). The results indicate that women hold more positive views than men on certain aspects concerning the development of rural tourism.

The test revealed that singles, based on their marital status, agreed with the following statement: "*Easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" at a higher level than married participants. (z=-3.408, p=0.001).

Similarly, a significant difference was observed in terms of marital status for the statement "*I think our region is an attractive place in terms of rural tourism activities*" (z=-2.032, p=0.042). Single participants expressed higher levels of agreement with the statement compared to married participants. However, in relation to the statement "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" no statistically significant difference was found by marital status ($z = –1.915$, $p = 0.056$). The analyses of other statements revealed no statistically significant differences based on marital status ($p > 0.05$).

It was noticed that single participants have a more positive perception of the opportunities provided by rural tourism and of the attractiveness of the region as a whole.

It is obvious that the participants connected to tourism consider and agree that "*Rural tourism increases the income of the local people*" at a higher level than those who do not have any link with this economic

sector (z=-1.965, p=0.049).

In addition, the analysis of the statement "*Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which has not yet developed in the region*" revealed significantly higher agreement among participants employed in the tourism sector (z = –2.669, p = 0.008). This finding suggests that individuals directly engaged in tourism place greater emphasis on promotional activities and highlights the importance of prioritizing sector stakeholders in strategies aimed at fostering the development of international tourism. In the analyses made regarding other statements, no significant difference was found according to the connection status with the tourism sector (p>0.05). The results obtained reveal that the perception of the economic contributions of rural tourism and the importance of international promotion is stronger among individuals connected with the tourism sector.

As a result of the test conducted according to whether they earn income from tourism or not, it was determined that participants who earn income from tourism agreed with the statement "*Rural tourism enables tourism activities to spread to four seasons in our region*" at a higher level than those who did not earn income (z=-2.584, p=0.010).

Similarly, it was observed that participants who earn income from tourism showed higher participation in the statement "*The tourist attractiveness of the region stems from the potential for rural tourism*" (z=-2.729, p=0.006). In addition, in the analysis of the statement "*The rural tourism opportunities of the region are attractive*", it was determined that those who earn income from tourism agreed with this statement significantly more (z=-3.294, p=0.001).

In addition, a significant difference was observed for the statement "*The number of places providing boarding house services in the region should be increased*" (z=-2.358, p=0.018). This finding shows that those who earn income from tourism are more supportive of increasing infrastructure for the development of rural tourism. In addition, in the test conducted on the statement "*Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which has not yet developed in the region*" it was seen that those who earn income agreed with this statement at a higher level (z=-2.306, p=0.021).

The analyses of other statements showed no statistically significant differences based on income generation from tourism (p > 0.05). Nevertheless, the findings indicate that individuals who derive economic benefits from tourism tend to hold a more favorable perspective on the development of rural tourism and the strengthening of related infrastructure.

As a result of the test conducted according to the type of economic activity carried out, it was determined that the level of agreement with the statement "*The tourist attractiveness of the region stems from the potential for rural tourism*" showed a significant difference regarding the type of economic activity (z=-2.221, p=0.026). Therefore, individuals engaged in different economic activities have affirmed tourist attractiveness has changed.

Similarly, a significant difference was found according to the type of economic activity for the statement, "*The sale of vegetables, fruits, sausage, cheese and dairy products produced by the people living in our region with their own means satisfies both the consumer and the producer*" (z=-2.502, p=0.012). In addition, in the analysis conducted for the statement "*Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which has not yet developed in the region*", it was determined that there was a significant difference according to the type of economic activity (z=-2.432, p=0.015).

In the analyses made regarding other statements, no significant difference was found according to the type of economic activity (p>0.05). The findings reveal that perspectives on the contribution of rural tourism to the regional economy and on promotional activities vary according to participants' type of economic activity. In particular, individuals engaged in farming or animal husbandry appear to hold different views regarding the

economic benefits of rural tourism and its influence on the region's attractiveness to tourists.

Kruskal-Wallis H Test Results

The results of Kruskal-Wallis H test showed that the participants have a different opinion on the development potential of rural tourism in Akçakoca depending on the age group This is confirmed by the level of agreement with the statement "*Easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" which is reflected by (H=26.616, p<0.001). This shows that different age groups have different perceptions of the impact of ease of transportation on rural tourism.

Similarly, a statistically significant difference was observed among age groups in relation to the statement "*I think our region is an attractive place in terms of rural tourism activities*" (H = 12.794, p = 0.005).

In addition, a significant difference was found between age groups for the statement, "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (H=18.997, p<0.001), this shows that the perception of rural tourism's employment creation potential varies depending on age.

Furthermore, the analysis of the statement "*The rural tourism opportunities of the region are attractive*" revealed a statistically significant difference among age groups (H = 8.514, p = 0.037). A similar pattern was observed for the statement "*The sale of vegetables, fruits, sausage, cheese, and dairy products produced by the local people with their own means satisfies both the consumer and the producer*" (H = 10.698, p = 0.013), indicating that perceptions of both the attractiveness of rural tourism and the benefits of local product sales vary significantly across different age groups.

However, in the analysis of the statement "*Providing brochures showing the historical and natural values of our region to tourists coming from abroad will increase foreign tourism, which has not yet developed in the region*" it was determined that there was a significant difference between age groups. (H=11.220, p=0.011). Similarly, significant differences were found between age groups for the statements "*Rural tourism provides the opportunity to meet new people socially*" (H=10.517,p=0.015) and "*Rural tourism contributes to the improvement of living conditions and the promotion of our culture*" (H=10.348, p=0.016).

In the analyses regarding other statements, no significant difference was found between age groups (p>0.05). The results obtained reveal that different age groups have different perceptions, especially regarding the economic, cultural and social contributions of rural tourism. Young participants and older age groups have different perspectives on the benefits of rural tourism to the region.

As a result of the test conducted according to occupational groups, it was determined that the level of agreement with the statement "*The number of places providing boarding house services in the region should be increased*" showed a significant difference according to occupational groups (H=7.701, p=0.043). This result shows that professional groups may have different views on the development of accommodation infrastructure in rural tourism. Similarly, in the analysis of the statement "*Harvest and other activities held on certain dates of the year cause great interest in the region*", it was observed that there was a significant difference between occupational groups (H=7.501, p=0.048). This finding suggests that different occupational groups may hold varying perceptions regarding the attractiveness of rural tourism activities. However, the analyses of other statements revealed no statistically significant differences across occupational groups (p > 0.05).

The findings indicate that while perceptions of rural tourism differ in certain respects across occupational groups, no substantial overall differences were observed. Nevertheless, examining variations in perceptions related to boarding houses and rural activities by occupational group may provide valuable insights for shaping rural tourism policies.

In terms of income levels, the analysis revealed a significant difference in agreement with the statement "*Easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" (H = 17.705, p = 0.001), suggesting that views on the role of transportation in rural tourism vary across income groups.

Similarly, a significant difference was found for the statement "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (H = 12.396, p = 0.006), indicating that perceptions of the economic benefits of rural tourism also differ according to income levels. This situation reveals that the perception of the economic benefits of rural tourism differs depending on income levels.

In addition, a significant difference was found between income groups in the analysis of the statement "*The tourist attractiveness of the region stems from the potential for rural tourism*" (H=9.437, p=0.024).

However, "*I think our region is an attractive place in terms of rural tourism activities*" (H=10.429, p=0.015), "*Rural tourism provides the opportunity to meet new people socially*" (H=10.971, p=0.012) and "*Rural tourism contributes to the improvement of living conditions and the promotion of our culture*" (H=10.560, p=0.014) significant differences were also found between income levels for the statements.

The analyses of other statements revealed no statistically significant differences across income levels ($p > 0.05$). Nonetheless, the results suggest that perceptions of the economic and social benefits of tourism vary according to income distribution, with particularly low- and high-income groups approaching the contributions of rural tourism from differing perspectives.

As a result of the test conducted according to graduation status, "*Rural tourism increases the income of local people*". It was determined that the level of agreement with the statement showed a significant difference according to graduation status. (H=7.198, p=0.027). This finding shows that the perceptions of individuals with different education levels regarding the economic contributions of rural tourism vary.

Similarly, "*The easy access to Akçakoca district contributes to the increase in mobility for rural tourism*". It was found that there was a significant difference between the graduation groups for the statement (H=7.758, p=0.021).

In addition, in the analysis made for the statement "*I think our region is an attractive place in terms of rural tourism activities*", it was determined that there was a significant difference according to graduation status (H=8.644, p=0.013).

However, a significant difference was observed according to graduation status for the statement "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (H=9.878, p=0.007). This shows that the perception of the employment creation potential of rural tourism varies depending on the level of education.

In the analyses made regarding other statements, no significant difference was found according to graduation status ($p>0.05$). The findings indicate that perceptions of the economic and social benefits of rural tourism vary according to education level, with individuals possessing higher levels of education demonstrating a more informed and conscious perspective toward rural tourism.

As a result of the test conducted according to professional experience, it was determined that the level of agreement with the statement "*Rural tourism increases the income of local people*" showed a significant difference according to professional experience (H=10.982, p=0.027). This finding suggests that perceptions of the economic contributions of rural tourism differ across groups with varying levels of professional experience. Similarly, a statistically significant difference was identified among professional experience groups regarding the statement "*Easy access to Akçakoca district contributes to the increase in mobility towards rural tourism*" (H = 23.329, p < 0.001).

In addition, in the analysis made for the statement "*The intactness of the natural environment in the region facilitates rural tourism activities*", a significant difference was found according to professional experience (H=9.888, p=0.042).

However, a significant difference was observed between the professional experience groups for the statement "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (H=12.983, p=0.011). This shows that the perception of the employment creation potential of rural tourism varies depending on professional experience.

In the analyses made regarding other statements, no significant difference was found according to professional experience (p>0.05). The results obtained reveal that the perception of the economic and social benefits of rural tourism differs according to professional experience, and especially individuals with long-term professional experience may have a different perspective on the contributions of rural tourism (Gurbuz et al., 2019) [15].

The analysis based on participants' length of residence in Akçakoca revealed no statistically significant differences for any of the statements (p > 0.05).

This situation shows that the perceptions of individuals living in Akçakoca for different periods of time towards rural tourism are generally similar. Participants' opinions about the economic, social and cultural contributions of rural tourism do not change depending on how long they have lived in the region. This finding suggests that rural tourism enjoys broad acceptance among the local population and that individuals with different lengths of residence share a common perspective. An examination of the demographic characteristics of the participants shows that the majority were middle-aged and relatively well educated. Of the respondents, 56% were male and 44% female, while married individuals (54.3%) slightly outnumbered single participants (45.7%). In terms of age distribution, the largest group fell within the 36–50 age range (37.7%), followed by the 18–25 age group (29.1%). With respect to occupation, nearly half of the respondents were classified in the "*other*" category (49.1%), while civil servants represented a substantial share (36.6%). Furthermore, although a significant proportion of participants (61.7%) reported a connection to the tourism sector, only 38.9% earned direct income from tourism. These findings indicate that while rural tourism is not yet economically widespread, a considerable number of individuals are indirectly linked to the sector.

It has been widely accepted by the participants that rural tourism and rural development will develop, rural tourism will contribute to the local economy, increase cultural interaction and improve living standards. The high mean score for the statement "*Rural tourism investments should be increased*" ($\bar{X}$ = 4.22) reflects a strong demand among participants for greater investment to support the development of rural tourism.

In addition, the statement "*The sale of vegetables, fruits, sausage, cheese, and dairy products produced by our local people using their own resources will satisfy both the consumer and the producer*" ($\bar{X}$ = 4.14) indicates that rural tourism is perceived as a model that generates economic benefits for local producers. Regarding its social effects, the high mean score for the statement "*Rural tourism provides the opportunity to meet new people socially*" ($\bar{X}$ = 4.13) demonstrates that rural tourism is also regarded as an important factor in fostering social interaction among individuals.

When perceptions towards rural tourism were evaluated in terms of demographic variables, it was determined that women participated more in the positive aspects of rural tourism than men in the analyses made according to the gender variable. In particular, "*The easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" (z=-2.918, p=0.004), "*The fact that the natural environment in the region is intact facilitates rural tourism activities*" (z=-2.430, p=0.015) and "*I think our region is an attractive place in terms of rural tourism activities*" (z=-2.609, p=0.009) women showed higher levels of agreement with the statements.

As affirmed before, single individuals have a more positive opinion on rural tourism compared to married persons. This is confirmed by "*The easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" (z=-3.408, p=0.001), where single individuals had a higher participation in the statement.

Individuals involved in the tourism sector believe more in its economic contribution to the development of the region. Also, the promotion of the region as a tourist historical and natural attraction will have a beneficial effect on the increase of the number of visitors. "*Providing brochures showing the historical and natural values of our region to tourists*

coming from abroad will increase foreign tourism, which has not yet developed in the region" led to good results (z=-2.669, p=0.008), reflecting higher levels of agreement with the statement.

Another important result showed that individuals with a higher income assessed rural tourism more positively, as confirmed by "*The easy access to Akçakoca district contributes to the increase in mobility for rural tourism*" (H=17.705, p=0.001) and "*Our local people will gain new job opportunities and additional income thanks to rural tourism*" (H=12.396, p=0.006).

Professional experience is also an important factor in connection with the future development of rural tourism. In this respect, it was found that the people with a long working life in rural tourism consider that: "*Rural tourism increases the income of local people*" (H=10.982, p=0.027).

These findings reveal that rural tourism is considered as an important development tool for the Akçakoca region. However, problems such as the relatively low income from tourism, infrastructure deficiencies and seasonality need to be solved.

It is clear, that for increasing the contribution of rural tourism to the region development it is needed to protect and promote the natural and cultural heritage within the framework of a sustainable tourism approach.

In this context, local governments and tourism businesses can collaborate to make the region more attractive. Furthermore, the active involvement of women and young people in the tourism sector is essential for enhancing the social and economic contributions of rural tourism.

For rural tourism, unspoiled nature and the peace and quiet it brings are still the most important factors, but there is also a need to change something in the daily monotony of rural life (Dimitrovski et al., 2012) [10]. In this context, the development of facilities such as walking trails, bicycle routes, tourist maps, and horse-riding paths in Akçakoca may represent important steps toward strengthening rural tourism.

Rural tourism must also align with the expectations of visitors. For instance, food offerings should be organic and of high quality, while opportunities to experience food production processes can allow guests to appreciate the distinction between village-based and city-based consumption (Dimitrovski et al., 2012) [10]. As local residents begin to derive greater economic benefits from rural tourism, their willingness to embrace and support this alternative form of tourism is likely to increase. Moreover, the integration of Akçakoca's distinctive natural beauty and rich cultural heritage into rural tourism activities will further enhance the district's appeal to visitors.

Rural tourism is a real driving force for the development of rural tourism in Akçakoca, because it produce both a higher income for local residents and also stimulates the tourist attraction the region. Therefore, the level of attractiveness and accessibility of the area have a crucial role in enhancing the potential of rural tourism (Zivcovic et al., 2025) [40].

Neumeier & Pollermann (2014) emphasized that fact that the regions should collaborate among them to enhance the potential of rural tourism [27]. While rural tourism creates attractions for visitors, it also provides significant economic benefits for local communities (Zivcovic et al., 2025) [40]. The active involvement of local residents is therefore essential for the success of rural tourism (Phillip et al., 2010) [32]. Moreover, fostering interaction between locals and tourists can contribute not only to cultural exchange but also to the social and personal development of community members (Lane & Kastenholz, 2015) [23].

Intensive and sustainable development of tourism in rural areas will provide rural residents with the opportunity to earn income from their homes, and will also develop families specializing in transportation, food products and other services provided in rural areas (Bestaeva, S., 2022) [6]. In the context of rural tourism, entrepreneurs can join forces by establishing cooperatives and contribute to the development of regional destinations (Aktürk ve Demir, 2021) [3]. This cooperation may also involve joint efforts from both the public and private sectors (Kuşat, 2016; Hall & Jenkins, 1998) [20, 16]. Rural tourism also offers a

great opportunity for the preservation of cultural heritage and the continuation of traditional handicrafts (Bessière, 1998) [5].
More than this, the development of rural tourism must take into account the need to preserve the natural resources, biodiversity and maintain the beauty of the landscapes, purity of forests, waters, soil, protecting them of pollution. Therefore, it is needed of an ecological thinking as affirmed Dorobantu & Nistoreanu, 2012) [11].
Gurbuz et al. (2019) [15] considers rural tourism is a generator of economic income, a driver of social collaboration, a promoter of cultural heritage, and a contributor to a better living standard of the local population.
To assure a sustainable development of the rural tourism it is needed to raise the local awareness, to build infrastructure facilities, to enlarge de accommodation capacity and service variety and sustain a continuous promotion of the local attractions as affirmed Zivcovic et al. (2025) [40].
In this context, the historical upper neighborhood market established in Akçakoca can be supported by new entrepreneurs and new touristic products can be created. For example, carpet weaving and wooden products can be diversified in this region.

CONCLUSIONS

In this study, the perceptions of local people residing in Akçakoca regarding the regional development of rural tourism were evaluated. Akçakoca was preferred because it was one of the first places where tourism started and because it has recently focused on rural tourism activities. Today, climate change has become noticeable and has necessitated tourism regions to focus on different types of alternatives. From this perspective, given Akçakoca's location on the Black Sea coast—where sea-swimming rates remain relatively low throughout the year—it is essential to prioritize rural tourism as an alternative form of tourism. This study was conducted to evaluate the rural tourism potential of the Akçakoca region and to examine its effects on regional development. Participants' perceptions of rural tourism were analyzed according to their demographic characteristics and various socio-economic variables, while the economic, social, and cultural contributions of rural tourism to local communities were assessed.
The results emphasize rural tourism as a driving force for the development of the local economy, creating jobs, income sources, maintaining the traditions and increasing life quality of the local people.
Also, the research results allowed to identify both the stimulating and constraining factors in the development of rural tourism.
As a result, the following recommendations are made to enable the local authorities to think about:
- Tourism activities should be extended across all four seasons;
- Local population to be more involved in tourism initiatives;
- Tourists must become aware that environment must be protected and preserved;
-Women must be encouraged to be more involved in developing rural tourism affairs;
-Single persons are encouraged to contribute to the development of the local tourism;
-The people with a long experience in tourism business to be an example for the others and teach them how to get a better income;
-Rural tourism development could become a reason to determine young people to remain in the rural localities and diminish migration to the cities.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EFFICIENCY OF THE USE OF TRADITIONAL AND INTRA-UTERINE METHODS OF ARTIFICIAL INSEMINATION OF SOWS IN INDUSTRIAL PRODUCTION CONDITIONS

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Abstract

The paper aimed to assess the economic efficiency in sows reproduction using artificial insemination in industrial production conditions. For this purpose, the post-cervical method was used to inseminate the sows, and this proved to be the most efficient method compared to other insemination methods. The results showed a tendency to increase the farrowing rate by 0.68% in sows in which semen was introduced by the post-cervical method. There was also a tendency to increase the total number of piglets born in sows using the intravaginal insemination method. At the same time, no difference in multiparity was found between sows inseminated with different methods. It was found that due to the improvement of artificial insemination techniques and the introduction of the post-cervical method, the number of doses of semen required to inseminate a sow per year decreased by -13.0%, the volume of a dose of semen decreased by 44.4% and the total amount of semen decreased by 51.7%. The total amount of semen used to inseminate a sow per year decreased by 7, which proportionally reduced the cost of inseminating the entire breeding herd, the amount and cost of semen diluent, main catheters and semen disinfectant used decreased by 13.0% and the number of boars decreased by 44.0.

Key words**:** *pig farming economics, artificial insemination, post-cervical method, resource saving, sow productivity*

INTRODUCTION

Today, the efficiency and profitability of industrial pork production, as asserted by [4, 12, 35] there are closely linked to the use of artificial insemination of sows.

According to [8, 13, 14, 25, 35] the procedure depends on the quantity and location of sperm deposition in the female reproductive tract. The traditional artificial insemination method was the first to be developed and remains the simplest to implement. It was reported [2, 3, 25, 27] that this method involves depositing 2.5–3 billion sperm cells in 80–100 ml of diluted semen into the cranio-cervical region of the cervix using a simple disposable catheter to a depth of 13–15 cm. As a result, only a small proportion of sperm reaches the sow's oviducts.

According to [6, 32, 38], effective fertilization outcomes require the introduction of at least 1 billion sperm per insemination, while [1] state that optimal results under production conditions are achieved with 2.5 billion sperm. As artificial insemination technology has advanced, producers increasingly aim to achieve high sow fertility while reducing the amount of sperm used per insemination.

According to [26], research into improving this technology began in Europe more than 15 years ago. Efforts have gradually reduced the number of sperm used in conventional artificial insemination, allowing more high-quality boars to be used and improving economic efficiency in pork production. It was the reported [7] that the use of intrauterine insemination and its economic advantages, but due to technical challenges, as noted [38], it was only adopted in production at the end of the 20th century. This technique involves using a transcervical catheter to deposit semen into the cranio-cervical region of the uterus or the proximal end of its horns.

The complexity of this method, as noted by [25, 38] arises from the difficulty of navigating the catheter through the cervical mucosal folds. In contrast, traditional artificial insemination deposits semen in the sow's cervix, requiring sperm, as noted [7], 5 minutes to 3 hours to reach the uterine horns. According papers [10, 25], the duration of this process depends on sperm motility, uterine contractions, and the presence of leukocytes. It was [18, 24] reported that leukocytes cleanse and prepare the uterine surface for embryo implantation and remove excess sperm.

At published paper [11, 19, 28, 36] was noted that leukocytes appear on the uterine mucosa within 30 minutes of insemination, with their numbers sharply increasing after 2–3 hours. During this time, uterine contractions occur under the influence of oxytocin, oestrogen, and prostaglandins, as reported by [20, 25, 32]. These contractions are essential for successful sperm penetration into the oviduct. It was suggested [20] that physical contact with a boar, mechanical massage of the sow's back and sides, and stimulation of her genitalia can accelerate this process. However, excessive uterine contractions, as [20, 23, 34] observed, may reduce fertility by increasing insemination time or the frequency of semen reflux.

In addition, a decrease in sperm concentration increases the risk of reflux - the backward flow of sperm, which can lead to losses of up to 35% of the administered dose [28, 33]. It was noted [32] that reflux could cause up to 35% of semen loss, particularly problematic with low sperm concentrations. The degree of reflux depends on the sow's reproductive cycle and the volume and density of semen used [29, 32, 39].

Post-cervical insemination requires 1 billion sperm, compared to 3 billion for cervical insemination, which [5, 31, 38] believe results in better sow fertility. It was recommend using 1–1.5 billion sperm in 45–50 ml of diluted semen for post-cervical insemination [8, 22]. Studies [3, 38] reported good fertility and high prolificacy with 1 billion sperm using post-cervical insemination compared to 3 billion with vaginal insemination.

However it was reported significant fertility reduction when using 1 billion sperm under production conditions [13, 28, 38].

The introduction of artificial insemination has significantly reduced the time needed for both estrus detection and sow insemination compared to natural mating [30]. Research indicates that natural mating requires approximately 22 minutes per sow for detecting estrus and mating, whereas artificial insemination reduces this process to 1–2 minutes for estrus detection and an additional 4–5 minutes for insemination per sow [37]. Increased boar utilization efficiency and improved economic reproduction performance with stable fertility and prolificacy results when using post-cervical insemination [2, 14, 15, 25].

However, the literature contains many contradictions regarding the effectiveness of various insemination methods with reduced sperm doses and their impact on the economic performance of pork production technology. Therefore, our study aims to investigate the economic consequences of traditional (cervical) and intrauterine (post-cervical) sow insemination methods under industrial conditions in the steppe zone of Ukraine.

The purpose of the research is the effectiveness of traditional and intrauterine insemination of pigs, with the cervical and postcervical method of insemination of sows. The impact of this method of insemination on their fertility, the percentage of farrowings and the size of the litter. Also, it was comparatively evaluated the time spent on these two methods of insemination and their economic feasibility.

MATERIALS AND METHODS

To compare the conventional and postcervical methods of insemination on the commercial gearbox number 1 in the city of Globino during 2022 in accordance with the methodological recommendations [17], each weekly group of half-breed sows of the Large White Landrace breed, which consisted of 256-260 heads, was randomly divided into two parts. According to the research scheme presented in Table 1.

Table 1. Research scheme

Indicator	Group of animals	
	I Group	II Group
Insemination method	traditional insemination	postcervical insemination
Number of sows in the experiment, head	7,300	7,300
Duration of the experiment, days	300	300
Time of inseminations, times	200	200

Source: own calculations.

During the placement of sows in the insemination unit every Thursday, all sows, immediately after weaning piglets, were placed in individual crates, where they were divided into two groups by marking them with spray numbers. Odd numbers were assigned to Group I (control), and even numbers to Group II (experimental). The first group of sows was inseminated using the traditional (cervical) method, while the second group was inseminated using the post-cervical method.

Detection of estrus in sows of both groups began on the Sunday of the current week after piglet weaning and was conducted once a day at 8:00 AM in the presence of a teaser boar, which was kept in the feeding aisle in front of the sows. Insemination was performed using mixed semen from boars of the synthetic line PIC-337. For cervical insemination, the semen dose consisted of 90 ml containing 2.5 billion spermatozoa, whereas post-cervical insemination required 50 ml with 1.5 billion spermatozoa. The semen extender used was Prymxcell Ultra at a ratio of 200 g per 5 liters of distilled water.

Traditional insemination of sows commenced immediately after the immobility reflex was observed in the presence of teaser boars and was repeated after 24 hours. The semen was absorbed into the uterus naturally due to its contractions. During insemination, mechanical stimulation of the sow was performed by pressing on its back and nudging its groin area. For insemination, catheters from Magapor, packaging for semen storage from Minitub, and equipment for semen analysis and packaging from IMV were used.

Post-cervical insemination began half an hour after the immobility reflex was observed in sows. Initially, a traditional Magapor catheter was inserted into the external part of the cervix for six sows simultaneously. Next, a flexible internal catheter was inserted through the conventional catheter into the sow's uterus. After the internal catheter was fully in place, it was attached to a semen package, and the semen was released into the uterus. The catheter was then removed.

Every third week, video recordings of both traditional and intrauterine insemination processes were made using surveillance cameras. These recordings were later analyzed by qualified specialists monitoring work processes. The preparation time for semen, the handling of boars, and the insemination of sows were recorded. Timing began when the operator brought the boar between the rows of sows. For the traditional insemination group, timing ended when the last sow finished absorbing the semen and the final catheter was removed. For the post-cervical insemination group, timing ended when the semen was fully expelled into the uterus of the last sow, and both catheters were removed. After data processing, the total insemination time for each sow was determined.

When entering sow insemination data into the recording system, a note was added regarding the insemination method. Using this data, the insemination rate was calculated as the proportion of sows confirmed pregnant via ultrasound to the total number of sows inseminated. The farrowing rate was determined by dividing the number of sows that farrowed by the total number of inseminated sows. After farrowing, the total number of piglets born and the number of viable piglets per farrowing were calculated. These

calculations were performed according to the biometric data analysis recommendations [16]. Based on the annual report on the use of different sow insemination methods, the economic efficiency of various insemination methods across the farm, with a population of 15,510 productive sows, was calculated using the methodology [17].

RESULTS AND DISCUSSIONS

As can be seen from Table 2, the same number of sows was taken in each group in the study. According to the results of ultrasound scanning of sows on the 35th day after insemination, no difference was found in the fertility rate of sows.

Table 2. Fertility and fecundity of sows using cervical and postcervical methods of artificial insemination

Indicator	Group of animals	
	I Group	II Group
Average number of sows in the group, head	258.9	255.5
Fertility rate, total,%	96.61±0.11	96.65±0.17
Farrowing rate, %	94.14±0.09	94.82±0.16
Total number of piglets born, head	16.11±0.17	16.33±0.24
Multiparity, head	15.11±0.15	15.10±0.21

Source: own calculations.

No notable differences were found in the farrowing rates of sows between the various insemination methods, though a slight trend indicated a 0.68% increase in farrowing rate for sows inseminated using the post-cervical method. Furthermore, a trend was observed suggesting an increase in the total number of piglets born to sows inseminated via the intrauterine method. However, no differences in prolificacy were noted between sows inseminated by the different methods.

To determine the annual economic efficiency of the cervical and post-cervical artificial insemination methods, a comparative analysis of these two approaches was conducted for the productive sow herd at LLC NVP Globinsky Pig Compleks. As shown in Table 3, due to a lower number of inseminations per sow, 0.75 fewer semen doses (13.0% less) were used for post-cervical insemination compared to the traditional method. Additionally, the volume of semen doses for post-cervical insemination was 40 ml (44.4%) lower than for the traditional method due to changes in the semen delivery location. As a result of these two factors, the total annual semen volume per sow was 519 ml for cervical insemination, compared to only 251 ml for post-cervical insemination - a difference of over twice as much (268 ml).

Considering that the cost of maintaining boars is the same for both methods, the cost per semen dose, due to its smaller volume, was 0.93 EUR (55.7%) lower for intrauterine insemination compared to the traditional method.

Table 3. Sperm quantity for insemination of sows by different methods

Indicators	Insemination method	
	Cervical	Postcervical
Average annual number of sows in the farm (heads)	15,510.0	15,510.0
Number of sperm doses per year, taking into account 20% of the void with double insemination	5.77	5.02
Volume of one sperm dose (ml)	90.0	50.0
Volume of sperm per 1 sow per year (ml)	519.3	251.0
Cost of one sperm dose (Euro)	1.68	0.74
Annual number of sperm doses for the entire livestock (ml)	89,493.0	77,860.0
Annual cost of sperm, for the entire livestock (Euro)	150,609.6	58,110.1

Source: own calculations.

The annual number of semen doses for the entire herd using intrauterine insemination amounted to 77,860, which is 11,632.5 doses or 13.0% less compared to the traditional insemination method. Overall, considering the differing semen dose volumes, the total cost of semen for intrauterine insemination over the year was 59,563.05 EUR, which is 94,811.85 EUR or 61.4% less than the cost for traditional insemination.

Due to the smaller number of semen doses, less semen diluent was used for intrauterine insemination compared to the traditional method. As shown in Table 4, 7,007.4 liters of

diluent were used for intrauterine insemination annually, which is 1,046.925 liters or 13.0% less than the amount used for traditional insemination.

With the price per liter of diluent being the same for both methods, the cost of diluent for traditional insemination was €1,965.08 higher, totaling 15,118.00 EUR.

The lower number of inseminations with the post-cervical method also required fewer primary catheters. The number of primary catheters used for post-cervical insemination was 77,860, which is 11,633 fewer than for traditional insemination. Consequently, the cost of primary catheters was 2,413.74 EUR lower for intrauterine insemination compared to the cervical method.

However, intrauterine insemination requires the addition of intrauterine catheters, amounting to 77,860 units at a cost of 29,197.58 EUR. Therefore, despite the lower number of primary catheters, the total cost of all catheters was 26,783.83 EUR higher for post-cervical insemination compared to traditional insemination, amounting to 45,353.58 EUR.

Table 4. Quantity and cost of inventory and additional ingredients for insemination of sows by various methods

Indicators	Insemination method	
	Cervical	Postcervical
Amount of diluent per year (l)	8,054.3	7,007.4
Cost of diluent per year (EUR)	14,749.3	12,832.1
Number of main catheters (pcs)	89,493	77,860
Cost of main catheters (EUR)	14,749.3	12,832.1
Number of intrauterine catheters (pcs)	742,789	646,240
Cost of intrauterine catheters (EUR)	0.0	28,485.4
Total cost of catheters (EUR)	18,116.8	44,247.4
Disinfectant for sperm, l	1,342.4	1,167.9
Annual cost of disinfectant (EUR)	26,193.0	22,788.4
Annual cost of additional insemination aids (EUR)	1,347,509.5	2,340,259.6

Source: own calculations.

Due to the smaller overall volume of semen used in the intrauterine insemination method, 174.5 liters less disinfectant was required, totalling 1,167.9 liters for this method. Since the market price per liter of disinfectant is the same for both insemination methods, the annual cost of disinfectant for the post-cervical method amounted to 23,358.06 EUR, which is 24,818.75 EUR less compared to the traditional insemination method. Considering the reduced amount of semen required to inseminate 15,510 sows using the post-cervical method, it becomes possible to decrease the number of breeding boars kept (Table 5).

For the traditional insemination method, inseminating 15,510 sows requires maintaining 103 boars, whereas intrauterine insemination reduces this number by 44.0% to 58 boars. Accordingly, the costs of purchasing these animals and their maintenance are also reduced. At a price of 2,812.5 EUR per high-index breeding boar and an average usage period of 0.7 years, the annual depreciation cost per boar for both methods is 4,017.86 EUR. Considering the larger number of boars required for inseminating all sows using the traditional method, the annual depreciation cost for this method amounts to 415,446.43 EUR, while for the post-cervical insemination method, it is 182,796.43 EUR lower.

Given the same annual maintenance cost of 4,017.86 EUR per boar for both insemination methods, the total maintenance cost for all boars required for inseminating 15,510 sows using the cervical method amounts to 415,446.43 EUR.

In contrast, for the post-cervical method, this cost is 182,796.43 EUR lower, amounting to 232,650.0 EUR.

Considering the need for skilled labor by insemination technicians for both methods, the time spent by a technician to inseminate one sow is a critical factor. Time measurements were conducted for both methods, revealing that traditional insemination, due to the need for massaging the sow and waiting for sperm

absorption, requires 7.5 minutes per sow. In contrast, post-cervical insemination, which eliminates the need for massaging and allows for forced sperm introduction into the uterus, reduces this time by 4.3 minutes or 57.3%, to 3.2 minutes.

Table 5. Depreciation cost and cost of keeping boars for insemination of sows by various methods

Indicators	Insemination method	
	Cervical	Postcervical
Number of breeding boars (heads)	103	58
Annual cost of keeping one boar (EUR)	224.7	224.7
Cost of keeping boars (EUR)	23,237.3	13,012.9
Purchase cost of one boar (EUR)	2,743.9	2,743.9
Average duration of use of a boar (years)	0.5	0.5
Annual depreciation cost of one boar (EUR)	5,487.8	5,487.8
Annual depreciation cost of all boars (EUR)	567,439.0	317,765.9
Insemination time of 1 sow (minutes)	7.5	3.2
Total time costs of artificial insemination technicians (hours)	11,186.5875	4,152.544
Cost of an hour of work of the operator and artificial insemination technician, (EUR)	2.5	2.5
Annual cost of work of the operator and artificial insemination technician (EUR)	28,212.0	10,472.5
Total costs of insemination of all sows (EUR)	828,557.0	479,229.4
Cost of insemination of one sow (EUR)	53.4	30.9

Source: own calculations own calculations.

For inseminating 15,510 sows, the traditional method requires 11,186.6 hours of labor annually, while the post-cervical method reduces this time by 7,034 hours or 62.9%, requiring only 4,152.5 hours. At a labor cost of 2.59 EUR per hour at LLC NVP Globinsky Pig Complex, the annual labor cost for the traditional method is 28,917.33 EUR, while for the post-cervical method, it is 18,183.0 EUR lower, amounting to 10,734.33 EUR.

Summarizing the overall costs for inseminating 15,510 sows, the traditional method totals 683,092.4 EUR, whereas the post-cervical method reduces these costs by 284,942.28 EUR, amounting to 398,150.11 EUR. The annual cost per sow for the traditional method is 44.04 EUR, while for the post-cervical method, it is 41.7% or 18.38 EUR lower, amounting to 25.67 EUR.

Therefore, the advancement of artificial insemination techniques and the adoption of the post-cervical method resulted in a 13.0% decrease in the number of semen doses needed per sow each year, a 44.4% reduction in the volume of each semen dose, and a 51.7% reduction in the total semen quantity required per sow annually. This contributed to a 61.4% decrease in semen costs for the entire sow herd. The introduction of the intrauterine insemination method also reduced the use of semen diluents and disinfectants by 13.0%, the number of boars required for sow herd insemination by 44.0%, and the corresponding depreciation and maintenance costs, while lowering insemination labor costs by 62.9%.

The increased use of intrauterine catheters led to a 144.2% rise in their total cost, slightly raising the overall expense of the intrauterine insemination process, the post-cervical method still resulted in an 18.38 EUR or 41.7% reduction in the annual insemination cost per sow compared to the traditional method. For the total of 15,510 sows, this represents a savings of 284,942.28 EUR.

Our findings, which show a 0.68% increase in the farrowing rate in sows inseminated using the post-cervical method, are consistent with the results of [5, 31, 38], but contrast with the research of [33], which indicated a trend toward a higher farrowing rate and larger litter size with the traditional insemination method. Our research findings also coincided with [21] regarding the increase in farrowing rates and the total number of piglets born with intrauterine insemination, but did not align with his results regarding an increase in sow prolificacy with this method, as no difference

in prolificacy was observed in our study when comparing the two insemination methods.

The results of our study regarding the significant reduction in time for post-cervical insemination of sows compared to traditional insemination agree with the conclusions of [8, 9, 33], but do not match in quantitative terms, which, in our opinion, is due to differences in the qualifications of the insemination technicians.

Our conclusions regarding the higher economic efficiency of the post-cervical insemination method compared to the traditional method were similar to the reports [2, 14, 15, 25], which mention the improved efficiency in the use of boars and increased labor efficiency of artificial insemination technicians.

CONCLUSIONS

A tendency towards an increase in the farrowing rate and an increase in the total number of piglets born in sows to which sperm was introduced using the post cervical method was established. At the same time, no difference in multiparity between sows inseminated by different methods was established.

With the post-cervical method of artificial insemination, the number of sperm doses required for insemination of one sow per year decreased by 13.0%, the volume of one sperm dose decreased by 44.4%, and the total amount of sperm decreased by 51.7%, as did the quantity and cost of sperm diluent used, the central catheters for insemination of one sow per year.

It was established that with intrauterine insemination, the working time of artificial insemination operators decreased by 57.3% for the insemination of one sow, and the total cost of their labor and payment decreased by 62.9%.

Intrauterine insemination reduces the number of boars, their depreciation costs, and maintenance expenses by 44.0%, resulting in a more efficient utilization of their highly productive capacity. The post-cervical insemination method cuts the cost of inseminating a sow by 41.7% compared to the traditional method. The post-cervical insemination method allows to reduce the cost of insemination of one sow by 41.7% compared to the traditional method of insemination.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EFFICIENCY OF FEEDING PIGLETS WITH MILK REPLACER

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Abstract

The study aimed to assess the impact of additional milk replacer feeding in the first week after weaning on growth, survival, feed efficiency, and economic indicators of piglets' growth. The reduction of weaning age and high multiparity of modern sows cause stratification of piglet litter by weight. This reduces their adaptability to housing and feeding conditions during growth. The inclusion of 130 g of liquid milk replacer per day in the first week after weaning provided 27.4% weight gain, 21.1% weight gain at the time of transfer to fattening, 10.3% improvement in feed conversion, 21.1% increase in piglet market value and 12.2% increase in profitability. At the same time, there was a 3.0% decrease in the cost of feed per 1 kg of gain, a 13.1% reduction in treatment costs, a 3.1% decrease in the price of 1 kg of gain, which contributed to a 2.7% increase in profitability and 6.9% higher profitability. Along with the positive results, a 13.9% increase in daily feed consumption, a 23.1% increase in its cost, 10.3% higher treatment costs, a 23.0% increase in the price of growing a piglet, and a 4.1% lower profitability of growing a piglet was recorded. Therefore, using milk replacer improves piglet productivity but requires additional costs to be considered.

Key words: *economic efficiency, feed cost, income, market value, profitability, pig*

INTRODUCTION

The life cycle of piglets in the industrial pig production system, from birth to slaughter, is filled with transitions between technological groups, the most important of which occurs during weaning. The weaning of piglets is stressful and, simultaneously, a critical period that affects them both socially and physiologically. According to [2, 3, 6, 7], piglets at this time experience dramatic changes in the physical and social

environment, as well as in care and diet. Weaning is traditionally associated with growth retardation and is often accompanied by post-weaning diarrhea [38]. Also, the rapid increase in litter size over the past decade has led to more significant variability in piglet weight within a litter. As a result, piglets are weaned at a lower weight, exacerbating the problems associated with this period. Piglets are weaned from their sows, mixed with other piglets, and as a result, the housing, microclimate, feed and feeding system are changed. All this leads to a high-stress load. A quick and trouble-free weaning period is the key to continued high productivity [10].

Weaning stress may result in decreased feed consumption, slower growth rates, and heightened vulnerability to diseases [46]. Following weaning, piglets undergo significant physiological adjustments, particularly in the structure and function of the gastrointestinal tract [39]. A decline in feed intake during this stage can cause atrophy of the small intestinal villi and a reduction in digestive enzyme activity, which adversely impacts nutrient absorption [1, 44, 50]. When the sow abruptly stops receiving milk, the function and structure of the digestive tract change: the height of the microvilli decreases, the depth of the crypts increases, and the absorption capacity decreases as the activity of the enzymes lactase and sucrase [24, 26] decreases. One method of mitigating this period is using rational feeding in the first days after weaning [45]. Simultaneously, advancements in pig breeding have considerably raised the number of piglets born per sow [7, 45]. As a result, the share of piglets with low weaning weight and potentially lower viability has also increased [33, 34]. Therefore, producers will face the problem of developing additional measures to improve the performance of low-weight piglets at weaning.

The most common way of feeding pigs post-weaning is dry compound feed, used on most pig farms due to its cost-effectiveness and simplicity [32, 35]. At the same time, liquid feeding is popular in European countries. It has its advantages, including improving the gut health of piglets [48], using food industry by-products, and reducing the cost of rearing [36]. Liquid feeds, such as milk replacers or prestarters, contribute to improved piglet weight at weaning and better adaptation to the post-weaning period [6, 30]. Studies show that moistened feed contributes to better hydration, enzyme activation, and faster weight gain in pigs [5]. A different opinion is held [17], which indicates that the consistency of the feed and its hydration level does not affect the growth rate of piglets from 3 days of age to weaning, as well as on the statement [43] - morphological characteristics of their stomachs. At the same time, according to reports [8, 17], feeding piglets with liquid or mash feed after weaning contributes to an increase in consumption compared to feeding the same diet in dry form. While some researchers [3] claim that adding liquid milk replacers to piglets during the suckling period improved growth before weaning but did not affect their growth in the subsequent growing and fattening periods. Also, published studies have confirmed that piglets fed liquid feed had higher average daily gains and better feed intake than counterparts fed dry feed only [12, 27]. In particular, an increase in average daily gains of 300-400 g during finishing and decreased veterinary treatment costs compared to piglets-fed dry feed mixtures were reported [29]. Other researchers [18] have recently shown that liquid feeding of piglets after weaning increases feed intake by 30% during the first 14 days of finishing.

However, at the same time, a number of scientists did not find a significant difference in the impact of different feeding methods on either the average daily gains of piglets [15] or feed conversion ratios [22, 23, 25] using both dry and liquid diets. This opinion is confirmed by [11], who report that liquid feeding of suckling piglets contributed to an increase in their weight before weaning compared to their peers who consumed only dry feed, but this did not subsequently affect their growth during the growing period. Also, it was stated [49] that feeding supplementary milk to piglets from 4 to 11 days after weaning helped reduce the negative effects of weaning and increased feed intake. However, its effect on growth, feed efficiency, and slaughter weight was not found. In support of this it was reported [47] that

feeding milk replacer, started 5 days before weaning, had a more pronounced effect than its introduction after weaning. It contributed to increased average daily feed intake and weight gain and improved feed conversion ratio 4 weeks after weaning. Also, it increased body weight by 1.4 kg at the end of the fourth week of growth compared to pigs that received the replacer only after weaning. It was stated [21] that about 46% of publications reported a positive effect of liquid supplementation of piglets during lactation on their performance before weaning, and 58% of studies noted its beneficial effect on the performance of piglets during the growing period. The best liquid feed for piglets during the growing period is a liquid milk replacer [16, 40]. Liquid supplementation with the same feed that the piglets received before weaning allows them to reduce their stress level after weaning. It was observed that such piglets showed fewer stressful behavioral reactions, which indicates their better adaptation to new conditions [19, 51].

Feeding piglets with liquid milk replacer improves their adaptation to the new diet [4]. It has been proven that using liquid feed in the first days after weaning reduces the risk of gastrointestinal disorders and increases the efficiency of nutrient absorption [49]. In particular, it was indicated [37] that piglets receiving liquid supplementary feeding during finishing had a lower incidence of diarrhea and other digestive disorders than the control group in which piglets consumed dry feed. In addition, using other liquid components allows to reduce the share of cereals in the diet, which is especially relevant in increasing prices for traditional feed [28]. The disadvantage of using liquid milk replacers, as with any liquid feed for pigs, is the possibility of pathogenic microflora spreading in the feed distribution equipment [9]. It is essential to recognize the significance of maintaining a clean and disinfected system, along with ensuring access to high-quality water. This process demands additional oversight and regular upkeep to sustain optimal conditions [14]. Also, liquid feeding of piglets requires additional costs for equipment installation and more qualified labor, but improved piglet productivity and reduced morbidity usually compensate for these costs in full [42]. However, contrary to the above, there is an opinion that supplementary feeding with liquid milk replacers in the first days after weaning requires minimal investment since the equipment for its distribution includes only portable or fixed feeders and additional costs for personnel [18]. However, according to reports [35], the main limiting factor for using milk replacers is their high cost, which accounts for 80–90% of the total cost of liquid feeding. This is estimated to result in additional costs of approximately DKK 430 per sow per year or approximately DKK 12 per weaned piglet. At the same time, the additional economic benefit is DKK 470, of which approximately DKK 300 is provided by increased piglet weight at weaning and DKK 170 by improved survival, equivalent to DKK 14 per piglet.

Therefore, despite the proven benefits of liquid milk replacers, scientists lack consensus regarding their impact on piglet performance and the economic feasibility of using liquid milk replacers during finishing, which requires further research.

The incorporation of liquid milk replacer in finishing piglets' diets can serve as an effective strategy to enhance survival rates and growth, particularly for those with lower birth weights. Research indicates that these piglets tend to exhibit considerably lower average weight gains, less efficient feed conversion, and reduced economic profitability in rearing [20]. It was found that liquid feeding improves feed conversion by 4.99%, reduces feed costs for raising an animal by 3.03%, and contributes to lowering veterinary expenses by 0.67%. At the same time, the feeding method significantly impacts the survival of piglets and feed conversion but does not significantly affect their growth rate [31]. The research demonstrated that implementing liquid and portioned liquid feeding enhances piglet performance, resulting in increased average daily gains (by 4.34–20.62%) and higher final weight at the end of the growing period (by 3.42–15.24%) compared to dry and wet feeding. However, piglet survival rates were slightly lower (by 0.03–0.53%) [41].

This study aims to assess the impact of liquid milk replacer on the adaptation of piglets after weaning, their average daily gains, feed consumption, feed conversion, and economic feasibility, and to determine the impact on the growth rate, survival, feed conversion, and economic efficiency of rearing one piglet and obtaining a unit of gain when feeding low-weight piglets milk replacer in addition to the main ration in the first week of rearing.

MATERIALS AND METHODS

The study focused on evaluating the productive traits and economic efficiency of raising hybrid pigs. These pigs were derived from crossbred sows of the Large White and Landrace breeds of English origin, mated with boars from the PIC-337 terminal line of the same genetic background.

For the research, a subset of low-weight piglets from the technological group at Reproducer No. 2 of LLC "NVP Globinsky Pig Complex" was randomly divided into two groups, ensuring a balanced distribution based on sex. Following group weighing, adjustments were made to equalize the weight distribution between the groups while maintaining the sex balance. Once the weight equalization was complete, piglets from the first group, determined by a counter-day system, were transferred to rearing workshop No. 4 and housed in building No. 1, with each pen accommodating 145 animals. Their counterparts from the second experimental group were transferred to the same complex but to building No. 2 with similar feeding and housing conditions.

The control group of piglets received a traditional diet from the first day of rearing according to the approved norms at the enterprise according to the standard three-phase scheme using the Hydro Mix Pro feed kitchen, where 2.7 parts of water were added to one part of dry compound feed.

The period of the experiment included a period of time of 3 months of 2024, namely: February, March and April. The experiment lasted 57 days. The number of piglets in group I (control) - 1,327, in group 2 (experimental) – 1,320 piglets. The duration of raising piglets in this experiment was 49 days. The average consumption of traditional feed during the growing period (49 days) in the control group was 0.7 kg per head/day. The experimental group's average consumption of experimental feed (Traditional feed and Milk replacer Nutrimilk Power) during the growing period (49 days) was 0.8 kg per head/day.

However, considering that Milk replacer Nutrimilk Power was consumed only 1 week out of 7, the average consumption of Milk replacer Nutrimilk Power without the main component was 0.120 kg per head/day (Table 1).

Table 1. Average feed consumption per day/head during rearing

Rearing period	Control group				Experimental group				
	Traditional compound feed, kg			Total	Traditional compound feed, kg			Milk replacer Nutrimilk Power	Total
	0-9	9-12	12-25		0-9	9-12	12-30		
1 week	0.250	0.0	0.0	0.250	0.220	0.0	0.0	0.120	0.340
2 week	0.420	0.0	0.0	0.420	0.420	0.0	0.0	0.0	0.420
3 т week	0.250	0.270	0.0	0.520	0.250	0.270	00	0.0	0.520
4 week	0.0	0.550	0.120	0.670	0.0	0.550	0.120	0.0	0.670
5 week	0.0	0.630	0.180	0.810	0.0	0.630	0.180	0.0	0.810
6 week	0.0	0.0	0.970	0.970	0.0	0.	0.970	0.0	0.970
7 week	0.0	0.0	1.250	1.250	0.0	0.	1.250	0.0	1.250

Source: own calculations.

The experimental group of piglets from the first day of rearing and up to the seventh day inclusive, in addition to the main diet, was fed the liquid milk replacer Nutrimilk Power using the modernization of the same feed kitchen. Veterinary treatments in the experimental and control groups were carried out according to the same protocol. In each of the experimental

groups, after the formation of the machines, two control machines were allocated, in which 290 piglets were simultaneously located, and these animals were weighed individually at the beginning and the end of rearing.

In both test groups, the intake of compound feed and whole milk replacer was tracked daily using the Hydro Mix Pro feed system, with all data systematically documented in the accounting records for each group. Deviations in the health of the animals and the veterinary care provided to them were also recorded daily. At the end of the rearing period, assessments were conducted based on group weighing, feed consumption records, and animal disposal data to evaluate survival rates, deviations from normal physiological conditions, and the number of piglets requiring veterinary care. Growth performance was analyzed using individual weighing in control units, while group weighing data were utilized to calculate feed conversion efficiency and economic viability in raising low-weight piglets.

Throughout the experiment, generally accepted standards of humane treatment of animals were observed. All procedures were performed by the current legislation on the use of animals in scientific research without causing pain or suffering. The results were analyzed using Microsoft Excel 2016. Values were considered statistically significant at the Student's t-test thresholds: $p<0.05$ – first level, $p<0.01$ – second, $p<0.001$ – third.

RESULTS AND DISCUSSIONS

The rise in sow fertility across most modern genotypes has resulted in greater variation in piglet litter weights at weaning. Consequently, a higher percentage of piglets in each litter exhibit slower growth compared to their peers. As the weaning age of piglets continues to decrease, leading to lower body weights at the start of the rearing phase, it becomes crucial to implement strategies that enhance their adaptability to housing and feeding conditions. One effective approach is extending the feeding of pig milk replacer beyond weaning. In our study, supplementing the piglets' diet with liquid milk during the first week post-weaning resulted in notable improvements in growth rates and feed conversion efficiency.

As presented in Table 1, the initial weight of piglets in both the control and experimental groups was similar at the beginning of the rearing period. However, after seven weeks, piglets in the experimental group demonstrated a significantly greater average weight—5.2 kg more or 21.1% higher than those in the control group—with a highly significant difference ($p<0.001$). This increase can be attributed to the enhanced growth rate observed in the experimental group, where average daily gains were higher by 106 g ($p<0.001$). Consequently, by the end of the rearing period, the absolute weight gain in the experimental group exceeded that of the control group by 5.3 kg ($p<0.001$), resulting in a greater body weight at the transition to the fattening stage. That is, daily consumption in addition to the main diet of about 130 g of liquid milk replacer in the first week after weaning of piglets contributed to an increase of 27.4% in average daily and absolute gains and an increase of 21.1% in the weight of piglets when transferred to fattening (Table 2).

Table 2. Growth rate of piglets on finishing

Indicators	Group of animals	
	I Group-Control 1,327 piglets	II Group-Experimental 1,320 piglets
The number of piglets at the beginning of the study, heads	1,327	1,320
Age of piglets upon placement for rearing, days	20.7	20.7
Average age of piglets at the time of transfer, days	70.1	70.1
Average body weight of an individual piglet at the start of the study, kg	5.1±0.11	5.0±0.09
Survival of piglets, %	96.83	96.77
Average weight of 1 piglet after completion of rearing, kg	24.6±0.36	29.8±0.24***
Absolute gain, kg	19.5±0.36	24.8±0.23***
Average daily gain during the rearing period, g	387±15.6	493±12.4***

Note: *** - $p<0.001$
Source: own calculations.

The variation in piglet growth rates is attributed to differences in feed consumption between the control and experimental groups. As can be seen from Table 3, piglets that were fed milk replacer in the first week in addition to the main diet throughout the growing period consumed 0.1 kg more feed daily. This resulted in 4.8 kg more of its consumption over the entire growing period by one piglet compared to analogs not fed milk replacer.

The variation in growth rates between piglets in the control and experimental groups led to differences in the consumption of feed from various formulations. Since the farm transitions animals to a new diet based on the average group weight, piglets in the experimental group consumed 0.5 kg more of the costliest initial prestarter (0-9 formulation) per pig, while their intake of the second prestarter (9-12 formulation) was 1.0 kg lower. In the final period of rearing, due to the greater intensity of growth, the piglets of the experimental group consumed 4.4 kg more of the cheapest starter feed during rearing compared to the analogs of the control group. Despite the greater daily consumption of feed and the amount consumed over the entire rearing period, the feed conversion in them was better by 0.18 kg due to the higher intensity of growth.

Table 3. Consumption of feed of different formulations for growing piglets and their cost

Indicators	Feeding method	
	I Group	II Group
Milk replacer used per piglet transferred to fattening, kg	0.0	0.9
Prestarter 0-9 used per piglet transferred to fattening, kg	8.6	9.1
Cost of prestarter 0-9 per 1 head, EUR	7.4	70.8
Prestarter 9-12 used per piglet transferred to fattening, kg	11.6	10.6
Cost of prestarter 9-12 per 1 head, EUR	6.0	5.5
Starter 12-25 used per piglet transferred to fattening, kg	14.2	18.5
Cost of starter 12-25 used per 1 head, EUR	5.3	7.0
Total feed used per 1 head, kg	34.4	39.2
Cost of all feed for finished pigs per 1 head transferred to fattening, EUR	18.7	23.0
Average cost of 1 kg of feed during finishing, EUR	0.5	0.6
Average daily feed consumption, kg	0.70	0.80
Conversion of feed for finished pigs, kg	1.76	1.58
Costs for prevention and treatment of 1 head transferred to fattening, kg	9.2	10.1
Costs for feed and veterinary drugs and treatment of 1 head, EUR	18.9	23.3

Source: own calculations.

Due to the use of an expensive milk replacer and a more significant amount of starter feed consumed, the cost of all feeds consumed by animals in the experimental group was 4.32 EUR higher compared to the cost of feeds consumed by analogs of the control group. As can be seen from Table 3. animals in both groups had uneven consumption of feeds of different formulations and, accordingly, their cost. Thus, per head, the cost of milk replacer consumed by an animal in the experimental group was 2.75 EUR, while the control group did not. Additionally, they spent 0.43 EUR more on the first prestarter feed and 1.64 EUR more on the least expensive starter feed, while the cost of the second prestarter feed they consumed was 0.51 EUR lower. Meanwhile, the inclusion of liquid milk replacers led to higher expenses for preventive veterinary measures in the control group, exceeding those of the experimental group by 0.02 EUR. Overall, the total costs for feed and veterinary products in the experimental group were 4.34 EUR greater compared to the control group.

Thus, piglets that continued to be fed liquid milk replacer in the first week of growth, which they were fed during the suckling period, compared to their counterparts that were not fed in this way, consumed 13.9% more feed during the entire growth period, had 23.1%

more feed cost. Still, due to higher absolute gains, they showed 10.3% better feed conversion. Additionally, expenses for disease prevention and treatment were 10.3% higher in the experimental group. The increased feed costs for rearing each piglet contributed to greater operational expenditures, which were 6.20 EUR higher in the experimental group than in the control. However, the greater live weight of the animals in this group at the end of the rearing period led to a market value increase of 15.34 EUR, generating an additional 9.14 EUR in revenue per piglet (Table 4). Considering the almost identical price of a piglet in both groups when placed for rearing and the different costs of the rearing process itself, upon its completion, the cost of one piglet was 5.87 EUR higher in animals that were fed milk replacer in addition to the main diet..

Table 4. Economic efficiency of growing one piglet using different feeding methods

Indicators	Feeding method	
	I Group	II Group
Cost of one piglet when placed for rearing, EUR	23.8	23.5
Cost price excluding VAT of 1 head upon completion of rearing EUR	27.0	33.2
Selling price (excluding VAT) of a single piglet at the end of rearing, EUR	72.7	88.1
Revenue from raising one piglet, EUR	45.7	54.9
Production cost of a piglet at the end of rearing, EUR	50.8	56.7
Profitability of rearing 1 head,%	169.6	165.4
Profit from the sale of 1 head, EUR	21.9	31.4
Profitability of sales,%	43.1	55.4

Source: own calculations.

The unequal cost of growing piglets under different feeding schemes and their different selling price upon completion caused a difference in the profitability of increasing piglets, which was 4.1% better in animals under the standard feeding scheme. In comparison, sales profitability was 12.2% better for animals, for which milk replacer was added to the main diet. Including whole milk replacer in the primary diet of growing piglets led to a 13.9% increase in average daily and total feed intake. However, due to the added expense of the milk replacer, feed costs were 23.1% higher compared to piglets on a conventional feeding regimen. This resulted in a 23.0% increase in the cost of rearing a single piglet and an 11.6% rise in costs by the end of the growth phase. At the same time, improved growth rates during rearing led to a 10.3% better feed conversion. The market price of a piglet at the end of the rearing period was 21.1% higher in the experimental group, contributing to a 12.2% increase in the profitability of selling animals when milk replacers were included in the diet. A radically different picture was observed when analyzing the economic efficiency of obtaining one kilogram of gain in the control and experimental groups (Table 5).

Table 5. Economic efficiency of a unit of gain under different feeding methods

Indicators	Feeding method	
	I Group	II Group
Expenses for whole milk replacer per 1 kg of weight gain, EUR	0.0	0.1
Feed cost per 1 kg of weight gain, EUR	1.0	0.9
Expenditures on treatment and disease prevention per 1 kg of weight gain in pigs transferred to fattening, EUR	0.0	0.0
Total cost of feed and veterinary medications per 1 kg of weight gain, EUR	1.0	0.9
Total production cost per 1 kg of weight gain, EUR	1.4	1.3
Revenue generated per 1 kg of weight gain, EUR	1.6	1.6
Profitability of weight gain during the rearing phase, %	113.9	120.8

Source: own calculations.

Piglets receiving milk replacers consumed 0.18 kg less feed per 1 kg of weight gain, leading to a reduction in feed costs by 0.02 EUR. Furthermore, the expenses for disease prevention and treatment decreased by 0.001 EUR per 1 kg of gain. Although the cost per head was higher, the increased growth rate contributed to a 1.8 kg lower cost per 1 kg of gain in the experimental group. Consequently, the additional revenue per unit of gain was 0.04 EUR higher, leading to a 6.9% improvement in profitability per kilogram gained. Incorporating milk into the primary diet of piglets during growth led to a 10.3% improvement in feed conversion, a 3.0% decrease in feed costs per 1 kg of gain, and a 13.1% reduction in treatment and prevention expenses per 1 kg of gain. Additionally, total expenditures on feed and veterinary drugs dropped by 3.2%, the cost of producing 1 kg of gain per piglet decreased by 3.1%, while profitability increased by 2.7% and overall profitability improved by 6.9%.

Our results indicate that supplementing the main diet with liquid milk replacer during the first week after weaning improved feed conversion, aligning with the findings of [49], who reported that providing additional milk to piglets between the 4th and 11th days post-weaning increased feed intake. However, our findings contradict their conclusion that milk supplementation does not influence growth and feed efficiency, as our study demonstrated increased average daily and absolute weight gains, as well as higher piglet weights at the transition to fattening. Conversely, our results are consistent with the research of [16, 40, 47], which found that feeding milk replacer before and after weaning enhanced daily feed intake, body weight gain, and feed conversion efficiency. Additionally, [21] reported that 58% of studies confirmed the positive impact of liquid milk replacer on piglet productivity during the growing phase. In contrast, our findings do not support the claims of [2], who stated that adding liquid milk replacer had no effect on piglet growth in later developmental stages.

Our conclusions about the higher cost of growing one piglet and its cost at the end of the period due to the high cost of milk replacer are in line with calculations [35] who consider their high cost to be the main deterrent to the use of milk replacers. Our studies also found increased costs for preventive and therapeutic measures for liquid feeding, which coincides with reports [9, 13], who also found additional costs for maintaining the zoohygienic parameters of the milk replacer and other liquid feed distribution systems.

It is appropriate to continue studies using different milk replacer formulations and study the impact on the economic efficiency of further fattening of animals fed liquid milk replacers during rearing.

CONCLUSIONS

Our study demonstrates that incorporating liquid milk replacer into the primary diet during the first week after weaning enhances feed conversion, which is consistent with the findings of [49]. They observed that supplementing piglets with additional milk between the 4th and 11th days post-weaning led to increased feed intake. However, our results contradict their assertion that milk supplementation has no effect on growth and feed efficiency, as we recorded higher average daily and absolute weight gains, along with greater piglet weights at the transition to fattening. On the other hand, our findings align with the studies of [16, 40, 47], which highlight that feeding milk replacer before and after weaning boosts daily feed intake, body weight gain, and feed conversion efficiency. Furthermore, [21] noted that 58% of studies identified a beneficial influence of liquid milk replacer on piglet productivity during the growing phase. Meanwhile, our data contradict the conclusions of [2], who reported no impact of liquid milk replacer on piglet growth in later development stages.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

RESEARCH ON CARBON FOOTPRINT THROUGH A SIMPLIFIED LIFE CYCLE ANALYSIS (LCA) FOR PEACH CULTIVATION IN THE SOUTHEASTERN AREA OF ROMANIA

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Abstract

At a time when the need for sustainable horticulture is becoming increasingly important worldwide, this paper highlights the environmental and economic aspects of peach cultivation (Prunuspersica (L.) Batsch) and conducts a life cycle analysis (LCA) based on carbon footprint at Research and Development Station for Fruit Tree Growing (RSFG) Băneasa, South-Eastern of Romania. It was applied to 2024-2025 activity data from technological sheets and yield records for three planting densities (4×1.5 m, 4×2.0 m, 4×2.5 m), using standard emission factors. Within this scope, spacing-driven yield differences largely explained per-kilogram indicators, while cultivation hotspots followed patterns reported for stone-fruit systems: nitrogen fertilisation and irrigation energy were dominant, diesel from field operations was secondary, and plant-protection inputs were comparatively minor. A parallel per-hectare cost appraisal, compiled from the same records, revealed a cost structure led by labour and crop protection, followed by fuel and routine items, consistent with an intensive orchard under research management. Building on these findings, the concept of carbon farming (CFarm) is proposed as a practical pathway, that groups nature-based practices such as residue retention, mulching, reduced soil disturbance, cover cropping, organic amendments, and efficient pesticide application to increase soil organic carbon and reduce cultivation-phase emissions. The analysis offers a diagnostic for the RSFG Băneasa peach trial and establishes a basis for integrating carbon-farming scenarios and more detailed metered datasets in future LCA/LCCA work.

Key words**:** *carbon footprint (CF), greenhouse gas emissions (GHG), high-density planting, life cycle assessment (LCA), sustainable horticulture*

INTRODUCTION

Peach (*Prunus persica* [L.] Batsch) is a key crop in Europe's fruit sector, and interest in its environmental performance has intensified in the context of climate change [4]. Because agriculture contributes substantially to greenhouse-gas (GHG) emissions yet also offers mitigation levers at field scale, assessing GHG outputs from orchard systems is essential [15]. A central metric is the carbon footprint (CF), the totallife-cycle GHG emissions attributed to a product or system, expressed as CO_2-equivalent per functional unit (*e.g.*, kg of fruit) or per hectare per year. In horticulture, CF is commonly quantified within an LCA framework and can also be derived via direct farm accounting using established defaults for field emissions [32]under ISO 14040/14044 [16,17], or by direct farm accounting using IPCC default methods and emission factors [12]. Monitoring requires compiling activity data (inputs, fuel, electricity, irrigation) and applying emission factors, including soil N_2O emissions from applied nitrogen [15]. Results are communicated as kg CO_2-eq·kg^{-1}of fruit (cradle-to-gate) and/or t CO_2-eq·ha^{-1}·yr^{-1} (annual farm-scale emissions).

Beyond reducing emissions, orchards can also act as carbon sinks, treating soil as a "carbon bank" that stores organic matter. Practices such as reduced tillage, permanent or seasonal cover crops, mulching and compost application, and optimized pruning-residue management increase soil organic carbon, enhance soil aggregation and water retention, and contribute to long-term climate mitigation [5,19]. These practices align with the European Green Deal and CAP eco-schemes that promote low-input, climate-smart horticulture [1,2].

LCA has been widely applied to fruit crops to identify environmental hotspots and improvement options [9]. For peaches specifically, case studies in Italy [14] and Iran [22] highlight fertilization and irrigation as dominant determinants of CF during cultivation, a finding echoed by other recent analyses [3,19,21]. In Romania, LCA applications are still limited [21, 27]. This study addresses that gap with a peach trial at Research Station for Fruit Trees Growing - RSFG Băneasa, Moara Domnească Research Experimental Base, while building on national breeding and orchard research [26, 27].

The specific objectives of the study were:

(i)Quantify the carbon footprint (cradle-to-farm-gate GHG emissions) of peach orchards at three planting distances (tree spacing 2.5 m, 2.0 m, 1.5 m) over the 2024-2025 seasons.

(ii)Identify main emission sources (*e.g.*, fertilizers, irrigation, diesel) and their contributions to the overall footprint.

(iii)Compare results with other studies and discuss implications for sustainable peach cultivation in Romania, including how the experimental peach trial at Moara Domnească (RSFG Băneasa) relates to commercial orchard conditions.

(iv)Explore mitigation options relevant to RSFG Băneasa: precision fertilization, SMART irrigation scheduling (using plant water status and weather data) [29], ultra-low-volume (ULV) drone spraying, conservation practices that strengthen the soil "carbon bank" (*e.g.*, cover crops, mulching, organic amendments), utilization of pruning biomass (*e.g.*, for bioenergy) [28], and integration of renewable energy for irrigation pumps (hortivoltaics) [11].

This article reports a streamlined baseline focused on diesel and cost accounting, while maintaining a framework that can later incorporate fertilizers, irrigation, and pesticides.

In this context, carbon farming (CFarm) bundles nature-based practices residue retention, mulching, reduced soil disturbance, cover crops, organic amendments, and more efficient applications, that increase soil organic carbon (SOC) while lowering cultivation phase emissions and improving soil function [19]. Evidence of net climate benefits from regenerative practice bundles at system level further reinforces this direction [5]. Where irrigation is a key hotspot, plant- and weather informed scheduling can improve water use efficiency and support emissions reductions [29].Moreover, evolving European policy discussions and emerging private schemes are increasingly linking verified soil carbon gains and avoided emissions to results-based incentive payments [12],opening pathways to reward ecosystem services alongside agronomic improvements. From an assessment standpoint, LCA can include CFarm by modelling these practices as management scenarios (and including SOC stock changes where data allow) to estimate potential reductions in the product carbon footprint, while LCCA can capture operational effects such as fewer machinery passes, improved water-use efficiency, or more efficient nutrient use. Therefore, the CF baseline established for peach production in South Eastern Romania also serves as a practical reference point for testing CFarm options that are both climate-smart and cost-effective under local conditions [19].

MATERIALS AND METHODS

Legend (glossary of terms and units)

- a.i. = Active ingredient (for plant protection products), kg a.i.·ha^{-1}·yr^{-1} [9]
- CF = Carbon footprint (GHG emissions expressed as CO_2-eq) [9,16,17]
- CFarm = Carbon farming [19]
- GHG = Greenhouse gases (*e.g.*, CO_2, CH_4, N_2O)

- GWP_{100} = Global Warming Potential over 100 years (dimensionless factor); this paper uses the IPCC 2006/AR4 set: CO_2=1, CH_4=25, N_2O=298 [15]
- EF1 = Default IPCC emission factor for direct soil N_2O from N fertilizer: 1% of applied N as N_2O-N [15]
- FU = Functional unit (here: 1 kg fresh peaches at farm gate) [9,16,17]
- IPCC = Intergovernmental Panel on Climate Change [5,15]
- LCA = Life Cycle Assessment (ISO 14040/14044) [16, 17]
- LCCA = Life Cycle Cost Analysis [8,31]
- kg CO_2-eq·kg^{-1} = Per-kg product GHG intensity [16,17]
- t CO_2-eq·ha^{-1}·yr^{-1} = Annual, area-based GHG total [15]
- NBS = Nature based solutions [19]
- PV/hortivoltaics = Photovoltaics integrated with horticulture (agrivoltaics) [11]
- OPEX = Operating expenditures) [8, 31]
- SDI = Subsurface drip irrigation [20, 23]
- SMART irrigation = Plant-based irrigation scheduling (*e.g.*, stem water potential, sap-flow, canopy/ET sensing) [29, 23]
- SOC = Soil organic carbon [5, 19]
- ULV = Ultra-low-volume spraying (≈25-40 L·ha^{-1})

Terminology and units used in this paper

- Intergovernmental Panel on Climate Change (IPCC)

When deriving field emissions, we follow the 2006 IPCC Guidelines for agriculture, using default parameters (*e.g.*, default EF1 = 1% of applied N emitted as N_2O-N) and GWP_{100} values (CO_2 = 1, CH_4 = 25, N_2O = 298) for consistency throughout the study [15].

- CO_2-equivalent (CO_2-eq)

A common unit that expresses the warming impact of different GHGs relative to CO_2 using GWP_{100}:

$$\text{CFP} = \sum_i \left(m_i \times GWP_{100,i}\right)$$

where m_i is the mass of gas i (*e.g.*, kg CH_4). For example, with $GWP_{100}(N_2O)$ = 298, emitting 1 kg N_2O is equivalent to 298 kg CO_2-eq [12].

- Functional units

Results are reported both per kilogram of product(kg CO_2-eq·kg^{-1}, cradle-to-gate) and per hectare per year(t CO_2-eq·ha^{-1}·yr^{-1}, farm-level) to provide both product-level and area-based perspectives [9,16,17].

Location and trial design

The case study was conducted at the Moara Domnească Experimental Base of RSFG Băneasa, near Bucharest, Romania. The experimental peach trial consisted of three intra-row spacing configurations (2.5 m, 2.0 m, and 1.5 m between trees), with a constant 4 m spacing between rows. These planting distances correspond to three increasing tree densities (~1,000, ~1,250 and ~1,600 trees·ha^{-1}) in a super-intensive system, aligning with recent high-density peach trials in Romania and abroad [20, 24]. All plots were managed using uniform conventional practices (pruning, fertilization, pest control, irrigation), ensuring that observed differences were primarily due to planting density rather than different management practices. The region's climate is temperate-continental, and soil is fertile chernozems typical of southern Romania's fruit-growing areas [24, 27].

Data collection

All cost and fuel data were calculated on a per-hectare basis for 2024-2025. Data were compiled from the station's technological crop sheets; diesel-related CO_2-eq emissions were derived from recorded diesel use (liters per hectare) using IPCC emission factors [15]. Costs were grouped into mechanical operations, manual labour, and materials for the life cycle cost analysis (LCCA). All monetary values are reported in EUR (€), assuming an exchange rate of 5.00 RON per 1 EUR. Inputs for which physical quantities were not available (*e.g.*, N, P_2O_5, K_2O nutrients, irrigation water volume or energy use, total pesticide a.i.) are described qualitatively but were not included in the CO_2-eq totals for this analysis.

Table 1. Average annual input use per hectare in the RSFG Băneasa peach experimental trial (2024-2025)

Input category	Nominal value	Sensitivity range
Nitrogen fertilizers	70 kg N·ha^{-1}	60-80 kg N·ha^{-1}
Phosphorus (P_2O_5)	35 kg·ha^{-1}	30-40 kg·ha^{-1}
Potassium (K_2O)	60 kg·ha^{-1}	50-70 kg·ha^{-1}
Pesticides (a.i.)	5 kg a.i.·ha^{-1}·yr^{-1}	4-6 kg a.i.·ha^{-1}·yr^{-1}
Diesel fuel	165 L·ha^{-1}	150-180 L·ha^{-1}
Irrigation water	5,500 m³·ha^{-1}	5,000-6,000 m³·ha^{-1}
Irrigation electricity*	800 kWh·ha^{-1}	700-900 kWh·ha^{-1}

Source: Own elaboration based on RSFG Băneasa technological crop sheets (2024-2025) [25] and peach LCA literature [6,11,16, 20, 27].

Technological sheets list inputs as commercial products and budgets rather than as elemental nutrients or active ingredient totals; therefore, the N, P, K nutrient amounts and pesticide a.i. values are estimates consistent with those reported for super-intensive peach systems in literature. Diesel use is based on the 2025 crop sheet entry (~184 L·ha^{-1}). Irrigation water and pump electricity were not directly metered; the values are estimated from local practice and comparable peach LCA studies [13, 20, 30].

Functional unit and system boundaries

The functional unit was one kilogram of fresh peaches produced (farm-gate basis). The system boundary was cradle-to-farm-gate, including upstream production of inputs (fertilizers, pesticides, diesel, electricity), on-farm operations (fertilizer and pesticide application, diesel combustion for field work, irrigation pumping); and in-field processes such as soil N_2O emissions from applied nitrogen [15]. Post-harvest operations (transport, storage, packaging) and orchard establishment impacts were excluded. Carbon sequestration in trees and soil was also excluded, consistent with the simplified scope of the analysis.

Emission factors

To calculate the carbon footprint, activity data from Table 1 were multiplied by corresponding emission factors (Table 2). These factors include standard IPCC (2006) values for field emissions [15], FAO/IEA grid emission data for electricity [13], and upstream production emission factors drawn from the literature [9,14, 20, 23,30].

Table 2. Key emission factors applied in the carbon footprint assessment

Activity / Input	Emission factor applied
Diesel fuel	2.67 kg CO_2 per liter (including CH_3, N_2O)
Electricity	0.35 kg CO_2 per kWh (Romanian grid average, 2021 FAO/IEA data)
Fertilizers (N)	1% of applied N emitted as N_2O-N; GWP_{100} N_2O = 298
Fertilizers (P, K)	CO_2 from production and transport ≈ 1-1.5 kg CO_2 per kg nutrient
Pesticides	5-10 kg CO_2 per kg active ingredient (manufacturing stage)

Source: Own calculation based on standard emission factors from IPCC [20], FAO [21], and published LCA studies on peach production [2, 3, 10, 9, 13, 14,15,20, 23, 30].

Analytical framework and limitations

Management intensity (*e.g.*, fertilizer rates, irrigation volume) was kept the same across the three spacing treatments on a per-hectare basis (not per tree). Therefore, differences in GHG intensity among the treatments primarily reflect differences in yield. Although data from two consecutive years (2024 and 2025) capture some seasonal variability [8], no full uncertainty analysis was performed. Thus, the results should be interpreted as indicative estimates useful for comparing scenarios and identifying hotspots, rather than as precise constants [9].

RESULTS AND DISCUSSIONS

Across 2024-2025, the calculated carbon footprint of peach production at RSFG Băneasa varied mainly with yield across the three planting layouts. Closer intra-row spacing increased fruit output per hectare and, consequently, lowered the cradle-to-farm-gate GHG intensity per kilogram of fruit. The highest-density configuration (4 × 1.5 m) achieved the highest yield and the lowest indicative GHG intensity, while the widest spacing (4 × 2.5 m) had the lowest yield and highest per-kg emissions, with the intermediate density falling in between. These results are summarized in Table 3 and reflect the dilution

effect whereby similar per-hectare inputs are spread over a larger output when yield increases [9,14,30].

Table 3. Yield and productivity under different planting densities (average 2024–2025)

Planting distance	Trees/ha	Yield t/ha	GHG intensity (kg CO_2-eq/kg fruit)
4 × 2.5	~1,000	22.52	~0.34
4 × 2.0	~1,250	21.80	~0.30
4 × 1.5	~1,600	28.00	~0.26

Source: Own calculation from RSFG Băneasa yield records (2024-2025) [25].

The source analysis indicates two dominant emission hotspots during cultivation. Nitrogen fertilizer use, through both the emissions embedded in manufacturing and, more significantly, direct soil N_2O emissions after application, accounts for the largest share of total GHGs (often on the order of 40-50% in comparable orchard LCAs). Irrigation energy (electricity for pumping) is the second major hotspot, frequently contributing around 25-35% of emissions depending on water use and the carbon intensity of the energy source. Diesel fuel for mechanized field operations is a smaller but non-negligible contributor, while pesticides and other inputs make only minor contributions by comparison. Where feasible, replacing some tractor spray passes with ultra-low-volume drone applications (for example, using a high-capacity drone such as the DJI Agras T50 under the station's research conditions) can trim the diesel component by eliminating those tractor trips and shifting some energy use to electricity. This practice can also reduce soil compaction, improve canopy coverage in dense plantings, and provide more flexibility in timing applications. Because the net effect depends on factors such as spray program design, local energy mix, and drone logistics, we present the drone spraying as a qualitative improvement scenario rather than quantifying it in this baseline. Overall, this pattern of hotspots is consistent with published assessments of Mediterranean stone-fruit orchards [9,13,14,15, 20, 30]. Although it lies outside the present system boundary, valorising pruning residues (*e.g.*, for bioenergy) can indirectly offset some fossil fuel use at the system level, as shown in studies on pruning-to-energy strategies [10], and thus represents a circular economy option complementing on-farm emission reductions.

To put the Romanian results in context, Table 4 presents indicative cradle-to-gate carbon footprints for peaches from several international studies. The range at RSFG Băneasa (~0.25-0.34 kg CO_2-eq·kg^{-1}) is comparable to values reported for Spain, Italy, Iran, and Greece, indicating similar dominant drivers and feasible mitigation options across these contexts [14,18,22,30].

Table 4. International studies regarding carbon footprint results

Country and study reference	Carbon footprint (kg CO_2-eq/kg peaches)
Romania (this study)	0.25-0.34
Spain [30]	0.20–0.40
Italy [14]	0.18–0.25
Iran [22]	0.25–0.30
Greece [19]	0.22–0.35 (with soil C dynamics)

Source: Own elaboration based on RSFG Băneasa field data (2024-2025) [25] for Romania; international values adapted from published LCA studies [30,14, 22,19].

All cost figures are per hectare and are taken directly from the 2024-2025 technological crop sheets. Using a fixed exchange rate of 5.00 RON/EUR, the total cultivation cost was €4,357 per ha in 2024 and €4,121 per ha in 2025 (Table 5). Based on the 2025 data, the corresponding operational production cost was about €0.77 per kg of peaches, obtained by dividing the per-hectare cost by the gross yield for that year. This figure reflects only operating expenditures (OPEX) captured in the technological sheets, capital expenditures (*e.g.*, trellis and irrigation infrastructure amortization), overhead, and financing costs are outside the scope of these records. In full LCCA evaluations that include those additional costs, farm-gate unit costs in commercial orchards typically run around €1 per kg, consistent with grower benchmarks and orchard cost-analysis studies [6,7,8,31,33].

Table 5. Indicative cost structure of peach cultivation per hectare (2024-2025)

Category	2024 (€/ha)	2025 (€/ha)
Fertilizers	356.00	50.00
Pesticides	400.00	400.00
Fuel (diesel)	320.00	276.00
Labor	2,586.00	2,815.00
Other (tools, repairs)	695.00	580.00
Total per year	4,357.00	4,121.00

Source: RSFG Băneasa technological crop sheets (2024-2025) [25].

In summary, the agronomic and economic signals are aligned. The higher-yielding, dense plantings spread similar per-hectare inputs over more fruit, improving per-kg performance, and the main environmental hotspots coincide with the largest cost components. In practical terms, prioritizing precise nitrogen dosing and timing (including fertigation where appropriate), along with plant and weather informed irrigation scheduling, offers a clear path to lower GHG footprints without compromising yield. Where site conditions allow, complementary measures such as ultra-low-volume drone spraying, careful groundcover management, and using renewable energy for irrigation pumping (*e.g.*, solar powered pumps) can further amplify these improvements, as documented in the fruit LCA literature [9,14,20,30].

CONCLUSIONS

This study offers a concise reference for the cultivation stage of peach orchards in South-Eastern Romania and indicates that planting layout is a decisive management factor: when per-hectare inputs were kept approximately constant, closer tree spacing consistently improved the carbon footprint per kilogram of fruit. Within the defined system boundary, nitrogen management and irrigation energy were the principal contributors to emissions, diesel use was secondary, and plant-protection inputs had only a minor influence.

Under this study's frame, **LCA** sets the system logic for tracking inputs and emissionsacross the orchard stage [16,17]; the **carbon** footprint (CF) is the reporting metric for climate impact per unit of fruit (and, where relevant, per unit area) [15,16,17]; **LCCA** reads the same activity data in financial terms over the option's lifetime [7, 29, 32]; and **CFarm** consolidates field practices residue retention, mulching, reduced disturbance, cover crops, organic amendments, and efficient applications, that build soil organic carbon and help curb cultivation-phase emissions [19,5]. Viewed together, LCA provides the logic, CF the impact signal, LCCA the cost signal, and CFarm the operational pathway for change.

Methodologically, the functional unit, system boundary, and emission-factor set used here are readily extensible. When metered information for nutrients, electricity, irrigation volumes, and plant-protection use becomes available, this initial reference can be developed into a more resolved assessment that also tracks soil carbon stocks where data support it. In practice, the immediate priority is to maintain high yields while improving nitrogen use efficiency and irrigation performance; within the CFarm concept, these adjustments can be combined with soil-focused measures to strengthen the climate profile without altering the core production system.

ACKNOWLEDGEMENTS

The authors thank SCDP Băneasa and ICDP Pitești-Mărăcinenifor their financial and logistical support provided through the Thematic Plan on the Implementation of the ASAS Strategy on Research, Development, and Innovation in Pomology for the period 2021-2027, coordinated by ICDP Pitești-Mărăcineni and the national network of Fruit Growing Stations (Section II. Orchard technologies with a favourable impact on the environment and rural development, Subsection 2.1. Technological solutions for land preparation, modern crop systems, and variety-plant combinations).

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF THE INTERDEPENDENCE BETWEEN FOOD CONSUMPTION AND THE DEVELOPMENT OF GASTRONOMIC TOURISM IN ROMANIA

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Abstract

The paper aims to analyze, from an economic and behavioral perspective, how food spending by non-resident tourists reflects and supports the development of gastronomic tourism in Romania. The research focuses on food consumption behaviors in a tourism context, specifically targeting the categories of breakfast spending and spending in restaurants and bars. Conceptually, the approach aims to correlate food consumption as a tourism experience with general trends in international tourism, in line with theories on gastronomic travel motivations and tourism spending analysis models. The research had the following objectives: to analyze the evolution of food expenditures of non-resident tourists in Romania for the period 2019–2024, with a focus on breakfast and restaurants/bars, to identify the relationship between tourist flow and food consumption in leisure tourism compared to business tourism, to evaluate the contribution of food consumption to shaping an authentic tourist experience, to using statistical techniques to examine theories about the relationship between the quantity of visitors and food spending. The findings demonstrated that the quantity of non-resident visitors had a major impact on breakfast spending, hence validating the link between visitor volume and consumption of staple foods. However, neither the link between the food categories examined nor restaurant spending turned out to be statistically significant, indicating that other factors other than the mere numerical change of tourists influence these forms of consumption. The analysis of statistical indicators for the period 2019–2024 also highlighted the existence of important structural changes in food consumption behavior, with a clear trend of increasing the share of leisure tourism in gastronomic spending and a progressive decrease in the role of business tourism in this structure. Therefore, the topic addressed provides an analytical framework for the creation of thematic gastronomic routes, for the integration of local food products into the tourist package, for the development of rural tourism by valorizing culinary traditions or for encouraging sustainable consumption and local production. Furthermore, the research contributes to the consolidation of an identity-based and sustainable tourism model, with positive implications for the local economy, the environment and the preservation of cultural heritage.

Key words: *gastronomy, tourism, food consumption, spending, sustainability*

INTRODUCTION

In the last two decades, gastronomic tourism has emerged as an essential dimension of cultural tourism, attracting increasing academic and professional interest. In this context, food consumption, especially among non-resident tourists, is no longer seen as a mere biological necessity, but as a cultural and identity experience that defines tourist routes, motivations and behaviors [26].

The specialized literature shows that gastronomy, as part of the intangible cultural heritage, plays a strategic role in the differentiation of tourist destinations [22, 26]. The concept of "gastronomic territories", introduced by Linard Macêdo et al. [18], integrates culinary practices, local ingredients and community traditions into a coherent system of tourist attraction and sustainable development. At the same time, research shows that the role of gastronomic identity is increasingly present in shaping tourist perceptions and influencing consumption choices, especially in multicultural contexts [23], being shaped by factors such as geography, climate, religion, traditions and economic resources of a destination, thus providing added value to the tourist experience [6, 11].

In Romania, gastronomic tourism is still an emerging sector, although the country has a rich regional culinary heritage, which has a significant potential to attract foreign tourists [5, 27]. Thus, a relevant part of the expenses of non-resident tourists goes towards food consumption, which legitimizes the idea that food becomes a vector of tourist attraction and an indirect indicator of the valorization of the local gastronomic heritage. In addition, Romanian specialized literature indicates that local gastronomy is not yet sufficiently integrated into tourism promotion strategies [22, 25], although important steps have been made in this direction in recent years. We considered that this lack of systemic valorization determines the need for research that correlates quantitative dimensions (expenditures, tourist flows) with qualitative analysis of the gastronomic experience.

Food consumption helps to distinguish the destination and adds to the development of tourists' identities since it is crucial in defining the genuine tourist experience. Furthermore, food is more than just a product in the context of gourmet tourism; it serves as a medium for transferring regional cultural values and a representation of the customs and way of life of the host communities [3, 7].

The consumption of local food products, whether in restaurants or through participation in fairs, festivals or visits to producers, contributes directly to regional economic development. Studies show that in some European regions, up to a third of the holiday budget is directed towards food, which confirms the status of food consumption as an economic vector in tourism. At the same time, gastronomy has the capacity to transform traditional food products into tourism marketing tools, contributing to the formation of a distinct brand image for a destination [4, 28]. According to UNWTO, over 88% of member countries consider gastronomy a strategic element for national tourism branding [29].

Food consumption fosters social cohesion and cross-cultural contact between visitors and local populations, according to sociocultural theory. In addition to providing opportunities for interaction and mutual learning, shared dinners, tastings, and culinary events enhance the quality of the visitor experience and the destination's reputation [1].

Another major impact of food consumption in tourism is the reactivation of gastronomic territories. These become centers of attraction that capitalize on local ingredients, traditional recipes and culinary heritage, playing an active role in the revitalization of rural communities and in supporting small local producers..

However, the literature also warns of the risks of excessive commercialization of culinary authenticity, which can transform gastronomic experiences into standardized spectacles, disconnected from the original cultural context [8, 10]. For this reason, it is essential that gastronomic tourism development strategies are balanced and sustainable, protecting natural resources, traditions and communities.

Therefore, food consumption is a central pillar of gastronomic tourism, having a complex and multidimensional impact: economic, cultural, identity and ecological. Understanding these relationships is important for the development of efficient, equitable and sustainable tourism policies.

Another essential aspect, especially in the context of new sustainable development paradigms, is that food consumption in gastronomic tourism must also be approached through the filter of sustainability, in relation to local production, food waste, biodiversity conservation and the impact on communities. According to UNWTO [30], sustainable gastronomy involves choosing foods that are produced locally, responsibly and ethically, with minimal impact on the environment. This principle is also supported by the Slow Food movement, which advocates for “good, clean and fair” foods, in contrast to the excessive industrialization and standardization of the culinary experience [2, 20, 24]. Furthermore, in gastronomic tourism, tourists’ food choices can encourage or, on the contrary, endanger the rural circular economy. For example, promoting seasonal, organic products and traditional recipes contributes to reducing the carbon footprint and maintaining the balance of local ecosystems [9]. In contrast, adopting a food consumption oriented exclusively towards “global” restaurants or fast-food

chains can lead to a loss of authenticity and local resources [8].

Sustainable gastronomy also contributes to the resilience of communities in the face of global challenges, such as climate change, food crises or rural depopulation. Tourism based on responsible local consumption can become such an engine of regional development, provided that it is properly managed and integrated into public policies for rural development and tourism.

Therefore, this paper aims to contribute to the theoretical and applied development of the field of gastronomic tourism, by correlating statistical data on food expenditures of non-resident tourists with the dynamics of food consumption in Romania. The study aims to fill a scientific gap noted in the international literature, especially regarding the interdependence between gastronomic identity, tourist consumption behavior and the sustainable development of destinations [19, 22].

MATERIALS AND METHODS

The research is quantitative, based on the analysis of official statistical series published by the National Institute of Statistics of Romania, for the period 2019–2024 [12, 13, 14, 15, 16, 17]. The data used include: the annual number of non-resident tourists arriving in Romania; total expenses incurred by them; expenses broken down by categories: breakfast, restaurant, bars, etc.; expenses differentiated according to the purpose of the trip (business, personal).

The data series were processed using statistical tools and Excel to calculate aggregate indicators, variation indices and test correlation hypotheses.

To highlight the evolution and structure of tourist food consumption, the following indicators were calculated: average expenditure/tourist (separately for breakfast and restaurant, bars, etc.); share of gastronomic expenditure in total expenditure; variation indices compared to the base year (2019).

The research included the formulation and verification of 3 hypotheses regarding the relationships between key variables, using simple linear regressions:

$$Y=\alpha+\beta X+\varepsilon Y \quad \text{.....[21]}$$

where:

Y is the dependent variable

X is the independent variable

α is the intercept, β is the regression coefficient

ε is the random error

To evaluate the significance of the relationships, the coefficient of determination (R^2) was used to measure the explanatory power and the p-value (p-value) was used to test statistical significance (significant if $p<0.05p$).

The three main hypotheses, aimed at exploring the relationships between the food consumption behaviors of non-resident tourists and their volume, based on statistical data for the period 2019–2024, were the following:

Hypothesis 1 (H0: "The number of non-resident tourists significantly influences total spending in restaurants", which started from the premise that an increase in the number of tourists should be reflected in a proportional increase in food spending outside accommodation units.

Hypothesis 2 (H1): "There is a significant correlation between breakfast and restaurant spending" which assumed the association between spending between the two food components, considering that tourists who allocate higher budgets for breakfast may also exhibit more generous eating behavior in other segments (restaurants).

Hypothesis 3 (H3): "The number of non-resident tourists significantly influences total breakfast spending" which was tested to verify whether tourist flow determines the evolution of breakfast spending.

The limits of the research are represented by the fact that it is based only on aggregated data at the national level, without allowing differentiation by regions, types of tourists or seasonality.

RESULTS AND DISCUSSIONS

Analyzing statistical indicators related to the number of non-resident tourists and food

consumption expenditures is an important step in understanding the dimension of gastronomic tourism. These indicators allow comparing how culinary experiences contribute to the attractiveness of a destination and understanding the consumption behavior of tourists. Their research enables the identification of consumption patterns, the estimation of the effect of tourism on the local economy, and the assessment of the effectiveness of gastronomic heritage promotion measures. At the same time, these parameters provide an analytical framework for formulating sustainable public policies and for consolidating Romania's tourism identity in an international context.

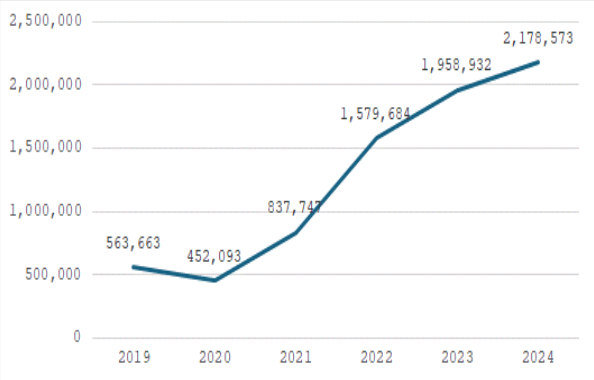


Fig. 1. Evolution of the number of non-resident tourists from 2019-2024
Source: own processing [12, 13, 14, 15, 16, 17]

Figure 1 shows the evolution of the number of non-resident tourists in Romania during the period 2019–2024. After a pronounced decline in 2020 due to the pandemic effect of Covid-19, the data indicate a gradual recovery, due to the resilience of the tourism sector and the resumption of international flows. This upward trend demonstrates the reconsolidation of confidence in tourist destinations, providing a favorable framework for the analysis of consumer behavior, including in terms of gastronomic tourism.

The analysis of the evolution of breakfast spending in the period 2019–2024, both overall and broken down by purpose of visit (business and personal), highlights a significant fluctuation during the pandemic period, followed by a gradual recovery in the post-crisis years, with a more consistent contribution from the business segment. This evolution demonstrates that breakfast constitutes a stable and predictable component of tourist food consumption, directly influenced by the typology of the trip and the type of accommodation unit. The importance of the analysis of this indicator lies in its ability to reflect changes in the structure of tourist services, but also in the adaptability of gastronomic offers to the requirements of international tourists.

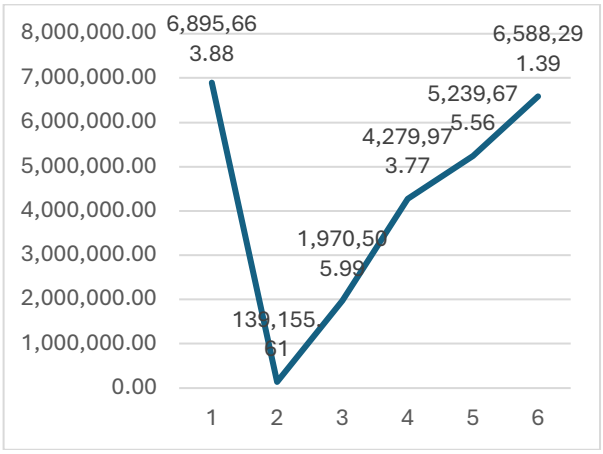


Fig. 2. Evolution of total spending by non-resident tourists in the period 2019-2024 (thousands RON)
Source: own processing [12, 13, 14, 15, 16, 17].

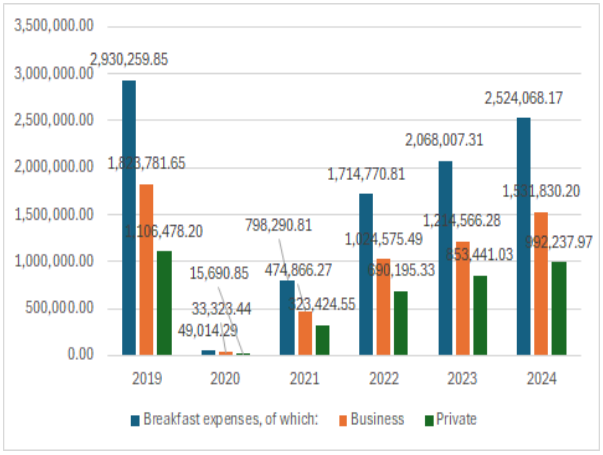


Fig. 3. Evolution of breakfast expenses, total and by category
Source: own processing [12, 13, 14, 15, 16, 17]

Figure 4 shows the evolution of non-resident tourists' spending in Romania on restaurant, bar and other public catering services, during the period 2019–2024, showing a significant decrease in 2020. The upward trend in the period 2021–2024 indicates a recovery in food consumption outside accommodation units, correlated with the reopening of the HoReCa sector and the reorientation of tourists towards

local gastronomic experiences. Analyzing this indicator is important for understanding the socio-economic role of tourist gastronomy, as well as for substantiating decisions regarding the development of food infrastructure and the promotion of local culinary specifics in sustainable tourism strategies.

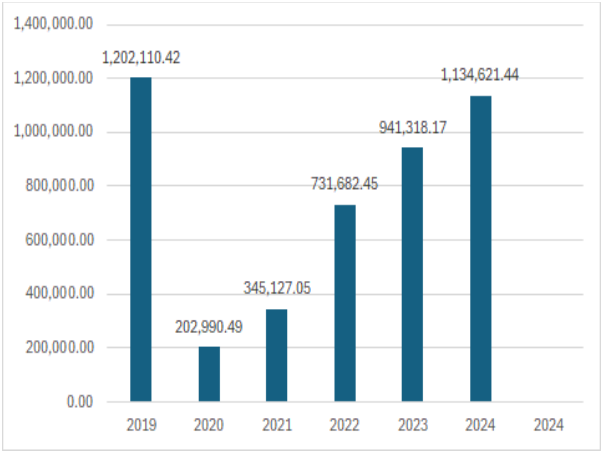


Fig. 4. Evolution of non-resident tourists' spending on restaurants, bars, etc.
Source: own processing [12, 13, 14, 15, 16, 17].

The data in Table 1 indicate a significant reconfiguration of food consumption behavior, influenced by global transformations in tourism. In the pre-pandemic period, the "for business" category held a dominant share (51.0% in 2019), but this steadily decreased to 36.2% in 2024, reflecting a reduction in the importance of business tourism in the total structure of gastronomic expenditures. In parallel, a sharp increase in the share of expenditures associated with holiday tourism is noted – from 7.4% in 2019, to approximately 29% in 2024, which demonstrates the redirection of food consumption towards recreational and experiential tourism. Also, participation in congresses and conferences decreases significantly in 2020–2021. A slight recovery is subsequently observed, as a result of the gradual adaptation of professional tourism. Other categories (visits to friends and relatives, cultural and sporting events, transit) show moderate variations, indicating a gradual diversification of tourist motivations associated with food consumption. This dynamic supports the idea that gastronomy is increasingly becoming a tool of leisure tourism, consolidating its function as an attraction and experience, not just a logistical necessity, especially among culturally and recreationally motivated tourists.

Table 1. Share of gastronomic expenses, by activity categories

Gastronomic expense categories	2019	2020	2021	2022	2023	2024
for business	51.0%	46.6%	43.9%	37.9%	35.1%	36.2%
for congresses, conferences, courses	21.3%	12.3%	11.9%	17.4%	16.7%	17.1%
for participation in fairs, exhibitions	7.0%	2.8%	2.6%	4.4%	5.5%	4.0%
for vacations	7.4%	25.7%	27.1%	28.8%	29.7%	29.1%
for shopping	0.9%	0.5%	0.3%	0.4%	0.5%	0.5%
for cultural and sports events	2.4%	1.2%	4.6%	2.2%	3.6%	2.8%
for visiting friends and relatives	6.0%	7.7%	5.4%	4.6%	5.4%	7.4%
for medical treatment	1.1%	1.2%	0.9%	0.8%	0.7%	0.7%
for religious pilgrimage	0.8%	0.1%	0.5%	0.3%	0.2%	0.1%
for transit	1.0%	1.6%	0.9%	1.7%	1.9%	2.1%
for other reasons	1.0%	0.2%	1.8%	1.5%	0.7%	**

Source: own processing [12, 13, 14, 15, 16, 17].

In the research, the analysis of costs associated with tourist food becomes a fundamental component for understanding the relationship between tourists' culinary preferences and regional development dynamics. Among the indicators of particular relevance in this context are the average cost per tourist for food consumption, the average cost of breakfast and expenses incurred in restaurants and public catering establishments. The average cost per tourist, which shows the financial volume allocated by a visitor for food during a stay,

constituting an aggregate indicator of consumer behavior, allows the assessment of the economic potential of gastronomic tourism, providing information on the capacity of regions to capitalize on local food products in the structure of the tourist offer. Moreover, comparing this indicator at regional or national level can identify disparities related to the development of gastronomic infrastructure, but also the efficiency of strategies for promoting local culinary identity.

The average cost of breakfast, especially in tourist reception structures with accommodation functions, is an indicator with double relevance. In one sense, it demonstrates the caliber and variety of the food offered as part of the travel package; on the other side, it shows how well local and traditional items are included into standardized menus. Given that breakfast is the tourist's first culinary interaction with the destination, it can significantly influence the overall perception of the authenticity of the gastronomic experience.

Equally, the analysis of costs related to consumption in restaurants provides information on the structure of voluntary spending, that is, those expenses that are not included in standard packages, but are determined by the individual choices of tourists. This type of consumption demonstrates the level of attractiveness of local dishes, visitors' food preferences, as well as their willingness to invest in authentic gastronomic experiences. Correlating these data with information on the origin of tourists, the type of tourist unit, and the length of stay, allows us to understand how gastronomic tourism contributes to local economic development.

Table 2. Evolution of the average cost per tourist, during 2019-2024

Indicator	2019	2020	2021	2022	2023	2024
Average expenses/tourist	2,583.11	307.80	2,352.15	2,709.39	2,674.76	3,024.13
Average food expenses/tourist	1,547.98	557.42	1,364.87	1,548.70	1,536.21	1,679.40
Average expenses (breakfast)/tourist	1,097.67	108.42	952.90	1,085.52	1,055.68	1,158.59
Average expenses (restaurant, bar, etc.)/tourist	450.31	449.00	411.97	463.18	480.53	520.81

Source: own processing [12, 13, 14, 15, 16, 17].

The analysis of the evolution of the average cost per tourist during the period 2019–2024 highlighted significant changes in tourism consumption behavior, especially regarding spending on food, a dynamic that was influenced by both general economic factors and major contextual transformations, such as the COVID-19 pandemic and post-pandemic tourism relaunch trends.

In 2019, the average total expenditure/tourist was 2,583.11 lei, of which approximately 60% was directed towards food, respectively 1,547.98 lei. This report highlights a substantial share of food consumption in the overall structure of tourism spending, confirming the importance of the gastronomic dimension in the tourist experience. The year 2020 marks a decrease in total spending, amid the restrictions imposed by the global health crisis. However, a relative constancy of spending in restaurants and bars (449.00 lei) is observed compared to the previous year (450.31 lei), signaling a resilience of preferences for food consumption in specialized locations, despite the significant reduction in tourist flow.

In the period 2021–2024, the data indicate a trend of progressive recovery and consolidation of tourist consumption, with a constant increase in average total spending, reaching a peak of 3,024.13 lei in 2024. Similarly, spending allocated to food records a relaunch, reaching 1,679.40 lei in 2024, which underlines the central role of the gastronomic component in shaping the complete tourist package (Table 2).

Expenses associated with breakfast, included in most accommodation offers, remain at a relatively high level, which is due to both the increase in prices, not only the lengthening of stay but also the morning offer's diversity due to the higher caliber of services provided.

Regarding expenses incurred in restaurants, bars and other food establishments, they

increased after 2021, reaching 520.81 lei in 2024, which confirms the consolidation of gastronomic tourism as a form of experiential tourism, in which the tourist does not only consume food products, but also seeks cultural and emotional contexts associated with food.

The analysis of the three hypotheses presented in the methodology was necessary to identify the essential relationships between international tourist flow and gastronomic expenditures of non-resident tourists, contributing to the understanding of how food consumption reflects differentiated tourist behaviors. These hypotheses allowed us to scientifically substantiate the role of gastronomy as an active factor in the travel decision and in the structure of tourist expenditures, in the context of experiential tourism.

The identification of the correlation relationship between the number of non-resident tourists arriving in Romania and the total expenditures made by them in restaurants and bars, in the period 2019–2024 was verified using ***Hypothesis H1:*** "*The number of non-resident tourists significantly influences total expenditures in restaurants*".

To test this hypothesis, we applied a simple linear regression model, in which the dependent variable was the volume of spending in restaurants, bars, etc., and the independent variable was the number of tourists.

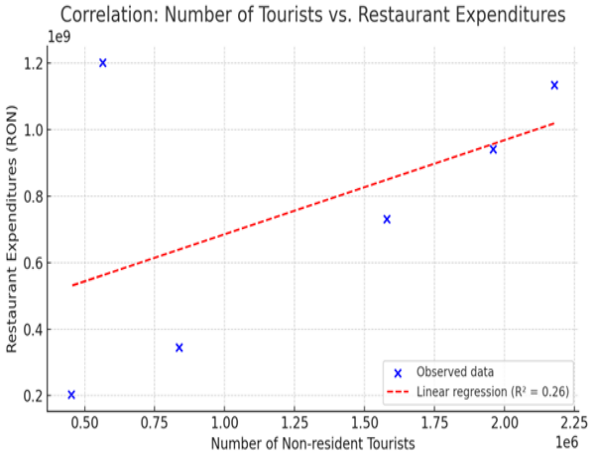


Fig. 5. Analysis of the correlation between the number of tourists and restaurant, bar, etc. expenses
Source: own processing [12, 13, 14, 15, 16, 17].

A coefficient of determination (R^2) of just 0.259 was found when the model's statistical significance was tested. This indicates that the fluctuation in the number of tourists accounts for just around 25.9% of the variation in restaurant spending. Furthermore, the statistical model does not support the hypothesis, as indicated by the p-value of 0.302, which is significantly higher than the typical statistical significance level of 0.05 (Fig. 5).

To verify hypothesis H2: "There is a significant correlation between breakfast and restaurant spending." a linear regression analysis was performed between the annual values of non-resident tourists' spending on breakfast and on restaurants and bars in Romania, during the period 2019–2024.

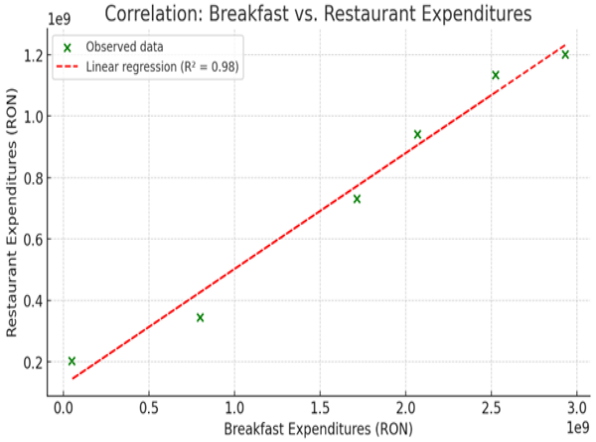


Fig. 6. Analysis of the correlation between breakfast expenses and those with restaurants, bars, etc.
Source: own processing [12, 13, 14, 15, 16, 17].

A positive relationship is thus observed between the two types of spending, which demonstrates the association between tourists' preference for food consumption and the general level of spending in the gastronomic segment. The statistical analysis generated a relatively low coefficient of determination (R^2), below 0.7, which shows that the variability of spending in restaurants is only partially explained by the level of spending on breakfast. Also, if the p-value is greater than 0.05. Although the two variables have a noticeable association, it is not robust or consistent enough to be regarded as statistically significant (Fig. 6). Because they are influenced by various circumstances, such

the style of lodging, the duration of stay, or the reason for the visit, consumption preferences for the various gourmet components do not necessarily evolve in a connected fashion.

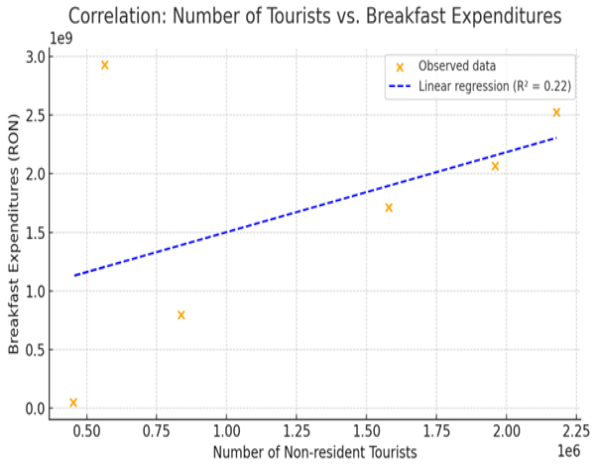


Fig. 7. Analysis of the correlation between the number of tourists and breakfast expenses
Source: own processing [12, 13, 14, 15, 16, 17].

Hypothesis H3: "The number of non-resident tourists significantly influences total breakfast expenses" was evaluated through a simple linear regression analysis, in which it was considered that the independent variable is the annual number of non-resident tourists, and the dependent variable is the total amount of expenses incurred for breakfast. The results of the graph show that as the number of tourists increases, the volume of expenses in this food category also increases. This is consistent with economic logic, i.e. tourists who stay in Romania frequently access breakfast services included or paid separately. From a statistical point of view, the regression line faithfully follows the distribution of points, and the coefficient of determination (R^2) has a significant value (> 0.7), showing that a large part of the variation in breakfast expenses is explained by the variation in the number of tourists (Fig. 7).

The analysis supports the idea that the number of tourists has a significant impact on overall breakfast expenses, indicating that the volume of tourists is a determining factor in the structure of food consumption specific to lodging. This supports the idea that breakfast services are a predictable component that are directly proportional to the number of tourists camped out, reflecting both the standardized offer of tourist accommodation units and the consumption behaviors associated with organized and business tourism.

The result of the statistical validation of this hypothesis provides an argument for including breakfast expenditures in models for estimating the economic impact of gastronomic tourism, especially in quantitative assessments of the contribution of non-resident tourism to the food sector.

CONCLUSIONS

The research results highlight that the gastronomic dimension of non-resident tourism in Romania has a value that goes beyond the strictly economic aspect, reflecting the cultural identity of the destination and the relationship between the tourist and the place visited, reflecting the structural transformations in tourist consumption behavior in the period 2019–2024. The analysis of statistical indicators and the testing of the formulated hypotheses allowed us to establish that breakfast expenses are directly influenced by the number of non-resident tourists, which confirms the role of this component as a reliable indicator of accommodation activity and the intensity of use of basic tourist services. This statistically validated correlation supports the integration of these data into forecasting models and development strategies for hospitality services.

In contrast, spending on restaurants and bars is not significantly influenced by the number of tourists, which shows that this category of consumption is conditioned by more complex factors, such as the socio-economic profile of the tourist, the type of visit, the urban vs. rural location or the degree of integration of the local gastronomic offer into the tourist package. Therefore, strategies to increase food consumption outside accommodation units must be targeted and adapted to the types of tourism practiced.

Also, the analysis of the correlation between breakfast and restaurant expenses did not reveal a statistically significant relationship, which indicates a degree of autonomy between the types of food consumption within the

tourist experience. This finding highlights the need for a differentiated approach in promoting gastronomic products and services, taking into account the motivation of the trip and the consumption context.

The changes in expenses by component (total, breakfast, restaurant) demonstrated both a return to tourism and a rise in the value of culinary elements in the overall design of the visit. Therefore, the growth of gourmet tourism depends on how visitors consume food, and keeping an eye on these indicators is crucial to the sector's success.

According to the research, cuisine actively and quantifiably shapes foreign tourists' experiences, however the ways in which this influence is expressed vary according on the expenditure category under consideration. A comprehensive and data-driven approach to the connection between food consumption and the kinds of travel that non-residents engage in is therefore crucial for the long-term growth of gourmet tourism in Romania.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

TRENDS ON THE PLATE: A TIME SERIES ANALYSIS OF TWEETS

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Abstract

This study complements food projections based on market data by social media analysis. It uses a sample of 162,000 food-related tweets to examine the trends in discourses about different food items. The findings reveal that most discourses intensify in the period 2012-2022, most significantly for milk, followed by fruits. In contrast, beer is the only category showing a significantly negative trend. These results confirm a growing desire to adapt diets to public health requirements.

Key words: *social media, food trends, Twitter, public health, dietary behaviour*

INTRODUCTION

Food demand projections are traditionally derived from economic and consumption data, drawing upon historical trends to forecast future dietary patterns [7], [29], [21].
On this basis, there is broad consensus that the demand for animal-based food, oilseeds, and rice is likely to expand [9]. Simultaneously, growing awareness of health and environmental concerns increasingly shapes food choices [12].
While market data remains central to understanding consumption trends, the proliferation of social media platforms has introduced new avenues for analysing dietary preferences and emerging food discourses [5], [15], [1].
It has been described how discourses lead to mental changes [27]and eventually to behaviour change [16].
Therefore, it should be expected that discourses on social media platforms can provide real-time insights into evolving public attitudes and may precede observable market shifts.
This strain of research is yet underdeveloped in the food sector. A study by Ghaffari and Stewart [11] highlights the role of social media in promoting plant-based eating by analysing the rise in vegan-related hashtags and positive sentiment over time. This study found that public perception toward veganism has generally grown more favourable, with increasing mentions of plant-based alternatives to traditionally animal-derived products, such as plant-based *milk*. Similarly, De Boer, Schösler, and Aiking [6] identify flexitarianism—the choice to reduce rather than eliminate meat consumption—as an emerging dietary trend that has gained traction on social media for appealing to those seeking dietary change without completely abstentaining from meat. Alongside dietary preferences, another important area of social media discourse studied by researchers is the representation and discussion of eating disorders. The ways in which social media platforms both reflect and reinforce narratives surrounding disordered eating have been highlighted in research by Opara and Santos [19], Fitzsimmons-Craft et al [10] and Wilksch et al [30]. These studies highlight how digital interactions contribute to shaping public attitudes towards body image, restrictive diets and food choices. They also highlight the importance of analysing food discourse within the broader context of health-related social media trends.
However, while there has been research into individual dietary trends, there is a need for

systematic research into how the wider discourse on food is evolving over time.

Analysing social media for food trends involves looking at how often terms associated with different dietary choices appear and how attention to them changes over time.

This study seeks to address this gap by applying a time series analysis to X (formerly Twitter) data to examine the temporal dynamics of discourse around key dietary terms, including ***vegetable(s), fruit(s), milk, bread, rice, sweet(s), wine(s) and beer(s),*** *and* within food-related contexts. Tufekci [28] warns of the challenges of representativeness inherent in social media data; however, by tracking patterns over an extended period, this study aims to capture general trends that reflect broader public perceptions. The findings help to understand how digital platforms influence dietary narratives and public health awareness

MATERIALS AND METHODS

This study uses quantitative content analysis to examine how food-related discourse on X (formerly Twitter) evolved over a decade. Data collection was conducted using academic access to X's API in 2023, retrieving approximately 945,000 tweets from six selected years: 2012, 2014, 2016, 2018, 2020, and 2022. These years were chosen to capture longitudinal trends while mitigating excessive data redundancy. The initial extraction targeted three primary keywords—***meat***, ***vegan***, and ***vegetarian***—to examine public discourse on dietary discourse dynamic over time. While the exact number of tweets per year varied due to platform usage and keyword popularity, to ensure consistency and manageability, a balanced sub-sample of 9,000 tweets per year was selected, totalling 162,000 tweets for analysis. The decision to use a database extracted in 2023 was guided by several practical and methodological considerations. Following the initial keyword-based extraction, a word frequency analysis was conducted to identify additional terms indicative of broader food-related discourse. This process resulted in the inclusion of the following keywords: ***fruit(s), vegetable(s), milk, bread, rice, sweet(s), beer(s),*** *and* ***wine(s).*** These terms were selected to facilitate a comprehensive examination of dietary discussions, encompassing plant-based foods, staple food items, and beverages.

To examine temporal trends, a linear regression analysis was applied, assessing changes in the frequency of keyword mentions over time. Additionally, a heat map visualization was generated to illustrate patterns of term co-occurrence and variations in keyword prominence across the selected years. This methodological approach facilitates a systematic investigation of shifts in dietary discourse, thereby offering insights into the extent to which social media discussions mirror broader transformations in food perception and public health awareness. It is noteworthy that this methodological approach also guarantees that the study captures macro-level patterns in food discourse.

RESULTS AND DISCUSSIONS

The analysis has revealed several key findings, which are outlined in Table 1 and illustrated in Fig. 1. These findings demonstrate changes in the prevalence of key food terms, influenced by health consciousness, cultural factors and evolving food preferences.

Bread frequency exhibits a positive trend, with a slope of 2.49 and a relatively low R^2 value of 0.35. While the data suggests some growth, the low R^2 indicates that other variables may also play a significant role. Scientific studies have highlighted the persistent popularity of bread as an affordable and versatile food item, particularly in regions where wheat is a primary agricultural product, with recent preferences shifting toward whole-grain and artisanal varieties, reflecting broader health and lifestyle changes [3].

For ***milk***, the regression analysis shows a consistent increase in frequency over time (slope = 6.31, R^2 = 0.73), indicating growing discussions or relevance of milk-related topics. This trend aligns with Schiano et al. [25], who highlighted that consumer perception of sustainability has significantly influenced the growth of both traditional dairy products and plant-based alternatives. The increasing focus

on milk could be driven by the dual interest in traditional dairy and emerging alternatives, as concerns regarding sustainability and dietary shifts continue to impact global consumption patterns

The data indicates a modest upward trend in ***rice*** frequency over time, as indicated by the slope of 2.13 and a R^2 of 0.27, reflecting a marginal positive correlation. The literature highlights the role of socioeconomic variables, including household income and educational status, in shaping patterns of rice consumption. The phenomenon has been observed in Nigeria, where the influence of household demographics on rice consumption is pronounced [8]. Similarly, data from the United States shows that eating rice is associated with better nutrient intake and diet quality, including higher intakes of fibre and lower intakes of saturated fat [2]. In Asia, rice remains a critical food source. However, consumption patterns are changing due to dietary diversification and urbanisation [17]. These findings suggest that the slight increase in rice frequency is being driven by its cultural importance and role in nutrition, despite challenges such as competition from other grains or cereals and changes in dietary habits.

With a slope of 3.93 and an R^2 of 0.70, *the* frequency of ***vegetable(s)*** on X demonstrates a consistent increase over time, reflecting a strong positive correlation. Increased awareness of the health benefits of vegetables and the public health community's concerted efforts to promote plant-based diets have contributed to this trend. Campaigns and dietary guidelines emphasize the importance of vegetable intake in preventing chronic diseases such as cardiovascular issues and obesity. Research underscores that targeted strategies, such as educating consumers about plant-based dishes can play a significant role in increasing vegetable consumption. These strategies often include making vegetable-based meals more appealing to consumers through better sensory and nutritional profiling [4].

The ***fruit(s)*** category exhibits a strong upward trend with a slope of 4.81 and an R^2 value of 0.96, driven by public health campaigns and increased awareness of health benefits. Initiatives like Go for 2&5 and global efforts to meet World Health Organization (WHO) recommendations have led to measurable gains, though challenges such as food waste and limited access in low-income regions persist [20], [18], [23].

The analysis of ***sweet(s)***presence shows a marked increase over time, with a slope of 4.29 and an R^2 of 0.67, suggesting a moderate-to-strong positive correlation. This trend is primarily attributed to urbanization, shifting dietary preferences, and the widespread availability of processed and sugary foods. In developing societies, there has been a notably increase in sugar use, particularly in the form of sugary beverages and desserts, driven by urban lifestyles and marketing strategies [14]. Additionally, global trends highlight increasing presence of added sugars in packaged foods, which has significant public health implications, including rising rates of obesity[24]. Further ecological analyses have established a correlation between elevated levels of sugar consumption to a greater prevalence of obesity and hypertension. This underlines the need for interventions targeting sugar intake in populations undergoing nutritional transitions [26].

The utilisation of ***wine*** in tweets shows negligible fluctuations over time, with a slope of 0.31 and accompanied by a R^2 value of 0.05, suggesting almost no predictive power. This stability reflects the cultural and regional specificity of wine consumption patterns, with certain regions demonstrating growth due to its perceived health benefits, while others exhibit stable or declining trends as a result of alternative preferences [13].

The regression analysis for the term ***beer*** reveals a declining trend over the years. A moderate negative correlation is indicated with a slope of -1.44 and an R^2 value of 0.65. This aligns with findings that suggest a reduction in alcohol consumption in some regions, which has been attributed to increased level of awareness regarding the adverse health impacts of excessive drinking. Recent research indicates that frequent consumption of alcohol has a negatively impact to physical health, contributing to chronic conditions such as

cardiovascular disease, diabetes, and even cancer. These findings emphasize the necessity for public health strategies and initiatives that are designed to reduce excessive alcohol consumption in the modern world [22].

The significant P-values for health-related categories like fruit(s) and vegetable(s) reflect the impact of sustained public health efforts. At the same time, the non-significant trend for bread and the declining trend for beer(s) underscore the need for further investigation into shifting consumer priorities, such as preferences for artisanal bread or reduced alcohol consumption.

For categories like *wine(s)* and *rice*, the lack of significant trends could indicate stability or competing influences, requiring more granular data to uncover nuanced patterns.

These findings underscore the evolving nature of dietary discourse on social media, reflecting broader societal shifts in food preferences and eating habits.

The increasing prevalence of discussions surrounding fruits, vegetables, and milk aligns with growing public awareness of health-conscious and environmentally sustainable diets, as documented in previous studies on plant-based consumption and nutritional awareness.

In contrast, the decline in beer-related discourse suggests a potential shift away from alcoholic beverages, possibly driven by health campaigns, regulatory measures, or changing social norms regarding alcohol consumption. Meanwhile, the stable trajectory of wine discussions indicates its enduring yet fluctuating role in dietary habits, potentially influenced by cultural and economic factors.

Beyond individual food categories, these trends highlight the broader impact of digital discourse on food-related attitudes, suggesting that social media serves as a dynamic space for shaping, reinforcing, and challenging dietary norms.

Table 1. Regression analysis results

Term	Slope	Intercept	R^2	P-value
Fruit(s)	4.814286	-9660.247619	0.960672	0.000588
Vegetable(s)	3.928571	-7833.095238	0.702062	0.037289
Milk	6.314286	-12676.580952	0.733807	0.029361
Bread	2.485714	-4945.685714	0.353940	0.212892
Rice	2.128571	-4197.161905	0.266780	0.294136
Sweet(s)	4.285714	-8559.952381	0.667095	0.047290
Beer(s)	-1.442857	2937.409524	0.648163	0.053285
Wine(s)	0.314286	-605.580952	0.048922	0.673636

Source: Own calculations.

While online conversations do not necessarily translate directly into behavioural change, they provide valuable insights into emerging consumer priorities and potential market transformations.

Future research could further explore causal relationships between social media discourse and actual consumption behaviours, incorporating market sales data, nutritional studies, and sentiment analysis to provide a more comprehensive understanding of how digital narratives influence food choices.

By integrating social media analytics with public health and consumer behaviour research, these insights contribute to a deeper understanding of how digital platforms function as indicators of shifting dietary landscapes. As discussions concerning health, sustainability, and food ethics continue to evolve, the role of social media in capturing and predicting these trends remains an important area for further investigation.

The heatmap visualization (Fig. 2) provides a complementary perspective to the linear regression analysis by illustrating the relative frequency and variation of selected food-related terms across different years. While regression analysis captures overall trends, the heatmap enables a more granular examination, highlighting shifts, fluctuations, and comparative prominence of keywords over time. This approach offers valuable insights into how certain dietary terms gain or lose attention in social media discourse, even

though it does not account for the full context in which these terms appear within tweets.

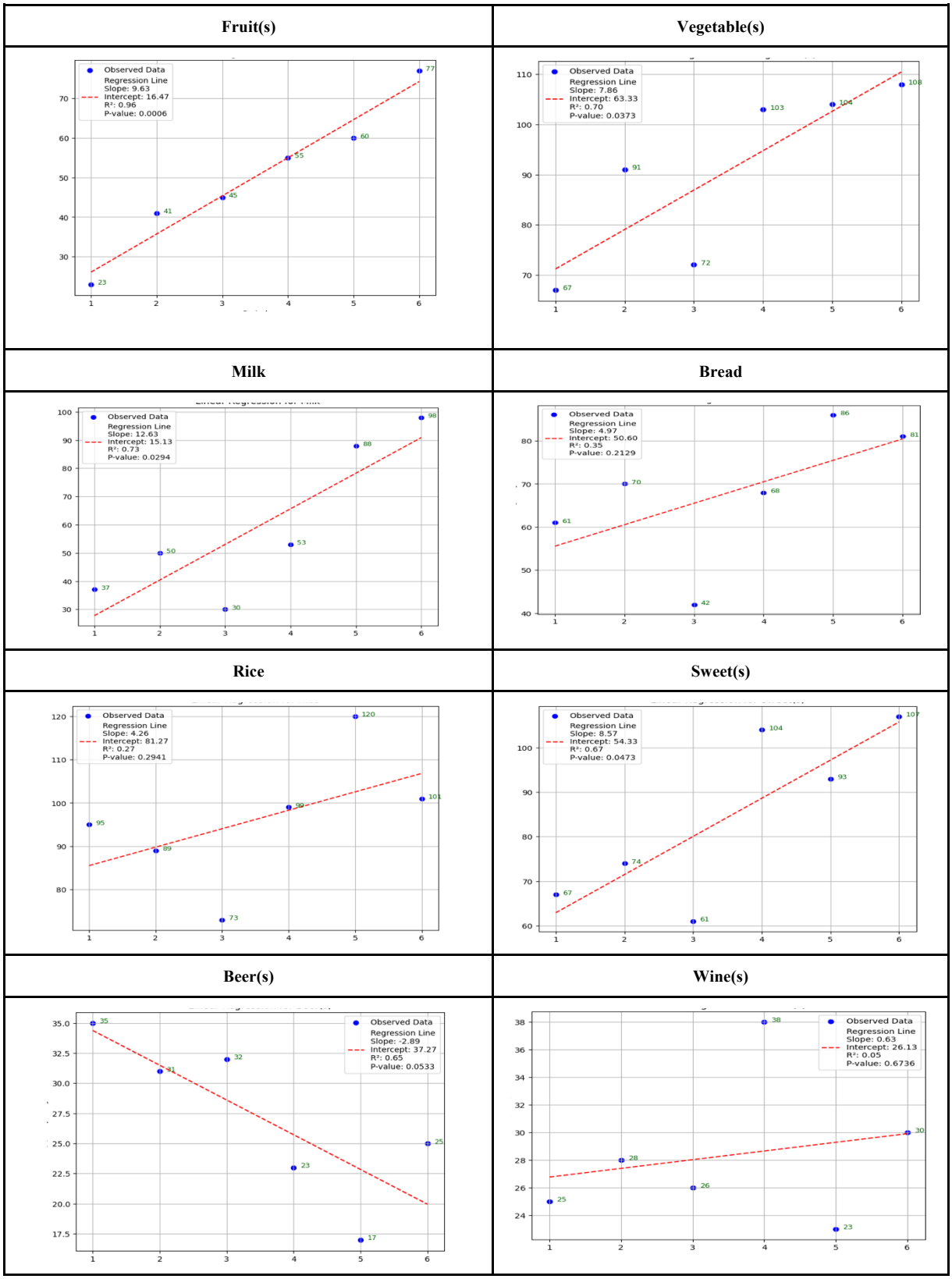


Fig. 1. Linear regression across keywords for food and beverage categories
Source: Own calculation.

A key observation from the heatmap is the consistent increase in mentions of *fruits, vegetables,* and *milk*, with darker hues indicating greater frequency in later years. This growth suggests a heightened focus on health-conscious eating and plant-based dietary choices, possibly influenced by public health narratives, sustainability discussions, and evolving consumer preferences. Notably, *milk* exhibits a sharp increase between 2018 and 2020, which may reflect an increased interest in dairy consumption or plant-based alternatives, though without sentiment analysis, the nature of this discussion remains unclear.



Fig. 2. Heatmap of frequency trends over years
Source: Own calculation.

Other food-related terms display more irregular trends. *Rice* mentions peak in 2020 before experiencing a decline in 2022, possibly reflecting regional shifts in staple food discussions or temporary fluctuations in public interest. Similarly, *bread* mentions increase between 2018 and 2020 before stabilizing, a pattern that may be linked to changes in dietary habits, global supply chain variations, or cultural trends such as home baking movements. Mentions of *sweets* follow a cyclical pattern, peaking in 2018, declining slightly in 2020, and rising again in 2022. This suggests fluctuations in consumer attitudes toward indulgence versus health consciousness, though further analysis would be required to determine the underlying drivers of these variations.

In contrast, *beer* and *wine* discussions remain stagnant or decline over time, with beer mentions showing a marked decrease from 2012 to 2020 before a slight recovery in 2022. This aligns with shifts in alcohol consumption behaviour, potentially influenced by health concerns, changing social drinking habits, or the rising popularity of non-alcoholic alternatives. Wine, however, maintains a relatively stable presence in discourse, indicating that while it does not experience strong growth, it also does not exhibit significant decline. These patterns suggest that while some foods gain increasing attention in online discussions, others maintain a consistent but less dynamic presence.

By integrating both quantitative trend analysis and qualitative heatmap visualization, this study provides a broader understanding of how food-related discussions evolve over time. The heatmap highlights shifts and anomalies that might be oversimplified in a linear regression model, making it a valuable tool for capturing the dynamic nature of social media discourse. As digital conversations continue to shape consumer awareness and dietary narratives, further exploration into how these discussions translate into real-world behaviours remains a promising direction for future research.

CONCLUSIONS

This study contributes to the understanding of food-related discourse on social media, offering insights into how discussions around dietary choices evolve over time. However, several limitations must be acknowledged.

The first limitation is the reliance on the sample extracted in 2023 for other keywords and also on the X(Twitter)'s API, which restricted access to comprehensive historical data. It is still possible to extract historical data from X(Twitter), but it requires navigating significant restrictions and potential costs.Thesecond limitation entails the potential bias introduced by focusing on specific keywords, which may not capture the full spectrum of dietary discussions or represent the diversity of public discourse across regions and demographics. Finally, the dataset reflects only English-language tweets, limiting the

generalizability of findings to non-English-speaking populations and culturally specific dietary practices.It is important to acknowledge that these findings are based solely on keyword frequency rather than sentiment or contextual analysis. The presence of a term in a tweet does not necessarily indicate positive or negative discourse, nor does it capture the motivations behind its use. Future research could enhance these insights by incorporating sentiment analysis, topic modelling, and demographic segmentation to better understand the nature and drivers of dietary discourse on social media.

Nevertheless, the analysis reveals significant developments over time. The rising numbers for most food items over time reveal a growing interest in nutrition-related issues. However, the significantly negative trend for beer and the stagnating numbers for wine also confirm a decreasing interest in items with considerable health risks, confirming the general trend to feed ourselves in line with health requirements.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

HEDONISM VERSUS HEALTH: A COMPARATIVE AND DYNAMIC ANALYSIS OF DISCOURSES ON MEAT, VEGETARIAN, AND VEGAN FOOD BASED ON TWITTER DATA

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Abstract

This study intends to determine the evolution of the attitudes to "vegetarian", "vegan", and "meat" between 2012 and 2022. For this purpose, cloud plots and qualitative and regression analysis employing 162,000 tweets between 2012 and 2022 were used. The comparison showed patterns such as "chicken" vanishing from meat-related tweets but remaining in vegan tweets. Also, the results showed that the discourse around meat was shaped by hedonism, first emphasizing enjoyment and then sympathy, followed by the strong matter-of-factly will for its enjoyment. The discourses around vegan and vegetarian food were much more shaped by promoting healthy diets and, particularly in the early phase of the period examined in the analysis, by exchanging recipes. Unlike previous studies that focused on short-term trends or limited data sets, our work offers a decade-long perspective, highlighting the dynamic nature of food-related attitudes toward dietary choices.

Key words**:** *food, attitudes, Twitter data, hedonism*

INTRODUCTION

One of the most debated issues in the current food discourse is the future of meat and other animal products. Although adverse health effects [18, 30] and environmental impacts [21, 45] effects make it advisable to reduce consumption levels in the Western world considerably, ethicists are increasingly questioning the ethical feasibility of killing animals for human food in general [43, 32, 48]. However, most explorations on consumer attitudes in this area are based on questionnaires [36, 41, 42], which may not ask consumers about aspects that are more important to them. Over the last few years, the collection of material from social media has emerged as an alternative method for the collection of empirical content from citizens and consumers who want to tell their real stories and experiences [5, 19, 20].

For a long time, Twitter, now known as X, has been among the most influential social networks helping people share their latest opinions and spread their messages among others [22]. Twitter is not only a rapid tool to exchange information, but it is also a valuable source of data for a variety of research purposes [23, 46, 51]. For example, Twitter and other social media data have been used to study public health and disease epidemics [7, 53, 8], monitor trends in public health practices [27, 38, 11], assess consumer preferences and brand perceptions [34, 3, 24], track social movements and activism [35, 29, 13], and conduct environmental studies and disaster responses [14]. Twitter (X) data has also been used to study attitudes towards food [49, 40, 44], and even for the tracking of food security and poverty [31, 15]. Drescher et al. [12] used the #veganuary to demonstrate how combining multiple social media analysis can provide rich insights into the public discourse on food topics.

The aim of this study is to use the most straightforward technique of Twitter analysis to carry out a comparative and dynamic analysis related to *vegetarian*, *vegan*, and *meat*

in the second decade of the 21st century. We constructed and studied a largeX(Twitter) dataset that includes almost a million tweets since 2012 and processed them using machine learning techniques.

This study, therefore, contributes to the debate on the evolution of the attitudes towards *vegetarian*, *vegan*, and *meat* dietaries among the English tweeting population.

MATERIALS AND METHODS

Table 1 describes the conventional method used for data processing. The main shortcoming of our dataset was that we could only extract the tweets registered at the end of each day. The total number of tweets that we extracted was 945,204. The yearly number of tweets during the considered time frame ranged from 47,020 to 53,944 for the years 2012, 2014, 2016, 2018, 2020, and 2022. This step aimed to ensure a representative sample of tweets related to the study's focus.

Table 1.The tweet data processing method used in this study.

Stage	The aim	R-package	Author
1	Dataset extraction		
2	Random 9,000 tweets for each key word	"random"	"stats", "base"
3	"Corpus" of words	"quanteda"	Benoit*et al*. [2]
4	Unified word forms and no meaningless words		
5	Association between the words and key words		
6	Frequencies calculation	"tm"	Feinerer*et al*. [16]
7	Word cloud plots	"wordcloud"	Fellows [17]

Note. We did not identify and exclude tweets from bots.

We randomly extracted a sub-sample of 9,000 tweets each year at Stage 2, creating a "corpus" of words, which is defined as "a collection of written or spoken material stored on a computer and used to find out how language is used" [4]. After giving unified forms for varying words and excluding syncategorematic words, we used this object ("corpus") to find out an association between the words and keywords *vegetarian*, *vegan*, and *meat*, employing frequency investigation and visualizations with wordcloud plots. A word cloud is "an electronic image that shows words used in a particular piece of electronic text or series of texts. The words are different sizes according to how often they are used in the text" [4].

We started with a dynamic analysis. From our database, we found out that only two terms occurred in all years for the three search terms: *dog* and *healthy*. Linear regression models were then fitted to where the dependent variable in each model was the annual tweet count of those keywords, while the independent variable was the year, treated as a continuous linear predictor. A systematic time-series analysis was conducted to detect systematic developments over time in the public discourse related to dietary habits and health consciousness.

The comparative analysis followed a qualitative pattern. The six "samples" per search term from the different years allowed for a well-founded comparison of the terms associated with the different keywords. Elements of objective hermeneutics [37] were then used to identify the meanings of the frequent terms.

RESULTS AND DISCUSSIONS

Dynamic Analysis

Figure 1 displays the numbers with which the two search terms *dog* and *healthy* identified in the tweets. Although the sample size was too small to identify significant trends, we perceived that, in general, the intensity of the discourse increased in both categories between 2012 and 2022.

Moreover, there was a clear distribution of the two terms, which we elaborated on in the comparative section.

When debating dog feed, posts focused primarily on meat, and questions of vegetarian and vegan nutrition covered only a fraction of it.

For healthiness, the situation was opposite: the occurrence of the term *vegan* usually outnumbered the figures for *vegetarian*, and both appeared approximately five times more often in health-related discourses than the term *meat*.

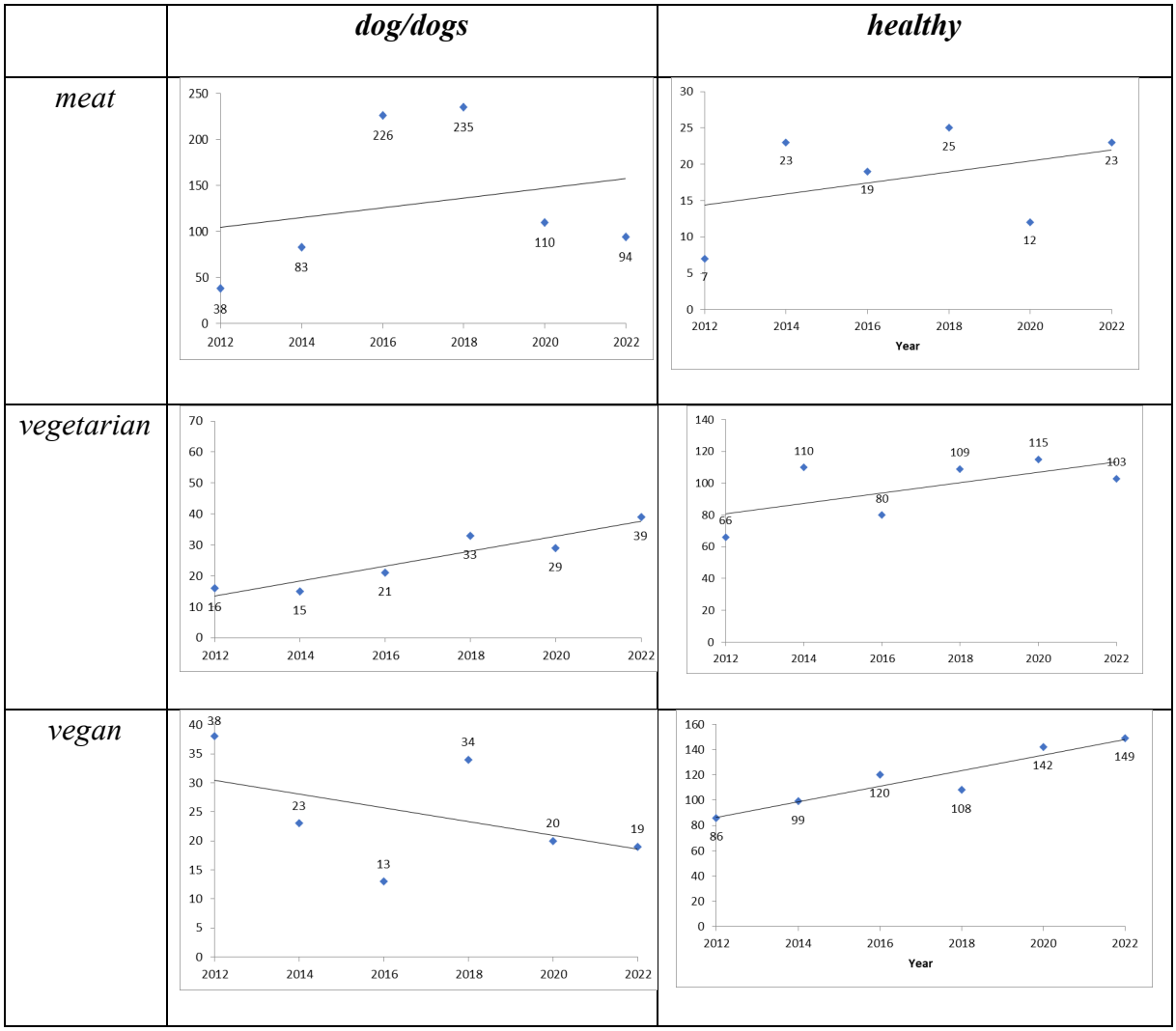


Fig. 1. Trends for tweet word "dog/dogs" and "healthy"
Source: Own design based on the results.

Figure 2 presents wordcloud plots for the six years and the three search terms from our study. The bigger the size of the word in the image, the more often it is used compared to other words in the plot. We have presented these plots in table format, identifying the keywords in the corresponding columns and the years in the corresponding rows of the figure.

Whereas it was impossible to identify significant linear trends over the 10 years, we observed certain developments for the different terms over time:

- In many parts of the world, chicken meat is considered a particularly trendy food choice [1, 6, 50]. This was somewhat confirmed by our results. In 2012 and 2014 and once again in 2018, **chicken** was the only specification of meat found at the top search terms. However, it vanished from the list in the last two years of analysis. It seems that chicken meat lost some of its fascination over the 10 years examined in the analysis. However, it remained a continuous mention in the tweets containing *vegan*, where it probably mostly referred to substitutes.

- A similar observation was made regarding **gluten free** in the tweets containing the *vegetarian* word. They appeared in 2014 and 2016, and in these years, vegetarian and gluten-free diets were often linked [9, 10]. In subsequent years, the novelty of this link faded, as did the occurrence of the term.In tweets containing *vegetarian* and *vegan*, ***recipes*** played a very prominent role at the beginning of the period. This changed in the years until

2022 for *vegetarian* but not for *vegan*. Indeed, the necessity of adapting cooking patterns as a vegetarian diet has been a challenge when vegetarian eating patterns increasingly emerged at the beginning of the study period [25]. It is obvious that preparing vegetarian meals is no longer unusual, whereas the transition to vegan-eating practices still suffers from a lack of practice [47].

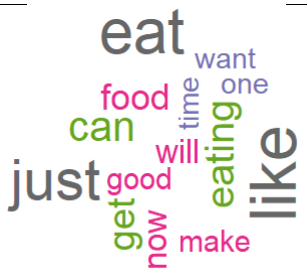
Year	meat	vegetarian	vegan
2012			
2014			
2016			
2018			
2020			
2022			

Fig. 2. Words associated with vegetarian, vegan, and meat in wordclouds.
Source: Own design based on the results.

In contrast to this observation, the usage of **make** and **made** showed up only in 2018 in vegetarian tweets and then increased in all three categories to become a major factor in 2022. Apparently, the messages over the period of observation switched from information about the "how to" to messages focusing on the "whether" and perhaps "when".

-For *meat* and *vegetarian*, there was a surprisingly clear development of the usage of **just**. It did not play a major role in 2012, but it increasingly did so until the year 2022. Lee [28] described the complexity of this term; however, in the context of food, it is very likely that it is used to describe simplicity and liberate the author from further reflection. This may be a mirror of the societal criticism that both meat eaters [26] and, increasingly, vegetarians [33] are facing.

Comparative Analysis

Some of the observations from the dynamic analysis also appeared in the comparative analysis. For example, the fate of **chicken**, which vanished from tweets containing *meat*, appeared in the tweets of *vegan*. Apparently, the vegan chicken meat substitutes attracted more attention from 2020 onwards than the original.

However, the main result of the comparative analysis was that the tweets containing *meat* had a much stronger affective component than the tweets in the other two groups. This started at the linguistic level. It was intriguing that **eat** was the overarching topic in the tweets, while the parallel for the vegetarian and vegan tweets was **food**. This is certainly connected with the grammatical differences between the noun *meat* ("eat meat") and the adjectives *vegetarian* and *vegan* ("vegetarian food"). However, it is also possible that the stronger emotionality of verbs compared to nouns [39] contributes to the visible differences.

This suggestion was provoked by the other, more easily detectable, differences between the *meat* category and the others. Most prominently, this was indicated by the verb **like**, which was consistently more frequent in the *meat*tweets category than in the other two categories. For both *vegan* and *vegetarian* tweets, two years showed a weak incidence of the verb **love**, but the occurrence of the term never came close to the level of **likes** in the *meat* category and which did not only describe affection for the food, but also for animals or the environment.

Two other dimensions of emotionality were identified in the tweets containing *meat*, which never made it into the other two categories we analyzed. In the years until 2014, terms such as **gt**(slang for great), **lol**(laugh out loud)**,** and **festival** described pleasant atmospheres that apparently were linked to meat consumption. Thereafter, this was replaced by **want** and **will**. It seemed that the need to justify meat consumption became more evident, and that this was accomplished by statements describing different preferences. However, both of these dimensions were missing in the *vegetarian* and *vegan* categories. Neither did consumers seem to have a particularly good time, as the terms above mentioned were indicating a pleasant atmosphere or enjoyable experience, nor was *vegetarian* or *vegan* food really urgently **wanted**. The counterpart seemed to be the term **diet**, indicating that food choices are not driven by enjoyment but by some sort of rationale, result that was visible one year in the category *vegetarian* and in all but one year in the category *vegan*.

CONCLUSIONS

Our study has several limitations that should be acknowledged. First, relying on X(Twitter) data limits our ability to generalize the findings to a broader population. As Wojcik and Hughes [52] showed, X users are not representative of the general population in terms of demographics, interests, or even social media usage habits. Second, the analysis of word frequency and word cloud visualizations is limited by the inherent subjectivity of defining and classifying keywords and this can lead to potential biases in the interpretation of the results. Finally, the study focused on a specific time, from 2012 to 2022 (with a span of every two years), and may not fully capture the full extent of the ongoing evolution of vegetarian and vegan trends.

Despite these limitations, our study provides valuable insights into the changing attitudes

towards vegetarian and vegan food. The analysis of the three keywords *meat*, *vegan*, and *vegetarian* through word clouds, word counts, and word frequencies suggest a certain scope of an emerging transformation process. In this process, hedonism is still linked to the meat shelf and has not reached the corner with plant-based substitutes. Vegan and vegetarian lifestyles are considered a diet and, unlike meat, not a tool to have good times.

Nevertheless, recipes for vegetarian dishes have reached the kitchens where they are needed and are still in the process of being exchanged for vegan dishes. Vegetarians and vegans are not just concerned with avoiding meat but also with promoting health and love. Further, eating meat has lost its innocence, and meat eaters defend their habits by highlighting their wants.

It is unlikely that these dynamics have come to an end; thus, there is ample room for future research to accompany the future of the discourse. Will the vegan wave be a fashion that vanishes as it has come? Or will the habit of killing animals and eating their corpses be considered a bad habit first and banned thereafter? This paper has shown that a thorough analysis of social media content can contribute to identifying new trends and likely developments.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

A MULTIDISCIPLINARY APPROACH TO THE SUSTAINABLE MANAGEMENT OF AGRICULTURAL LAND AND RURAL RESILIENCE DEVELOPMENT

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Abstract

This research intricately explores the interconnections among biodiversity conservation, climate change, territorial fragmentation, and socio-economic challenges, with a specific focus on the Northwest side of Romania villages. Emphasizing the national importance of discerning land utilization practices, this paper draws on land distribution impact and consolidation. Adopting a multidisciplinary approach, the study integrates specialized studies to unravel the nuanced evolution of land management and rural resilience development. The research, traversing subsequent chapters, elucidates methodological intricacies, conducts a comparative analysis, and globally contextualizes discussed issues, additionally implementing a suitable analysis to develop viable solutions in the global context of land conservation. With a focus on identifying land parcels, ascertaining ownership, and updating land use dynamics the meticulous analysis contributes nuanced insights into sustainable land management. The rural resilience concept is valued by suitable analysis performed using Geographical Information System, which will serve as decision-making factor.

Key words**:** *biodiversity conservation; land consolidation; rural resilience; suitability analysis; sustainable land management.*

INTRODUCTION

Land is the most precious production factor which assure food for the globe population, life and perenity [12].
The sustainable management of agricultural land is one of the most important aspects of agricultural production and land use planning.
Proper land management helps ensure a stable source of income for residents in rural areas, contributes to food security, preserves soil healt, and mitigates environmental degradation in the face of global challenges such as climate change.
Additionaly, land use suitability assessment plays a key role in planning for both agricultural and urban development, helping to optimize land use while balacing economic, environmental and social needs [2, 13].
During the World War II, the concept of development has been increasingly utilized across various domains related to modernization and economic progress.
Numerous theories examine the most effective methods for achieving development; however, a fundamental aspect of sustainable development lies in addressing citizens' perceived needs and resolving issues that directly or indirectly impact their quality of

life, resulting high impacts in the demografic results such as history, tradition or economic approach. (Williamson *et al.,* 2010; UNECE, 1996) [16, 14].

Land fund needs to be preserved and that is why important strategies are set up to protect land from degradation and preserve its qualities and fertility [1].

However, land property is the limiting factor in strengthening the agricultural farms [3].

In Romania, moving to the Northwest region, one of the main challenges is the excessive fragmentation of land, a consequence of post-communist restitution policies and successive inheritances [5].

This fragmentation negatively impacts agricultural productivity by hindering mechanization, irrigation, and the establishment of efficient farming operations [9].

Additionally, the absence of coherent policies for land consolidation and sustainable management exacerbates economic and social issues in rural areas, limiting investmentopportunitiesand infrastructure development [15, 4].

Land administration establish ownership, assess land value, and regulate land use, functioning as a driver of economic development supporting agricultural productivity and contributing to sustainable territorial planning [11].

Land used for agriculture looks to be diminished by receiving other destinations in the peri-urban areas [6].

Recent research highlights the interconnections between biodiversity conservation, climate change, territorial fragmentation, and socio-economic challenges, emphasizing the national importance of effective land-use practices.

This paper aimes to develope a strategy of rural resiliencedevelopment, including the importance of accurancy of land parcels, in according with clarification of ownership rights, and continuous assessment of land-use dynamics.

The analysis will integrate two sectors from the studied area situated in Maramureș county using a multidisciplinary approach, integrating advanced methods such as geospatialanalysis and suitability analysis using Geographic Information Systems (GIS) to provide viable solutions within theglobal context of land conservation and sustainable development.

The research aims to answer to questions such as: *Is land consolidation a solution for agricultural facilities?*

The use of such technologies supports informed decision-making regarding land consolidation strategies and the implementationof policies aimed at addressing territorial fragmentation.

As highlighted above, land fragmentation in the hilly regions of North – West Romania presents a barrier to the sustainable development of rural area. This research aims to propose a practical solution that integrates local customs and lifestyle with scientific finding, ultimately contributing to the well-being of local communities.

MATERIALS AND METHODS

Study Area

The territorial organization of Maramureș County into four distinct "lands," resulting from the consolidation of regionalsocio-economic development micro-associations, positions the commune of Botiza in the southern part of *"Țara Maramureșului,"*at the border with *"Țara Lăpușului."*

This region is characterized by diverse landforms, a temperate continental climate, an extensive hydrographic network, and a mineral rich subsoil containing gold-silver ores and complex deposits.

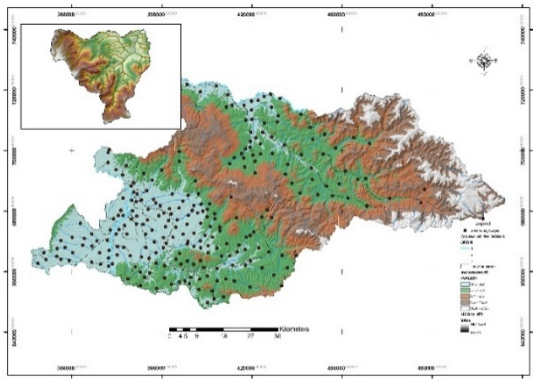


Fig. 1. Localization Map
Source: Original Neag et al, 2024 [10].

There are two main paradigms of research: to create a suitability analysis for providing

solutions to the land fragmentation issue and to unravel the nuanced evolution of land management.

Determination of aggregation weight

Based on land use suitability principles, the availability of local experimental data relating factors to land use suitability, and well-defined workflow for data collection, this study aims to develop a suitability analysis framework. By systematically organizing inputs and outputs within the analysis, the proposed methodology seeks to provide insights into mitigating the effects on land fragmentation and promoting sustainable agricultural practices. As presented in the Figure 2, the workflow outlines the key steps involved, ensuring a structured and reproducible approach.

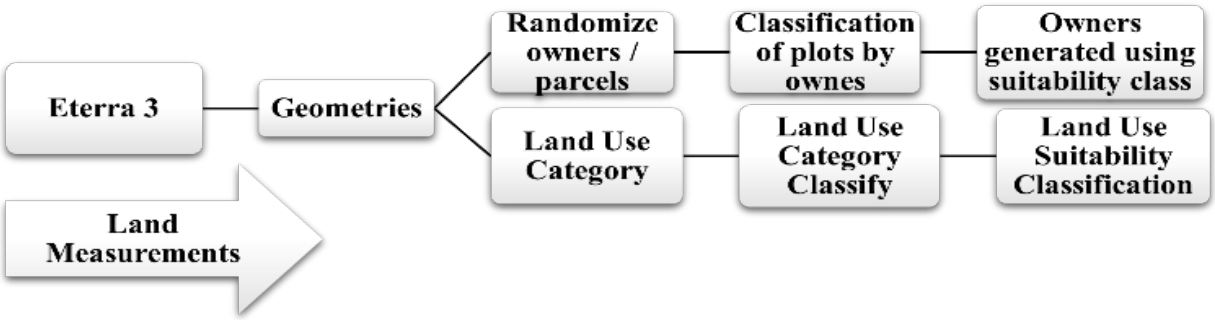


Fig. 2. Workflow for data collection
Source: Figure created by the authors.

Determination of data collected for analysis

To enhance understanding, it is important to introduce a schematic representation of data acquisition and the sequential processing steps involved in the analysis, highlighting the approach used for assessing land fragmentation and evaluating the evolution of land management.

The paper divides into three important sections of data collection, combined to data analysis:

-*Topographical measurements* – consisting in the use of GNSS technology for data collection within the framework of the systematic cadastral survey.

-*Information about land management and land category*, using an authorized platform of ANCPI.

-*Data provided from ANCPI* (National Agency For Cadastre and Land Registration) [17].

Each of the previously mentioned steps corresponds to a distinct component of the analysed sectors, individually characterized and allocated exclusively to the studied area. This process was made possible using ArcGIS Pro software, employing various methods to conduct the suitability analysis effectively.

The challenges of agriculture

A major challenge in rural areas, including the commune of Botiza, is the predominance of subsistence farming, which remains largely unproductive due to inadequate land consolidation, minimal mechanization, and excessive parcel fragmentation. These structural deficiencies hinder agricultural efficiency and limit economic growth in the region.

In the recent studies is proved that Botiza officially encompasses approximately 7,500 hectares of which 1,527 hectares are registered with the Agency of Payments and Intervention in Agriculture (APIA) for subsidy eligibility, comparing to the total surface to analyse of 199.34 ha. As will be presented in the analysis, the remaining land consists primarily of forested areas, while approximately 500 hectares area classified as non – agricultural land.

Analysing the current statistics from APIA [18] regarding land distribution and usage, alongside the data collected in this study, reveals significant insights into land ownership and utilization. The most prevalent land use consists of individually owned meadows, followed by communal permanent grasslands designated for individual use, and individually owned permanent grasslands.

A comparison between statistics and the findings of this research shows that from a total

area of 458 parcels owned by 289 individuals, 78 hectares are distributed among 198 owners, each holding a single parcel. It is important to note that for the 289 property-owners, randomized names were employed to ensure compliance with GDPR regulations, such as: *Owner_1* or *Owner 1*.

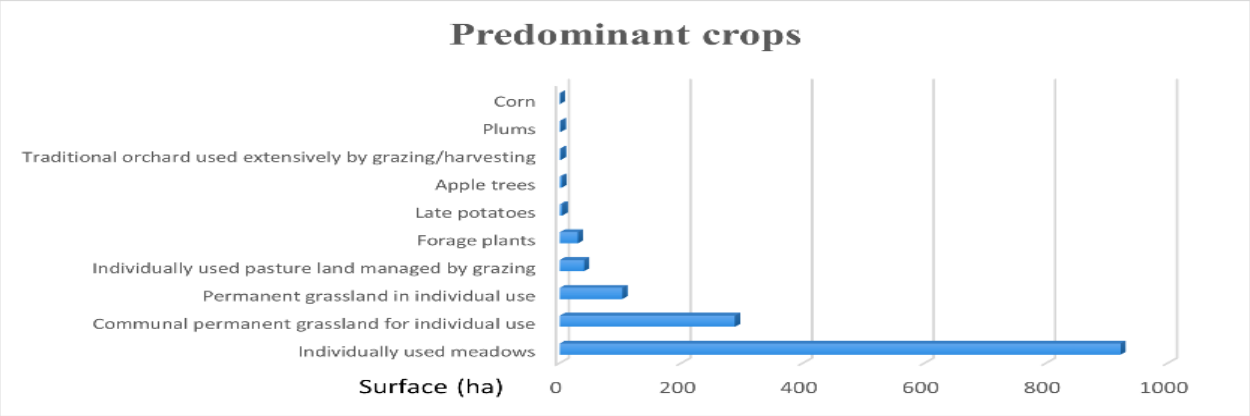


Fig. 3. Predominant crops
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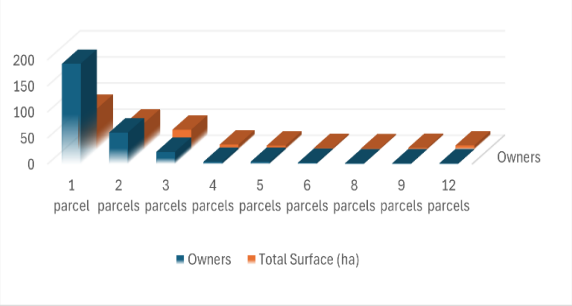


Fig. 4. Landowners' statistics and total surface of parcels
Source: Figure created by the authors.

Data acquisition and standardization

For conducting a suitability analysis, it is necessary to collect and process a variety of relevant geospatial data that reflect the land`s condition and characteristics. These data include information on landowners, land use categories, and land type – important factors in assessing land suitability for various use. It is important to note that land suitability analysis programs are often conducted at various scales, and harmonizing the data inputs and results in a way that is effective for decision-making presents a significant challenge [8].

In the present paper, data was sourced from two specific sectors: Sector 7, respectively Sector 22. In Sector 7, the integrated data for suitability analysis were obtained from topographic measurements conducted in 2021 as part of the systematic cadastral re-establishment process, while for Sector 22, geometries were retrieved from the Eterra platform.

All these data were processed and standardized in attribute tables associated with the respective geospatial layers, providing a solid foundation for the suitability analysis. For the current analysis the impact factors selected include landowners, land use categories and land type which represent important factors in assessing the potential land use in the context of agricultural land fragmentation.

It is important to highlight that, in the suitability analysis, parcels that were unclaimed at the time of the systematic cadastral survey were excluded. The issue of unclaimed land is one that cannot be overlooked, as it has become increasingly prevalent due to the high number of property owners who have emigrated. The absence of local landowners further complicates effective land management and poses challenges in consolidating land for agricultural use or other development purposes.

As the unclaimed parcels, roads were excluded from the suitability analysis to prevent the inclusion of unproductive areas and to ensure an accurate assessment of the land`s potential for consolidation and sustainable use. Another key factor in the suitability analysis was the Digital Elevation Model, created for the area studied using the boundaries of the sectors of interest. This model allowed for the

determination of the land`s slope, essentially in assessing its agricultural potential. Lands with steep slopes is more difficult to work with mechanically and has lower agricultural productivity. Additionally, such lands are more prone to erosion, making them less suitable for intensive agricultural use.

The preparation of inputs for suitability modeling begins with defining the goals that characterize the studied phenomenon and the purpose of the analysis. There are three possible approaches to suitability modeling: a) simple suitability model, b) fuzzy suitability model and c) weighted suitability model. Given the complexity of land use patterns in the study area, the third approach was selected as it enables a more detailed and context – sensitive evaluation.

During the derivation stage, the data that characterize the model variables are defined based on the imposed criteria. For instance, the slope was classified into four categories based on the steepness of the terrain, which determines the type of machinery that can be used: slopes of less than 12 degrees are suitable for all agricultural machinery, between 12 and 20 degrees can accommodate most agricultural machinery, up to 35 degrees can be worked by tracked vehicles, and greater than 35 degrees are only suitable for work by animals or humans. These derived inputs were incorporated into the Suitability Modeler after the data transformation process.

The layers representing Owners and Land Use Category were classified using single-value classification according to the respective owners and land use types, then transformed into raster format.

In the Suitability Modeler [7], the derived rasters serve as the inputs for the model. These layers were transformed in accordance with the defined suitability criteria, using a suitability scale ranging from 1 to 3. The transformation process is depicted with corresponding images that demonstrate the changes applied.

The final step of the process is defined by the *locate and analysis,* represented in Fig. 5.

Furthermore, a suitability weight model was introduced, assigning weights of 15% for land use category, 60% for owners, and 25% for slope Subsequently, a suitability map was generated, followed by a Suitability Location map. Finally, a sensitivity analysis was conducted by varying the weights to assess the impact of these changes on the suitability results.

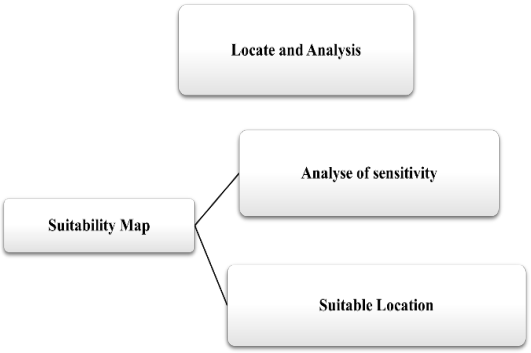


Fig. 5. Locate and Analysis results
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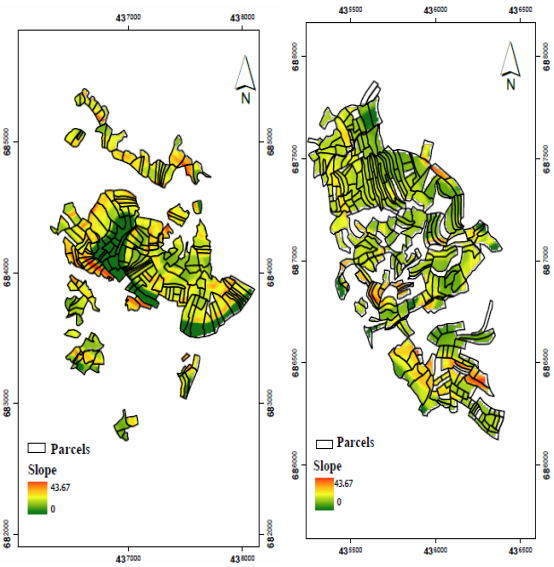


Fig. 6. Slope for Sector 7 Fig. 7. Slope for Sector 22
Source: Figure created by the authors.

In this study, the analyzed land parcels are classified as either outside the built-up areas or within the built-up areas in both sector 7 and 22. Given the objectives of the suitability analysis and land consolidation assessment, the focus is primarily on the within the built-up areas parcels, as they constitute the majority and serve as the pilot units for the final evaluation. The data processing and analysis were conducted using ArcGIS Pro for spatial analysis and SPSS 26 software for statistical evaluation, ensuring methodological rigor and accuracy in the results (Suitability Modeler) [7].

RESULTS AND DISCUSSIONS

The studied area encompasses a total of 199.34 hectares, subdivided into 458 parcels, owned by 289 individuals as mentioned above. Of these, extravilan parcels cover a total of 196.78 hectares, while the remaining 9, located within the built-up area, accounts for 2.56 hectares. Given the constraints of land consolidation, which requires uniform land use types, these 9 parcels were excluded from further analysis. The distribution of parcel size indicates a considerable degree of variability, which is further influenced by the presence of outliers. The smallest parcel measures 198.86 m^2, while the largest covers 6.94 hectares.

For this analysis, the parcels were ranked according to their size, and the median was determined as the central value of this ordered dataset, resulting in the median parcel value of 3,245.35m^2, with an interquartile range (IQR) of 3,482.28 m^2. These findings highlight the significant challenges posed by land fragmentation, emphasizing the need for targeted strategies to address these issues.

Furthermore, these results underscore the importance of accounting for parcels size variability when developing land consolidation strategies. The differences in parcel sizes can greatly influence the feasibility of consolidation efforts and the potential for agricultural optimization. A detailed statistical overview of the parcels, along with additional attributes relevant to suitability analysis, is presented in Table 1. These outcomes emphasize the complexity of land distribution and reinforce the need for customized strategies to ensure effective land management and optimization of land use in the studied area.

Table 1. Parcels characterization

	Number of parcels	**Numbers of owners**	**Surface area [m^2]**			
			Median	IQR	Minimum	Maximum
Sector 7	262	162	2,215.25	2,090.43	198.86	15,079.15
Sector 22	196	138	5,002.86	4,506.73	221.26	69,448.18

Source: Table created by the authors.

Some landowners possess parcels in both sectors; however, this factor is not relevant for the suitability analysis, as parcels located in different sectors cannot be consolidated due to the considerable distance between them. This spatial separation restricts the feasibility of land consolidation and affects the potential for agricultural optimization within the study area. During the documentation process, it was found that due to the lack of land claims at the time of the cadastral update, the land was transferred into the possession of the Botiza Municipality. This is reflected above in Figure 8 (b), where it is shown that the municipality owns a total of 11 parcels. Additionally, the municipality holds another parcel located in Sector 7, which is categorized separately by owners with a single parcel.

Preparing raster`s for suitability analysis

Suitability modeling for land parcel consolidation represents an analytical approach used to identify areas that are suitable for consolidation, based on criteria tailored to the specific characteristics of the studied region.

As presented in the previous section, in the first stage of the suitability analysis, the criteria were defined, relevant variables were selected and the methods for representing these variables were determined.

The main objective of this article is to find feasible solutions for consolidating land parcels.

Analysing the results from the previous subsection, it was observed that the most important factor is land ownership. To identify a suitable consolidation solution, the new plots must be suitable for mechanized work. Therefore, the second criterion is based on the study of the land slope, in conjunction with the potential for mechanized work on the meadows.

The study of the land parcels identified that the parcels belong to three different land use categories: *hayfields, pasture* and *forest.*

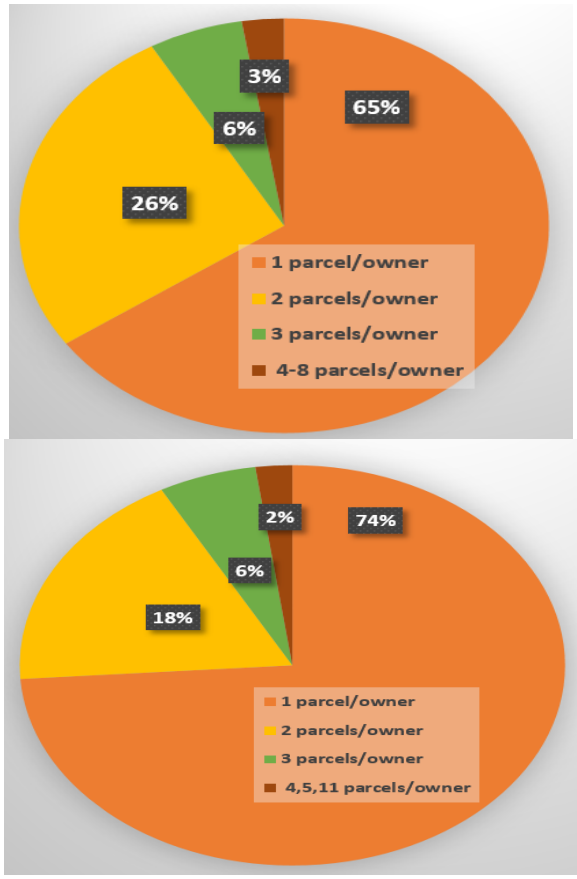


Fig. 8. Number of parcel(s)/owner
Source: Figure created by the authors.

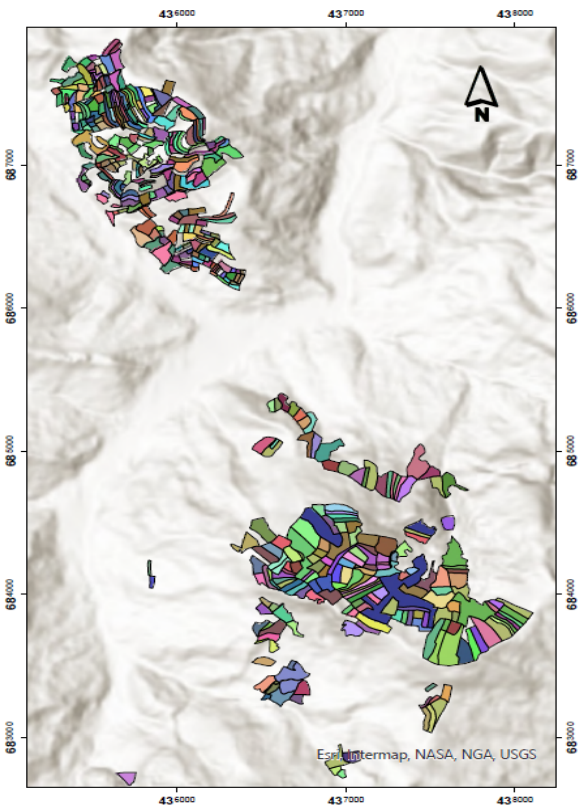


Fig. 9. Parcel(s)/owners
Source: Figure created by the authors.

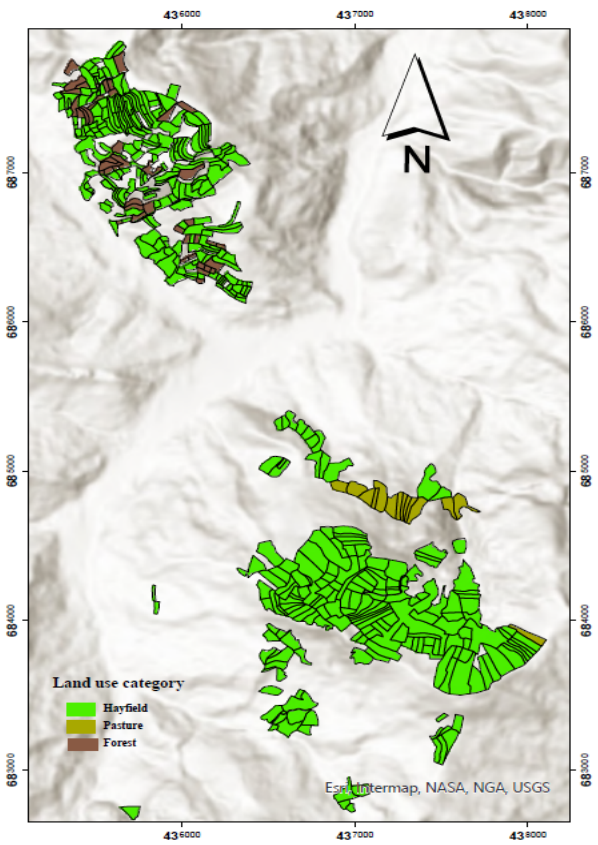


Fig. 10. Land use category
Source: Figure created by the authors.

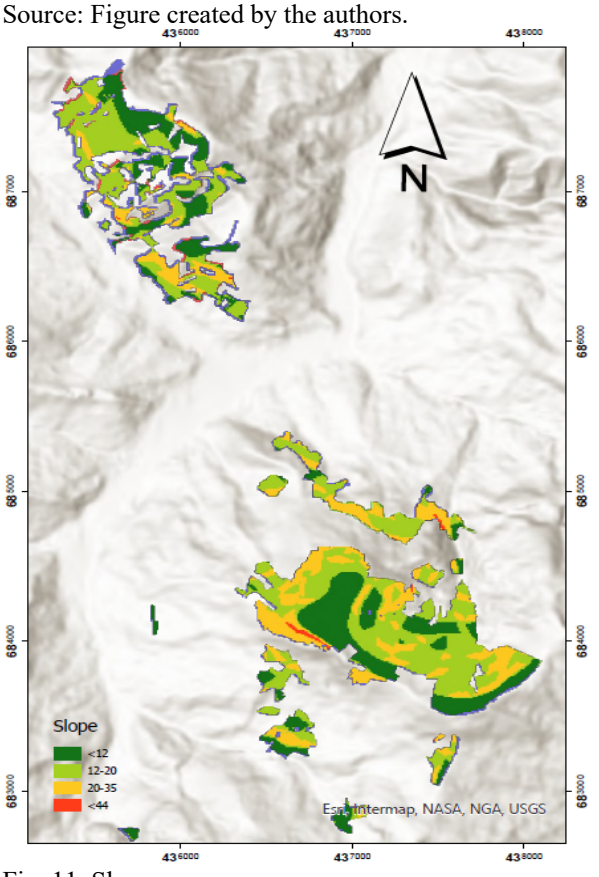


Fig. 11. Slope
Source: Figure created by the authors.

The derive stage of suitability model preparation consists in generating derived layers for data normalization and reclassification.

The collected data were analysed using geoprocessing tools in ArcGIS Pro and the results were consist in classified parcel layer by owners and by land use category followed by their transformation in raster files with 10 m resolution.

The slope raster was reclassified by four classes as presented in Figure 11, with the same resolution as the previous raster files from Figure 9 and Figure 10.

Transformation of derived data and imposing weight to the model

In each derived dataset the values are transformed by assigning to each cell from the studied surface a suitability score.

In this research the suitability scores range from 1 and 3 to each cell, where 3 indicates the most suitable areas.

The transformation process for raster data assigns scores between 1 and 3 to each cell, ensuring that the consolidated parcels are suitable for mechanized work. Areas with a slope of less than 12^0 are considered the most suitable and are assigned a score of 3. Areas with slope between 12^0 and 35^0 receive a score of 2, while areas with steeper slopes are assigned the lowest suitability score. The distribution of suitability based on slope is illustrated in Figure 12.

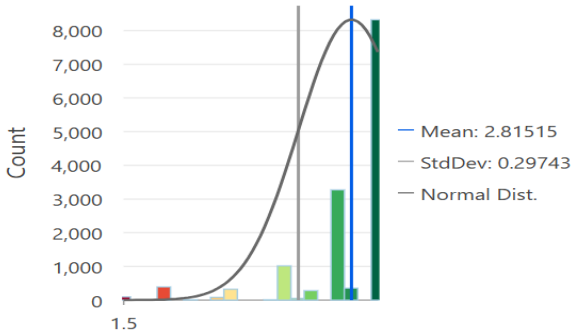


Fig. 12. Distribution of the suitability after slope transformation
Source: Figure created by the authors.

Figure 13 displays the transformed slope on the left side and the derived raster on the right, along with a detailed view of the transformation process. No significant differences are observed, as the regions with slopes greater than 35 are relatively small. However, these areas still contribute to land fragmentation, as illustrated in Figure 4.

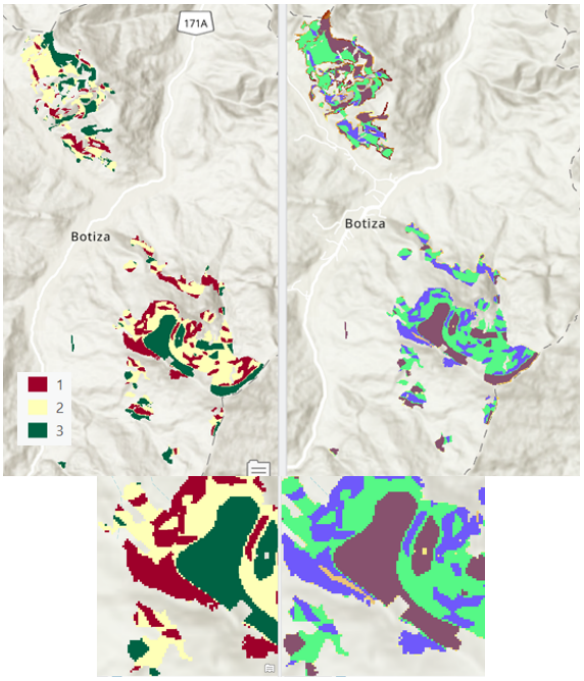


Fig. 13. Slope transformation
Source: Figure created by the authors.

The transformation of land use categories involved categorizing each land type based on its suitability. Hayfields, considered the most suitable for consolidation, were given the highest score of 3, while pasture received a score of 2. Forested areas were deemed the least suitable due to the significant effort needed for conversion and environmental regulations that limit such changes. The distribution of suitability after this transformation is illustrated in Figure 14.

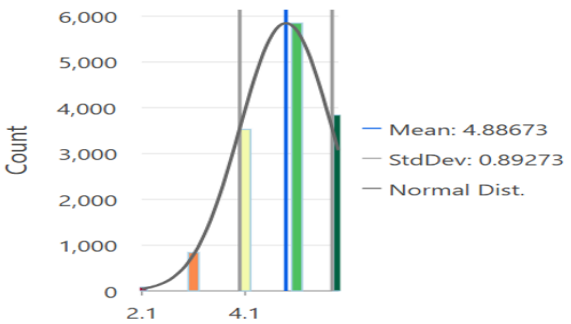


Fig. 14. Suitability distribution for land use category
Source: Figure created by the authors.

The most notable transformation occurs with the ownership data. The derived raster file includes 286 owners, with only a few owning more than two parcels. The consolidation solution lies in fostering cooperation among owners to create larger land parcels, which can contribute to higher income and sustainable development in the area. Owners with one, two, or three parcels, as well as parcels assigned to the Botiza Municipality, were given a suitability score of 3. Owners holding four, five, or six parcels received a suitability score of 2, while others received a score of 1. The transformation of the ownership data is presented in Figure 15.

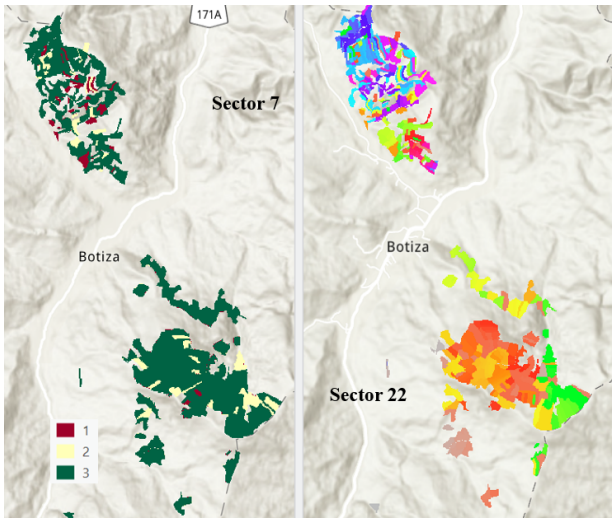


Fig. 15. Transformation of owner`s raster
Source: Figure created by the authors.

This transformation emphasized that many of the parcels from Sector 7 have a low suitability score due to the fact that there are owners that have more than 3 parcels of small areas.

Suitability map

Figure 16 highlights the suitability map, revealing that the majority of the land suitable for consolidation is concentrated in Sector 22. In contrast, Sector 7 has numerous areas deemed unsuitable due to the scattered presence of forests as a land use category and the fragmentation of property rights, which creates isolated „islands" within the sector.

The contribution of the transformed raster to the suitability map were 60% owners, 25% slope and 15% land use category. Over the 84% of the area is appropriate for consolidation with a score over 2.6 from a maximum of 3 points.

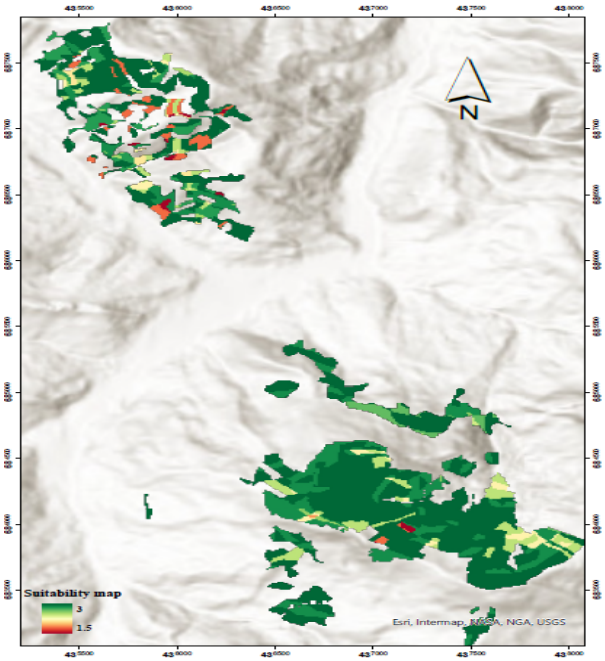


Fig. 16. Suitability map for Sector 7 and Sector 22
Source: Figure created by the authors.

Suitable regions

Suitable Regions are distinct, well-defined areas that meet specific suitability criteria.

To achieve parcel consolidation, the criteria were designed to ensure economic efficiency while remaining practical for implementation.

A balance was established between parcel geometry and suitability score, with a Shape/Utility trade-off set at 20%. Additionally, a minimum area requirement of 3,000 m² was imposed, aligning with the threshold set by the Paying and Intervention Agency for Agriculture for agricultural subsidies.

Figure 17 presents the suitability map, highlighting the parcels eligible for the consolidation process.

The findings about sustainable regions shows that 214 parcels are appropriate as suitable region for consolidation, covering 54.80% from entire era.

In the following Table 2, the suitable regions for both sectors is emphasized.

Table 2. Suitable regions

	Number of parcels	Sector's contribution to the suitable regions area (%)
Sector 7	96	25.06
Sector 22	118	74.94

Source: Table created by the authors.

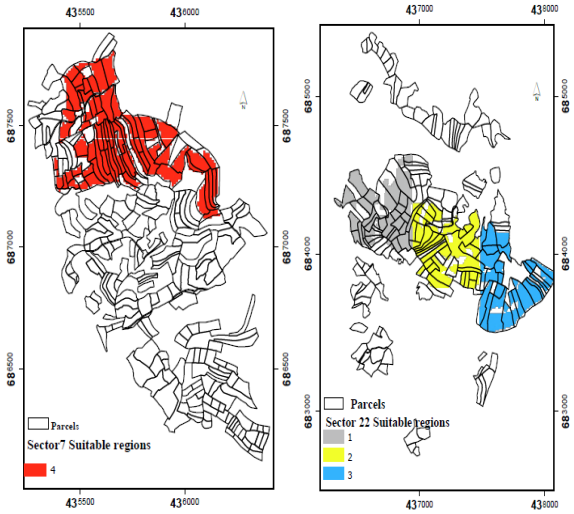


Fig. 17. Suitable region for Sector 7 and Sector 22
Source: Figure created by the authors.

Sensitivity analysis

To validate the proposed model, a sensitivity analysis was conducted by examining how variations in weight allocations impact the suitability map. Two additional models were generated using the same parameters as the initial model, differing only in weight distribution.

-*In the first scenario* (Sensitivity 1), weights were assigned as follows: 35% for land use category, 40% for owners, and 25% for slope.

-*In the second scenario* (Sensitivity 2), the weights were adjusted to 35% for land use category, 30% for owners, and 35% for slope.

The raster files generated by computing the differences between the new suitability maps and the original suitability map showed values ranging from -1.5 to 1.45.

These differences were then reclassified into three categories, with values between -0.1 and 0.1 considered as indicating no significant change. The results of this analysis are presented in Table 3.

Table 3. Sensitivity analysis results express in percent of values in raster files

	Small changes Between -0.1 and 0.1 (%)	Other changes (%)
Suitability(35*LU*,40*O*,25 *S*)-Suitability (15 LU,60 O,25 S)*	96.23	3.77
Suitability(35 LU,30 O,35 S)-Suitability (15 LU,60 O,25 S)*	75.01	24.99

*LU-Land use category raster, O – Owners, S- Slope
Source: Table created by the authors.

CONCLUSIONS

In the context of sustainable land management, our research on land consolidation in the hilly region of North-West Romania highlights that landowners play a central role in the process. This conclusion is strongly supported by the results of the suitability and sensitivity analyses.To identify suitable regions for consolidation, we applied specific conditions regarding minimum and maximum area constraints while ensuring the absence of isolated "islands" within the consolidated zones.

However, computational processing to determine these areas proved to be highly time-consuming. In Sector 7, it was not possible to identify viable solutions due to the presence of steep slopes, contiguous parcels with differing land use categories, and the existence of plots with incomplete ownership information.

It is important to note that the workflow presented in Figure 2 and Figure 5, can be applied to other hilly regions in North-West Romania.

To enhance the effectiveness of land consolidation efforts, we propose the following recommendations:

-Exclude forested areas subject to other administrative regulations and ensure continuity of land use categories between neighboring parcels.

-Resolve any outstanding issues related to land ownership status.

-Establish access routes to facilitate mechanized agricultural operations in the consolidated areas.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SELECTION OF GREEN PACKAGING SUPPLIERS UNDER INTUITIONISTIC FUZZY ENVIRONMENT: CASE STUDY OF AGRO-FOOD COMPANY

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Abstract

The main goal of the performed research is scientific-based selection of supplier of "green" packaging (environmentally friendly) that is adequate for the long-term partnership with the observed enterprise ("Farm Land") active within the agro-food sector. Accomplishment of defined research objective required establishment of research model that involves ten criteria, based on which was analyzed the properness of each of ten potential packaging suppliers. According to existing model, there was developed the research methodology based on the Intuitionistic Fuzzy Set (IFS), due to inclusion of the uncertainty in decision-making process while considering the best possible option for the enterprise. To determine the importance of used criteria, the DiWeC (Direct Weight Calculation) method was used, while the derived results show that the focus during the selection of "green" packaging suppliers has been turned on their products, i.e. mentioned products must be biodegradable, produced from ecological materials, certified and of high quality. Meanwhile, towards the selection of optimal supplier, the CORASO (COMpromise Ranking from Alternative SOlutions) method was used. Performed research shown that in line to analyzed values of preselected criteria, the supplier S3 could serve as the best possible solution for long-term business cooperation. Validity of gained research results was also confirmed by the application of sensitivity analysis. The contribution of performed research is multiple. It primarily supports development of existing MCDM methodology, through testing and designing the new approaches. Then it offers ecological aspect, corresponding to reduction of overall environmental pollution, while it also affects advancement of business activity of observed enterprise.

Key words**:** *suppliers, "green" (ecological) packaging, agri-food industry, intuitionistic fuzzy approach, waste management, decrease in environmental pollution*

INTRODUCTION

Sustainability is one of the key factors in contemporary unstable global business environment [10; 71; 78]. No matter to economy sector, by applying the principle of sustainability, enterprises differentiate themselves towards rapidly growing competition [44]. Nowadays, sustainability has been becoming the widely recognized factor of competitiveness. In practice, the most often it does not imply the fulfillment of all three components of sustainability, emphasizing the economy above all [8; 55]. In recent times, business of the companies from the agri-food sector is affected by the changes emerged due to the increasing demands of final consumers, as well as certain environmental concerns by various groups and activists [21; 66]. By the life logic, food has prefix of ecology before economy, as it is considered as existential factor for humans greatly affecting the health status [38; 42]. Agricultural producers and companies from mentioned sector do not have just to be concerned about environmental impact of the production process, further products logistic and distribution, or product's quality and expected health status [56; 61; 73], but also about how to reduce or even eliminate the pollution caused by food packaging [14; 37, 54]. Due to that in practice are more and more available eco-friendly packaging (use of bio-composite materials characterized by high renewability and biodegradability), which has

negligible or no impact on the environment, i.e. which leaves a shallow environmental footprint [49; 51]. This represents "green" packaging, that tends to be the standard in upcoming future in agri-food sector [47], as administratively driven production and marketing policies for the enterprises are more turned to their social and environmental responsibility [7]. As was previously mentioned, such packaging is made from biodegradable materials, or materials that could be easily recycled, meanwhile fully preserving the food products quality and safety, freshness, chemical and biological composition, texture, etc. [28, 79]. Agri-food enterprises usually do not produce the packaging for their products, while they are procuring it from adequate suppliers [4]. So, the suppliers (producer or distributor of packaging materials) are generally the key factor in supporting enterprises to acquire „green" packaging and implement sustainable practices [46], while adequate selection of "green" packaging supplier represents significant activity that contributes enterprise strivings to reduce its impact on pollution of immediate or wider environment.

Presently, consumers are asking from agri-food enterprises that their products are safe for health [39], while used packaging does not harm the environment [20]. Established trends show that enterprise who uses „green" packaging can improve its market reputation, or even develop, in some extent recognizable brand [67]. Mainly, this is more important for new enterprises that are entering certain market, as they have to fight for the initial market share. Except the agri-food sector, "green" packaging could be used in any sector that practices circular economy, as it affects waste reduction [33; 52]. Briefly, circular economy could be considered as economic mechanism turned to preserving long-distance economic indicators, but under highly optimized use of nonrenewable natural resource and strict reduction or elimination of emerged waste in economic activities (continuity and completity in recycling and reusing). It is part of human strivings to protect available environmental potential and capacity, while fulfilling social needs [72].

Besides environmental impact, the most often, packaging has some additional functions, mainly it protects the product from damaging and external influences, while as a part of marketing strategy it attracts consumers to buy certain products, or it initiates the value-added creation [53; 64]. Therefore, the packaging must be developed or involved in enterprise in cooperation with proper supplier towards the fully achievement of all previously set enterprise's goals. Therefore, developing the long-term cooperation with certain supplier, due to buying „green" packaging, or at the end realizing the enterprise sustainability strategy has been the primary scientific motivation for performing following research.

During the establishment of long-term cooperation with supplier, primarily there has to be determined which supplier can support in the best way achieving the enterprise's goals. This research uses the multi-criteria analysis method, and in order to select some of the alternatives, we must first determine the necessary criteria [5; 45]. The selection concerns suppliers of packaging materials to an agricultural and food company. Selected supplier that is the most suitable solution for enterprise (it satisfies the preset criteria in the best way) will sign the long-term cooperation contract. Preset selection criteria have to represent all things that enterprise expects from suppliers to fit in (facilitators in goals achieving). Traditional MCDM approach has not consider the uncertainty and insecurity in supplier selection. Due to that Intuitionistic Fuzzy Approach (IFS) will be used in performed research. Approach allows the use of subjective evaluations in the form of linguistic terms in order to make a correct decision. Besides, the application of IFS enables enterprise to handle the market changes occurred in dynamic business environment.

In performed research has been involved the enterprise "Farm land" that is active in agri-food sector. As case study, chosen enterprise will serve to show how to select the adequate supplier of „green" packaging applying the intuitionistic fuzzy approach (IFS). So, the main paper goal is to select, using the key criteria analysis and IFS, the best fitting supplier who will enter the long-term partnership with the enterprise "Farm Land" that will enable development of sustainable business. Research goal complexity requires determining of specific goals, as are:

- Identifying available „green" packaging suppliers, as well as key selection criteria;

- Applying IFS due to determination of the weights of key criteria, while further ranking of available suppliers;
- Recommending steps for development of similar research in future.

There is multiple scientific-practical contribution of performed research. Firstly, the development of the methodological framework for the selection of proper supplier involves adjustment of the criteria to enterprise needs. Secondly, theoretical contribution of research could be seen in IFS development appropriate to used methods. Thirdly, the practical contribution of the research assumes the provision of guidelines for enterprises towards selection of "green" packaging suppliers. Fourth, research will serve as the base for development of new approaches for selection of suppliers in further research. Fifth, derived research results will support agri-food enterprises to develop sustainable practices within the supply chain as well as in the entire business.

Literature review

Process of literature review will be focused on few segments, such are: the impact of packaging on environment and human behaving, selection of packaging suppliers, or the use of MCDM methods in selecting adequate packaging and packaging suppliers.

There are several researches that observe the impact of packaging for food products on environment. Some of them have been made retrospection of impacts of packaging on environment in case of online sale [20; 23; 36], while others were turned to investigation in use of nanocellulose as alternative to synthetic packaging films [1; 13; 30], or use of different sensors in packaging due to monitoring the quality of food products, while supporting the recycling processes [17; 63; 85]. More specific, some researches were investigated the use of hydrogels as a valuable sensor in packaging the food products [12; 70; 83]. Some researches have been observed how ecological („green") packaging affects the consumers due to food products purchasing [27; 53; 57], while some of them were focused to impacts of plastic used in food packaging in order to develop strategic approaches to mitigate negative characteristics of plastic on environment [16; 34; 50]. So previous initiate researches considering the issues of plastic packaging for food products from the side of consumers and level of consumers involvement in plastic packaging recycling [82], or systematization of knowledge related to problems occurred in plastic packaging recycling in food sector [22], and difficulties occurred in running sustainable business due to use of plastic packaging for food products [74]. There were also performed certain literature reviews related to „greening" of packaging due to decrease in its impact on environment [41; 69; 80]. In line to previously mentioned scientific references there could be underlined that packaging generally has very strong impact on environment, while its decreasing requires deep awareness and large efforts form overall society.

Otherwise, there were certain research based on MCDM methods use related to supplying of packaging, such is research focused on packaging suppliers for shoe box when was applied DEMATEL (Decision-Making Trial and Evaluation Laboratory), ANP (Analytic Network Process), and WZOGP (Weighted Zero-One Goal Programming) methods [26], or drawing attention to the fact that implementation of QMS (quality management system) and selection of suppliers for packaging and raw materials in meat processing could be key factor affecting the quality and safety of final products [32]. In other research there was selected the packaging suppliers (on the example of the sector of beverage in Pakistan) underlying the implementation of Industry 4.0 concept, when were used FUCOM (Full Consistency Method), MULTIMOORA (Multi-objective Optimization Based on Ratio Analysis with the Full Multiplicative Form) and ODT (Ordinal Dominance Theory), [3], while other research summarized all MCDM methods generally used for supplier selection under industry 4.0 concept [65]. Some research was linked to packaging suppliers and their impact on cutting of packaging costs. For that purpose, targeted programing and ANP and DEMATEL methods have been used [25]. Through other research was made global selection of packaging suppliers required for food packaging due to strivings for reduction of costs occurred in functioning of supply chain [40]. In previous works, certain methods were used to select an adequate sustainable supplier. [81] [84] [9] Some of them were also applicable in the food

industry. On that occasion, they used their fuzzy variant. [2] [24] [29].

Based on made literature review, there can be noticed just few researches focused on selection of „green" packaging suppliers using the MCDM, so this research tried to fill some research gaps. Before all, performed research covers research gap on „green" packaging supplier selection based on MCDM methods, as just very few researches have been done in recent period towards this topic. Secondly, performed research is providing methodological guidelines regarding the preselected criteria that could be used in subsequent research. Third, by the development of intuitionistic fuzzy approach, there will be used some relatively new methods that have not been previously used in this form, expecting their contribution to the development of applied approach in practice. Fourthly, performed research will be also connected with certain postulates of the circular economy, while it will describe one more way how the selection of packaging suppliers can contribute to the improvement of environmental protection activities.

MATERIALS AND METHODS

During the beginning of 80' of the XX century, in order to include uncertainty and insecurity in decision-making processes and procedures, there was developed Intuitionistic Fuzzy Set (IFS) by the Atanassov [6]. Up to current time procedure is tested and widely used in many sectors of economy [15; 18; 19; 43; 75].

Contrary to classic fuzzy theory, where each element of the set has a membership function $(\mu_A(x))$ IFS considers both degree of membership $(\mu_A(x))$ and non-membership $(v_A(x))$ of the set of elements *A*, as well as degree of uncertainty $(\pi_A(x))$. According to that, IFS of set *A* is defined as:

$$A = \{(x, \mu_A(x), v_A(x)) \mathrm{I}\ x \in X\} \quad (1)$$

While the degree of uncertainty $(\pi_A(x))$ is defined as:

$$\pi_A(x) = 1 - \mu_A(x) - v_A(x) \quad (2)$$

IFS is applied when there is uncertainty, subjectivity and insecurity in the available data set which underlies the decision-making process [68]. On the example of selection of „green" packaging supplier, it is very difficult to assess the qualitative criteria, so there is always a certain level of uncertainty within the evaluation. Besides, mentioned evaluations are purely subjective, while there is uncertainty in decision making. Therefore, IFS approach was chosen for performed research. Basic operations with IFS are defined by Atanassov [6], including:

$$A \cap B = \{x, \min(\mu_A(x), \mu_B(x)), \max(v_A(x), v_B(x), \mathrm{I}\ x \in A\} \quad (3)$$

$$A \cup B = \{x, \max(\mu_A(x), \mu_B(x)), \min(v_A(x), v_B(x), \mathrm{I}\ x \in A\} \quad (4)$$

$$A.B = \{x, \mu_A(x).\mu_B(x), v_A(x) + v_B(x) - v_A(x).v_B(x), \mathrm{I}\ x \in A\} \quad (5)$$

$$A + B = \{x, \mu_A(x) + \mu_B(x) - \mu_A(x).\mu_B(x), v_A(x).v_B(x), \mathrm{I}\ x \in A\} \quad (6)$$

$$A - B = \{x, \min(\mu_A(x), \mu_B(x)), \max(\mu_B(x), v_A(x), \mathrm{I}\ x \in A\} \quad (7)$$

For evaluating the importance of preset criteria, while to select adequate suppliers according to these criteria, the same linguistic terms were used (Table 1).

Table 1. Linguistic terms for assessing the criteria importance and supplier's selection

Ling. terms	Abbreviation	IFNs
Extr.-good	E G	[1.00, 0.00]
Very very- good	V V G	[0.85, 0.10]
Very -good	V G	[0.80, 0.15]
Good	G	[0.70, 0.20]
Med.- good	M G	[0.60, 0.30]
Fair	F	[0.50, 0.40]
Med.- bad	M B	[0.40, 0.50]
Bad	B	[0.25, 0.60]
Very- bad	V B	[0.10, 0.75]
Very very -bad	V V B	[0.10, 0.90]

Source: [31].

In order to enable applying of the IFS in decision-making process, firstly the Intuitionistic Fuzzy Numbers (IFN) have to be transformed into ordinary numbers, while some classical methods will be then applied. The steps for IFN transforming are [31]:

Step 1. Determining the importance of decision maker (DM)
Step 2. Evaluation of DMs with grades presented in Table 1.
Step 3. Forming the aggregate decision matrix for IFN. Mentioned matrix is defined as
$\check{R} = \left[\check{A}_{m\alpha}\right]_{nxk}$
Step 4. Determining IFN positive ideal solution (τ^{+}) and negative ideal solution (τ^{-})
Step 5. Determining the measure of distance, by defining the positive (δ_m^{+}) and negative distance (δ_m^{-})

$$\delta_m^{+} = \sqrt{\left(\mu_{\check{A}_m} - \tau^{+}\right)^2 + \left(v_{\check{A}_m} - \tau^{+}\right)^2 + \left(\pi_{\check{A}_m} - \tau^{+}\right)^2} \quad (8)$$

$$\delta_m^{-} = \sqrt{\left(\mu_{\check{A}_m} - \tau^{-}\right)^2 + \left(v_{\check{A}_m} - \tau^{-}\right)^2 + \left(\pi_{\check{A}_m} - \tau^{-}\right)^2} \quad (9)$$

Step 6. Calculating the Closeness Coefficient (CC)

$$CC_m = \frac{\delta_m^{-}}{\delta_m^{+} + \delta_m^{-}} \quad (10)$$

Step 7. Forming the decision-making matrix, as a last step in IFS transformation in ordinary crisp numbers.
First step in any MCDM analysis is determining the weight of criteria. In this research for weights determining has been used DiWeC (Direct Weight Calculation) method. This method was used in several researches, but it has been named, while defining of all method steps was done by Puška and associates [59]. Method belongs to the group of simplest methods for subjective determining of criteria weights. It follows normalization of aggregate criteria evaluation. Steps of method applying are:
Step 1. Evaluation of criteria importance by the DM
Step 2. Appliance of the IFN transformation into the crisp numbers and forming the decision matrix
Step 3. Aggregating the grades per criteria, i.e. summing the all grades for certain criteria

$$v_j = \sum_{j=1}^{n} x_j \quad (11)$$

Step 4. Calculating the weights of criteria

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \quad (12)$$

After determining the weights of individual criteria, there has to rank the suppliers according to previously given ratings by the DM. In practice, there are many methods that can be used for ranking the suppliers. In this research, the CORASO (COMpromise Ranking from Alternative SOlutions) method was chosen. This is a newly developed MCDM method that ranks the available alternatives due to solution alternatives, which represent the maximal and minimal values of alternatives for individual criteria. The CORASO method was used in order to propagate its application in practice, as in some of previous research of Puška et al. [58] there was demonstrated that method could give similar results to other alternative ranking methods. The steps of the method are:
Step 1. Evaluation of alternatives by selected criteria
Step 2. Appliance of IFN transformation into the crisp numbers and forming the decision matrix
Step 3. Normalization of decision matrix

$$n_{ij} = \frac{x_{ij}}{\max x_j}; \text{ for benefit criteria} \quad (13)$$

$$n_{ij} = \frac{\min x_j}{x_{ij}}; \text{ for cost criteria} \quad (14)$$

Step 4. Determining the alternative solutions
Step 5. Weighting

$$v_j = w_j \cdot n_{ij} \quad (15)$$

Step 6. Forming the aggregate values

$$S_j = \sum_{i=1}^{n} \tilde{v}_j \quad (16)$$

Step 7. Deviation form alternative solutions

$$R_j = \frac{S_j}{S_{j\,max\,AS}} \quad (17)$$

$$R'_j = \frac{S_{min\,AS}}{S_j} \quad (18)$$

Step 8. Results defining for CORASO method

$$Q_i = \frac{R_j - R'_j}{R_j + R'_j} \quad (19)$$

Case study "Farm Land" enterprise

The enterprise "Farm land" is one of the newly established but promising legal entities engaged in agri-food production at national level, located in the Brcko District, Bosnia and Herzegovina. Striving to establish a recognizable brand on the market, enterprise have been decided to use “green” (environmentally friendly) packaging, while distancing itself from the competition. For procuring “green” packaging there are identified ten possible suppliers on the market, from whom the enterprise could purchase needed input. As it wants to improve its business, enterprise is decided to identify which of these ten suppliers

would be the most suitable for establishing a long-term cooperation. Therefore, selected supplier has to meet certain criteria. Initially, enterprise has selected five decision makers (DM), i.e. its employees who will evaluate the importance of predefined criteria, and then preselected suppliers. These DMs are selected according to their experience, as all of them had to have at least ten years of experience in agri-food production, specifically in relations with suppliers.

The criteria selected by experts, or decision-makers, at one of the previous meetings were of an economic and environmental nature. In order to make evaluation procedure easier, there was decision to select just ten criteria. Each of the DMs proposed certain criteria, while in total there was collected 23 criteria. Explaining the importance of each criteria by DMs, list with criteria was gradually shortening (by joint DMs decision), until finally list of ten criteria were selected, as they fit the best preset business goals of the "Farm land" enterprise (Table 2).

Table 2. Criteria for selection of "green" packaging supplier

Id	Criteria	Description	Reference
C1	Packaging quality	Complying the quality standards in terms of basic functions of packaging	[32; 53; 80]
C2	Packaging price	Value paid for packaging as ratio between the packaging costs and value	[22; 32; 53; 82]
C3	Delivery date	Supplier's capability to deliver the products on time and in volume that overlaps with enterprise need	[3; 32; 83]
C4	Reputation	Current supplier's reputation	[3; 82]
C5	Innovativeness	Possibility of supplier to adjust the requests and offer innovated packaging	[3; 80]
C6	Ecological certificate	Possession of ecological certificates and their usability in practice	[3; 32]
C7	Waste management	Practices oriented to decrease in volume of waste during the common business activity, or reuse policies	[22; 53; 80; 82]
C8	Bio-degradability	Capability of packaging material to decompose in nature without negative environmental impact	[22; 53; 80]
C9	Ecological material	Use of environmentally friendly materials that do not leave, or leave so shallow environmental footprint	[3; 20; 80]
C10	Recycling the packaging	Possibility to easily recycle the packaging material if it is not bio-degradable	[20; 22; 53; 80; 82]

Source: Developed by authors.

After defining the criteria that will serve for reconsideration of available suppliers of „green" packaging, DMs have been evaluated the importance of each criteria, while evaluated the preselected suppliers according to predefined criteria. In order to facilitate the selection process, there was used the same value scale to determine the criteria importance and to evaluate suppliers. Besides, construction of used linguistic terms, Table 1 has allowed DMs not to think about criterion's types, what additionally made their work easier. Based on the preselected criteria and suppliers, there was created the adequate questionnaire, while distributed to all DMs. After completing the questionnaire, gained datasets were prepared for further MCDM analysis. Further suitability of available suppliers for long-term contracting was done by the use of IFS, where the DiWeC method was applied to determine the importance (weight) of predefined selection criteria, while CORASO method was performed to rank the available suppliers that meet initially set criteria.

In order to confirm the derived research results, or to determine which criterion causes the largest effects on process of adequate supplier selection, a sensitivity analysis was additionally performed, i.e. there was determined the impact of certain criteria on the final ranking of suppliers.

RESULTS AND DISCUSSIONS

Research results

Determining which of available suppliers have and offer the most suitable characteristics in line to enterprise's needs, or to determine which supplier is the best option for long-term cooperation with the enterprise "Farm Land", initially there has to be determined the importance (weight) of each individual criterion used in supplier's assessment. Mentioned requires expert evaluation of preselected criteria by linguistic terms (Table 3).

Table 3. Importance of criteria according to DM's evaluation

No.	Criteria	DM1	DM2	DM3	DM4	DM5
C1	Packaging quality	VVG	VVG	EG	VVG	EG
C2	Packaging price	VG	VG	VG	G	G
C3	Delivery date	G	G	VVG	MG	VG
C4	Reputation	VVG	MG	VG	VVG	G
C5	Innovativeness	VG	F	G	VG	MG
C6	Ecological certificate	EG	VVG	EG	EG	VVG
C7	Waste management	VVG	VG	VVG	VVG	VG
C8	Bio-degradability	EG	EG	VVG	EG	VVG
C9	Ecological material	EG	VVG	EG	EG	VVG
C10	Recycling the packaging	VVG	VG	VG	VVG	VG

Source: Developed by authors.

Later, it is transformed into the IFS, while degree of uncertainty will be determined. For example, the linguistic term VVG (very very good), as the most represented, will be transformed into [0.85, 0.10], while based on this, the degree of uncertainty has been calculated as: 1 - 0.85 - 0.10 = 0.05. In same way there will be transformed other values, but with the use of membership functions (Table 1).

The next step in this simplified methodology is to determine the average values for all IFS parameters (Table 4).

Table 4. Calculations by DiWeC method

no.	μ	N	Π	δ+	δ-	CW	W
C1	0.910	0.060	0.030	0.112	1.309	0.921	0.108
C2	0.760	0.170	0.070	0.302	1.128	0.789	0.093
C3	0.730	0.190	0.080	0.340	1.093	0.763	0.090
C4	0.760	0.170	0.070	0.302	1.128	0.789	0.093
C5	0.680	0.240	0.080	0.408	1.023	0.715	0.084
C6	0.940	0.040	0.020	0.075	1.344	0.947	0.111
C7	0.830	0.120	0.050	0.214	1.211	0.850	0.100
C8	0.940	0.040	0.020	0.075	1.344	0.947	0.111
C9	0.940	0.040	0.020	0.075	1.344	0.947	0.111
C10	0.820	0.130	0.050	0.228	1.197	0.840	0.099
					sum	8.508	

Source: Developed by authors.

On the example of criterion C1 – Packaging quality, it looks as:

$\bar{\mu}_1 = \frac{0.85+0.85+1+0.85+1}{5} = 0.910; \bar{v}_1 = \frac{0.10+0.10+0.00+0.10+0.00}{5} = 0.060;$

$\bar{\pi}_1 = \frac{0.05+0.05+0.00+0.05+0.00}{5} = 0.030$

In same manner there will be calculated the average value for other criteria. Then, the measures of distance are determined as they are required for calculating the positive and negative distances. For example, for criterion C1, it looks like as:

$\delta_1^+ = \sqrt{(0.910-1)^2 + (0.060-0)^2 + (0.030-0)^2} = 0.112$

$\delta_1^- = \sqrt{(0.910-0)^2 + (0.060-1)^2 + (0.030-0)^2} = 1.309$

At the end, there was calculated the Closeness Coefficient under previously defined procedure:

$CC_1 = \frac{1.309}{0.112 + 1.309} = 0.921$

Then, using derived coefficient the value of weights was determined, i.e. each individual coefficient was divided by the sum of all coefficients. On example of criterion C1, calculating process could be presented as:

$w_1 = \frac{0.921}{8.508} = 0.108$

According to DM's evaluations, it is obvious that three criteria had been marked with the same importance: C6 - Ecological certificate, C8 – Biodegradability, and C9 - Ecological material. Frankly, importance of these criteria was somehow expected, since in focus was selection for supplier of green packaging. Mentioned criteria are followed by C1 – Packaging quality, what was also expected.

After determining the importance of criteria, in next step, there was done the ranking of preselected suppliers. As in case of determination of criteria importance, initially was done the evaluation of alternatives by the use of preset criteria and linguistic terms (Table 5.).

Table 5. Evaluation of suppliers by DMs

DM1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Supplier 1 (S1)	VG	MG	G	VG	G	VVG	VG	VVG	VVG	VG
Supplier 2 (S2)	VVG	F	MG	VVG	VG	VG	G	VG	VG	G
Supplier 3 (S3)	EG	G	VG	EG	VVG	EG	VVG	EG	EG	VVG
Supplier 4 (S4)	G	G	MG	G	MG	G	G	G	G	G
Supplier 5 (S5)	MG	VG	G	MG	MG	MG	MG	MG	MG	MG
Supplier 6 (S6)	VG	MG	G	VG	G	VG	G	VG	VG	G
Supplier 7 (S7)	VVG	MG	VG	VVG	VG	VVG	VG	VVG	VVG	VG
Supplier 8 (S8)	G	G	MG	G	MG	MG	MG	G	G	MG
Supplier 9 (S9)	VVG	G	VG	VVG	VG	VVG	VG	VVG	VVG	VG
Supplier 10 (S10)	VG	MG	G	VG	G	VG	G	VG	VG	G
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
DM5	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Supplier 1 (S1)	VG	MG	G	VG	G	VVG	VG	VVG	VVG	VG
Supplier 2 (S2)	VVG	F	MG	VVG	VG	VG	G	VG	VG	G
Supplier 3 (S3)	EG	G	VG	EG	VVG	EG	VVG	EG	EG	VVG
Supplier 4 (S4)	G	G	MG	G	MG	G	G	G	G	G
Supplier 5 (S5)	MG	VG	G	MG	MG	MG	MG	MG	MG	MG
Supplier 6 (S6)	VG	MG	G	VG	VG	VG	G	VG	VG	G
Supplier 7 (S7)	VVG	MG	VG	VVG	VG	VVG	VG	VVG	VVG	VG
Supplier 8 (S8)	G	G	MG	G	MG	MG	MG	G	G	MG
Supplier 9 (S9)	VVG	G	VG	VVG	VG	VVG	VG	VVG	VVG	VG
Supplier 10 (S10)	VG	MG	G	VG	G	VG	G	VG	VG	G

Source: Developed by authors.

The further procedure is similar to this active in the DiWeC method, except that a Closeness Coefficient is calculated for each criterion. Using this procedure, a summarized decision matrix is formed (Table 6).

Table 6. Aggregate decision-making table

no.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Supplier 1 (S1)	0.772	0.645	0.703	0.821	0.741	0.869	0.821	0.850	0.850	0.789
Supplier 2 (S2)	0.840	0.549	0.645	0.850	0.789	0.821	0.741	0.789	0.789	0.703
Supplier 3 (S3)	0.921	0.741	0.821	0.947	0.869	1.000	0.869	0.947	0.947	0.869
Supplier 4 (S4)	0.684	0.741	0.645	0.741	0.645	0.741	0.703	0.703	0.703	0.703
Supplier 5 (S5)	0.607	0.821	0.741	0.645	0.645	0.645	0.645	0.645	0.645	0.645
Supplier 6 (S6)	0.772	0.645	0.741	0.789	0.772	0.789	0.741	0.805	0.798	0.703
Supplier 7 (S7)	0.840	0.645	0.821	0.850	0.821	0.869	0.821	0.850	0.850	0.821
Supplier 8 (S8)	0.684	0.741	0.645	0.741	0.645	0.645	0.645	0.703	0.703	0.645
Supplier 9 (S9)	0.840	0.741	0.821	0.850	0.821	0.869	0.821	0.850	0.850	0.821
Supplier 10 (S10)	0.772	0.645	0.741	0.789	0.741	0.789	0.741	0.789	0.789	0.703

Source: Developed by authors.

Later, based on that steps of the CORASO method are performed.

The mechanism of the CORASO method will be explained at the example of the first supplier (S1) and for the first criterion (C1).

First step is normalization, where at each criterion individual values are divided with maximal value in observed criterion.

$$n_{11} = \frac{0.772}{0.921} = 0.839$$

Further, alternative solutions have been determined.

There has be underlined that the maximum alternative solution is actually the maximal value of alternative for each criterion, while the minimum alternative solution is the minimal value of alternative for each criterion.

Then the weighting process has been done, when the normalized values are multiplied by the weights.

$v_1 = 0.108 \cdot 0.839 = 0.091$

In next step, the aggregate values are calculated, or for each alternative is determined the aggregate value (S_j), while the same is done for alternative solutions too (Table 7).

Then the level of deviation from alternative solutions are calculated, as well as the final values of the CORASO method are determined (Table 7).

$$R_1 = \frac{0.8729}{1.0000} = 0.8729;$$

$$R'_1 = \frac{0.7003}{0.8729} = 0.8023;$$

$$Q_1 = \frac{0.8729 - 0.8023}{0.8729 + 0.8023} = 0.0421$$

Table 7. Results gained by CORASO method

No.	S_j	R_j	R'_j	Q_i	Rank
Supplier 1 (S1)	0,8729	0,8729	0,8023	0,0421	4
Supplier 2 (S2)	0,8324	0,8324	0,8413	-0,0054	6
Supplier 3 (S3)	0,9909	0,9909	0,7067	0,1674	1
Supplier 4 (S4)	0,7776	0,7776	0,9006	-0,0733	8
Supplier 5 (S5)	0,7415	0,7415	0,9445	-0,1204	10
Supplier 6 (S6)	0,8376	0,8376	0,8361	0,0009	5
Supplier 7 (S7)	0,9080	0,9080	0,7713	0,0814	3
Supplier 8 (S8)	0,7539	0,7539	0,9290	-0,1041	9
Supplier 9 (S9)	0,9188	0,9188	0,7622	0,0931	2
Supplier 10 (S10)	0,8315	0,8315	0,8422	-0,0064	7
MAX AS	1.0000				
MIN AS	0.7003				

Source: Developed by authors.

Derived results are shown that the supplier S3 has the best indicators, followed by suppliers S9, and S7. Supplier S5 has the worst indicators based on DMs evaluation. So, the supplier S3 is the most suitable for the long-term contracting, while it could affect further business improvements of the „Farm land" enterprise.

Validation of gained research results and determining the impact intensity of certain criteria on ranking of suppliers is performed by sensitivity analysis. So, analysis aims to determine how much the change in criteria weights affects the ranking of available alternatives. Sensitivity analysis could be done in several ways [77]. In this research are applied two different methods of sensitivity analysis. The first one uses the weights obtained by the Simple Weight Calculation (SiWeC) method as was tested in some previous research [58]. Establishment of the scenarios for this analysis considers that individual criterion is reduced by 90% while other criteria are increased by 10%, keeping the overall sum of criteria weights approximately around one. So, the first scenario is formed as the weight of criterion C1 is reduced by 90%, while the other criteria (C2-C10) are increased by 10%. Then, the other scenarios are created in a similar way, with the weight being changed for the next criterion C2, C3, ... C10.

The second sensitivity analysis is performed independently of the gained weights for the observed criteria. Within this analysis there are created special scenarios when one of the criteria is favored, while the other criteria are given less importance. So, for example, to one of the criteria is given a weight of 0.28, while the other criteria are weighted with 0.08. In such a way, there are formed in total 10 scenarios, since there are 10 criteria in performed research.

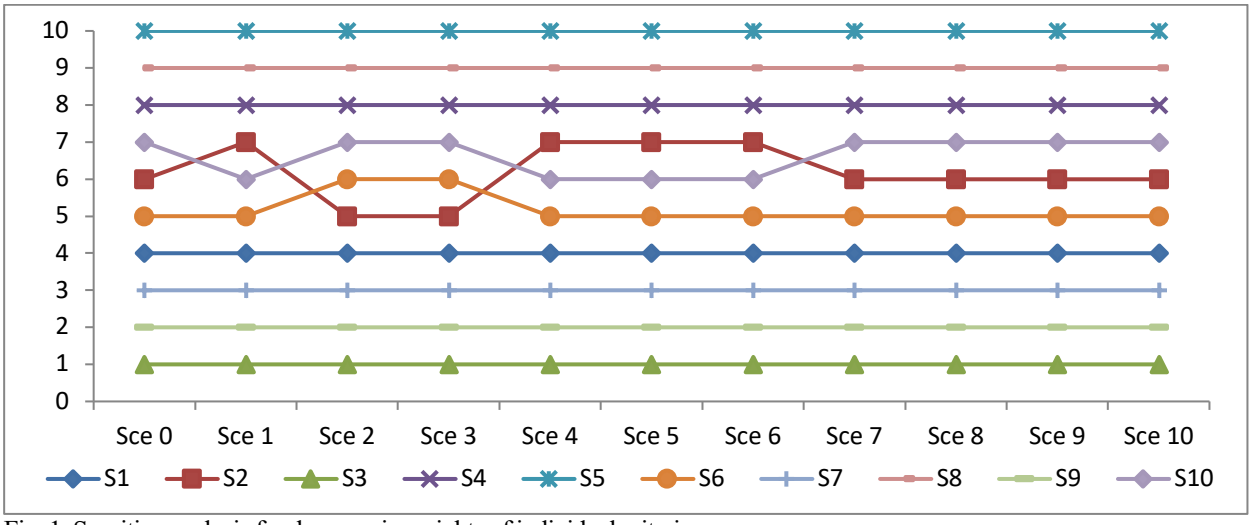


Fig. 1. Sensitive analysis for decrease in weights of individual criteria
Source: Developed by authors.

The results derived from the first sensitivity analysis (Figure 1) show that the ranking order of the first four suppliers has been remained the same, as well as for the three worst ranked

suppliers. Meanwhile, for suppliers ranked from fifth to seventh place, there came to change in ranking. Mentioned is caused by the fact that those three suppliers had similar ratings, so small change in weight of criteria could affect their final ranking. If supplier S6 is observed, it has changed its ranking order in two scenarios (Scenarios 2. and 3.). That was caused as supplier S6 had better values for criteria C2 and C3 compared to supplier S2. Due to decrease in importance of these two criteria, supplier S2 had a better ranking order than supplier S6. In the same way could be explained other changes in supplier's ranking.

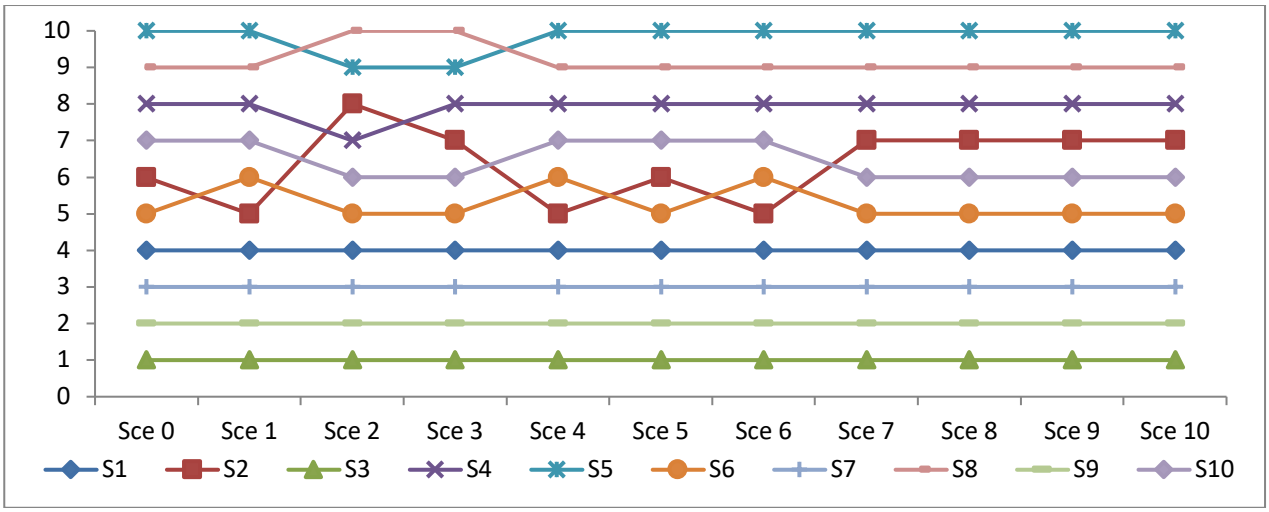


Fig. 2. Sensitive analysis for giving larger importance to individual criteria
Source: Developed by authors.

By observing both images, it can be seen that the ranking order of these three suppliers, that changed the places in the first analysis, is actually inverted. A supplier that in certain scenario was better in the first analysis found itself worse in the second analysis. Of course, in second analysis comes to minor deviations, as the initial weight of criteria was not used.

Such a ranking was somehow expected, as in the first analysis the individual value of weight of certain criterion decreased, while in the second analysis the value of same criterion has increased. If there comes that certain supplier is better in the second analysis, that means it had better values for certain criterion compared to another supplier.

Performed sensitive analysis are shown that previously established supplier's ranking remains the same, confirming the derived results and conclusion that the supplier S3 sounds as the best alternative for long-term contracting.

Discussions

For business venture of any enterprise suppliers have huge importance [48]. In practice, there are not too many enterprises that succeed to complete its overall business process. For this reason, they have to purchase certain inputs from suppliers, whether it is raw material, services, semi-finished products, packaging material, etc. [76]. At agri-food products, especially at agricultural products, the product itself does not pollute or leave so shallow footprint in environment, while the packaging of mentioned products usually has negative effects on environment [3; 11]. According to mentioned, enterprise "Farm Land" strives to acquire environmentally acceptable packaging in order to distance itself from competition. Besides, in this way it tries to improve its brand, providing more value to consumers than they expect [35].

Research was performed with the goal to select proper green packaging supplier that will serve as long-term cooperator of the enterprise "Farm Land". Process was supported by adequately developed methodology, while criteria selection for supplier assessment had strong environmental tone. Research considers 10 predefined criteria for observing economic and environmental dimensions of potential suppliers. So basically, there was done selection of green supplier [62], that delivers green packaging. So, research additionally underlines environmental importance that food packaging should be generally green,

without impact on environment and human health. By research was once again touched the global problem of plastic waste or packaging that is non-degradable and not recyclable [22; 86].

Selecting the most optimal supplier of „green" packaging, as potential long-term partner of the enterprise "Farm Land", requires defining five DMs who will assessed the preset selection criteria and preselected suppliers. The IFS approach was used for determining the criteria importance and ranking the suppliers. The reason why this approach was used, while not the usual fuzzy approach, is the fact that DMs are not always in position to have all necessary information required for decision making. Therefore, there always exists certain level of uncertainty in decision making process. So, unlike classic fuzzy sets, IFS insert this uncertainty into IFN, while enabling proper decision.

Results derived from this approach applying (including DiWeC method) have been showed that, according to DMs opinion, the most important criteria are ecological certificates (environmental friendliness of packaging), biodegradability, use of ecological materials and quality of packaging. In line with mentioned, the focus in process of selecting suppliers was on their products. Of course, besides aspect of "greening", there should be also required the basic function of packaging, its ability to preserve the agri-food products. To other assessed criteria were given a lower importance, for example the weight of innovation criteria is for 25% less than the weights of the most important criteria. During the ranking of suppliers by the CORASO method, derived results have been showed that supplier S3 has the most desired characteristics. According to the performed sensitivity analysis, i.e. changing the weights of observed criteria, there are concluded that DMs generally agreed with the assessed criteria for the top four suppliers, as their ranking order does not change due to changes in the weight of the criteria. So, validation shows correctness of gained results in previously selected supplier for the „Farm Land" enterprise. Establishing of long-term cooperation between the legal entities could be the win-win situation for both of them.

Results of performed sensitivity analysis have been verified the previously gained results by CORASO method. Wherever was small difference between the observed suppliers after appliance of CORASO method, there were later come to change in ranking during the sensitivity analysis. Besides, results under CORASO method could theoretically range from minus one (-1) to man (1). If gained results are closer to one, they show greater dominance of certain alternative over others, or if gained results are closer to minus one, they show how much worse are the results of certain alternative than others. In this way derived results from CORASO method could be used, due to examine what alternative and for how much is better than other alternatives.

Research implications

Performed research indicated significant implications on theoretical and practical development of the "green" packaging issue. Initially, research requested development of relevant methodological frameworks used for selecting potential suppliers. Preselected criteria have strong environmental focus, i.e. its considered ecological dimension of packaging, as packaging have much expressed impact on environmental cleanness than agri-food products. So, from supplier is expected to boost the environmental aspect of enterprise business sustainability. Further, research implication is in applying and testing certain elements of IFS methodology. By purpose, although specific, methodological approach was simplified, striving to enable wider application of used methods in practice. Efforts have been directed in inclusion of uncertainty and insecurity in decision-making process, while to make their transformation into some classic approach that uses crisp values. In this way, decision-making activity is facilitated even for those DMs who have no deep prior knowledge about used MCDM approach. By applying the CORASO method, there are given certain indications for further development of this method, i.e. mentioned method is newer method and so far, it has been used just in fuzzy and crisp form. Using this method at IFS strongly contributes to its further theoretical and practical development. One of the most important research implications is tendency to apply sustainability concept in certain agri-food enterprise in its overall cycle of business. In this process supplier has crucial role as enterprise is buying several inputs from him, including packaging. Avoiding the economic trap, „garbage in - garbage out",

what could endanger the sustainability even survival of enterprise, mutual correspondence has to be based on trust. So, (un)consciously supplier supports building and keeping the business sustainability at enterprise.

Limitations and further research steps

Research has certain limitations that have to be exceeded in upcoming period. Limitations are mostly turned to the appliance of criteria for supplier's selection. Previously was mentioned that initially 23 criteria were identified that could be used in selection of adequate supplier. But, it is so hard to identify and use unified all criteria with potential impact in certain research.

Therefore, in future research, as many criteria and as many experts as possible should be involved in research in form of preliminary activities. After grouping of all criteria by their specificities, while determining which of them affect the most the process of suppliers' selection, there will be done final selection of criteria that will be used in research. This process could also facilitate performing of some future research on same or similar issue. Besides, research limitation could be number of DMs (respondents), due to the fact that enterprise „Farm Land" belongs to the group of legal entities with a several employees involved in decision making process. Option could have been involvement of external experts, but in the end, by the economic logic, they cannot be the part of final decision, as it has to be made by enterprise management. The use of IFS can be also characterized as research limit, as there are several other approaches appropriate for decision-making. Therefore, in future research, available approaches could be compared, with development of certain guidelines for presenting available approach, while suggesting to which situation they fit the best.

CONCLUSIONS

Performed research was oriented to examining suppliers of "green" packaging, as a part of enterprise (Farm Land) strivings to impact the reduction in its environmental footprint. Enterprise is trying to build a competitive brand. Enterprise marketing logic was to offer recognizable products by applying "green" (environmentally friendly) packaging. Therefore, it requires long term cooperation with reliable local supplier of "green" packaging. Selection of adequate supplier was based on combination of preselected economic and environmental criteria. Besides, IFS approach was applied, trying to incorporate uncertainty in decision making. Derived results (based on DiWeC and CORASO methods) have directed the research focus and final decision to final product (quality and environmental suitability of packaging). Opposing the preselected criteria and characteristics of available suppliers, as the best possible solution for the enterprise is underlined the supplier S3, expecting that after the establishment of mutual long-term cooperation, supplier would affect improvement of overall enterprise business sustainability.

Performed research gained following contributions:

- Establishment of methodological framework for selection of „green" packaging supplier.
- Use of "green" packaging at enterprise "Farm land" will support establishment of recognizable enterprise's brand, while to decrease the negative impact on environment.
- Supplier of „green" packaging will contribute to decrease of negative impact on environment in enterprise „Farm land".
- Simplified IFS approach was presented in order to promote its more frequent use in practice.
- There are established certain guidelines how could be improved ecological sustainability of the enterprise by adequate supplier selection and green packaging use.

Briefly, used methodology and criteria have been demonstrated one simple and flexible way for green packaging supplier selection, that has to be further developed in upcoming research.

ACKNOWLEDGEMENTS

Paper is a part of research financed by the MSTDI RS, agreed in decision no. 451-03-136/2025-03/200009 from 4.2.2025.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE INFLUENCE OF AGROECOLOGICAL CONDITIONS AND TECHNOLOGY ON QUALITY INDICATORS IN THE PLUM CULTIVARS 'ANNA SPÄTH' AND 'STANLEY' CULTIVATED IN THE SOUTH-EASTERN REGION OF ROMANIA

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Abstract

The fruit-growing sector in Romania faces continuous challenges related to climate variability, production efficiency, and market competitiveness, requiring farmers to adopt cultivars with high adaptability and profitability. This study analyzes the yield performance of two plum cultivars, 'Anna Späth' and 'Stanley', cultivated under the agroecological conditions of the Moara Domneasca Experimental Base, aiming to provide a scientific basis for economic optimization in fruit-growing farms. The data were collected during the 2024 production season, focusing on fruit yield per tree, biometric indices (fruit weight, height, diameters), physico-chemical traits (firmness, pH, soluble solids). The results indicate that 'Anna Späth' produced smaller but sweeter fruits, with an average weight of 16.5 g, mean height of 32.2 mm, and sugar content of 18.9% °Brix. In contrast, 'Stanley' recorded larger fruits, averaging 22.9 g in weight, 42.9 mm in height, and superior firmness (2.25 kgf/cm^2), though with a slightly lower sugar content of 16.5% °Brix. Morphological traits such as fruit diameters were consistently higher in 'Stanley', confirming its better structural quality and storage potential. These findings underline clear cultivar-specific differences, with 'Anna Späth' offering a sweeter profile, while 'Stanley' provides larger, firmer fruits more suitable for commercial markets. The findings support decision-making processes in farm management by identifying 'Stanley' as the most advantageous cultivar from an economic perspective, thus contributing to improved resource allocation and long-term sustainability in the Romanian plum sector.

Key words**:** *agroecological, fruit quality, climate resilience, farm management, plum cultivars*

INTRODUCTION

Fruit growing represents a strategic sector in Romania's agricultural economy, with plum (*Prunus domestica L.*) as the dominant species, accounting for nearly half of the orchard area and production value [12]. The adaptability of plum to diverse pedoclimatic conditions explains its prevalence, yet its economic role is increasingly challenged by climate variability, aging orchards, and market competitiveness [15,16].

The modernization of Romanian fruit farms requires the introduction of intensive orchard systems and cultivar-rootstock combinations that ensure higher yield stability, superior fruit quality, and improved profitability. Research has shown that the choice of rootstock significantly influences yield efficiency, fruit size, and adaptation to local environmental stresses [4]. Furthermore, breeding advances and the conservation of plum genetic diversity are essential for long-term sustainability, especially in the context of narrowing genetic bases in commercial production [14]. Usually

in Romania plum blooms in mid-April depending on weather conditions [1].

At the economic level, plum production is characterized by large fluctuations in profitability. Studies from Romania and neighboring regions emphasize that profitability depends not only on cultivar performance but also on technological investments, market orientation (fresh vs. processing), and value-added products such as dried plums [3].

In Turkey and the Balkans, cost-benefit analyses confirm that cultivars like 'Stanley' combine high yield potential with relatively low production costs, making them more competitive in both domestic and export markets [17]; [8].

Recent experimental results also highlight the critical role of modern orchard management technologies: irrigation, fertigation, and pollination, in boosting productivity and economic returns.

Pollination alone accounts for up to 80% of fruit production value in Romanian orchards [11], while optimized fertilization and irrigation significantly enhance growth and yield in cultivars such as 'Stanley' [18].

Given these challenges and opportunities, the present study aims to compare the productive and economic performance of two major plum cultivars, 'Anna Späth' and 'Stanley', cultivated under the agroecological conditions of the Moara Domnească Experimental Base. Specifically, the research addresses the following questions: which cultivar rootstock combinations ensure superior yield efficiency and profitability? and how can these findings inform economic decision-making in Romanian fruit-growing farms?

MATERIALS AND METHODS

Location

The experiment was conducted at the Moara Domnească Experimental Base (Ilfov County, Romania), which belongs to the Research and Development Station for Fruit Tree Growing Baneasa(SCDP Baneasa), established in 2022 at the Moara Domneasca Experimental Station.

The site is characterized by a temperate-continental climate with mean annual temperatures of 10-11 °C and average annual precipitation of 550-600 mm.

The study area is dominated by soils of the Luvisols class, with reddish Preluvosolsas the predominant soil type Reddish Luvisols and Stagnosols are also found in the depressional areas and in the crovs [10].

The experimental orchard was irrigated using a drip irrigation system, with an application rate of 2 L/h per emitter, operated for 2 hours in the morning and 2 hours in the evening throughout the vegetation period.

The soil profile is dominated by a clay loam texture across all horizons.

Clay content ranges from 36.18% in the C horizon to 47.39% in the Bt horizon, while sand fractions (coarse and fine) remain relatively low.

The dust fraction is highest in the Ao/Bt horizon (56.28%), indicating significant textural differentiation.

Overall, the soil structure suggests good water retention but moderate aeration (Table 1).

Table 1. The granulometric composition of the soil (Experimental Base Moara Domneasca, 2019)

Horizon	Depth (cm)	Clay (%)	Coarse sand (%)	Fine sand (%)	Dust (%)	Texture
Ao	0-40	40.55	0.36	34.33	24.75	Clay loam
Ao/ Bt	41-53	41.63	0.52	21.54	56.28	Clay loam
Bt	54-200	47.39	0.37	27.59	30.34	Clay loam
C	Over 200	36.18	0.42	32.04	32.04	Clay loam

Source: SCDP Baneasa [13].

As shown in Table 2, the soil has a moderate humus content at the surface (3.26%), which decreases with depth, balanced cation exchange capacity, and a high degree of base saturation (78–88%).

Soil reaction varies from slightly acidic (pH 6.4) at the surface to alkaline (pH 8.3) in the C horizon, creating favorable conditions for plum cultivation, although additional nitrogen fertilization is required.

Table 2. Physical and chemical properties of the soil profile (Moara Domneasca Experimental Base, 2019)

Horizons / Properties	Ao	Ao/Bt	Bt	C
Humus (%)	3.26	1.87	1.0	1.0
Soluble Ca (mg / 100 g soil)	55	32	32	30
Hydrolitic acidity (meq)	2.8	2.04	1.72	0.18
Exchangeable Bases (meq)	22.6	23.62	26.28	-
Total cation exchange capacity (meq)	28.65	28.04	30.01	-
Degree of saturation in bases (%)	78.94	84.28	87.53	-
pH	6.4	6.6	6.8	8.3
Total N (%)	0.144	0.102	0.075	0.07
Soluble P (mg / 100 g soil)	50	40	40	30

Source: SCDP Baneasa [13].

Plant Material

Two plum cultivars, 'Anna Späth' (Photo 1), (origin: Germany, late ripening, high sugar content, mainly for processing) and 'Stanley' (Photo 2), (origin: USA, mid-late ripening, self-fertile, suitable for fresh consumption and drying), were evaluated. Trees were grafted on 'Mirobolan' (*Prunus cerasifera*) rootstock [9].



Photo 1. 'AnnaSpath' variety
Source: Original SCDPB Baneasa [13].

The most popular rootstock in the plum orchards from Romania is 'Myrobalan' seedling, which is very vigorous, incompatible with some cultivars, causes late bearing and intensive suckering [19].



Photo 2. 'Stanley' variety
Source: Original SCDPB Baneasa [13].

The selection of rootstock across countries is influenced by the plum species and cultivars cultivated, soil characteristics, cultivation intensity, and the applied harvesting methods [5].

Experimental design

The orchard was established according to a randomized block design with three replications for each cultivar rootstock combination. Each experimental plot contained a minimum of 10 trees, planted at a spacing of 4 × 3 m, corresponding to a density of approximately 833 trees/ha. Standard orchard management practices (soil tillage, fertilization, pest control, irrigation) were applied uniformly across all treatments.

Data collection

During the 2024 production season, fruit quality indices were evaluated for each cultivar. A random sample of 20 fruits at commercial maturity was collected per replication to determine average biometric traits (fruit weight, height, and diameters) and physico-chemical parameters (firmness, pH, and soluble solids content, °Brix).

The analyses were conducted in the laboratory of the Research and Development Station for Fruit Tree Growing Baneasa.

Fruit sugar content was determined with a Hanna Instruments HI 96800 digital refractometer, while pH was measured using a Hanna HI 700630 pH meter. Biometric parameters (height, small and large diameter) were recorded with a digital electronic caliper,

and fruit weight was measured on an XT620M balance.

Titratable acidity (citric acid content) was assessed with a Hanna Instruments fruit juice Minititrator (230V model).

Figure 1 shows the monthly variation of average minimum and maximum temperatures.

Winter months record the lowest values (down to -5.1°C), while July reaches the annual peak (39.4°C).

Transitional months display moderate values, reflecting a continental climate with cold winters and hot summers.

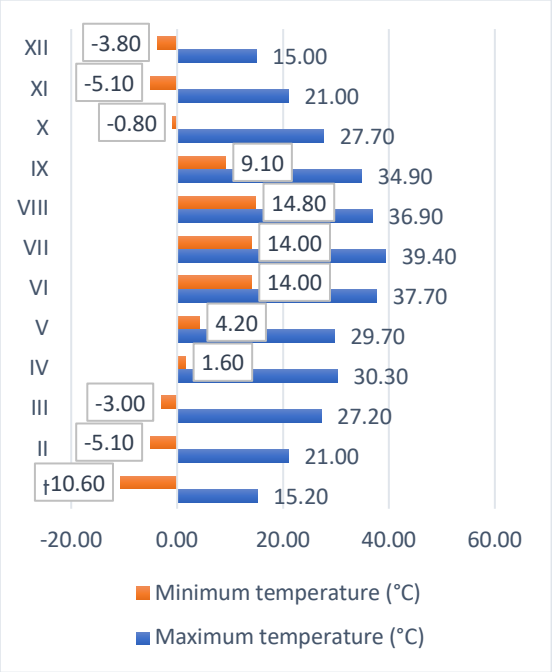


Fig. 1. Distribution of maximum and minimum temperatures in 2024.
Source: Moara Domneasca Meteorological Station [6].

Figure 2 illustrates monthly precipitation levels according to Moara Domneasca Meteorological Station [7].

The driest months are February (0.4 mm) and November (1.6 mm), while December records the highest value (119.2 mm). Spring and early summer show moderate rainfall (31-66 mm), highlighting an uneven distribution typical of continental climates.

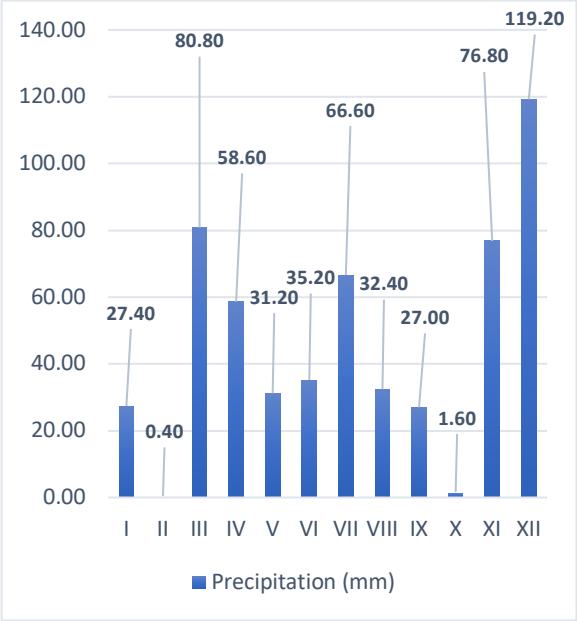


Fig. 2. Distribution of precipitation in 2024
Source: Moara Domneasca Meteorological Station [6].

In Table 3, the orchard management combined manual works (hoeing, fertilizer application, pruning, spraying, branch collection, grass cutting, irrigation) with mechanical works (transport, tractor spraying, mowing, soil tillage, equipment maintenance), ensuring efficient crop care and cost control.

Table 3. Technological works applied

No.	Manual works	Mechanical works
	Hoeing along the tree rows	Various transport operations
	Administered chemical fertilizers manually	Spraying the orchard (tractor sprayer)
	Removing dry/dead trees	Mechanical mowing
	Gathering branches into piles	Soil cultivation with rotary tiller (with sensor) along tree rows ×5
	Crown training and pruning	Tractor and equipment maintenance
	Spraying with knapsack sprayer	
	Preparing spraying solution	
	Operating the spraying machine	
	Grass cutting with trimmer (manual)	
	Operating the irrigation system	

Source: SCDP Baneasa Crop technological sheet [13].

RESULTS AND DISCUSSIONS

Inputs used in the plum tree technology

These inputs categories showed by Table 4 represent the essential items of expenditures that sustain orchard maintenance and production. From an economic perspective, fertilizers (chemical and organic) account for the main share of input use, while diesel fuel and lubricants reflect the mechanized operations applied. This structure confirms the dual nature of orchard technology, integrating both manual and mechanized practices, with a balanced distribution between energy, nutrition, and maintenance costs.

Table 4. Materials used in the crop technology

No.	Materials
1.	Diesel fuel
2.	Chemical fertilizers
3.	Oils and lubricants
4.	Spare parts
5.	Other unforeseen materials
6.	Organic fertilizers

Source: SCDP Baneasa Crop technological sheet [13].

Costs of inputs used in the plum tree technology

The cost structure from Table 5, highlights the predominance of manual works, which represent nearly half of the total expenses, followed by materials (fertilizers, fuel, spare parts) and mechanical works. This distribution indicates that, in young irrigated plum orchards, labor remains the main cost driver, while mechanization contributes comparatively less. Optimizing manual labor and improving mechanization efficiency could therefore enhance economic sustainability.

Table 5. Costs of materials used in the crop technology

No.	Category	2024 (RON/ha)
1.	Mechanical works	1,515.27
2.	Manual works	4,192.88
3.	Materials	3,625.50
Total		9,333.65

Source: The accounting documents of the unit [18].

Fruit quality parameters by plum tree cultivar

The comparative assessment of fruit quality parameters is presented in Table 6.

'Stanley' fruits demonstrated superior biometric and physical traits compared to 'Anna Späth'. 'Stanley' recorded higher fruit weight (22.91 g vs. 16.54 g), larger dimensions (height: 42.90 mm vs. 32.22 mm; diameters: 32.49 mm and 29.38 mm vs. 29.11 mm and 25.14 mm), and greater firmness (2.25 kgf/cm^2 vs. 1.23 kgf/cm^2). In terms of chemical composition, 'Anna Späth' had slightly higher soluble sugar content (18.88% vs. 16.48%) and a marginally higher pH (4.0 vs. 3.95), highlighting its sweeter profile, while 'Stanley' maintained better structural quality and marketability potential.

Table 6. Biometric and Physico-Chemical Indices of Plum Cultivars

	Anna Spath	Stanley
Weight (g)	16.54	22.91
Height [mm]	32.22	42.90
Diameter [mm]	29.11	32.49
Diameter [mm]	25.14	29.38
Firmness kgf/cm^2	1.23	2.25
pH	4	3.95
Sugar [%BRIX]	18.88	16.48

Source: Own data. Own calculations.

Losses were assessed as the difference between potential and marketable yield, being influenced not only by cultivar traits but also by climatic conditions; in 2024, irregular precipitation and high summer temperatures increased fruit drop and quality defects in 'Anna Späth', while 'Stanley's larger size and higher firmness helped reduce both field and post-harvest losses.

The evaluation of fruit quality in relation to chemical composition highlights contrasting strengths between the cultivars. 'Anna Späth', with its smaller fruit size (16.5 g) but higher soluble solids (18.9 °Brix), offers a sweeter sensory profile, favoring fresh consumption. In contrast, 'Stanley', characterized by larger fruit size (22.9 g), greater firmness (2.25 kgf/cm^2), and slightly lower sugar content (16.5 °Brix), is better suited for storage, transport, and processing. This correlation between biometric traits and chemical indices demonstrates that sweetness and marketability are inversely balanced, with 'Stanley' providing technological advantages and 'Anna Späth' emphasizing taste quality.

Distribution and marketing of plum production

The plum production obtained by Romania ensures the necessary consumption on the

domestic market and at the same time represents the raw material for the processing activity [2]. Regarding the preferences of Romanian consumers on the fruit market, plums, cherries, and berries are categories that are less commonly found in consumer choices, accounting for 3.5% (plums), 2.12%, and 2% (berries) of total fruit consumption [11].

The impact of price volatility on the processing sector

Fruits are among the most widely consumed horticultural products, used either fresh or processed into a variety of food items. The European Union (EU) action plan for the circular economy could be an effective strategy to reduce the level of waste and by-products generated during fruit processing. This plan is based on the reduction, reuse, recovery, and recycling of materials and energy, so as to enhance the value and consequently the useful life of products, materials, and resources in the economy [7].

CONCLUSIONS

The comparative assessment of 'Anna Späth' and 'Stanley' plum cultivars under the agroecological conditions of Moara Domneasca during the 2024 growing season revealed significant cultivar-specific differences. 'Anna Späth' was characterized by smaller fruits but higher soluble solids content (18.9 °Brix), conferring superior sweetness and suitability for direct consumption. In contrast, 'Stanley' exhibited larger fruits, enhanced biometric traits (fruit height and diameters), and markedly greater firmness (2.25 kgf/cm), features which ensure higher storage potential, transportability, and broader technological applicability.

Although the present findings reflect the early stage of orchard development, as the trees have not yet reached full maturity. Continuous maintenance and technological care remain essential to ensure long-term productivity and sustainability.

Collectively, these results underline the critical role of cultivar–rootstock interactions in determining both productive and qualitative performance, with 'Stanley' confirming its potential as a superior cultivar for sustainable plum cultivation under Romanian agroecological conditions.

ACKNOWLEDGEMENTS

This research was carried out with the valuable support of the SCDP Baneasa team, whose expertise and involvement greatly contributed to the implementation of the experimental activities. The work is part of the Tematic Plan on the Implementation of the "ASAS Strategy on Research-Development-Innovation in Pomology" for the period 2021-2027 coordinated by ICDP Pitești-Mărăcineni and the network of Pomology Research Stations. Specifically, it relates to Priority Area II: Pomological technologies with a favorable impact on the environment and rural development, under Subsection 2.1: Technological sequences for land preparation in the establishment of orchards, orchard cropping systems, and soil management systems through mechanized operations.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF CLIMATE CHANGE EFFECTS ON CASSAVA PRODUCTION IN NIGERIA

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Abstract

This study ascertained how climate change affects cassava production in Nigeria. The study was done based on a 60-year dataset covering rainfall, temperature, relative humidity, and sunshine duration from 1963-2022, using multiple regression models, unit root, and co-integration tests for assessment of these climate variables' influence on the yield of cassava. The results indicated that temperature had the most substantial positive effect on cassava production (β=28,422,368.77, p=0.000), followed by relative humidity (coefficient = 147,217.28, p=0.000) and rainfall (β = 22,111.27, p=0.034). Sunshine duration, however, showed no significant effect (p=0.892). The model's high R-squared value (0.705) supported its robustness, and diagnostic tests confirmed no issues with serial correlation or heteroskedasticity. These findings highlighted the vulnerability of cassava production to climate variability and suggested the need for adaptive measures to sustain agri-food system in Nigeria.

Key words: *climate change, cassava production, Nigeria, rainfall, temperature*

INTRODUCTION

One of the staple crops that is essential to Nigeria's agri-food system is cassava. It is a significant source of carbohydrates and gives millions of smallholder farmers a way to earn money and ensure food security [15]. With production areas spanning the country's central and southern regions, Nigeria is the world's largest producer of cassava [22], [20]. However, in the last few years, the consequences of climate change have become a significant issue in both the production of cassava and the agricultural sectors [19]. Long-term changes in the average temperature, normal rainfall patterns, and other climatic variables brought on by natural processes and human activity like burning fossil fuels and deforestation are referred to as climate change [12]. Agriculture is greatly affected by climate change since each crop has specific weather requirements for its efficient growth. Cassava, although very tolerant to hostile environmental conditions, does not exclude vulnerability to impacts caused by climate change. Changes in the amount of rainfall and temperature can directly impact its yield, pest prevalence, and soil conditions [14], [18].

Cassava production is very important in Nigeria for food and economic security, adding immense value to the livelihood of rural households [17, 15]. Drought tolerance is one of the strengths of the crop, though the changing climate brings more uncertainty concerning its productivity. For example, irregularity in the rainfall season affects water availability and therefore water use efficiency during planting and growth of the crop, yield and farmers' income [5]. Similarly, extreme heat may reduce the potential of cassava to produce at optimal levels [2]. The climate of Nigeria varies, with the South being humid because of the coastal regions and the North being semi-arid. Rising temperatures, more frequent extreme weather events, and a shifting rainfall pattern over the last few decades have all demonstrated it [10]. These are anticipated to persist into the future, and it is necessary to assess these developments in relation to important crops like cassava. Different studies show that climate change is most likely to

increase the occurrence of droughts, floods, and heatwaves in Nigeria [3].

The majority of earlier research from around the globe has shown how climate change affects agricultural output. For example, [2] discover that climate variability, particularly with regard to temperature increases and water availability, has a substantial impact on crop productivity in Nigeria. In the meantime, research on how climate change affects Nigerian agriculture's productivity with relation to staple crops like cassava has been conducted in [9] and [7]. Notwithstanding this growing corpus of research, it still seems unclear how exactly environmental factors like temperature, rainfall, relative humidity, and sunshine length impact cassava productivity in Nigeria over the long run.

The majority of the research tends to concentrate more on the broad effects of climate change on Nigeria's agri-food systems than on the special function of cassava, a crop that is both poor soil-tolerant and highly drought-tolerant [16]. While the works of [13], [6] and [18] suggested cassava as one of the crops that is suitable for climate adaptation, these studies have been mostly based on short-term assessments. This, therefore, makes the gap this study tries to address is very relevant concerning issues in detailed and long-term analysis of climate change effects on cassava production in Nigeria.

By addressing that gap, this study will help develop climate-smart agricultural methods and policies that will support cassava production even in the face of climate change.

MATERIALS AND METHODS

Nigeria, which lies between latitudes 4°N and 14°N off the equator and longitudes 3°E and 15°E of the Greenwich meridian, was the study's location. Legislatively, Nigeria is a democratic, secular country divided into 36 states, with Abuja as the Federal Capital Territory. Cassava is mainly grown in the Southern and Central Zones of the country prominently in States like Benue, Kogi, Edo, Delta, and Oyo where conditions are more favourable for its cultivation. These areas fall within the tropical and sub-tropical climates, having distinct wet and dry seasons. However, with the effect of climate change, there has been considerable change in the pattern of rainfall and temperature throughout the country. These States have become critically vulnerable to the unpredictable weather conditions of those zones traditionally known for cassava production.

Data Collection

A set of time series data were used which contained the mean annual temperature, relative humidity, rainfall, sunshine duration, and cassava production output from 1963 to 2022. Data were extracted from Food and Agriculture Statistics (FAOSTAT) and the Central Bank of Nigeria (CBN) database.

Data Analysis

The descriptive statistics of mean annual temperature, relative humidity, rainfall, and sunshine duration variations in Nigeria from 1963 to 2022 were used. In this regard, the series was subjected to a unit root test so that the time series data could check whether they were stationary or nonstationary. A co-integration test was conducted to study the long-run relationship among the variables. Multiple regression analyses were used to establish the effect of varied climate factors on the production of cassava.

Unit Root Test

The analysis began with a stationarity test to determine whether the variables were stationary and if the model specification was suitable. The regression equation used to assess stationarity, as described by [11] as cited by [21], is as follows:

$$\Delta lnCAS = \alpha_0 + \sum_{t-1}^{p} \alpha_1 \Delta lnRFL_{t-1} + \sum_{t-1}^{p} \alpha_2 \Delta lnTEMP_{t-1} + \sum_{t-1}^{p} \alpha_3 \Delta lnRH_{t-1} + \sum_{t-1}^{p} \alpha_4 \Delta lnSSD_{t-1} + \beta_1 lnRFL_{t-1} + \beta_2 lnTEMP_{t-1} + \beta_3 lnRH_{t-1} + \beta_4 lnSDD_{t-1} + U_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

The unit root problem was accessed through hypothesis as follows:

H0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ (the time series CAS has a unit root)

Ha: $\alpha_1 < 0$, $\alpha_2 < 0$, $\alpha_3 < 0$, $\alpha_4 < 0$ (the time series CAS has no unit root)

Where:

α_0= constant term

U_t =white noise

α_1- α_4 = coefficients of the first difference variables
β_1- β_4 = coefficients of the explanatory variables
p = lag length
CAS = Cassava production (metric tonnes)
RFL = Rainfall (millimetres)
TEMP = Temperature (°C)
RH = Relative humidity (percentage %)
SSD = Sunshine duration (hours)

Co-Integration Test

The Johansen maximum likelihood co-integration test was used to ascertain the variables' long-term association. As described by [11] as cited by [21], co-integration identifies long-run equilibrium between variables, this is shown below:

$$\Delta lnCAS_t = \alpha_0 + \beta_1 lnRFL_{t-1} + \beta_2 lnTEMP_{t-1} + \beta_3 lnRH_{t-1} + \beta_4 lnSDD_{t-1} + u_t \dots\dots\dots\dots$$

.....2

Multiple Regression Model

The multiple regression model is as specifiedd below:

$$CAS_t = f(RFL_t, TEMP_t, RH_t, SDD_t)$$

……..3

The regression model can further be specified in linear form as follows:

$$CAS_t = \beta_0 + \beta_1 RFL_t + \beta_2 TEMP_t + \beta_3 RH_t + \beta_4 SDD_t + U$$

…….....4

RESULTS AND DISCUSSIONS

Descriptive Statistics

The result in Table 1 shows the descriptive statistics summarizing variability and central tendencies related to cassava production and its associated climatic factors in Nigeria. On one hand, cassava production is highly concentrated, with a mean of over 28 million tonnes, and the difference between the minimum and maximum is large, which indicates considerable fluctuation over time. On the other hand, rainfall is similarly characterized by high means of 1,149.705 mm, with considerable variability that could be an influential factor in determining cassava yield. Meanwhile, other meteorological conditions, such as temperature, relative humidity, and sunshine duration, are relatively steady because their mean and median values are close, indicating stable conditions in general as also observed by [23].

Standard deviations further emphasize variability, especially in cassava production and rainfall. The standard deviation of cassava production is high, indicating high variability across the years, probably because of climatic or socioeconomic factors. Rainfall indicates a medium variation due to the value of its standard deviation-a result that could be impactful since cassava growth is sensitive to water. The lower variabilities in temperature, humidity, and duration of sunshine indicate very stable climatic conditions that are quite generally favourable to cassava production because most extreme values are few, disrupting such aspect of production.

Table 1. Descriptive statistics

Statistics	CAS	RFL	TEMP	RH	SSD
Mean	28152837	1149.705	27.089	57.626	6.251
Median	29656000	1160.655	27.110	57.386	6.237
Maximum	65350850	1335.280	27.860	61.770	8.800
Minimum	7783000	872.040	26.270	53.950	4.500
Std. Dev.	18341552	86.056	0.388	1.494	0.901
Skewness	0.468	-0.539	-0.208	0.268	0.419
Kurtosis	1.856	3.600	2.293	3.109	3.415
Jarque-Bera	5.460	3.805	1.679	0.749	2.186
Probability	0.065	0.149	0.432	0.688	0.335
Sum	1692847315.428	68982.286	1625.362	3457.567	375.049
Sum Sq. Dev.	19812475938624157.277	436932.771	8.888	131.656	47.866
Observations	60	60	60	60	60

Source: Made by authors based on Data Analysis, 2024.

There is a slight positive skewness of cassava production, indicating that the yield was extremely high in some years. The rainfall data have a mild negative skewness, with kurtosis just a little above 3, indicating a peaked distribution with extreme low values of rainfall. Temperature, humidity, and duration of sunshine have distributions near normal. The Jarque-Bera test results in confirming normality approximation for all climatic variables; this will further enable the analysis, such as regression modelling, for any assessment of their impacts on cassava yield. This analysis thus suggests that rainfall might be an important variable driving cassava production variability, whereas temperature, humidity, and sunshine provide relatively stable cultivation conditions over the observed period.

Trend of Climatic Variables and Cassava Production in Nigeria

The long-term trend in Nigeria's climate and cassava production is depicted in Fig. 1, which also demonstrates the sudden shifts in both variables between 1963 and 2022. According to the data set, Nigeria's cassava production increased from 7.8 million tonnes to nearly 60 million tonnes between 1963 and 2022. This probable long-term growth emanates from improved agronomic practices, government supports and initiatives for the crop, and farmers' adaptation to climatic conditions. However, periodic declines-most notably in the early 1980s, 2009-2010, and 2015 indicate sensitivity of this production to fluctuating climate and other external factors. While cassava production has been resilient, recent fluctuations might insinuate that emerging challenges are linked to the impacts of climate change on the staple crop.

The temperature is slowly rising from year to year; the average annual temperature increased from about 26.6°C in the early 1960s to over 27.5°C in recent years. Such a warming-up trend is in line with the global pattern promoted by climate change and thus may affect cassava physiology and yield. Cassava is normally resistant to moderate temperature increases, but very high temperatures or continuous rise may stress the plants, thereby reducing production. Indeed, slight cassava production has been seen during periods of temperature increases or variability, as in the early 1980s and 2000s, which suggests that temperatures could play a factor in its production.

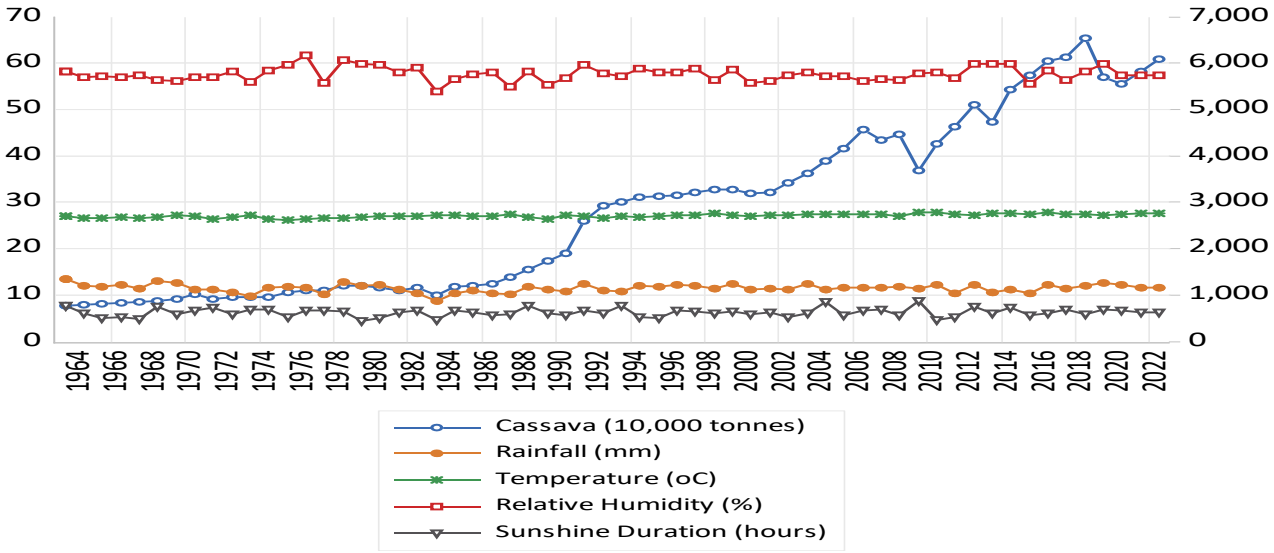


Fig. 1. Trend of climatic variables and cassava production in Nigeria
Source: Made by authors based on Data Analysis, 2024.

Other climate parameters such as relative humidity, rainfall, and sunshine duration vary from year to year and thus show a positive correlation with some aspects of production variation. For instance, rainfall is very inconsistent between years, and this may be reflected by poor production in dry years such as 1983 and 2010.

Variations happened in relative humidity and sunshine duration, and those would probably have effects on production through their influence on cassava growth and yield. These climatic factors are interrelated in such a way that they expose cassava producers in Nigeria to a myriad of challenges toward adapting to climate variability. With the persisting current climate movements of rising temperature and unpredictable rainfall patterns, cassava output may reach a breaking point beyond which adaptation measures have to be taken to sustain its productivity levels.

Unit Root Test

The data were subjected to Unit Root Tests, namely the Augmented Dickey-Fuller (ADF) Test, in order to deduce their stationarity and their order of integration for the annual data ranging from 1963 to 2022.

In this regard, results show in Table 2 that all the variables are integrated of order 1 (1st difference).

Table 2. Unit root test

Variable	Level difference	prob	1st diff	prob	Order of integration
CAS	0.372	0.980	-7.965	0.000	I (1)
RFL	-6.161	0.000	-12.879	0.000	I (1)
TEMP	-1.298	0.625	-11.145	0.000	I (1)
RH	-7.061	0.000	-13.868	0.000	I (1)
SSD	-7.287	0.000	-9.612	0.000	I (1)

Source: Made by authors based on Data Analysis, 2024.

Lag Order Selection Criteria

Table 3 displays the results for the selected lag order based on the criterion used. In this model, Lag 1 was chosen, as all selection criteria indicated a significant probability level of 5% at this lag.

Table 3. Lag Order Selection Criteria

Lag	Log L	LR test	Final prediction error	Akaike information criterion	Schwarz information criterion	Hannan-Quinn information criterion
0	-1538.44	NA	228473692158264915.382	54.156	54.335	54.225
1	-1403.36	241.719*	4803527916284735.649*	50.293*	51.369*	50.711*
2	-1386.4	27.374	6504193287561842.317	50.576	52.547	51.342
3	-1368.33	26.002	8741658392475216.853	50.819	53.686	51.934
* Shows lag order chosen by the criterion						

Source: Made by authors based on Data Analysis, 2024.

Cointegration Test

Table 4 results show that the null hypothesis (H_0) of no co-integrating equation is rejected, revealing at least one co-integrating equation at the 5% significance level.

Table 4. Cointegration Test

Cointegration Test				
Endogenous variables: CAS, RFL, TEMP, RH, SSD				
Johansen-Hendry-Juselius: Cointegrating				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	Prob.**
No. of CE(s)	Eigen value	Statistic	Critical Value	Critical Value
None *	0.602	118.057	69.819	0.000
1* at most	0.462	64.667	47.856	0.001
2 at most	0.246	28.688	29.797	0.067
3 at most	0.189	12.300	15.495	0.143
4 at most	0.003	0.175	3.841	0.676
Trace test shows 2 cointegrating equation(s) at the 0.05 level				

Source: Made by authors based on Data Analysis, 2024.

Regression Analysis

The effect of several climatic parameters on Nigeria's cassava output from 1963 to 2022 is

displayed in Table 5's regression analysis results. According to this result, the rainfall coefficient at 22,111.266 has a p-value of 0.034, making it significant at the 5% probability level. As a result, a one-millimeter increase in rainfall over the preceding time has resulted in a very significant rise in cassava yield of almost 22,111 tonnes. In an agri-food system that relies only on rainfall, such as Nigeria, this positive link serves as further evidence that rainfall is the primary driver in cassava production, especially when it comes to providing the moisture needed for crop growth. [22] also reported the positive influence of rainfall on cassava production and food security in general in Nigeria and suggested the use of irrigation facilities in the areas with low rainfall as the surest way of maintaining the level of productivity of cassava. The result therefore calls for water management mechanisms in the form of water use efficiency, especially in cases where climatic variability has increased erratic rainfall patterns.

On the one hand, temperature also explains a strong beneficial influence on cassava production, with a high coefficient of 28,422,368.765 and statistical significance of p=0.000. The result shows that such a case indicates that with an increase in temperature by one degree Celsius from the previous period, there is the possibility of an increase of about 28 million tonnes of cassava. These findings agree with those of [1], who indicate that temperature is indeed an essential determinant of cassava yield and sometimes outweighs the impact of rainfall on production. However, this relationship might be complicated, as too much heat can evaporate the moisture and thus make the conditions unfavourable for growth. On the other hand, increased temperature may have benefited cassava to a point but could be expected to be eventually reversed by extreme fluctuations or too much heat. This would again create a need to breed cassava for the adaptation of heat and drought tolerance. Another climate variable, relative humidity, has a positive and significant coefficient with a value of 147,217.280 (p=0.000) showing increasing levels of humidity are positively linked with increased yields of cassava. This finding finds support in [20], which postulated that humidity played a significant role in cassava production, given its predominant contribution to an environment suitable for growth due to low evaporation rates, hence the maintenance of soil moisture. Highly humid conditions may be quite favourable in that there could be a reasonably assured supply of moisture that the cassava plants would require for their good development. The findings give more strength to the notion that there should be an integrated perception of temperature, rainfall, and humidity for sustainable cassava production under a changing climate.

The effect of sunshine duration on cassava output, however, does not reach statistical significance (p = 0.892), suggesting that the variation in sunshine hours during the preceding period is not very important for cassava yield in this investigation. Indeed, [8] discovered that while the length of daylight may have an impact on agricultural output, other climate factors like humidity and rainfall have a greater impact on cassava productivity. The insignificance in sunshine could therefore mean that cassava is a hardy crop and less responsive to changes in sunshine than to water availability and temperature.

The estimated Error Correction Model (ECM) coefficient is -0.589, with a p-value of 0.000, highly significant, hence indicating rapid adjustment speed toward long-run equilibrium in response to any disequilibrium in cassava production. This negative value of the ECM coefficient justifies the fact that any deviation from the long-term trend of cassava production, due to external shocks or climate variability, has been corrected by about 58.9% every year. This finding is concurrent with that of [9], who found that the ECM coefficient indicates the resilience of cassava production to climate-induced shocks. This rapid adjustment shown suggests adaptability by farmers of cassava in Nigeria, who might have embraced certain practices to minimize the impacts of climatic variation, change on cassava, hence ensuring stability in the levels of output.

In this model, the constant term, C, has a negative sign and is statistically significant;

this may suggest that fluctuations in the level of cassava produced in Nigeria are determined by other non-climatic factors. Probably, the significant negative constant captures the structural problems inherent in the agricultural sector of Nigeria, such as input non availability, inadequate market linkage, and land degradation, which over time may be affecting cassava yield adversely, irrespective of climate conditions. Ajayi [4] also identified farm size, farmer experience, and the cost of inputs as significant determinants in cassava production, suggesting that the productivity level may, otherwise, be shaped by non-climatic variables. This further buttresses the fact that policies for sustainable cassava production should aim at both the climatic and non-climatic aspects.

The R^2 value of 0.705, which indicates that 70.5% of the variation in cassava production is explained by the included climate variables, therefore reflects a very strong model fit. The F-statistic stands at 25.387 and is statistically significant, thus generally confirming the reliability of the model in explaining cassava production trends. In addition, the Durbin-Watson statistic is 1.784, showing no problem of autocorrelation and further enhancing these findings for robustness.

Table 5. Regression Analysis

Variable	Coeff.	Std. Error	t-Statistic	Prob.
RFL (-1)	22111.266**	11647.522	1.898	0.034
TEMP (-1)	28422368.765***	3801758.251	7.476	0.000
RH (-1)	147217.280***	45493.437	3.236	0.000
SSD (-1)	213838.862	1561085.660	0.137	0.892
ECM (-1)	-0.589***	0.127	-4.657	0.000
C	-776493119.311	126972699.454	-6.115	0.000
R^2	0.705	F-statistic		25.387
Adjusted R^2	0.678	D.W. Stat.		1.784

Where *** and ** are significant at 1% and 5% respectively.
Source: Made by authors based on Data Analysis, 2024.

Normality test

Normality test of residuals in Fig. 2 indicates that the model behaves well and meets some important regression assumptions. According to the Jarque-Bera test statistic of 0.401 (p-value = 0.818), residuals are normally distributed, with their mean effectively at zero at 6.50e-09 and standard deviation of approximately 9.93 million units. The negligible negative skewness of -0.151 and a near-normal kurtosis of 2.73 reflect a minimal deviation from normality, and the symmetry around zero suggests an unbiased model. All that put together points to the model demonstrating the link between climate variables and cassava output reliably.

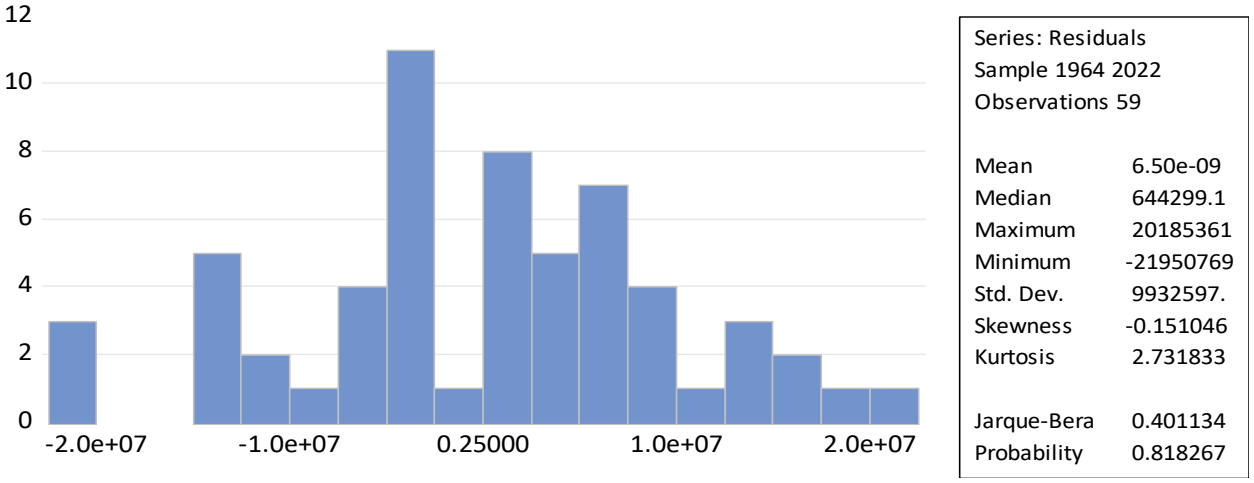


Fig. 2. Normality test
Source: Made by authors based on Data Analysis, 2024.

Ramsey reset Test

The Ramsey RESET test results in Table 6 indicate that the model used is appropriately specified, with no evidence of functional form misspecification. Both the t-statistic (1.338) and F-statistic (1.790) yield p-values of 0.187, which are above conventional significance levels, suggesting that there is no need to reject the null hypothesis of correct specification. The likelihood ratio result (1.997, p=0.158) further supports this conclusion, reinforcing that the model does not suffer from omitted nonlinearities or interaction terms that would improve its fit. Consequently, the results suggest that the significant climatic factors such as rainfall, temperature, and relative humidity are well-captured in the model, affirming the reliability of its findings on climate impacts on cassava production.

Table 6. Ramsey reset Test

Statistic	Value	df	P-value
t-stat.	1.338	52	0.187
F-stat.	1.790	(1, 52)	0.187
Likelihood ratio	1.997	1	0.158

Source: Made by authors based on Data Analysis, 2024.

Breusch-Godfrey Serial Correlation LM Test

Table 7 presents results that surpass standard significance standards (e.g., 0.05), including an Obs*R^2 value of 1.869 with a p-value of 0.172 and an F-statistic of 1.701 with a p-value of 0.198. According to these findings, there is insufficient data to rule out the null hypothesis that there is no serial association at up to one lag. This suggests that the model's residuals are not significantly autocorrelated, supporting the reliability of the regression model and reinforcing that the estimated effects of climate variables on cassava production are not distorted by serial correlation.

Table 7. Breusch-Godfrey Serial Correlation LM Test

F-Stat.	Obs*R^2	Prob. F(1,52)	Prob. χ^2 (1)
1.701	1.869	0.198	0.172

Source: Made by authors based on Data Analysis, 2024.

Heteroskedasticity Test: Breusch-Pagan-Godfrey

The test results in Table 8 assess for heteroskedasticity, or non-constant variance, in the residuals of the regression model analysing climate change effects on cassava production. The null hypothesis of homoskedasticity is supported by the F-stat. (1.663, p=0.160) and Obs*R^2 (7.999, p=0.156), which both produce p-values above accepted significance limits. Additionally, the scaled explained sum of squares result (5.590, p=0.348) indicates that the model does not contain heteroskedasticity.

Table 8. Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-stat.	Prob. F(5,53)	Obs*R^2	Prob. χ^2 (5)	Scaled explained SS	Prob. χ^2 (5)
1.663	0.16	7.999	0.156	5.59	0.348

Source: Made by authors based on Data Analysis, 2024.

CONCLUSIONS

has analysed the effect of climate change on cassava production in Nigeria based on how variations in rainfall, temperature, relative humidity, and length of sunshine affect cassava output. The estimated results indicate that rainfall, temperature, and relative humidity positively and significantly affect cassava production, while sunshine duration is insignificant. According to these findings, cassava will be impacted by climate variability, mostly through the adoption of water use efficiency and a slight increase in temperature, even though it is resistant to these changes. Extreme weather beyond these, meanwhile, would put cassava's tolerance and higher output per hectare to the test. The study therefore promotes the implementation of climate-smart agricultural techniques that will guarantee the sustainability of Nigeria's cassava output, given that the country's climate change estimates show an increase in the frequency of extreme weather events. Since cassava is a staple commodity that is associated with food security, these results from the study call for immediate adaptation in agriculture to ensure livelihoods at the level of smallholder farmers, hence ensuring food security at a national level. In the light of the importance of rainfall in cassava, it is hereby recommended that irrigation systems should be invested in,

especially in areas that experience unpredictable rainfall patterns. It will address the risk associated with water shortages in critical growth phases.

ACKNOWLEDGEMENTS

The authors wish to thank the Department of Agricultural Economics, Dennis Osadebay University, Asaba, Delta State, for extending their guidance and technical assistance in conducting this research work.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC AND TECHNICAL EFFICIENCY ANALISYS OF THE SPRAY IRRIGATION SYSTEM FOR CORN, BARLEY AND WHEAT CROPS

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Abstract

The paper aimed to analyze the economic and technical efficiency of the spray irrigation system for maize, barley and wheat cultivated in the North-East part of Romania. In order to obtain stable and marketable products, it is necessary to optimize the amount of water indispensable for plant growth and fruiting, even when there is no water from natural precipitation or when plants cannot grow due to a lack of groundwater. In the North-East Region of Romania, by using local water sources and implementing modern irrigation techniques, it is possible to fully satisfy the water needs of plants, contributing to the improvement of irrigation efficiency. Thus, a profitable, sustainable and environmentally friendly agriculture can be achieved. The main production costs for the agricultural year 2022-2023 were about 4,000 lei for the non-irrigated maize crop and about 5,000 lei in the case of irrigation systems. For the production of wheat, increases of cca. 1,000 lei were recorded for the irrigated crop, compared to the non-irrigated one, similarly recorded in the case of the barley crop. This is mainly due to the increase in the cost of inputs price, the increase of water price and the fuel used for irrigation electricity generators. On average, the results obtained for the three investigated crops show that grain corn produces a higher profit per hectare when it is cultivated in an irrigated system (10,600 lei/ha) than when it is cultivated in a non-irrigated system (4,400 lei/ha). For the wheat crop, a profit of 3,500 lei/ha was recorded in the irrigated regime compared to the crop in the non-irrigated regime, where the profit was 20 lei/ha. Moreover, in the case of barley, a profit of 5,480 lei/ha was recorded in the irrigated system compared to the non-irrigated one.

Key words: *spray irrigation, technical and economic efficiency, maize, barley, wheat, North-Eastern Romania*

INTRODUCTION

Most of the irrigated agricultural area is found in developing countries, followed by developed countries and then least developed countries. Of this total area, 71.7% is located in the developed areas of Oceania and Asia, 15.6% in North and South America, 7.8% in Europe and 4.9% in Africa [6].

Currently, only about 20% of agricultural land is irrigated, but this portion produces 40% of global production and 60% of total cereal production [6]. The sources of water used for irrigation are purified wastewater, groundwater and rivers. The irrigation sector in Romania has experienced an involution, going from the development of important facilities between 1970-1975 to 1989, when the area equipped for irrigation was approximately 3.1 million hectares with 375 large irrigation systems [6]. After 1989, land fragmentation, poor infrastructure management and lack of investment led to a significant deterioration of the irrigation sector. By 2004, only 50% of the area equipped with irrigation systems had functional installations, a percentage that decreased to 45% in 2013 [6]. As for the effectively irrigated areas, they represented only 11% of the total of 2004 and decreased to 5% by 2013 [12]. In the post-1990 period in Romania, with political changes and restructuring of public institutions, the land reclamation sector was significantly affected from an organizational point of view (management, design, implementation and exploitation), as well as from a research point of view [6].

Romania's accession to the European Union has brought a particularly important contribution to the irrigation infrastructure in Romania. Starting with the multi-annual financial envelope 2007 – 2013, the first grants

funds were allocated for the modernization of the irrigation infrastructure. Until 2024, most Water User's Associations in Romania have benefited from investments of 1 million Euros amount for the modernization of this infrastructure. European policies do not only target the irrigation segment as a means of ensuring quality food on markets at affordable prices. There are other levers also, such as the financial stimulation of optional crop insurance. Accessing thesefunds is a major opportunity for farmers in Romania, regardless of the size of the farmthey manage, which is why it is imperative toknow and understand the role of the Common Agricultural Policy byfarmers who undertake the organization of thecomplete activity for agricultural farms [8]. However, crop irrigation brings a specific benefit, demonstrated by this paper as well, being a much more efficient method than simply issuing insurance policiesfor crops against drought.

As it is known, water deficits can be compensated by adding the necessary amount of water to the active soil layer, during or outside the vegetation season. These approaches are meant to ensure stable and reliable agricultural production, taking into account the improvement or maintenance of soil quality by applying other appropriate agricultural techniques. The selection of the most suitable irrigation method, whether it is flood irrigation, furrow or strip irrigation, sprinkler irrigation, drip irrigation or sub-irrigation, is influenced by the particularities of the soil, the terrain and the crop type, each of these methods presenting both specific benefits and disadvantages.

Other researchers have also researched and found the major importance that irrigation has on the crops that occupy the largest share of arable land in Romania, such as those researched in this paper.Luca et al found that following investigations over a three-year period (2009-2011), it can be said that the additional water intake determined an increase in profit in each of the three experimental years, regardless of the variety cultivated [3].

Rusu and Simion (2015) conclude that the rehabilitation of irrigation systems had a positive effect on the development of competitive/intensive agriculture: land consolidation, increase in cultivated areas, increase in the share of crops with high economic value and increase in agricultural productivity [10].

[9] studied the yields in irrigated and non-irrigated systems as in the study case of Braila County, Romania.

[5] researched the influence of irrigation on the structure of crops on arable land.

Analyzing the evolution of crop yields per unit of land area in Romania compared to other countries, [4] concluded that smaller production level is caused, among other factors, by the lack of irrigations.

Other authors studied the both the technical and economic efficiency of the use of irrigations [13, 2, 7].

In this context, the purpose of this research was to assess the economic and technical efficiency of the spray irrigation system compared to the non-irrigated system for maize, barley and wheat cultivated in the North-East part of Romania.

MATERIALS AND METHODS

The study was conducted in the North-East region of Romania, during 2022-2023, on corn, winter wheat and winter barley crops. The main objective was to analyze the economic efficiency of using the sprinkler irrigation system, compared to the non-irrigated practice, in terms of water consumption, production costs and obtained profits.

In terms of location choice and climatic conditions the experiment was conducted in the forest-steppe area of the Moldavian Plain, a region with semi-arid climatic characteristics, which presents precipitation deficits during the growing season. The areas selected for the study were representative in terms of soil structure, typical for the region. A carbonate chernozem soil, loamy-sandy, with an average root depth of 80 cm for corn and 50 cm for wheat and barley.

In terms of irrigation system and technical parameters, for the comparative analysis, two sprinkler irrigation systems were used: a linear displacement system for corn and a center pivot system for wheat and barley. The systems

were adjusted to ensure a constant water application rate of 20 l/m² on the irrigated area. The duration of irrigation application was 5 days for the corn crop and 7 days for the wheat and barley crops based on scientific literature and past experience.

Determination of water consumption was an important purpose within the research, the water consumption being estimated using the Thornthwaite method for calculating potential evapotranspiration (ETP) and optimal actual evapotranspiration (OET). ETP was calculated based on the average monthly temperature and the annual thermal index of the area, applying the formula specific to the region. In addition, the correction coefficient (kφ) specific to each crop and climatic zone was taken into account. The irrigation water requirement was determined for each crop individually, depending on weather conditions and soil characteristics.

As for the calculation and monitoring methods, for each crop, the soil absorbed water quantity was determined, based on gravimetric methods of measuring soil moisture. Measurements of the soil water reserve (IR – Initial Reserve and FR – Final Reserve) were also made, both during and out of the growing season, using parameters such as bulk density and water retention capacity. The total amount of water required for each crop was calculated by adding the water inputs from precipitation and the irrigation system, corrected for evaporation and infiltration factors.

In terms of production costs and profitability determination, production costs were estimated for both regimes (irrigated and non-irrigated) based on input costs such as seeds, fertilizers, fuel for electricity generators, costs of mechanization works and maintenance of the irrigation system. The productions obtained for each crop were analyzed per hectare, and profitability was calculated based on the difference between the income from the sale of the crop and the total production costs. Financial analyses were also performed to evaluate the profitability of the irrigation system compared to the non-irrigated system and the summary results were included in the paper.

The data obtained were statistically analyzed to compare the economic performances of the two irrigation regimes. The average water consumption and yield for each crop were compared, and significant differences were highlighted. The analysis was performed using standardized calculation methods and agricultural statistics software.

All the research assumed tenths of site visits by the authors which made advanced monitorization and analysis of both relevant technical parameters and economical-accounting eloquent financial documents of the economic agent.

RESULTS AND DISCUSSIONS

Economic sustainability is a result of efficient crop management, irrigation system selection, proper crop rotation, and crop yield [11].

Irrigation water management, over a given period of time, determines how much and when water is used for the crop benefit. Accordingly, the following are taken into account: the irrigation rate, the precise timing of irrigation, the time intervals between irrigations, the number of irrigations. The water requirements of crops are threshold variables and depend on the water deficit. This is determined by climatic and hydrogeological conditions, the physical properties of the soil and the water requirements of the crop during the cold period of the season or the vegetation period [1]. The number of irrigations depend on the crop requirements and thus usually one to 5 irrigations can be performed. In the presented analysis, on average, 1-2 irrigations were performed, each with 400 - 600 m3/ha. Potential evapotranspiration (ETP) in m³/ha was calculated using the Thornthwaite method, applying the following formula:

$$\mathrm{ETP} = 160 \cdot \left(\frac{10 \cdot \mathrm{tn}}{\mathrm{I}}\right)^{\mathrm{a}} \cdot k\varphi \quad \text{.....(1)}$$

where:

t_n- the average temperature of the month being calculated ETP, în °C,

I –annual heat indexa=0.000000675· I^3 - 0.0000771·I^2+0.01792·I+0.49239

K_φ- the correction coefficient depending on the latitude of the location, the annual thermal index of

the area, this being obtained by adding the monthly thermal indices, was calculated using the formula:

$I = \sum_{n=0}^{n^1=12} \ln$.....(2)

where the dermal index equals $\left(\frac{t}{5}\right)^{1.154}$.

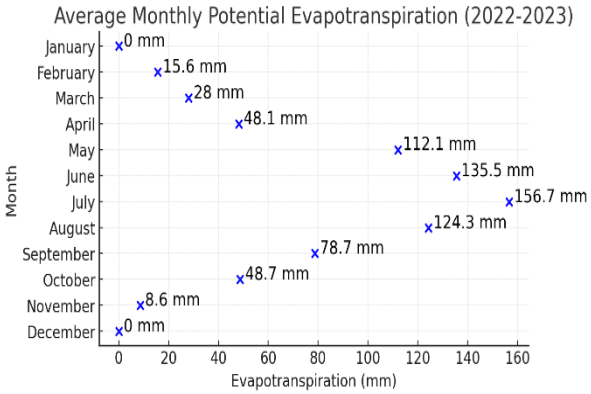


Fig. 1. Monthly average of evapotranspiration potential in 2022-2023
Source: own analysis, determination and centralization.

For Fig. 1 ETP (evapotranspiration) is calculated by adding the monthly values according to the collected and centralized data in Table 1, ETP=24+188+524+980+1,299+1,485+1,333+827+460+162 = 7,272 m³/ha.

Table 1. Potential evapotranspiration (ETP m³/ha)

Calculation elements	Month of the year									
	2	3	4	5	6	7	8	9	10	11
Monthly thermal indices (in)	0.16	1.31	3.76	6.66	9.1	10.4	10.1	6.95	4.00	1.48
Annual thermal index I	53.92									
Mean monthly air temperature (tn)	1.5	6	12	17.5	21.5	23.5	23	18	12.5	6.5
Correction coefficient (kφ)	0.81	1.02	1.13	1.28	1.29	1.31	1.21	1.04	0.94	0.79
eA Exponent	1.33									
ETP m3/ha	24	188	524	980	1,299	1,485	1,333	827	460	162

Source: own analysis, determination and centralization

The optimal real evapotranspiration (ETRO) is obtained by multiplying the calculated ETP value and k_φ, known as the correction coefficient for ETP, specific to each crop and natural area in Romania. The irrigation water requirement for a specific crop structure is determined proportionally, based on the water requirement for each crop in particular. ETRO = k_φ. ETP (m3/ha). ETRO – water consumption of a cultivated soil, when the soil moisture varies between field capacity and the minimum threshold, in the optimal range for obtaining an efficient economic yield. This value can be determined by experiments or by calculations. For the three analysed crops (maize, wheat and barley), the average water consumption is presented in Table 2.

Table 2. The average water consumption for maize, wheat and barley

Calculation elements	Month of the year								Total
	3	4	5	6	7	8	9	10	
ETP m³/ha	188	524	980	1,299	1,485	1,333	827	460	7,096
Maize									
k_φ	-	0.86	1.05	0.86	1.31	1.07	0.92	-	
ETRO=ETP· k_φ m³/ha	-	450	1,029	1,117	1,945	1,426	761	-	6,728
Winter wheat									
k_φ	2.71	1.55	1.20	0.91	-	-	-	-	
ETRO=ETP· k_φ m³/ha	509	812	1,176	1,182	-	-	-	-	3,679
Winter barley									
k_φ	2.71	1.55	1.20	0.91	-	-	-	-	
ETRO=ETP· k_φ m³/ha	509	812	1,176	1,182	-	-	-	-	3,679

Source: own analysis, determination and centralization.

The determination of water consumption for the crops of grain maize, winter wheat and winter barley in the conditions of North-East Region of Romania is done using the Thornthwaite method.

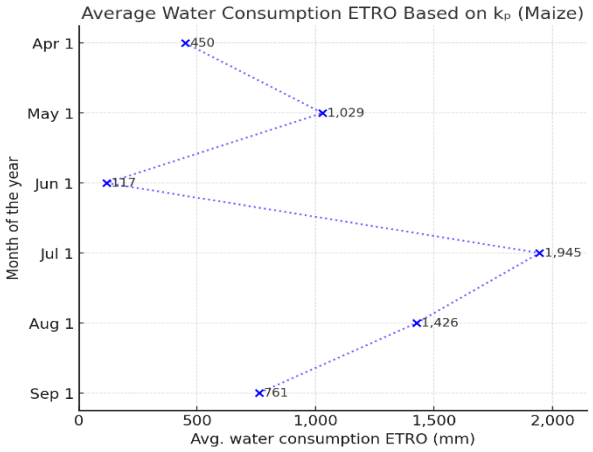


Fig. 2. Average water consumption ETRO based on k_φ (maize)
Source: own analysis, determination and centralization

As it can be seen, the maximum water consumption coincides with the months of maximum corn growth (June-July).
The decrease in consumption towards the end of the vegetation cycle (August-September) indicates a maturation of the crop.
The following Figure 3 shows the evolution of average water consumption (ETRO) for wheat crops depending on the month of the year, more precisely in the period March - June.

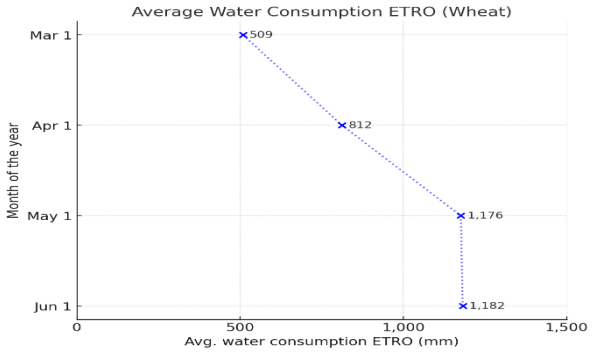


Fig. 3. Average water consumption ETRO based on k_φ (wheat)
Source: own analysis, determination and centralization

As it can be seen, the maximum water consumption is recorded in the months of May and June, coinciding with the critical phases of development. Irrigation is essential in April and May, when any water deficit can negatively affect the final production.

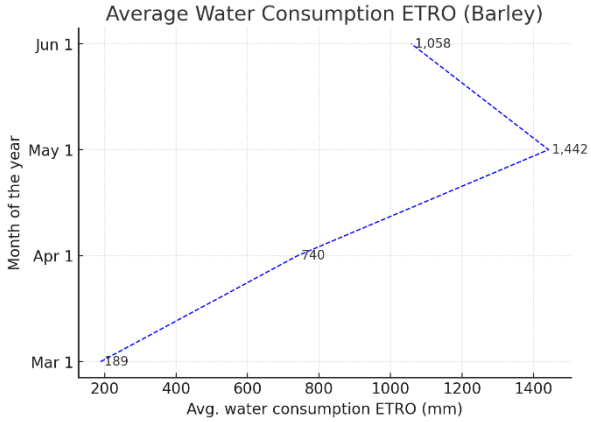


Fig. 4. Average water consumption ETRO based on k_φ (barley)
Source: own analysis, determination and centralization

From Fig. 2, 3 and 4 it can be seen that in maize there was an average water consumption that varied from one month of vegetation to another, but in wheat and barley, on average, the water consumption was the same. In all three studied crops the average water consumption was calculated according to the correction coefficient.
The total amount of water in the soil during April 1 – August 31 for the grain maize crop is obtained by adding the monthly average of water consumption i.e. 6,796 m³/ha. The total amount of water absorbed from the soil during March 1 – June 31 for the winter wheat and winter barley crops is 3,679 m³/ha.

The initial soil water reserve (IR), available to crops during the vegetation period is located in a limited soil layer, determined by the depth at which the root system develops or by the soil conditions. Outside the growing season, the accumulation layer from which water can be accessed by plants is taken into account. In soils with a water regime independent of the groundwater level, such as in the forest-steppe zone, this reserve can be a maximum of 500 m³/ha.
The field water capacity reserve (WCR) is calculated as follows:

WCR=H*BD*FC.....(3)

where:
BD – bulk density in t/m3,
CC – field water capacity in % g/g,
H – depth for which the soil water reserve is considered (cm).
In the case of wilting coefficient (WC), the unit % g/g provides a measure of the intensity of wilting, indicating how much mass (usually water) was lost from the plant structure as a result of this process. And for field water capacity (FC), "g/g" means "grams of water per gram of soil", that is, the mass of water retained in the soil compared to the total mass of the soil, and "%" indicates that this ratio is expressed as a percentage, to show the proportion of water retained by the soil compared to the total mass of the soil. The final soil water reserve (FR) is the amount of water remaining in the soil at the end of the growing season or during autumn. In the forest-steppe area, this value generally exceeds 800 m³/ha.
The water reserve corresponding to the wilting coefficient (WCR) is calculated according to the formula:

WCR=$H*DA*CO$.....(4)

where: SWR - soil water reserve at the beginning of the growing season, expressed in m³/ha.
The calculation formulas for the initial and final soil water reserves are presented in Table 3, which contains the values (FR) for the final reserve and the initial reserve (IR), at a depth

of H=150 cm, noted in m³/ha, for the forest-steppe.

Table 3.FR and IR valuesof soil water

Zone	FR	IR	Winter precipitation storage coefficient (c)
Forest-steppe	R_{CO}+800	R_{CC}-500	0.5

Source: own analysis, determination and centralization

The water from precipitation during the growing season (GS) for a given month is equivalent to the total amount of precipitation recorded in that month (including amounts less than 5 mm). In calculating this amount of precipitation, water losses through runoff to the soil surface are not taken into account, and infiltration is taken into account only when the soil reaches its water retention capacity at the specified depth, allowing for runoff only for amounts of water exceeding this capacity, after deducting the actual optimal evapotranspiration. PV is equal to 10 times the thickness h in mm of the precipitation layer, with an 80% supply, according to Table 4 and Fig. 5.

Table 4. Precipitation during the growing season is supplied by 80%

Calculation elements	UM	Month of the year							Total
		3	4	5	6	7	8	9	
Precipitations (Pv) supplying 80%	m³/ha	350	300	390	470	290	230	300	2,330

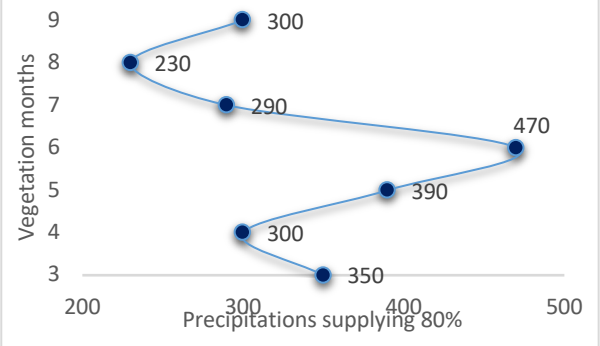


Fig. 5. Precipitation (Pv) supplying 80% (m3/ha)
Source: own analysis, determination and centralization.

From Fig. 5 it can be seen that the rainiest months were May and June, with quantities between 390 m³/ha and 470 m³/ha.

In table 5, are the values of the physical and hydro physical indices for carbonate chernozems from the Moldavian Plain, where we encounter a sandy loamy texture. WCR at a depth of 150 cm has the value:

WCR=H*BD*CO=150*1.37*8.9=1,829 m³/ha;

FR is equal to:

FR = WCR +800=1,829+800=2,629 m³/ha;

WCR is calculated using the relationship: WCR =H*DA*FC =100*1.37*23.1=3,165 m³/ha.

Thus, IR is equal to:

IR = WCR – 500=3,165–500=3,665 m³/ha.

The irrigation norm (M) is the amount of water required to irrigate a cultivated area of one ha. It is expressed in m³/ha and is calculated as follows:

M=ETRO+ FR – IR – VP.....(5)

Using the previously calculated values, M is determined as follows:

- corn: M=ETRO+FR – IR–VP=5,967 m³/ha+2,629 m³/ha–3,665 m³/ha–2,330 m³/ha=3,601 m³/ha;
- wheat: M=ETRO+FR – IR–VP=3,679 m3/ha+2,629 m³/ha–3,665 m³/ha–1,510 m³/ha=2,133 m³/ha;
- barley: M=ETRO+FR – IF–VP=3,679 m³/ha+2,629 m³/ha–3,665 m³/ha – 1,150 m³/ha=2,133 m³/ha.

Table 5.Physical and hydrophysical indices – carbonate chernozem

Soil grouo	Physical-geographical unit	Texture	Depth h (cm)	Aparent density (t/m³)	Wilting coefficient WC (% g/g)	Field Capacity FC (% g/g)
Carbonate chernozem	Moldavian Plateau	Sandy clay loam	50	1.32	10.7	25.7
			100	1.36	9.6	24.4
			150	1.37	8.9	23.4

Source: own analysis, determination and centralization.

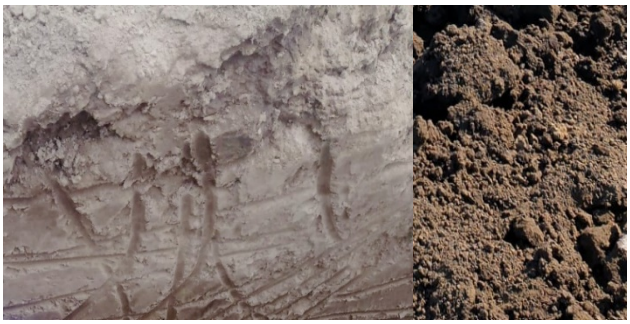


Fig. 6.Studied soil profile, sandy clayey loam texture
Source: author's photo and analysis.

Figure 6 shows the soil profile with a sandy loam texture, according to the data presented in Table 5.

The irrigation norm during the growing season represents the amount of water applied at one watering for a crop on an area of one ha. The sum of the watering rates forms the irrigation rate. H, where the roots are mainly located, is

80 cm for the corn crop and 50 cm for the wheat and barley crops.

The watering norms for the three crops are calculated according to the minimum threshold values: for corn 1,000 m^3/ha, for winter wheat and winter barley 675 m^3/ha.

Thus, for corn crops, approximately 4 irrigations are required, and for winter wheat and winter barley crops, an average of 3 irrigations are required. The irrigation rate is adjusted: for corn 867 m^3/ha, for wheat and barley 711 m^3/ha. For the analyzed irrigation systems, the duration of irrigation application is 5 days for the linear displacement sprinkler for corn crops, with a rate of 20 l/m², and for the center pivot sprinkler irrigation system, the duration of irrigation application is 7 days for wheat and barley crops.

Humidity determination is carried out by the gravimetric method and thus irrigation application for the analyzed crops takes place when the soil water reserve decreases and its value approaches the minimum threshold.

The amount of water distributed, application times and duration of irrigation in the agricultural years 2022 and 2023 are presented in Tables 6 and 7.

Table 6. The amount of water distributed and the duration of irrigation during 2022 agricultural year

Description	U/M	Vegetation months						Total	M m^3/ha
		4	5	6	7	8	9		
80% supply	m^3/ha	300	390	470	290	230	300	1,980	
ETP	m^3/ha	524	980	1,299	1,485	1,333	827	6,448	
kφ	m^3/ha	0.86	1.05	0.86	1.31	1.07	0.92	-	
ETRO=ETP· kφ m^3/ha	m^3/ha	450	1,029	1,117	1,945	1,426	761	6,728	
P_v-ETRO	m^3/ha	-150	-639	-647	-1,655	-1,196	-461	-4,718	3,500
R_{CC}	m^3/ha	3,165							
R_{PM}+m/2	m^3/ha	3,288+433=3,721							
R_i	m^3/ha	3,665	4,390	3,751	3,979	4,074	2,785	-	
m	m^3/ha	875	-	875	875 875	-	-	-	
R_f	m^3/ha	4,390	3,751	3,979	4,074	2,875	2,417	-	

Source: own analysis, determination and centralization

Table 7. The amount of water distributed and the duration of irrigation during 2023 agricultural year

Description	U/M	Vegetation months						Total	M m^3/ha
		4	5	6	7	8	9		
80% supply	m^3/ha	300	390	470	290	230	300	1,980	
ETP	m^3/ha	524	980	1,299	1,485	1,333	827	6,448	
kφ	m^3/ha	1.55	1.20	0.91	-	-	-	-	
ETRO=ETP· kφ m^3/ha	m^3/ha	812	1,176	1,182	-	-	-	3,170	
P_v-ETRO	m^3/ha	-512	9,786	-712	-	-	-		2,133
R_{CC}	m^3/ha	3,165							
R_{PM}+m/2	m^3/ha	3,288 + 355 = 3,643							
R_i	m^3/ha	3,665	3,854	3,779	3,778	-	-	-	
m	m^3/ha	711	711	711	-	-	-	-	
R_f	m^3/ha	3,854	3,779	3,778	3,778	-	-	-	

Source: own analysis, determination and centralization.

For the irrigation applications, the first irrigation is applied on April 22; the 2nd irrigation is applied on May 15, and the 3rd irrigation is applied on June 15.

In the studied area, a technical budget was developed for the established crops.

Table 7 presents the economic indicators in irrigated and non-irrigated regimes.

It can be seen that all studied crops have a significant increase in production under irrigated conditions: maize: from 7,000 kg/ha (unirrigated) to 13,000 kg/ha (irrigated) (+85%).Wheat from 2,200 kg/ha to 5,000 kg/ha (+127%).Barley from 2,400 kg/ha → 6,000 kg/ha (+150%).

Table 8. Economic indicators, irrigated and non-irrigated

System	Economic index	Maize	Winter wheat	Barley
Irrigated	Avg. production (kg/ha)	13,000	5,000	6,000
	Avg. production cost (lei/ha)	5,000	4,500	4,500
	Avg. selling price (lei/kg)	1.2	1.6	1.8
	Avg. total profit (lei/ha)	10,600	3,500	6,300
Non irrigated	Avg. production (kg/ha)	7,000	2,200	2,400
	Avg. production cost (lei/ha)	4,000	3,500	3,500
	Avg. selling price (lei/kg)	1.2	1.6	1.8
	Avg. total profit (lei/ha)	4,400	20	820

Source: authors analysis from company primary data.

Total costs per hectare increase in the irrigated system due to additional water and irrigation management costs: Maize: from 4,000 lei/ha to 5,000 lei/ha (+25%).Wheat: from 3,500 lei/ha to 4,500 lei/ha (+29%).Barley: from 3,500 lei/ha to 4,500 lei/ha (+29%).

The cost per kilogram remains relatively constant, suggesting that the increased yield covers the investment in irrigation.

As we can also see, a considerable profit for the corn crop results, but also a small difference in profit for the wheat crop, because this is not a demanding plant, being drought-resistant, and irrigation did not have a major effect on its development.

From Figures 7 and 8, we can observe the days during the vegetation months when the largest amounts of water were allocated by irrigations due to the lack of precipitation, as we can see, 2022 being a drier year than 2023.

As we can see in Fig. 7. And Fig. 8., the highest amounts of water were applied in June and July, indicating a peak requirement during this period.

In August and September, the volumes applied are lower, which may suggest a maturation of the crops and a reduction in water need.

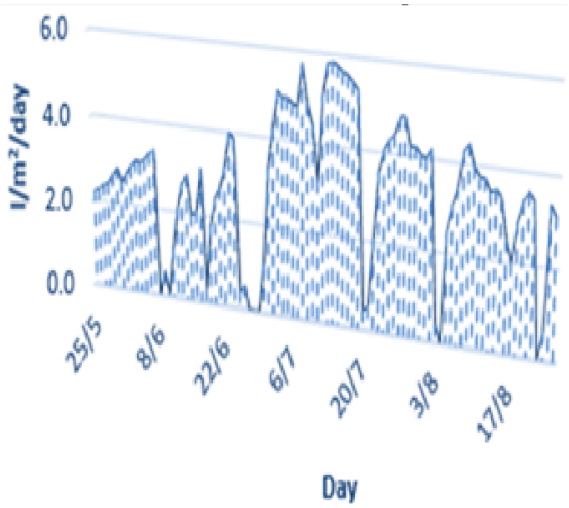


Fig. 7. Irrigated water amount in 2022
Source: primary data analysis and centralization of the water pumping station flowmeter.

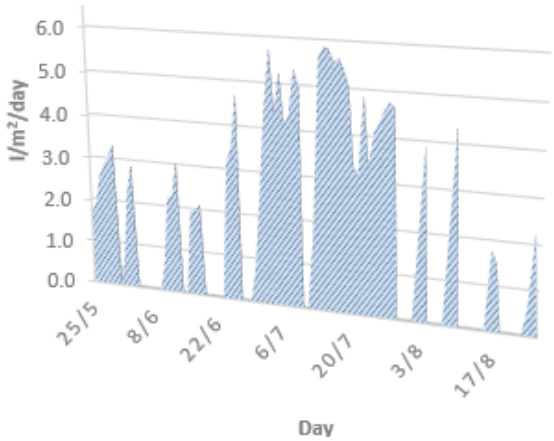


Fig. 8. Irrigated water amount in 2023
Source: primary data analysis and centralization of the water pumping station flowmeter.

CONCLUSIONS

The present paper compares production, costs, and profits for irrigated and non-irrigated systems, providing a clear perspective on the benefits of irrigation.

In terms of irrigation influence on agricultural production we can observe significant increase in production for all crops studied: for corn from 7,000 kg/ha (non-irrigated) to **13,000 kg/ha irrigated, +85%. For winter wheat from 2,200 kg/ha to 5,000 kg/ha, +127%. For barley from 2,400 kg/ha to 6,000 kg/ha, +150%. This increase confirms the importance of water as a limiting factor in agriculture and demonstrates the positive impact of irrigation on crop yield.

In terms of production costs and economic analysis, we can observe that production costs increase with the use of irrigation, but remain justified by the increase in production. For corn from 4,000 lei/ha, non-irrigated to 5,000 lei/ha, irrigated+25%. For wheat from 3,500 lei/ha to 4,500 lei/ha, +29%. For barley from 3,500 lei/ha to 4,500 lei/ha, +29%. The cost per kilogram **remains constant, which indicates that the investment in irrigation is economically sustainable. Wheat is the most affected in the absence of irrigation, with an almost non-existent profit in the non-irrigated regime. This fact emphasizes the need for irrigation to avoid economic losses.

In terms of water management and irrigation needs we observe that water consumption varies depending on the crop and phenological stage, as follows: corn has the highest consumption (6,796 m³/ha, between April-August).Wheat and barley require 3,679 m³/ha (March-June). As stated within the paper, irrigation must be adapted according to evapotranspiration and precipitation. The maximum water consumption coincides with the periods of intensive growth (June-July for corn, May-June for wheat and barley), which requires efficient Water User's Association strategies and organizing for the whole agricultural year.

Irrigation brings a clear increase in production and profit for the analyzed crops, justifying the additional costs of implementing an irrigation system. Wheat is the most vulnerable to water shortages, while corn is the most profitable under irrigated conditions. The study highlights the need to modernize and expand irrigation systems to support efficient and sustainable agriculture in Romania.

Given the recent years that have shown an increasing, unusual degree of drought, with a maximum temperature of 44.5° C during 2024 summer, it is expected that national and European policies will continue to encourage the development of the irrigation system through financial incentives, deductions and other measures.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STRATEGY FOR SUSTAINABLE DEVELOPMENT OF TERRITORIAL COMMUNITIES IN UKRAINE: A CASE STUDY OF IVANO-FRANKIVSK REGION

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Abstract

The purpose of the article is to develop effective measures for setting up a strategy for sustainable development and mutually beneficial cooperation, as well as increasing the level of capacity of rural, settlement and urban territorial communities in the Ivano-Frankivsk region in the process of decentralization in Ukraine. The data on the dynamics of the formation of 62 territorial communities in the region during 2015–2020 is graphically illustrated: of which 24 or 39% belong to the rural type, 23 or 37% to the settlement type and 15 or 24% to the urban type. It was found that the majority of territorial communities of Ivano-Frankivsk region are harmoniously formed in cities of regional and district significance and have a capable potential, which was assessed according to the criteria of the level of capability – population, area of the territory, and number of populated areas. It was determined that the large Ivano-Frankivsk, Kalush and Kolomyia districts, where 84% of populated areas, 72% areas of the territory and 82% of the population are concentrated, can significantly influence the development of small Verkhovyna, Kosiv, Nadvirna districts and balance the development of Ivano-Frankivsk region as a whole. A number of initiatives for the sustainable development of rural, settlement and urban territorial communities of Ivano-Frankivsk region are proposed, which consist in expanding their mutually beneficial cooperation in the direction of exchanging experience and creating joint projects: socio-economic, administrative-legal, educational and cultural, environmental and tourist, transport and infrastructure. The conclusions of the study confirm the importance of joint implementing international projects under the "U-LEAD with Europe" and "USAID DOBRE" programs, which will ensure an improvement in the quality of life of the rural and urban population of the region.

Key words: *sustainable development, territorial communities, capacity, decentralization process, administrative-territorial reform, Ivano-Frankivsk region*

INTRODUCTION

An important event for the regions of Ukraine was the successful start of the decentralization reform, when on April 1, 2014, by order of the Cabinet of Ministers of Ukraine, the Concept of Reforming Local Self-Government and Territorial Organization of Power in Ukraine was approved [16]. The relevance of its implementation is determined by the formation of effective local self-government to create and support a full-fledged living environment for the rural and urban population of Ukraine, provide them with high-quality and accessible public services, and satisfy their interests in all spheres of life. In this context, cooperation between rural, settlement, and urban territorial communities was initiated in all regions of Ukraine, which was based on the principles of legality, voluntariness, mutual benefit, transparency and openness, equality of participants, and mutual responsibility for the results of activities [10]. In 2015, Ukraine began regulating relations that arose in the process of voluntary unification of territorial communities of villages, towns and cities of Ukraine [11], and approved a methodology for their formation based on determining capacity [25]. Thus, establishing the capacity of rural, settlements and urban territorial communities, implementing their effective and mutually beneficial cooperation is a key stage in the process of decentralization and development of local self-government in all regions of Ukraine, including Ivano-Frankivsk region. After all, this is an important step to ensure effective

regional management, which will contribute to improving cooperation between rural and urban population for sustainable economic growth.

In order to best meet the needs of society, Ukrainian and foreign scientists in the process of decentralization have explored various ways for sustainable economic growth of rural, town and urban territorial communities. For example, they determined the effectiveness of regulating the financial support of territorial communities in the regions of Ukraine [9], implementing innovative projects based on the rational use of resources [20], and improving administrative services for the population [24]. The prospects for socio-economic growth of territorial communities in Ukraine have been clarified [30], and their patterns and priorities in the cross-border space have been established [31]. Of great importance is the coverage of demographic and economic changes that characterize the rural population of Romania [21], the analysis of the differences between rural and urban areas of Romania in comparison with the European Union [22], and the clarification of the differences in the levels of education of the rural and urban population of the European Union [23]. The important role of rural development strategies is noted: avoiding a decrease in the rural population and ensuring the preservation of the attractiveness of rural areas in Romania [4; 5], expanding investments in agriculture in Turkey [7], obtaining subsidies for the agrarian sector in Bulgaria [8], introducing digital technologies for the development of the agrarian sector in the Republic of Moldova [15]. It is necessary to note the significant contribution of Ukrainian and foreign scientists to highlighting the ways of strategic planning of regional development of Ukraine in the context of decentralization. At the same time, aspects of sustainable development of rural, settlement and urban territorial communities have not been sufficiently disclosed for Ivano-Frankivsk region.

The purpose of the article is to clarify the strategy for sustainable development of rural, settlement and urban territorial communities in the Ivano-Frankivsk region, which is based on the development of effective measures to increase their capacity and mutually beneficial cooperation in the process of decentralization in Ukraine.

MATERIALS AND METHODS

The basis of the research information base is the legislative and regulatory legal acts of Ukraine, information from the official websites of the Ministry of Community and Territorial Development of Ukraine, the Ministry of Finance of Ukraine, and the web portal «Decentralization in Ukraine». The article uses a wide range of scientific works by Ukrainian scientists from scientific-research institutions of the National Academy of Sciences of Ukraine and higher education institutions of the Ministry of Education and Science of Ukraine, as well as foreign scientists who have devoted their research to solving the problems of decentralization and ensuring local development of territorial communities. Information sources of international organizations and programs “U-LEAD with Europe” and “USAID DOBRE”, as well as analytical calculations of the authors, were used.

Thanks to retrospective and comparative analysis, as well as the calculation-constructive method, trends of long-term changes in the main indicators of the study were identified: the formation of rural, settlement and urban territorial communities; the presence of populated areas, the area of the territory and the population in various districts and territorial communities of Ivano-Frankivsk region in the process of decentralization in Ukraine. The dynamics of these indicators during 2015–2020, as well as their distribution in 2020, are illustrated using a graphical method. The criteria were analyzed: population, area of the territory and the populated areas in rural, settlement and urban territorial communities of the region and the level of their capacity was established. Using the abstract-logical method, the effective implementation of international projects between rural, settlement, urban territorial communities of Ivano-Frankivsk region and foreign partners was revealed, which ensured their mutually beneficial cooperation. Conclusions are formulated and a

number of measures are proposed to improve the quality of life of the rural and urban population in the region.

RESULTS AND DISCUSSIONS

Before the 2014 decentralization reform, a large number of local government bodies of various levels operated in Ivano-Frankivsk region, as in other regions of Ukraine, which, during the centralization process, had limited opportunities to manage and develop the region [20]. Their unification into larger administrative units, which was part of the all-Ukrainian process of decentralization, contributed to the transfer of most of the powers and resources to the local level and provided territorial communities with a significant strengthening of their powers and financial independence [3]. This ensured more effective management of the development of territorial communities, in particular in rural areas, where previously there was a significant fragmentation of local councils that did not have enough resources for effective activity. In particular, thanks to the pooling of resource potential, budget revenues have increased and the efficiency of solving local infrastructure problems has increased; the provision of transport, social, educational and medical services has improved; the development of the agrarian and tourism, environmental and energy sectors has accelerated [31].

One of the first was the Perspective Plan for the Formation of Community Territories of Ivano-Frankivsk Oblast, developed in October 2015, according to which 61 united territorial communities (UTCs) were to be created in 14 districts [17]. At the same time, it was improved seven times during 2017–2020 and was finally approved in April 2020[12; 18]. It should be noted that during 2015–2019, the voluntary formation of UTCs in Ivano-Frankivsk region occurred at a somewhat slow and not entirely uniform pace (Fig. 1).

Already at the end of October 2015, the first three UTCs were created: two rural ones, Stari Bogorodchany and Verkhnia, and one settlement, Pechenizhyn [1]. In the following year, 8 UTCs were organized, of which the largest number was rural – 6, as well as 1 settlement and 1 urban. In 2017, the largest number of UTCs was formed – 12, of which 6 were rural and 6 were settlement. In 2018, this process slowed down somewhat: out of 7 UTCs created, 4 were rural, 2 were settlement and 1 was urban. In 2019, the number of UTCs formed was 10, of which 5 were rural, 2 were settlement and 3 were urban.

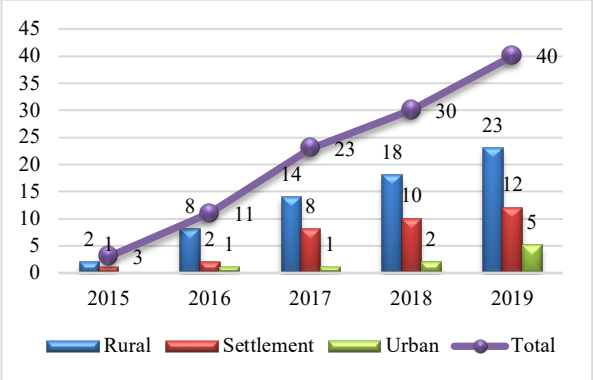


Fig. 1. Dynamics of formation of united territorial communities in Ivano-Frankivsk region by type, 2015–2019

Source: Own design based on data [12; 17; 18].

Thus, at the beginning of the decentralization process in the direction of uniting territorial communities, there was an active creation of rural UTCs, the total number of which at the end of 2019 was the largest – 23. The creation of settlement UTCs was slower, of which at the end of 2019 there were only 12. The smallest total number was urban UTCs, of which at the end of 2019 there were 5. Their administrative centers were formed in the cities of regional significance – Ivano-Frankivsk, Kalush and Kolomyia, as well as in the cities of district significance – Dolyna and Tlumach. It is obvious that in the Dolyna, Kalush, Kolomyia and Tysmenytsia districts, where the corresponding administrative centers were located, the decentralization process took place more actively and with the involvement of a larger part of the district's territories.

At the same time, instead of the planned creation of 61 UTCs, only 40 UTCs were actually formed [1; 18]. In addition, only 14 of them were created in accordance with the Perspective plan, and 26 – without adhering to it; some, instead of unification, were formed into separate UTCs, and some – with a smaller number of populated areas and local councils.

In total, out of 14 districts of Ivano-Frankivsk region, only 13 were partially involved in the creation of UTCs. Thus, the five-year process of decentralization in the direction of unification of territorial communities underwent constant transformation but was imperfect and required consistent completion.

In order to eliminate these shortcomings and increase the efficiency of the decentralization process, in June 2020, administrative centers were determined and territories of 62 territorial communities of Ivano-Frankivsk region were approved [1; 13; 19]. Of these, the largest number is rural territorial communities – 24 or 39%, a slightly smaller number is settlement territorial communities – 23 or 37%, the smallest number belongs to urban ones – only 15 or 24% (Fig. 2).

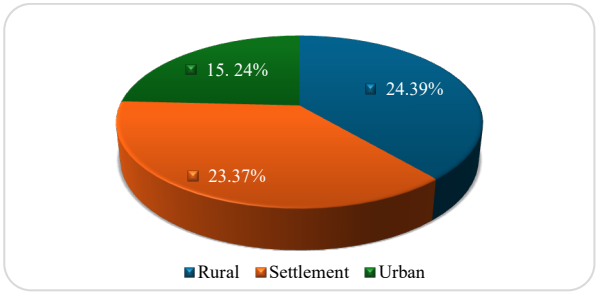


Fig. 2. Structure of territorial communities in Ivano-Frankivsk region by type, 2020
Source: own design based on data [1; 13; 19].

A characteristic feature of urban territorial communities in the region is their harmonious formation in cities of regional significance – Bolekhiv, Burshtyn, Ivano-Frankivsk, Kalush, Kolomyia and Yaremche, as well as in cities of district significance – Dolyna, Halych, Horodenka, Kosiv, Nadvirna Rohatyn, Snyatyn, Tlumach and Tysmenytsia [13; 19]. In addition, urban territorial communities concentrate a small area of the territory and the largest population – 35% and 60%, respectively (Fig. 3). In view of this, urban territorial communities have a developed economy, a high level of infrastructure and can independently cover their expenses from their own profits. It should also be noted the balanced placement of rural and settlement territorial communities, of which there are 76% in the region, located at a relatively short distance from administrative centers, which ensures their capacity. At the same time, rural and settlement territorial communities occupy a large area of the territory – 65%, but with a low population – 40%, which causes limited financial capacity and requires support from the state and other sources of financing. After all, the development of rural areas plays a particularly important role in accelerating the economic growth of the entire region through the expansion of the agrarian, tourism and energy sectors. Thus, cooperation between rural, settlement and urban territorial communities in the Ivano-Frankivsk region is an important aspect of their development in the process of decentralization in Ukraine. It involves the creation of joint projects, exchange of experience, as well as solving problems that go beyond the boundaries of individual administrative units.

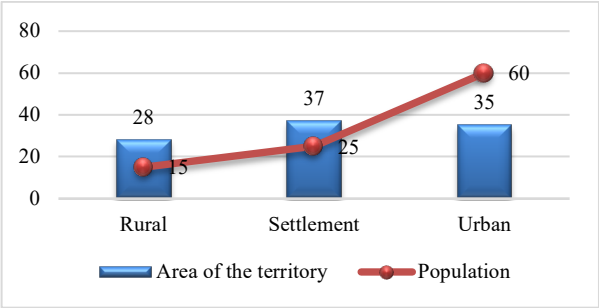


Fig. 3. Distribution of area of the territory and population by type of territorial communities in Ivano-Frankivsk region, %, 2020
Source: own design based on data [13; 19].

In July 2020, a reorganization of districts took place in all regions of Ukraine, including Ivano-Frankivsk region, where six districts were created instead of fourteen. Thanks to this process, 804 populated areas, located on an area of 13.9 thousand square kilometers, with a population of 1 million 361 thousand 241 people, were included in the territorial communities of the region today [13; 26]. Among the large districts, we note Ivano-Frankivsk, Kalush and Kolomyia, where 84% of settlements, 72% area of the territory and 82% of the population are concentrated (Fig. 4); which are distributed in 71% rural, 74% settlement and 80% urban territorial communities [13; 19; 26].The influence of large districts on small ones, including Kosiv, Nadvirna, and Verkhovyna, is ensured by optimizing the distribution of resources and

investments, because large districts have better opportunities for attracting public and private investments, a greater number of projects and initiatives. Therefore, mutually beneficial cooperation between large and small districts is important for the balanced development of the Ivano-Frankivsk region as a whole.

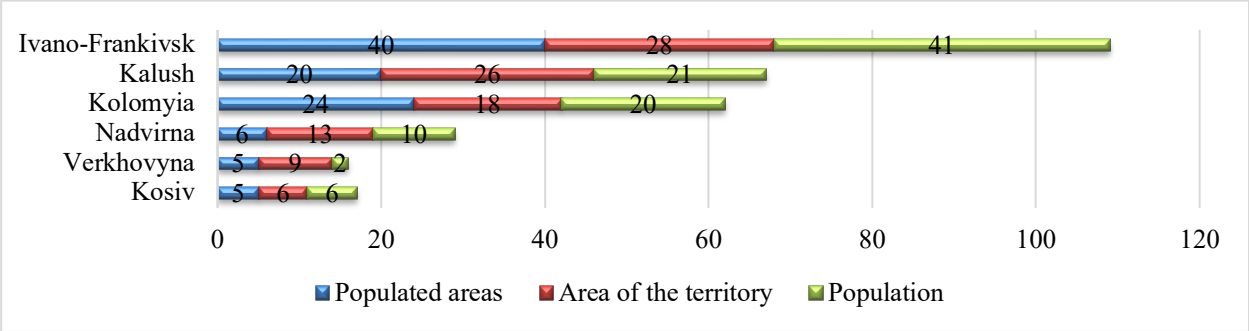


Fig. 4. Presence of populated areas, area of the territory and population in different districts of Ivano-Frankivsk region, %, 2020
Source: own design based on data [13; 26].

It is important to determine the capacity of rural, settlement and urban territorial communities to ensure sustainable development and improve the quality of life of the rural and urban population. Among the criteria for preliminary assessment of the level of capacity of a territorial community, an important indicator is the population size [25]. If this indicator is less than 3 thousand people, then the numerical value of the capacity criterion will be 0.3; 3–7 – 0.6; more than 7 thousand people – 1. The higher the numerical value of the capacity criterion, the higher the level of capacity of the territorial community. The distribution of rural, settlement and urban territorial communities of Ivano-Frankivsk region by population was carried out with an emphasis on four groups: less than 3 thousand people, 3–7, 7–20 and more than 20 thousand people (Fig. 5).

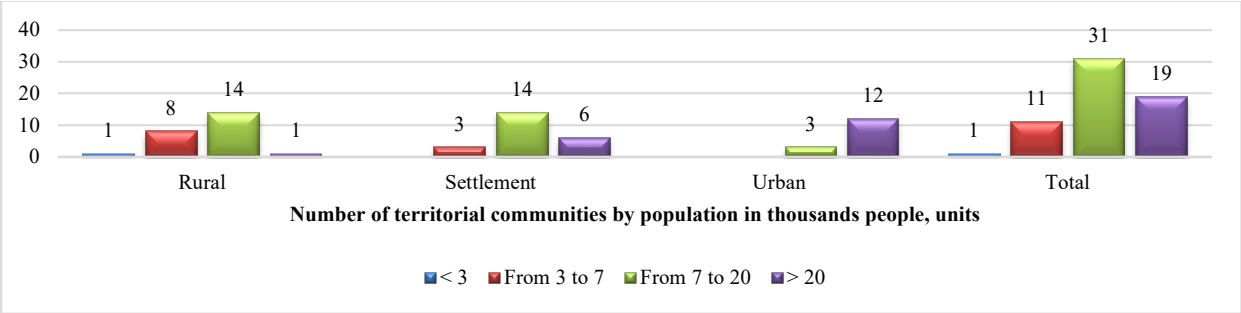


Fig. 5. Distribution of territorial communities of Ivano-Frankivsk region by population, 2020
Source: own design based on data [13; 19].

The third group with a population of 7–20 thousand people was noted as the largest [13; 19]. If the third group is combined with the fourth, which includes territorial communities with a population of more than 20 thousand people, then these groups will form the majority among the 62 territorial communities of the Ivano-Frankivsk region – 81%. The largest number of fillings in the third group, which includes territorial communities with a population of 7–20 thousand people, is rural and settlement territorial communities – 81%. In contrast, in the fourth group, which includes territorial communities with a population of more than 20 thousand people, there are the largest number of urban territorial communities – 63%. At the same time, in the second group, which includes territorial communities with a population of 3–7 thousand people, there is the largest number of rural territorial communities – 73%. In addition, the Zelene rural territorial community

belongs to the first group with a population of less than 3 thousand people, which somewhat reduces the capacity of rural territorial communities of Ivano-Frankivsk region.

Thus, among the 62 territorial communities of Ivano-Frankivsk region by population: one rural territorial community has a numerical value of the capacity criterion of 0.3; 11 territorial communities, of which 8 are rural and 3 are settlement – 0.6; 50 territorial communities, of which 15 are rural, 20 are settlement and 15 are urban – 1. In general, today the list of territorial communities whose population density is half the average population density in Ukraine includes only two: from Nadvirna district – Vorokhta, which belongs to the settlement type; from Verkhovyna district – Zelene, which belongs to the rural type [14]. It can be concluded that the majority of territorial communities of Ivano-Frankivsk region are capable according to the population size criterion, including rural and settlement ones.

An important criterion for the preliminary assessment of the level of capacity of a territorial community is the area of the territory. The area of the territory of less than 200 square kilometers has a numerical value of the capacity criterion of 0.3; 200–400 – 0.6; more than 400 square kilometers – 1 [25]. The higher the level of capacity of the territorial community corresponds to the higher the numerical value of the capacity criterion. Four main groups of territorial communities of the region have been identified by area of the territory: less than 100 square kilometers, 100–200, 200–400 and more than 400 square kilometers (Fig. 6).

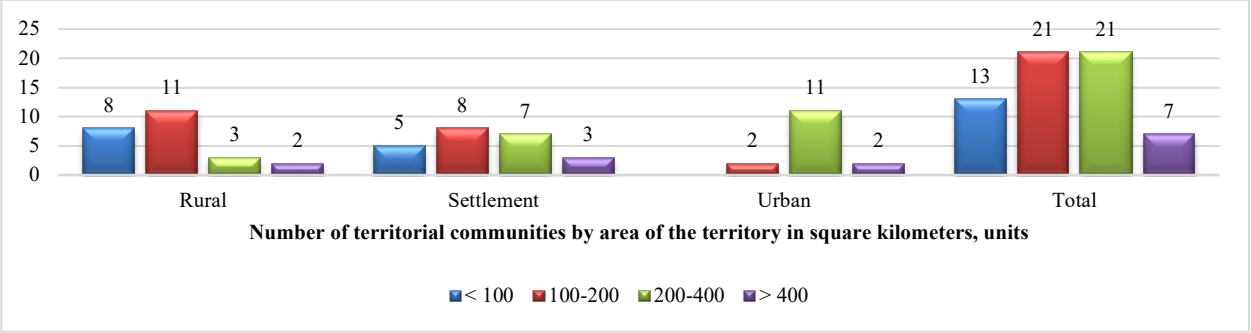


Fig. 6. Rating of territorial communities of Ivano-Frankivsk region with different area of the territory, 2020
Source: own design based on data [13; 19].

The majority of them belong to the first and second groups, which include territorial communities with an area of the territory of less than 200 square kilometers and form the majority among the 62 territorial communities of Ivano-Frankivsk region – 55%, among which a high number are rural [13; 19]. The third group, which includes territorial communities with an area of 200–400 square kilometers, is mostly populated by urban and settlement territorial communities – 86%. In the fourth group, which includes territorial communities with an area of more than 400 square kilometers, there is a high number of settlement territorial communities – 43%.

Thus, among the 62 territorial communities of Ivano-Frankivsk region by area of the territory: 34 territorial communities, including 19 rural, 13 settlement and 2 urban, have a numerical value of the capacity criterion of 0.3; 21 territorial communities, including 3 rural, 7 settlement and 11 urban – 0.6; 7 territorial communities, including 2 rural, 3 settlement and 2 urban – 1. Therefore, it can be argued that in the Ivano-Frankivsk region, the capacity of rural and settlement territorial communities based on the criterion of the area of the territory is at a slightly lower level compared to urban ones.

An important indicator is the number of populated areas that are part of the territorial communities of Ivano-Frankivsk region, which we also took into account when determining the level of capacity. According to this criterion, territorial communities are divided into four groups, which include: less than 5 populated areas, 5–10, 11–20, and more than 20 populated areas (Fig. 7).

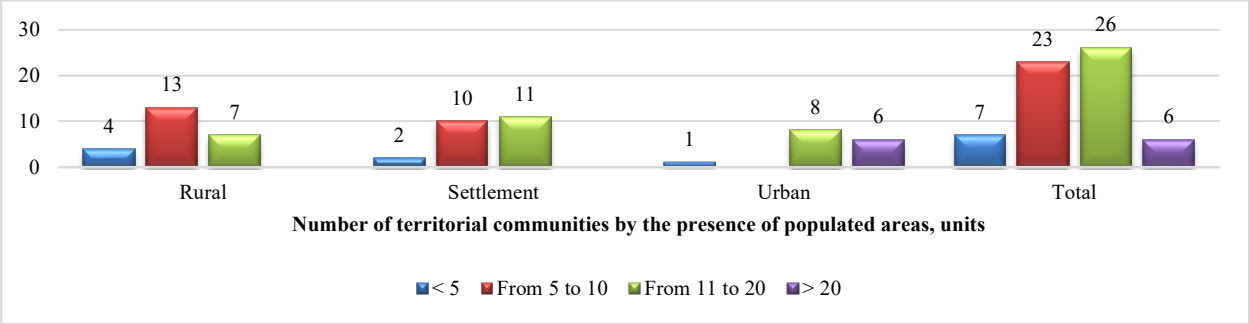


Fig. 7. Rating of territorial communities of Ivano-Frankivsk region with different numbers of populated areas, 2020
Source: own design based on data [13; 19].

Of the 62 territorial communities of Ivano-Frankivsk region, the majority belong to the second and third groups with 5–20 populated areas – 79%, among which a high number are rural and settlement type [13; 19]. The entire content of the fourth group, which includes territorial communities with more than 20 populated areas, is made up of urban territorial communities. However, in the first group, which includes territorial communities with less than 5 populated areas, there is a high number of rural territorial communities – 57%. Thus, it can be argued that, based on the presence of populated areas, the capacity of urban territorial communities of Ivano-Frankivsk region is somewhat higher than that of rural and settlement communities.

Therefore, in the context of decentralization in Ukraine, an important aspect of sustainable development of the Ivano-Frankivsk region is improving the capacity of rural and settlement territorial communities on the basis of mutually beneficial cooperation with urban territorial communities, which needs to be expanded. For example, for the implementation of transport-infrastructure projects, economic cooperation based on the joint use of resources is important: natural, labor, material, financial, investment, technological, scientific, informational, etc. The organization of joint economic zones or business forums plays a major role in supporting small and medium-sized businesses in rural and settlement territorial communities or providing jobs for the rural population in the city. Urban territorial communities have larger markets for goods and services, which can stimulate the rural population to develop agrarian business or cooperate with urban enterprises. Educational and cultural cooperation consists of holding joint cultural and tourist events, festivals and educational programs to exchange experiences and involve young people to providing quality education and resource support. Improving transport infrastructure consists in jointly organizing transport routes between rural, settlement and urban territorial communities for the convenience of moving residents to medical and educational institutions and other infrastructure facilities, as well as developing tourism. Joint solutions to environmental problems, such as waste management, environmental protection, greening and land reclamation, are gaining promising development. Cooperation is an important step in attracting funding from the state budget and international funds, as well as creating joint projects with the involvement of investors. It is important to exchange experience in managing local affairs, as well as to joint participation in the development of regional programs and development strategies.

In Ivano-Frankivsk region, there are many examples of successful projects between rural, settlement and urban territorial communities, which have been organized since 2014. For example, within the framework of the “U-Lead with Europe” projects of the German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ), Bolekhiv, Burshtyn, Dolyna, Halych, Horodenka, Kalush, Kosiv urban; Vytvytsia rural; Broshniv-Osadsk, Kuty, Pereghinske, Rozhnyativ settlement territorial communities cooperate [2; 27; 28; 32]. The projects are aimed at ensuring sustainable development of territorial

communities, improving their economic and energy situation and improving the quality of services provided to the population. Its include infrastructure development, improvement of educational, medical and social services, development of tourism and cultural activities. Within the framework of these projects, territorial communities receive support in the form of consultations, training, as well as funding for the development of local initiatives [6]. Their implementation has become an important stage in the reform of public administration in Ukraine through sustainable development of territories based on increasing the ecological and energy capacity of the region.

In the field of education and youth development, joint regional projects are being implemented with the participation of state bodies, local communities, organizations and international partners. In particular, within the framework of the project "Development of Communities and Youth Initiatives", which is initiated with the support of the United States Agency for International Development "USAID Dobre", financing and training for activists, organizations and local leaders is provided [29]. It is participated by the Biloberizka rural, Bogorodchany settlement and Halych, Ivano-Frankivsk, Kalush, Kolomyia, Nadvirna, Tysmenytsya urban territorial communities. This project is aimed at developing leadership qualities, increasing civic activity and involving rural youth in solving socio-economic problems [33]. It can be concluded that to improve the quality of life of the rural and urban population of Ivano-Frankivsk region, cooperation between rural and settlement territorial communities with urban territorial communities, as well as their joint implementation of international projects with foreign partners, is of great importance.

CONCLUSIONS

It was found that in 2014, the Ivano-Frankivsk region transferred most of its powers and resources to the local level, which significantly strengthened the rights and financial independence of territorial communities that united in the process of decentralization in Ukraine. In particular, during 2015–2020, 62 territorial communities were created in the region, of which 24 or 39% belong to the rural type, 23 or 37% to the settlement type, and 15 or 24% to the urban type. At the same time, their formation took place at an uneven pace: in 2015, 3 communities were formed, in 2016 – 8, in 2017 – 12, in 2018 – 7, in 2019 – 10 communities with an annual preference for the creation of rural and settlement communities.

It was found that a characteristic feature of 24% of urban territorial communities is their harmonious formation in cities of regional significance – Bolekhiv, Burshtyn, Ivano-Frankivsk, Kalush, Kolomyia and Yaremche, as well as in cities of district significance – Dolyna, Halych, Horodenka, Kosiv, Nadvirna, Rohatyn, Snyatyn, Tlumach, and Tysmenytsia with a concentration of a small area of the territory and the largest population – 35% and 60%, respectively. In view of this, urban territorial communities have a developed economy, a high level of infrastructure and can independently cover their expenses from their own income. The location of rural and settlement territorial communities, which number 76%, is located at a relatively short distance from administrative centers, which ensures their capacity, but with a concentration of a large area of the territory and a low population – 65% and 40%, respectively, which causes limited financial capacity and requires support from the state and other sources of financing. After all, the development of rural areas plays a particularly important role in accelerating the economic growth of the entire region through the expansion of the agrarian, tourist and energy sectors. Thus, the cooperation of rural, settlement and urban territorial communities in the Ivano-Frankivsk region is an important aspect of their development in the process of decentralization in Ukraine.

It has been established that the large Ivano-Frankivsk, Kalush and Kolomyia districts, where 84% of populated areas, 72% areas of the territory and 82% of the population are concentrated, can significantly influence the development of small Verkhovyna, Kosiv, Nadvirna districts and balance the development of Ivano-Frankivsk region as a

whole. For example, through better distribution of resources and investments, because in large districts there are better opportunities for attracting public and private investments, a greater number of projects and initiatives. It can be argued that the majority of territorial communities of Ivano-Frankivsk region are capable according to the criteria for assessing the level of capacity – population, areas of the territory and number of populated areas.

For the sustainable development of the region, effective measures have been proposed, which consist in expanding mutually beneficial cooperation in the direction of exchanging experience and creating joint projects between rural, settlement and urban territorial communities. In particular, socio-economic, administrative-legal, educational and cultural, environmental and tourist, transport and infrastructure. An example of mutually beneficial cooperation of rural, settlements and urban territorial communities of Ivano-Frankivsk region is the implementation of international projects under the programs "U-LEAD with Europe" and "USAID DOBRE". It can be concluded that territorial communities of Ivano-Frankivsk region, thanks to mutually beneficial cooperation, have great potential for sustainable development and within the framework of such initiatives can achieve an improvement in the quality of life of the rural and urban population in the region.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PERFORMANCE OF SMALL-SCALE MUNG BEAN (*VIGNA RADIATA WIL.*) SHELLING CUM CLEANING MACHINE

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Abstract

High-capacity shellers equate to high initial investment costs, unsuitable for most local mung bean farmers. This study developed a shelling cum cleaning machine to address the need for small-scale mung bean production. The design was registered in the Intellectual Property Office of the Philippines (IPOPHL) with a registration number of 3/23/051293. The machine performance was evaluated using speed and pod moisture content variations. Speed variations in the shelling and cleaning assembly were achieved using different pulley sizes at the shelling shaft, while moisture variations were tested using the oven-dry method from newly harvested and air-dried pods. It also assessed the economic performance of the machine to determine what ownership scheme is best for the farmers. It was concluded that satisfactory performance was obtained using a shelling speed of 600 rpm and 12% moisture content. The machine has an input capacity of 64.24 kg/hr, shelling capacity of 30.99 kg/hr, shelling efficiency of 97.84%, blower and separation efficiency of 95.51%, blower and separation losses of 5.29%, and unshelled losses of 2.16% and was affected significantly by the pod moisture content. The mechanically damaged kernel is 1.79% and is affected by both the speed and pod moisture content variations. On the other hand, the shelling recovery, scattering losses, and output purity are 91.01%, 1.53%, and 98.35%, respectively, and were not significantly affected. The machine cost is ₱14,675.00, and the operating cost is ₱0.80/kg. Considering a payback period of 1 year, processing 10,411 kg of inputs will break even all the costs at a custom rate of ₱1.00/kg.

Key words**:** *shelling cum cleaning machine, performance, moisture content, shaft, speed variations*

INTRODUCTION

Most of small farmers who dominate agriculture in the developing countries have not the financial resources to buy high capacity machinery [8].
For this reason, small farmers could be helped with innovations in small-sized machinery to improve productivity and diminish costs in various agricultural activities [5].
New strategies regarding agricultural mechanization are required to enhance sustainable production [9].
Mung bean (*Vigna radiata* Wilczek), locally known as “mongo” or “balatong” in the Philippines, is a leguminous crop among the cheapest sources of protein. Due to its nutritional value and nitrogen-fixing capabilities, it plays a significant role in the food, herbal, and agriculture industries [16, 13]. Mung bean is a good source of vitamins A, B1, B2, C, niacin, folate, iron, calcium, and zinc. Research showed that mung bean has anti-oxidant effects, antifungal and antimicrobial activity, anti-inflammatory activity, and activity against diabetes, hypertension,5and cancer [12].
Mung bean is a seasonal crop planted only after the rice crop during the dry season and is only available during the first half of the year [3]. In the crop production survey of the Philippines, released by the Philippine Statistics Authority, the Ilocos Region leads among the mung bean-producing areas, followed by Central Luzon and Western Visayas with a total production of 8.44 metric tons in the first quarter of 2024. Although the mung bean industry helps generate income and employment in the country, the decreasing domestic production has kept the country a net importer [1]. The

country's imports increased to 49 thousand metric tons in 2021 [2]. It is important to improve the productivity of grain legumes to address global challenges of food security [14]. Many farm operations in the Philippines are still done manually [4]. Recommendations to address the problems of the industry, which include, among others, the lack of storage facilities, inadequate supply of quality seeds, lack of established markets and credit facilities, and the entry of lower-priced legumes-based products, include the provisions for adequate research and development support on production, processing, and improvements on government credit-marketing support services that will promote productivity and link, and expand markets [1].

Low farm gate prices, high labor requirements, and losses for harvest and postharvest operations have contributed to the low profitability of mung bean farmers. In general, shelling is still done by manual threading, and the seeds are cleaned by winnowing [3]. Large-capacity shellers may not be appropriate because most mung bean farmers are engaged only in small-scale production. The average farm size is 1.29 ha, where 38% of the 5.56 million farms are under half a hectare [11]. Thus, to address the problem of the local mung bean industry, this study developed a small-capacity mung bean shelling cum cleaning machine.

MATERIALS AND METHODS

Design considerations

The mung bean shelling cum cleaning machine was designed based on the following considerations: (a) should be electric motor-driven and made from locally available materials; (b) safe to operate; (c) able to shell the harvested mung bean pods and clean by separating the shells and kernels; (d) the machine should only exhibit a maximum mechanical damaged kernel of 2%; (e) the machine should not produce noise of more than 92db; (f) can be operated by only one (1) laborer assigned for loading and bagging; and, (g) the break-even weight of the machine should be less than the volume of harvest of the farmer or an association to ensure ownership.

Machine parts and principle of operation

The designed machine comprises the hopper, frame, shelling, cleaning, and transmission assembly. It has an overall dimension of 1.6 m x 0.89 m x 0.93 m (L x W x H).

The machine is designed to be powered by a one (1) horsepower (hp) electric motor. Its power is transferred to the shelling unit and cleaning assembly with the aid of a belt and pulley connections.

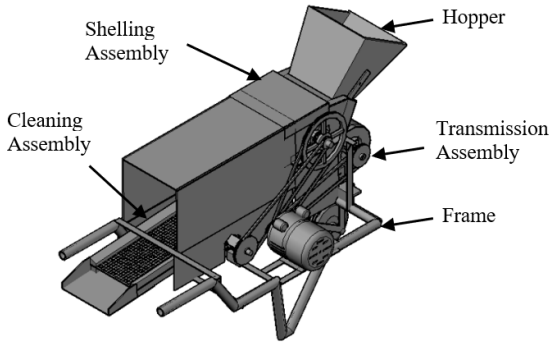


Fig. 1. Conceptualized design of the machine
Source: Original.

To determine the pulley diameter and the belt length of the transmission assembly, the following formulas were used [17]:

$$n_D D_D = n_d D_d \quad \text{.....(1)}$$

where:
n_D = speed of the driver pulley
D_D = diameter of the driver pulley
n_d = speed of the driven pulley
D_d = diameter of the driven pulley

$$L = 2C + \pi/2\,(D_D + D_d) + (D_D - D_d)^2/4C \quad \text{.....(2)}$$

where: L = belt length, inch
C = center distance between pulleys, inch.

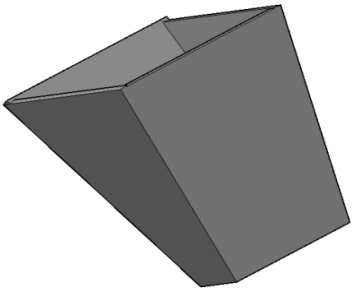


Fig. 2. Hopper design
Source: Original.

The machine requires only one (1) operator whose primary work is to load the pods into the hopper.

The hopper is designed to be continually fed with a feed regulator to avoid over-feeding during the operation.

The mung bean pods are then directed to the shelling assembly, which consists of a cylinder-concave mechanism responsible for the shelling process. The shelling drum is constructed from a 170 mm diameter metal pipe, with four equally spaced rubber around its circumference. The concave comprises flat bars and 8 mm round bars, which serve as rollers. These rollers are fitted with slats designed to allow the passage of shelled pods.

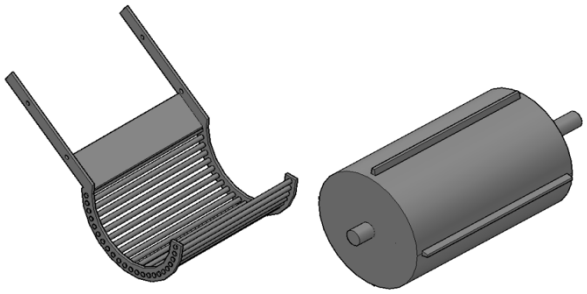


Fig. 3. (A) Shelling concave assembly and (B) cylinder drum design
Source: Original.

The mixture of kernels, shells, and other impurities is then discharged from the shelling unit through the concave slots and falls in the oscillating screen where kernels and small broken shells are separated from the large shells. Oscillation is achieved by attaching the sieve to a cam mechanism with a pulley speed of 220 rpm. Actual measurement of the kernels prompted using a screen with ¼ inch-diameter holes at the sieve.

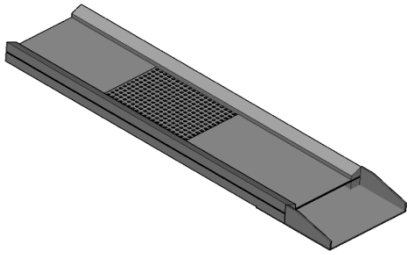


Fig. 4. Sieve assembly design
Source: Original.

Small broken shells and light impurities are separated from the kernels with the aid of the blower. The kernels are then discharged in the kernel outlet, and the shells are conveyed to a separate outlet located at the end of the sieve.

The kernels were collected by placing an appropriate container below the kernel outlet during the shelling operation. A sack can be attached to the shell outlet to prevent the shells from scattering.

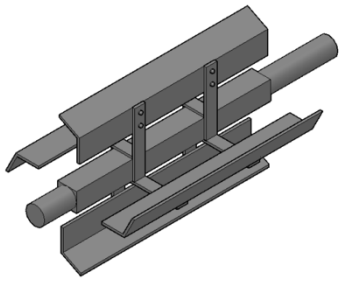


Fig. 5. Blower blade design
Source: Original.

Performance evaluation

After fabricating the major components of the machine following the design, preliminary tests were conducted to evaluate its operational efficiency. These tests served as an initial investigation to identify potential flaws in the machine and a guide for further improvements. The test follows the Completely Randomized Design (CRD) experimental layout with speed and moisture content variations as the factors. There are two (2) speed settings (500 rpm and 600 rpm), and two different pod moisture contents (MC) (19% and 12% wet basis) were tested and replicated three (3) times. Trial runs were performed to assess the machine's performance. Statistical analysis using Analysis of Variance (ANOVA) was used to determine the best machine settings.

The final performance test was conducted at Bohol Island State University-Bilar Campus, Zamora, Bilar, Bohol, Philippines. Sample mung bean pods consist of one (1) kilogram per replication. The performance parameters determined during the tests are the following [12]:

Input Capacity: It refers to the weight of mung bean pods per unit loading time into the hopper, expressed in kilogram per hour.

$$\text{Input Capacity} = \frac{\text{Weight of mungbean pods}}{\text{Loading time}} \text{.....(3)}$$

Shelling Capacity: It is the weight of shelled kernel received at the main kernel outlet per unit time of operation, expressed in kilogram per hour.

$$\text{Shelling Capacity} = \frac{\text{Weight of shelled kernel}}{\text{Operation time}} \text{.....(4)}$$

Shelling Efficiency: It is the shelled kernel received at all outlets with respect to the total kernel input expressed as a percentage by weight.

$$\text{Shelling Efficiency} = \frac{W+B_L+S_L+SC_L}{W+L_T} \text{.....(5)}$$

where:
W = weight of shelled kernel, kg
B_L =Blower loss, kg
S_L = Separation loss, kg
SC_L = Scattering loss, kg
L_T = Summation of all losses, kg

Blower and Separation Efficiency (BS_e): It is defined as the ratio of the weight of the shelled kernel to the shelled kernel plus blower losses expressed as percentage by weight.

$$BS_e = \frac{W}{W+B_L} \times 100 \text{.....(6)}$$

Shelling Recovery (S_r)**:** It is defined as the ratio of the weight of the cleaned shelled kernel collected at the main kernel outlet to the total kernel input expressed as a percentage by weight.

$$S_r = \frac{W}{W+L_T} \text{.....(7)}$$

Output Purity (P): It refers to the capacity of the machine to separate shelled kernels from the shells and other impurities.

$$P = \frac{\text{Weight of cleaned kernel}}{\text{Weight of uncleaned kernel}} \times 100$$
.....(8)

Mechanically Damaged Kernel (D_k) **:** It refers to the damaged kernels during the shelling operation

$$D_k = \frac{\text{Weight of mechanically damaged kernel}}{\text{100 gram sample}} \text{.....(9)}$$

Total Loss: It refers to the sum of the weight of blower loss, separation loss, unshelled loss, and scattering loss.
Blower loss is defined as the ratio of the weight of kernels blown by the sheller fan to the weight of the total kernel input of the sheller.

$$\text{Blower loss} = \frac{\text{Weight of blown kernel}}{W+L_T} \text{.....(10)}$$

Separation loss is the ratio of the weight of kernels that come out of the shelling unit at the shell outlet, to the weight of the total kernel input of the sheller.

$$\text{Separation Loss} = \frac{\text{Weight of Separated Kernel}}{W+L_T} \text{.....(11)}$$

Scattering loss is the ratio of the weight of kernels that fell out from the machine during shelling operation to the weight of the total kernel input of the sheller.

$$\text{Scattering Loss} = \frac{\text{Weight of scattered kernel}}{W+L_T} \text{.....(12)}$$

Unshelled loss is the ratio of the weight of kernels that remained in the pods collected from all outlets, to the weight of the total kernel input of the sheller.

$$\text{Unshelled Loss} = \frac{\text{Weight of unsheled kernel}}{W+L_T} \text{.....(13)}$$

Cost Analysis: The economic performance of the machine was evaluated based on annual cost, fixed costs, variable costs, unit operating cost, break-even cost, and payback period. Fixed costs include depreciation, interest on investment, property tax, insurance, and housing/shelter expenses. Variable costs include labor, repair, and maintenance per 100 hours of operation. On the other hand, the break-even cost and payback period indicate the point at which the total benefits offset the total costs.

RESULTS AND DISCUSSIONS

Machine Description

The fabricated machine has five (5) major components: the hopper, shelling, cleaning, transmission, and frame. The frame was designed in a garden cart-like structure to enhance mobility and facilitate easy transport of the machine. It is powered by a one (1) hp electric motor and connected to the shelling and cleaning assembly using a belt and pulley. It can be operated by at least one (1) operator (Photo 1).



Photo 1. Fabricated shelling cum grading machine
Source: Original.

Performance of the Machine

Analysis of the results after the evaluation of the machine showed that the sheller exhibited acceptable values of all the criteria for evaluation. Statistically, the mung bean pod moisture content significantly affects the machine's performance. The use of 12% MC pods resulted in a significantly higher input capacity, shelling capacity, and shelling efficiency, and significantly lower unshelled losses compared to 19% MC pods. On the other hand, 19% MC resulted in a significantly higher blower and separation efficiency and significantly lower blower and separation losses.

Moreover, the speed variations and the mung bean pod moisture content significantly affected the performance of mechanically damaged kernels. Based on the results, significantly lower mechanical damage kernels were observed when the combination of 500 rpm and 12% MC was used compared to other combinations.

Furthermore, the observed shelling recovery, scattering losses, and output purity of the sheller were not affected by the speed variations and mung bean pod moisture content levels (Table 1).

Table 4. Performance of the mung bean sheller cum cleaner using the best setting.

Machine Performance	600 rpm & 12% MC	600 rpm & 19% MC	500 rpm & 12% MC	500 rpm & 19% MC
Input Capacity, kg/hr	64.24	46.64	60.06	44.08
Shelling Capacity, kg/hr	30.99	20.27	28.37	18.76
Shelling Efficiency, %	97.83	96.22	97.49	94.16
Blower and Separation Efficiency, %	95.51	96.84	95.90	96.72
Shelling Recovery, %	91.01	91.60	91.95	89.45
Output Purity, %	98.35	98.59	97.55	98.27
Mechanically Damage Kernels, %	1.79	2.80	0.93	1.21
Blower and Separation Loss, %	5.29	2.98	3.94	3.04
Scattering Loss, %	1.53	1.63	1.60	1.66
Unshelled Loss	2.16	3.78	2.51	5.84

Source: Original.

The capacity of the machine is comparably lower than the developed machine of the Philippine Center for Postharvest Mechanization (PhilMech), which is powered by a 5 hp gasoline engine [7].

Compared with the small-scale mung bean sheller powered by a 1 hp electric motor developed by Gallegos et al., the machine's performance has no significant difference [6]. According to Abdimalik et al., recommended minimum performance of a sheller cum cleaning machine for grains in terms of efficiency, damage, and purity must be 99%, 2%, and 96%, respectively [10].

While the machine fell short with the minimum shelling efficiency, it exceeded the minimum performance in terms of purity and below the minimum damage. Still, the sheller performed well when pods with a higher speed of 600 rpm and a moisture content of 12% were used.

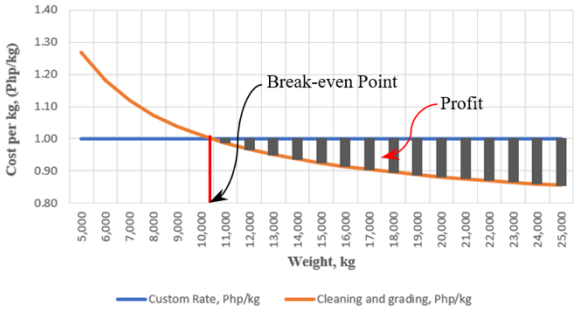


Fig. 6. Operating cost curve of the machine
Source: Original.

The cost of fabricating the machine was 14,674.70 Php. Operating the machine will cost 51.60 Php or 0.80 Php per kg.
The exchange rate between 1 Philippine Peso and 1 USD is 1 Php. = 0.017 USD.
As shown in Fig. 6, the machine will break even after operating a total input of 210 bags, assuming 50kg per bag.
Ownership of the machine must consider that the volume of harvest must exceeds the break-even weight to compensate for all the costs in one (1) year.
Farmer's associations can also prompt for group ownership. However, they must consider a custom rate of 1Php/kg to efficiently use the machine.

CONCLUSIONS

Based on the performance of the machine, the following conclusions were drawn:
- The fabricated mung bean shelling cum cleaning machine is operational and has met the design considerations;
- The best machine operational setting is 600 rpm and 12% moisture content on a wet basis;
- Although operational, further modifications to optimize the ergonomics and performance must be done;
- The ownership of the machine must be in a group. Individual ownership must be done if the volume of harvest of the area owned can exceed the break-even weight.

ACKNOWLEDGEMENTS

The researchers want to thank the BISU-Bilar administration for their support and for granting them permission to conduct the study on campus.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE ASSESSMENT OF CUT FLOWER CONSUMER PREFERENCES: A CASE STUDY OF ISPARTA PROVINCE IN TÜRKİYE

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Abstract

The consumption of cut flowers is a widespread practice, valued for their aesthetic appeal and ability to enhance emotional well-being. Flowers beautify living spaces and positively influence mood in homes, workplaces, and public areas by offering stress relief and promoting positive emotions. This study investigates the potential for cut flower consumption and examines consumer trends based on primary data collected through face-to-face interviews with 384 urban residents of Isparta province, Türkiye. The survey sample size was determined using the 'unclustered single-stage simple random probability sampling' method. A logistic regression model was employed to identify key factors influencing cut flower purchasing behavior. The results show that 64.6% of participants reported purchasing cut flowers, with birthdays (41.7%) and Mother's Day (40.1%) being the most common occasions for these purchases. Roses (54.7%), carnations (34.1%), and daisies (33.6%) were the most preferred flower types, while red (29%) and white (12.4%) were the most popular colors. Consumers prioritized flower type and variety when purchasing, followed by price considerations. Notably, 55% of respondents perceived cut flowers as expensive, and 42% reported that price increases affected the quantity of flowers they purchased. Logistic regression analysis revealed that age and income level were statistically significant variables of purchasing behavior at the 1% level. Education level also had a significant impact, with the first and third categories being significant at the 5% and 10% levels, respectively. The findings suggest that the likelihood of purchasing cut flowers increases with higher age, education, and income levels.

Key words: *cut flower, consumption, preference, behavior, logistic regression*

INTRODUCTION

The history of ornamental plants in Türkiye dates back to the Ottoman Empire, representing a sector once valued highly enough to lend its name to a historical era. The production of flowers and potted plants in Türkiye began in the 1940s and continues today [26]. Ornamental plants are defined as decorative plants grown for aesthetic, functional, and economic purposes. They can also be described as plants that display visual appeal through their buds, flowers, fruits, leaves, branches, or forms, or as plants that stand out due to these characteristics. Globally, ornamental plants are categorized into three groups: cut flowers, outdoor plants, and indoor (potted) plants, while in Türkiye, they are classified based on usage purposes into four groups: cut flowers, outdoor ornamental plants, indoor ornamental plants, and native flower bulbs [25]. The concept of cut flowers generally refers to fresh, dried, dyed, or bleached flowers, buds, branches, and leaves used in bouquets, baskets, wreaths, and arrangements [24]. Additionally, cut flowers are now offered in creative arrangements featuring chocolates, sweets, and fruits to appeal to new consumer preferences and younger consumers.

The initiation of cut flower production in developed countries is largely attributable to the fact that these countries are also the largest consumers of cut flowers. Initially, developed countries produced only to meet their own domestic needs; however, as consumption increased and became more widespread, they combined their accumulated expertise with new technologies and emerged as major producers of cut flowers globally. Today, however, it is observed that most production areas have shifted to developing countries. From a commercial perspective, this shift indicates that almost all developing countries have become exporters, while most developed

countries have transitioned to being importers [13].

Colombia, Brazil, India, Indonesia, Ecuador, Mexico, China, and South Africa are among the world's leading countries in cut flower cultivation and are also some of the richest nations in terms of global plant biodiversity. According to 2021 data, global cut flower exports reached $11.6 billion. The top exporting countries in this sector are the Netherlands, Colombia, Ecuador, Kenya, and Ethiopia, with Türkiye ranking 15th. In 2022, Türkiye's cut flower exports decreased by 17% compared to the previous year, totaling $49.4 million. The primary export markets for this product group are the Netherlands, the United Kingdom (UK), and Russia. In 2021, global cut flower imports amounted to $10.354 billion. Major importing countries for cut flowers include the United States of America (USA), Germany, the Netherlands, and the UK [1].

Given the delicate and perishable nature of cut flowers, the development of cold chain logistics from harvest to marketing is critically important [11]. Although the sector has yet to achieve the desired and anticipated levels under current conditions, its substantial production and export potential necessitate dedicated attention and focus.

Türkiye, located at the intersection of three major gene centers of the world, possesses remarkable plant genetic diversity and rich potential due to its varied geomorphological and climatological characteristics [40]. In Türkiye, cut flower production has notably developed in the Marmara, Aegean, and Mediterranean regions. In 2022, ornamental plant cultivation spanned a total of 5,687 hectares, with 70% of production areas dedicated to outdoor plants and 26% to cut flowers. Antalya and Izmir are the leading provinces for cut flower production, with Antalya producing high-quality, export-oriented flowers, primarily grown in greenhouses [2]. The study area, Isparta, has also become an important province for cut flower production in recent years. According to 2022 data from the Turkish Statistical Institute (TUIK), Isparta produced 750,000 roses and 243 million carnations across 1,815 decares [41].

The consumption of cut flowers is a common practice worldwide due to their aesthetic appeal and natural beauty. From an aesthetic and psychological perspective, flowers enhance living spaces, positively influencing mood in homes, offices, and public areas. They help reduce stress and promote positive emotions [37]. In terms of ecosystems and natural resources, cut flowers are derived from plants cultivated with essential resources like water, soil, and sunlight, thereby supporting the horticulture and floriculture sectors [42]. Economically, the cut flower industry represents a multi-billion-dollar market globally. It contributes significantly to the agricultural sector by creating jobs in many countries and promoting economic growth. Additionally, it holds substantial value in international trade [14]. Socially and culturally, flowers are used as symbols of love, appreciation, and respect on important occasions such as weddings, birthdays, and graduations [23]. Environmentally, the cultivation of flowers requires a significant amount of energy, water, and chemicals. Therefore, sustainable resource use is an important consideration for both producers and consumers [33].

The increasing number of informed consumers in society has led to a growing emphasis on consumer behavior in the literature. Consumer behavior refers to the processes involved in individuals' decisions regarding which goods and services to purchase, from whom, how, where, and when to make purchases—or whether to purchase at all. In other words, consumer behavior encompasses how and why individuals, as consumers, make decisions and behave in relation to goods and services that meet their needs. The foundation of consumer behavior is purchasing behavior [3].

The literature includes various studies on the consumption of cut flowers or ornamental plants [5, 6, 15, 20, 21, 22, 27, 28, 30, 32, 34, 35, 36, 39]. However, studies specifically focused on Türkiye are relatively scarce [8, 10, 12, 17, 31, 43, 44, 45]. A review of the literature on consumer behavior related to flowers reveals that past studies have not adequately addressed preferences concerning

cut flower products. This underscores the significance of the present study.

This study aims to assess the potential for cut flower consumption and analyze consumer preferences in Isparta province, Türkiye. By examining consumer behavior, we seek to identify the key factors driving purchasing decisions for cut flowers. Understanding the factors influencing cut flower purchases and developing targeted production and marketing strategies are crucial for stakeholders directly or indirectly involved in the cut flower industry, including private sector representatives and policymakers. Thus, this research aims to serve as a reference for producers, consumers, researchers, and policymakers.

MATERIALS AND METHODS

Data

The primary data source for this research comprises responses collected from a survey conducted through face-to-face interviews with 384 consumers residing in the province of Isparta who voluntarily participated. The sample size for the survey was determined using the 'unclustered single-stage simple random probability sampling' method [9].

(1) $N = t^2 \frac{(p*q)}{e^2}$

where:

N: Sample size

t: Table value corresponding to a 95% confidence level (1.96)

p: Probability of the event occurring (set to 0.50 in this study to maximize the sample size)

q: Probability of the event not occurring (q = 1 - p, i.e., 0.50)

e: Acceptable margin of error in sampling (5%)

Given this information, the sample size was calculated as 384, and participants were randomly selected. The collected data were analyzed using the SPSS 26.0 statistical software package [38] and MS Excel [29].

The survey questions prepared to obtain primary data were designed in alignment with the research objectives, drawing on previous studies conducted for similar purposes. The survey includes questions on demographic information, preferred days for purchasing cut flowers, reasons for preferences, types of preferences, locations, and times of purchase. Proportional distributions and the logistic regression model were used in the data analysis—the logistic regression model aimed to identify the factors influencing the purchase of cut flowers.

Additionally, various secondary data sources were utilized, including past studies on consumer behavior related to cut flowers, reports, theses, and existing statistical data obtained from national and international research organizations.

Model

The logistic regression model was employed to analyze the factors influencing the purchase of cut flowers using primary data collected through face-to-face surveys with participants. The model is a nonlinear regression model specifically designed for binary dependent variables. The econometric model, based on the logistic probability function, is expressed as follows [18]:

(2)
$$Prob(Y_i = 1) = P_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{\left(1+e^{-(Z_i)}\right)} = \frac{1}{1+e^{-(\alpha+\beta X_i)}}$$

(3) $$Prob(Y_i = 0) = 1 - P_i = \frac{1}{1+e^{(\alpha+\beta X_i)}}$$

Here, F represents the cumulative probability function, e is the exponential constant, α is the intercept coefficient, β is the parameter to be estimated for each explanatory variable, and X_i denotes the i-th independent variable. From Equations (2) and (3):

(4) $$\frac{Prob(Y_i=1)}{Prob(Y_i=0)} = \frac{P_i}{1-P_i} = e^{Z_i}$$

Taking the natural logarithm of both sides of Equation (4) yields the following equation.

(5)
$$L_i = ln\left[\frac{P_i}{1-P_i}\right] = Z_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon_i$$

In the model, the dependent variable (WP: willingness to purchase cut flowers) is expressed as the natural logarithmic value of

the ratio of preferring a particular option to not preferring it. It is assumed that if participants are willing to purchase cut flowers, y = 1; and if not, y = 0. The independent variables included in the model were determined based on the information obtained from the literature review. Thus, the identified independent variables are, respectively, the participant's gender (GND), age (AGE), education level (EDU), occupation (OCP), and monthly income (INC).

(6)

$$WP = \alpha + \beta_1 GND + \beta_2 AGE + \beta_3 EDU + \beta_4 OCP + \beta_5 INC + \varepsilon_i$$

The logistic regression model is advantageous because it does not rely on the assumption of linearity between the dependent and independent variables, nor does it assume homoscedasticity. Due to these advantages of the approach, logistic regression estimation has been used in the study. To assess the model's fit between the observed and predicted values, the Hosmer-Lemeshow test [19] was applied. Additionally, the analyses were conducted using SPSS 26.0 [38].

RESULTS AND DISCUSSIONS

Research Findings

It was observed that 55.7% of the individuals who agreed to participate in the survey are male, 58.6% are married, 41.1% hold a bachelor's degree, and 35.4% are civil servants. Among the occupational groups, civil servants (35.4%) constitute the largest group, followed by students (17.4%) and workers (15.6%). When analyzing the participants by age group, the highest proportion (26%) belongs to the 16-25 age range, followed closely by the 26-35 age group at 25.1%. These proportions are significantly lower than those reported in the study by Djokoto et al. (2018) [15]. In Gençer's (2014) [17] research, the majority of consumers (42%) were over the age of 40, while only 24% were aged 30 or below. Regarding the participants' average monthly personal income, those earning above 10,000₺ represent the highest proportion at 60.4%. In terms of average household income, it was found that 81% of participants have a household income exceeding 10,000₺. This figure is relatively low in comparison to the study by Li et al. (2016) [27], where 53% of the sample reported earning approximately 50,000 $ annually.

Table 1. Descriptive statistics of the sample population

Variables	Group	f	%
Gender	Female	170	44.3
	Male	214	55.7
Marital Status	Married	225	58.6
	Single	138	35.9
	Divorced/Separated	21	5.5
Occupation	Student	67	17.4
	Civil Servant	136	35.4
	Worker	60	15.6
	Retired	22	5.7
	Housewife	26	6.8
	Freelancer	48	12.5
	Farmer	3	0.8
	Unemployed	11	2.9
	Other	11	2.9
Age	16-25	100	26.0
	26-35	97	25.1
	36-45	88	23.0
	46-55	62	16.2
	56-65	28	7.4
	66-75	9	2.5
Monthly Income (Personal)	Below 5,000 ₺	95	24.7
	5,001-10,000 ₺	57	14.9
	Above 10,000 ₺	232	60.4
Monthly Income (Household)	Below 5,000 ₺	21	5.5
	5,001-10,000 ₺	52	13.5
	Above 10,000 ₺	311	81.0
Education	Primary School	34	8.9
	Secondary School	89	23.2
	Bachelor's Degree	222	57.8
	Postgraduate	39	10.1

Source: The author's calculations.

When examining consumer preferences for cut flowers, it was found that 248 out of 384 participants (64.6%) expressed a preference for purchasing them. In a study by Djokoto et al. (2018) [15], only 30% of participants reported buying cut flowers, while in a study by Asiedu (2014) [4], 79% of participants made a purchase. When the participants were asked about specific occasions for which they preferred to buy cut flowers, it was found that the most popular occasions identified were birthdays (41.7%) and Mother's Day (40.1%). In contrast, the least popular occasions were holidays (0.8%) and funerals (1.6%) (see Table 2). Additionally, a study by Yazıcı and Gülgün (2020) [44] conducted in the Tokat province of

Türkiye revealed that the most popular occasion for purchasing cut flowers was Valentine's Day (64.3%), followed by birthdays (50.6%) and Mother's Day, which ranked third at 43.8%. Regarding expenditures on cut flowers for special occasions, the highest amount spent was 3,000₺ for engagements, weddings, and bridal ceremonies. This was followed by 2,000₺ for Mother's Day and Father's Day. The lowest expenditure recorded was 10₺ for World Working Women's Day.

Table 2. Preferences for cut flowers on special occasions

Special Occasions	f	%
Birthday	160	41.7
Mother's Day	154	40.1
Valentine's Day	99	25.8
Wedding Anniversary	76	19.8
Father's Day	54	14.1
Hospital Visit	48	12.5
Teacher's Day	41	10.7
World Working Women's Day	29	7.6
Birth Congratulations	23	6.0
Engagement, Wedding, and Bridal Ceremonies	21	5.5
Promotion and Appointment Celebrations	19	4.9
New Year	10	2.6
Grave Visit	9	2.3
Religious Holidays	6	1.6
Funeral	3	0.8
Other Special Occasions	3	0.8

Source: The author's calculations.

When examining the preferred types of cut flowers, the results showed that roses (54.7%), carnations (34.1%), and daisies (33.6%) were the most preferred. In contrast, the least favored types were eryngium (1.0%) and lisianthus (0.8%). In terms of purchasing frequency, most consumers typically buy cut flowers two to three times a year (43.2%), followed by those who purchase them once a year (See Table 3). Regarding potted ornamental plants, the majority of respondents (60.9%) reported that they do not purchase them at all. Among those who do, the most common frequency was once per year (15.1%). Similarly, when it comes to artificial flowers, most participants (85.4%) indicated that they do not prefer to buy them, while a smaller portion (9.4%) reported purchasing them annually.

Table 3. Frequency of Purchasing Cut Flowers

Ferquency	f	%
Once a week	1	0.3
2–3 times a week	1	0.3
Once a month	15	3.9
2–3 times a month	10	2.6
Once a year	58	15.1
2–3 times a year	166	43.2
Never	133	34.6
Total	384	100.0

Source: The author's calculations.

When choosing cut flowers, consumers prioritize various factors. The type and variety of flowers rank first, followed by price, which comes in second. In the survey, 55% of respondents considered cut flowers to be expensive, while 42% stated that increases in the price of cut flowers affected the quantity they purchased. These findings highlight the importance of price as a secondary factor in consumers' decision-making processes regarding cut flowers. Flower color was identified as the third most important criterion, while the longevity of the flowers was deemed the least significant factor in the selection process.

The preferred points of purchase for cut flowers were identified as follows: florist shops (55.2%), online platforms (33.6%), street vendors (13.3%), and supermarkets (10.4%). The least popular sales channel was flower stalls, with only 5.2% of participants choosing this option (see Table 4). In a study conducted by Paiva et al. (2020) [32] in Brazil with 1,047 participants, flower shops were the most favored locations for purchasing cut flowers (61.5%), followed by supermarkets (37.8%). In contrast, only 3.2% of participants preferred online shopping for cut flowers. Similar to our findings, a survey by Rombach et al. (2018) [36] in Germany indicated that 47.5% of participants purchased cut flowers online. These findings underscore the growing importance and role of online platforms in the purchase of cut flowers, especially in Türkiye.

Table 4. Preferred places for purchasing flowers

Places	f	%
Florist shop	212	55.2
Street vendors	51	13.3
Supermarket	40	10.4
Internet	129	33.6
Flower stalls	20	5.2
Telephone orders	35	9.1

Source: The author's calculations.

The findings indicate that 41% of consumers perceive flower sales outlets as adequate, whereas 22% consider them inadequate. Additionally, 37%

of consumers did not express an opinion on this matter. When asked whether they could find flowers of the desired quality and type, 47% of respondents answered affirmatively, while 15% reported otherwise. An analysis of the reasons for consumers' preference for cut flowers revealed that the primary factors were aesthetic appeal (39.6%), perceived meaningfulness (33.3%), a preference for cut flowers by the person from whom they purchased (29.9%), and the availability of a wide range of colors and varieties (26.8%). These findings align with those of Yazıcı and Gülgün (2020) [44], who identified aesthetic appeal (20.5%), perceived meaningfulness (13.7%), and the recipient's preference (12.3%) as the most significant factors influencing the choice of cut flowers.

An analysis of the preferred seasons for purchasing cut flowers revealed that a significant proportion of consumers (29.7%) do not differentiate between seasons; they purchase cut flowers year-round. Among those with seasonal preferences, spring was the most favored season (12.5%), followed by summer (10.4%). Regarding color preferences, the most commonly chosen colors were red (29%), white (12.4%), and pink (5.7%). Similarly, Yazıcı and Gülgün (2020) [44] found that white (56.1%), red (41.1%), and pink (28.6%) were the most preferred colors for cut flowers. Their findings align with the current study, particularly in identifying red, white, and pink as the leading color choices, albeit with differing proportions.

Model Estimation

To determine the factors influencing the willingness to purchase cut flowers, a logistic regression analysis was conducted, as previously mentioned. For this purpose, this analysis incorporated various socio-demographic factors, such as gender, age, and education, as well as economic factors, including income and occupation, which are hypothesized to affect individuals' willingness to purchase cut flowers. The results of the logistic regression model are presented in Table 5.

The Hosmer-Lemeshow test yielded a goodness-of-fit statistic of 11.99 (p-value = 0.15, which is greater than 0.05). This indicates that there is no significant difference between the model and the observed data, confirming the model's suitability for the dataset. According to the findings, the age and income level factors are statistically significant at the 1% level. Among the education level variables, the first is statistically significant at the 5% level, while the third is significant at the 10% level. In contrast, the variables of gender and occupation were found to have no statistically significant effect on consumers' willingness to purchase cut flowers.

Table 5. Logistic regression results

Variable	B	S.E.	P value	Exp (B)
GND	0.27	0.25	0.28	1.31
AGE	0.03	0.01	0.01***	1.03
EDU (1)	1.49	0.72	0.04**	4.42
EDU (2)	0.72	0.55	0.19	2.06
EDU (3)	0.89	0.52	0.09*	2.43
OCP	0.10	0.06	0.10	1.11
INC (1)	1.39	0.34	0.00***	3.99
INC (2)	1.37	0.34	0.00***	3.94
Constant	-3.86	0.76	0.00***	0.02
Hosmer- Lemeshow Test			11.99	
-2 Log likelihood			444.51	
Nagelkerke R Square			0.18	

Source: The author's calculations.

The estimation results indicate that consumers' willingness to purchase cut flowers increases by 3% with each additional year of age, aligning with the findings of Li et al. (2016) [27]. Income level also emerged as a significant factor, with higher income associated with a greater likelihood of purchasing cut flowers. Similarly, Djokoto et al. (2018) [15] found that participants with higher income levels were more likely to buy cut flowers. This finding reinforces the understanding that cut flowers are a discretionary purchase valued for their aesthetic appeal rather than a necessity. In contrast to Rombach et al.'s (2021) [35] findings in Germany, this study demonstrated that education level significantly influenced the willingness to purchase cut flowers. Similarly, a survey by Dalgıç et al. (2024) [12], which analyzed the consumption of ornamental plants in Eskişehir province, Türkiye, found that education level was statistically significant at the 5% level, aligning with our results. Specifically, our research indicates that primary school graduates and undergraduate degree holders are 4.4 and 2.4 times more likely, respectively, to purchase cut flowers compared to postgraduate degree holders.

These findings suggest that consumers' purchasing behaviors are influenced by social, economic, and demographic factors. As individuals age, they tend to prioritize aesthetic and emotional values, leading to a greater interest in gifts or decorative products such as cut flowers. This shift can be attributed to accumulated life experiences and a growing appreciation for aesthetic values over time. Additionally, individuals with higher education levels are more likely to choose environmentally friendly products and to place greater importance on aesthetics. This trend can be explained by the fact that increased education often correlates with higher levels of knowledge and awareness, which in turn drives greater investment in the consumption of cut flowers. The practice of giving cut flowers as gifts or using them for decorative purposes also aligns with social norms and fulfills psychological needs. As individuals' income levels rise, their spending on items associated with social interactions and aesthetic appeal is expected to increase. Cut flowers, which are considered nonessential yet carry aesthetic and social prestige, become more desirable to individuals once their basic needs have been met. This inclination toward luxury and aesthetic products typically grows with higher disposable income [7, 16]. Consequently, the findings align with our expectations.

CONCLUSIONS

Although cut flowers, in particular, are not considered essential needs, they play a significant role in social life by allowing individuals to express their emotions and thoughts, and they bring joy when purchased for themselves or loved ones. Despite Türkiye's considerable potential for cut flower cultivation, there is a notable lack of scientific studies addressing this subject.

This study investigates the potential for cut flower consumption and consumer trends through face-to-face interviews conducted with 384 individuals residing in the urban area of Isparta province, Türkiye. The findings reveal that 64.6% of participants reported purchasing cut flowers. Birthdays (41.7%) and Mother's Day (40.1%) emerged as the most common occasions for buying flowers. Regarding expenditures, the highest amounts were allocated to engagements and weddings, whereas the lowest expenses were associated with World Working Women's Day. The most preferred types of cut flowers were roses (54.7%), carnations (34.1%), and daisies (33.6%). Regarding color preferences in cut flower purchases, red was the most popular (29%), followed by white (12.4%). Most consumers did not limit their purchases to specific seasons, with 29.7% purchasing cut flowers throughout the year. On average, participants reported buying cut flowers 2–3 times per year. However, the majority expressed a low preference for potted ornamental plants, with 60.9% indicating they did not purchase them. In terms of purchase locations, 55.2% of consumers favored florists, while 33.6% preferred online shopping. The primary motivations for choosing cut flowers included aesthetics (39.6%), their symbolic or meaningful value (33.3%), the recipient's personal preferences (29.9%), and the availability of diverse colors and varieties (26.8%). When prioritizing their purchasing decisions, consumers placed the greatest emphasis on the type and variety of flowers, followed by price. Notably, 55% of consumers perceived cut flowers as expensive, and 42% indicated that price increases influenced the quantity of flowers they purchased.

The results of the logistic regression analysis indicate that the variables of age and income level were statistically significant at the 1% level, while the first of the education level was significant at the 5% level and the third at the 10% level. The analysis further revealed that as consumers' age and education level increased, their tendency to purchase cut flowers also increased. Similarly, higher income levels were associated with an increased likelihood of purchasing behavior.

Consumer demand plays a crucial role in the growth and development of the cut flower sector. Consequently, it is imperative to focus on diversifying product offerings and implementing effective advertising strategies to stimulate cut flower consumption. For example, high-quality or designer-cut flowers can be specifically marketed to educated and

older consumers. Furthermore, cut flowers sourced from organic or sustainable farms may appeal to this demographic. Highlighting environmental benefits through the use of labels or certifications indicating sustainability can further attract environmentally conscious consumers. Given that individuals in this group tend to prefer culturally and aesthetically appealing products, developing targeted advertising campaigns is essential. Additionally, creating engaging social media content tailored to their preferences can enhance consumer interest and engagement.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SCENARIOS AND VIABILITY OF RURAL AREAS BASED OF SOCIO-DEMOGRAPHIC INDICATORS IN BULGARIA THROUGH THE GREEN DEAL

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Abstract

The purpose of this study is to analyze and assess the viability in rural areas in Bulgaria. The focus is on demographic and social indicators. On this basis, three scenarios for the development of rural areas by 2030 are proposed, with reference to the main priorities of the Green Deal. The working-age population was chosen as an indicator for evaluation. In a methodological aspect, an extrapolation method of proportions based on the Territorial Share Shift Analysis (TSSA) proposed by Ivanov (2024) is approved. The model is proportional and extrapolated, which means that trends are more reliable than exact figures. The results present a positive trend in rural areas by 2030, expressed in an increase in the number of working-age population based on statistical data for the period 2010 - 2020. Naturally, under the hypothesis of preserving the socio-economic characteristics of these regions. The most likely scenario to happen is the realistic one. According to the results, favorable changes in demographic aspect are expected, which will affect the economically active population in rural areas of Bulgaria. At the local level, cross-border cooperation and investment in infrastructure projects should be strengthened.

Key words**:** *scenarios, viability, rural areas, socio-demographic indicators, Green Deal*

INTRODUCTION

Bulgaria is looking forward to launching new infrastructure projects in rural areas. The new Strategic Plan for the Development of Agriculture and Rural Areas (2023-2027) envisages encouraging policies and supporting activities to strengthen the viability of rural areas in Bulgaria [14]. This would increase employment opportunities, increase incomes and make municipalities attractive centers for living. Despite the ongoing demographic crisis in the country (permanent depopulation, constant reduction and deterioration of the age structure of the rural population, incessant internal migration processes from villages to large urbanized areas, etc.), policies to strengthen the socio-demographic sustainability of rural areas are increasingly being promote.

The attractiveness of rural areas includes various indicators that are decisive for viability. These include income levels, employment opportunities, investment activity, development and availability of cultural, social and transport infrastructure, public works, improvement of the living environment, solving environmental challenges, etc. [2], [11], [12], [13], [15]. In this case, one of the demographic factors with a direct bearing on income and employment in rural areas is the working-age population.

The purpose of this document is to examine and assess the viability of rural areas through a selected demographic indicator, such as the working-age population, as well as to develop scenarios and outline the prospects in the considered aspects for 2030 through the expected impact of the Green Deal.

To achieve the goal, the following tasks are set:

(1) Calculating the influence of factors at the local, national and regional levels on the change in the working-age population in 2020 compared to 2010.

(2) Calculating scenario estimates for the viability indices of rural areas

(3) Summarizing the probabilities of the emergence and occurrence of the developed scenarios for changing the viability indices of rural areas.

(4) Deriving relevant recommendations and conclusions from the developed scenarios, as well as assessing the significance and impact of each of the developed scenarios in rural areas through the Green Deal.

MATERIALS AND METHODS

The number of working-age population was chosen as a demographic and social indicator. The choice is justified by the available statistical information. According to the methodology National Statistical Institute of Bulgaria (NSI methodology): "These limits for the working-age population are up to the age of 61 years and 10 months for women and 64 years and 5 months for men per 100 persons of the population in the "independent" ages (from 15 to 64 years)" [10]. "For 2023, these limits are from 16 to the age of 62 years for women and 64 years and 6 months for men." "The age limits for the distribution of the population by categories below, at and above working age are determined according to the current retirement age in the respective year, adopted by a Decree of the Council of Ministers." (NSI methodology) [10].

On this basis, scenarios are developed for the prospects in the considered aspects for 2030. They are proposed with a view to finding the optimal opportunity provided by the data for their inclusion in the established econometric model and calculation of demographic forecasts (prospective population projections). These assumptions are made on the condition that certain assumptions are made about the natural increase, the future development of the birth rate and mortality in rural areas in the perspective of 2030. The influence of factors at the local, national and regional levels is taken into account. Data from the National Statistical Institute (2010-2020) are used. The unit of measurement of the selected indicator is expressed in percentage.

Three scenarios for the projections of the working-age population are envisaged. The main research tool is the Regional Factor Analysis (RFSA), designed to assess the demographic, socio-economic changes between rural and non-rural areas, at the level of planning regions and at the local level. Based on Shift Share Analysis (SSA), a subcategory RFSA is built. It is an analytical approach and is applied to find the value of individual components to certain changes in the study of regional development of regions at the level of NUT2 [9]. The classical SSA is applied at the level of economic sectors, following the basic principles and logic of this analysis, a regional shift analysis has been developed and proposed, adapting the RFSA computational algorithm [9]. The methodology is based on an extrapolation method of proportions, based on the Territorial Shift Share Analysis (TSSA) [7], [8], [9]. SSA analysis itself is based on a methodology for studying "local shifts" in production [6], and the technique was developed and used for the first time as an analytical tool in the early 1960s. [1], [3]. An "extrapolation method of proportions based on the Territorial Share Shift Analysis (TSSA)" [9]. In which two periods are selected in this case - 2010 and 2020. The positive attitudes among the public regarding the proposals by the Ministry of Health and the Strategic Plan adopted by the EC for the new Programming period 2023-2027 are taken into account as a reference point. The scenarios illustrate the final year 2030 of the period and are constructed based on criteria [10], as follows:

• First scenario – is assumed to be realistic. It covers the regulations of the European Union, which are related to the demography and socio-economic development of the member states;
• Second Scenario – optimistic. According to it, upward demographic processes are expected in the member states;
• The third scenario is pessimistic: It assumes a negative trend in terms of socio-demographic indicators in the analysed member state.

The last group of coefficients (Scenario Likelihood) in the matrix provides information about the probability of the scenarios (not) occurring.

RESULTS AND DISCUSSIONS

Influence of factors at local, national and regional levels for positive change in the working-age population in 2020 compared to 2010

According to the results (Fig. 1), in the municipality of Chuprene, local factors have a dominant role in the favorable change in the rural population of active economic age, a positive change for the period 2020-2010 - 43.9%. Factors at the regional level occupy second place with 10.8%, and the influence of national factors has a minimal participation with 0.38%. In the municipality of Sarnitsa, local factors again prevail in the change in the number of the working-age population - 35.9%, followed by factors at the regional level with 9.1%, and in last place - national level - 0.74%. Madzharovo municipality reports the highest influence of national factors, with a positive effect on the relative share of the working-age population - by 0.78%. Except for the municipality of Kuklen, all other municipalities with a positive trend during the ten-year period under review are located in the border regions of Bulgaria: these are the municipalities of Nevestino, Treklyano, Godech, Sarnitsa, Lyubimets, Madzharovo, Svilengrad. As a reason for this trend, it can be assumed that it is due to the opportunities for diversity of tourist services and cross-border cooperation in the implementation of territorial strategies under the INTEREG program aimed at tourism development, soft training and business cooperation. The main objectives of the measures, also set out in the Operational Program "Regions in Growth" 2014-2020, are precisely the creation of conditions for the development of tourism. This is also one of the activities aimed at improving the business climate in the municipality, building infrastructure, protecting natural resources, and collaborating on business relations with regional and international effect**.**

In this regard, it is the municipality of Madzharovo that has implemented many national programs with grant funding, such as: Human Resources Development Program of the Ministry of Labor and Social Policy; beneficiary under sub-measure 7.2. "Investments in the creation, improvement or expansion of all types of small-scale infrastructure" of the Rural Development Rrogramme of the Common Agricultural Policy2014-2020; project under Operational program "Environment“ 2014-2020; participation in the National Program "Provision of Care in a Home Environment"; project "Economic Development through the Creation of Social Infrastructure for Educational Purposes" with a partner from the Republic of Turkey - Specialized Regional Directorate of Kırklareli, etc. Evidence of coordination of policies at local, municipal and national levels with public importance and visibly positive results. According to data from the Institute of Market Economy (2024) the coefficient of mechanical population growth for 2023 ranks the municipality fourth among all municipalities in Bulgaria with 16.7%. According to the methodology of the NSI, "Mechanical population growth in a territorial aspect represents the difference between the number of settled and the number of displaced persons in and from each settlement. The migration balance from external migration is the difference between the displaced and the settled in the country."

Madzharovo Municipality is located in the Eastern Rhodopes, with the unique meanders of the Arda River and sandy beaches near the Ivaylovgrad Dam.

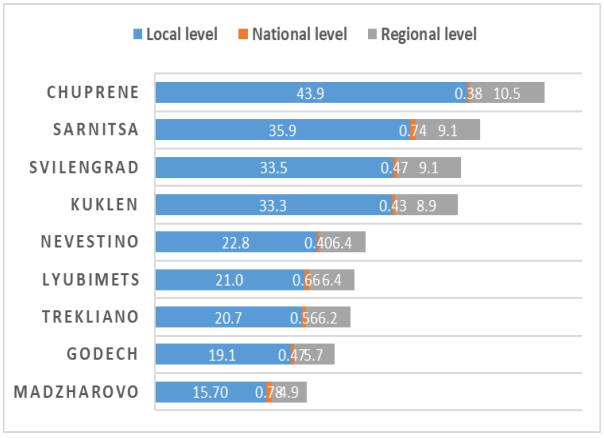


Fig. 1. Influence of factors at local, national and regional levels for positive change in the working-age population in 2020 compared to 2010.
Source: own figure based on Ivanov's calculations (2024).

The built road infrastructure allows the southeast to reach the regional center Haskovo in minimal time or in the direction of Svilengrad to the Kapitan Andreevo border checkpoint or the Kapitan Petko Voyvoda border checkpoint for access to Turkey and

Greece - attractive tourist destinations and high consumption.

Attractive for tourism are the relief forms of the Thracian cult-funerary complex "Deaf Stones", the Medieval Fortress "Efrem", the Roman road connecting Edirne with the interior of the Rhodopes [16] the Church "St. Athanasius" - an artistic monument of culture located in the village of Efrem, an opportunity to observe the symbol of the Eastern Rhodopes and Madzharovo - the Griffon Vulture).

Influence of factors at the local, national and regional levels for a negative change for the period 2020-2010 on the labor force of the population in rural areas.

Regional factors in the municipality of Novo Selo have contributed negatively to the number of the working-age population for 2020 compared to 2010 - 18%, followed by those at the local level - 11.9% and at the national level - by 1.1% (Fig. 2).

Next is the municipality of Makresh. Regional factors also contribute to the negative trend for the ten-year period, respectively close to those of the municipality of Novo Selo - 18%. Local factors have influenced the economically active population by over 11%, and factors at the national level by about one percent. The most significant share of the negative trend in the working-age population (-1.12%) is reported by the municipality of Svishtov. Excluding Hisarya Municipality, the remaining municipalities with a negative trend over the ten-year period are also located in the border regions of Bulgaria: Nedelino Municipality, Djebel, Ardino.

Novo Selo Municipality is located in Northwestern Bulgaria and is a constituent municipality of Vidin District. As the results show, district-level factors project a negative trend on the labor force. Therefore, the root cause of the negative trends for 2020 compared to 2010 is the leading role of the district administration.

Through the Danube River, the municipality borders the Republic Romania and is 15 km from the border with the Republic Serbia. In this regard, cross-border projects and cooperation should be developed. The processing industry, which remains as a legacy of the past and the old material base before 1990, mainly grapes and grain, plays a huge role in the economy of the Novo Selo municipality. Although tourism is among the priority areas of development, the municipality cannot boast of any particular achievements. Among the main challenges in the municipality are the poorly built transport infrastructure, water supply, educational centers, business, and tourist unattractiveness. During the period under review 2010-2020, the population decreased by a quarter. [5], [10]. At the end of the period, almost half of the population in the municipality of Novo Selo was economically active, and only 10% was under working age.

For the period 2020-2010, statistics report an over 30% decrease in the working age population. If we refer to the exact figures, in 2010 the economically active population was 85%, in 2020 it reached 54%.

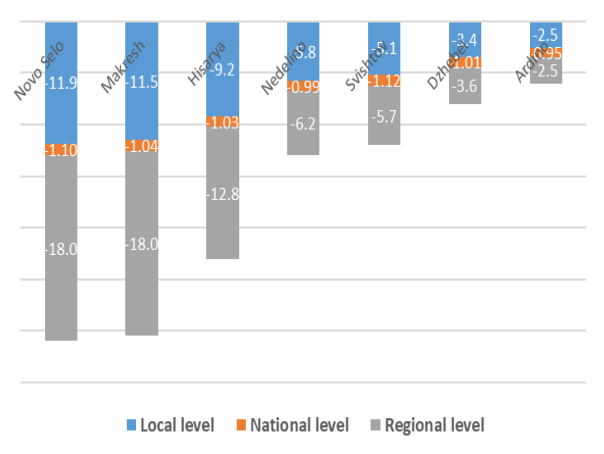


Fig. 2. Local, regional and national factors that negatively impacted the working-age population in 2020 versus 2010.

Source: own figure based on Ivanov's calculations (2024).

Calculation of scenario estimates for the viability indices of rural areas for 2030.

According to the calculations, Chuprene municipality has the highest index of scenario estimates for 2030 based on the change in 2020 compared to 2010 in terms of the working-age population (Fig. 3). The scenarios assume an anticipatory increase in the active population by 2030. According to the approved calculation methodology, an internal migration wave of economically active population to the municipality from other settlements in the country should be expected.

Chuprene municipality is located in Northwestern Bulgaria in the southern part of Vidin district. According to data from the [4] in Chuprene municipality the economically active population for 2020 is 1,049 people, respectively 591 men and 458 women. The economic and social profile of the municipality shows that it ranks one of the last places according to the researched indicators: value added at factor costs (2022) - 3.6 million BGN; share of own revenues from the total revenues of the municipality (2023) - 4.9%. It has more satisfactory indicators in terms of municipal capital expenditures per capita (2023) - 533 BGN/person and according to the coefficient of mechanical population growth (2023) - 2.2% [17].

Sarnitsa Municipality was separated as an independent municipality on January 1, 2015 by Decree of the President of Bulgaria. According to calculations, all three scenarios for the development of the economically active population are possible in the municipality of Chuprene.

The Municipality of Sarnitsa is located in the southern part of the Pazardzhik district. The strategically important territory of Sarnitsa is included in the road infrastructure of the Republican Road network of Bulgaria. One of the leading industries in the municipality is tourism. With its unique landscape, it has favorable conditions for summer and winter tourism. Guest houses are among the attractive businesses. The population is also engaged in logging, livestock breeding, potato production, herbalism, fishing. The working-age population is increasing its interest in opportunities for internal labor migration to the municipality. This indicates optimistic forecasts for an increase in the number of the population with active labor employment by 2030. The remaining municipalities with the highest expected absolute % growth of the economically active population for all three scenarios. In the municipalities of Svilengrad, Kuklen, Garmen, Dolna Banya, Gurkovo, Nikolaevo, Yablanitsa, Dolni Chiflik and Vulchedrum, the scenarios assume an increase in the active labor population.

The remaining municipalities with the highest expected absolute % growth of the economically active population for all three scenarios are Svilengrad, Kuklen, Garmen, Dolna Banya, Gurkovo, Nikolaevo, Yablanitsa, Dolni Chiflik and Vulchedrum. The listed municipalities, with minor exceptions, have certain similar characteristics, such as the presence of natural and historical landmarks, tourist attractiveness, located in semi-mountainous to mountainous and hilly terrain and access to the Republican Road network.

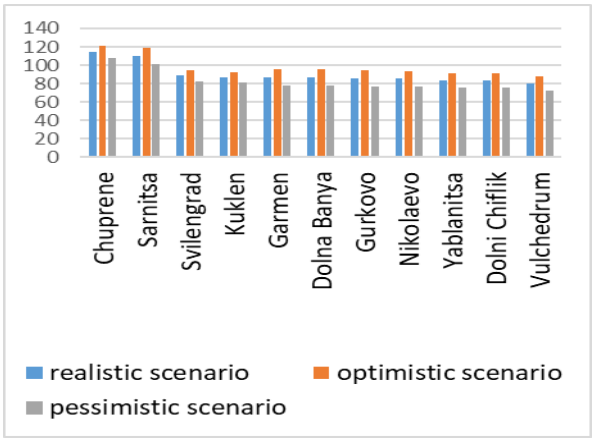


Fig. 3. Optimistic, realistic and pessimistic scenario for viability of municipalities located in rural areas with the largest increase in the economically active population for 2030.

Source: author's figure based on Ivanov's methodology (2024)

According to the amendment for 2020 - 2010, the municipality with the lowest scenario assessment index for 2030 is Makresh municipality (Fig. 4). The scenarios assume a significant decrease in absolute % of the active population by 2030. The municipality of Makresh is located in Northwestern Bulgaria and is a constituent municipality of the Vidin district. Agriculture, and in particular crop production, is the main livelihood for the population in the municipality. The largest share in crop production is occupied by grain production and technical crops.

To a large extent, this also determines the unattractiveness of the municipality of Makresh for the economically active population. Although the location of the municipality falls within a zone of three roads of the Republican Road network of Bulgaria with a total length of 43.5 km between the borders with Serbia and Romania, the potential

for development is blocked. According to the scenarios for 2030, the economically active population of the Makresh municipality will be over thirty-eight percent of the total population. In the pessimistic scenario, it will be ten percent less. The Institute of Market Economics in Bulgaria (2024) [17] reported that it occupies one of the last places in terms of added value at factor costs (2022) - 4.5 million BGN; number of employees under employment and service contracts (2022) - 173 people; population according to censuses (2021) - 1,079 people; natural population growth rate (2023) - minus 36.3 ‰. It has higher indicators in terms of municipal capital expenditures per capita (2023) - 3,788 BGN/person and according to the coefficient of mechanical population growth (2023) - 16.8%, which ranks it in 3rd place among all municipalities in the country.

According to socio-economic indicators, the border region of Vidin is not among the most attractive municipalities in Bulgaria. Naturally, this finding does not apply to the Chuprene municipality. Calculations show that, other things being equal, by 2030, the municipalities of Makresh, Novo Selo, Boynitsa and Kula located in Vidin district will have the lowest absolute % of the working-age population. Out of 10 municipalities in the district, 4 of them are expected to be unviable by 2030.

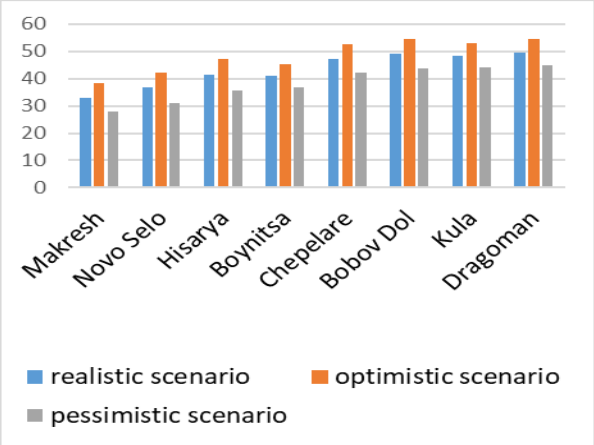


Fig. 4. Optimistic, realistic and pessimistic scenarios for the viability of municipalities located in rural areas with the lowest share of the economically active population for 2030.

Source: author's figure based on the methodology of Ivanov (2024).

The challenges are many and the local authorities in the district will have to collaborate at the national level to restore Vidin to its pre-1990 appearance.

Summary of the probabilities of the emergence and occurrence of the developed scenarios for changes in the viability indices of rural areas for 2030

According to the calculations, all other things being equal and the environment being repeated, in the realistic scenario the absolute percentage of the economically active population in rural areas in 2030 is expected to be 69 percent, and in non-rural areas - seventy percent.

Optimistic scenario - the working-age population by 2030 will be 76 percent, five more than in non-rural municipalities.

In the pessimistic scenario, the economically active population by 2030 will have a parity of 62 percent in rural versus non-rural municipalities (Fig. 5).

With the closest indicators to those of the average in the realistic scenario are the municipalities of Roman, Hayredin (Vratsa district); Ugyrchin municipality (Lovech district); Dolni Dabnik, Iskar and Knezha municipality (Pleven district); Zlataritsa and Polski Trambesh municipality (Veliko Tarnovo region); Kubrat and Loznitsa municipality (Razgrad region); Glavinitsa, Sitovo and Tutrakan municipality (Silistra region); Kavarna municipality in Dobrich region; Veliki Preslav, Novi Pazar and Smyadovo municipality in Shumen region; Primorsko municipality (Burgas); Kazanlak and Radnevo municipality (Stara Zagora); Elhovo and Straldzha (Yambol region); Razlog municipality in Blagoevgrad region; Svoge, Samokov, Mirkovo, Kostenets and Slivnitsa municipality (Sofia region); Chernoochene and Bratsigovo municipality (Pazardzhik); Brezovo and Saedinenie (Plovdiv region).

With levels closest to those of the average in the optimistic scenario are the municipality of Hayredin (Vratsa region); Brusartsi (Montana); Knezha (Pleven); Zlataritsa municipality (Veliko Tarnovo region); Glavinitsa and Sitovo municipality (Silistra region); Novi Pazar and Smyadovo in Shumen district; Razlog municipality and Sandanski in

Blagoevgrad district; Treklyano municipality (Kyustendil district); Kostenets and Svoge (Sofia district); Chernoochene municipality (Pazardzhik).The municipalities with the closest percentages to the average in the pessimistic scenario are Roman, Hayredin (Vratsa district); Ugarchin municipality (Lovech district); Knezha (Pleven); Zlataritsa and Polski Trambesh municipality (Veliko Tarnovo district); Zavet municipality (Razgrad district); Aksakovo (Varna); Kavarna municipality (Dobrich district), etc.

The most likely scenario to occur is the base realistic scenario – 33%. The probability of the optimistic and pessimistic scenarios is equal – 25%. The guarantee factor, through which the confidence probability is expressed, is z = 2.58 in the interval

$$\bar{x} \pm 2.58\sigma_{\bar{x}},$$

which means that 99% of the area is covered.

For the realistic scenario, the variation of the working-age population in rural areas in 2030 compared to 2010 will have increased by 105 percent, and in non-rural areas by eighty-three percent. Compared to 2020, the population in this category is expected to decrease to 103% in rural municipalities and to reach 93% in non-rural ones.

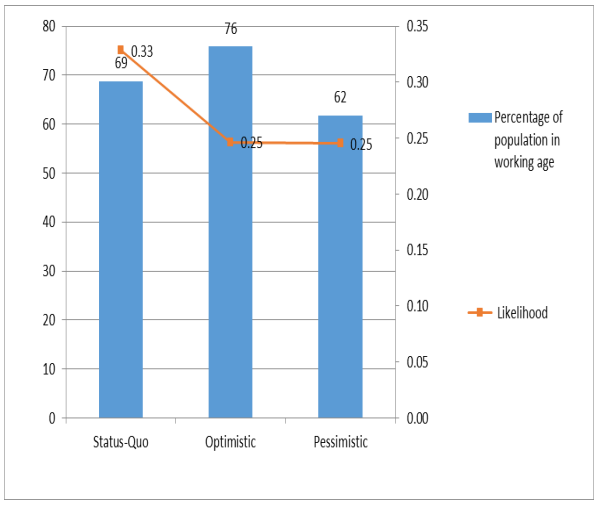


Fig. 5. Probabilities of the emergence and occurrence of the developed scenarios for changing the rural viability indices for 2030.
Source: Ivanov calculations (2024).

For the optimistic scenario for 2030 compared to 2010, the percentage change for non-rural municipalities is expected to be 96 percent and 116% in rural ones. A much lower percentage of change is observed in the pessimistic scenario. According to it, the change in the working-age population for 2030 compared to 2010 in non-rural compared to rural municipalities will be 74% to 95%. The change for 2030 compared to 2020 non-rural/rural will be 95 vs. 93%.

CONCLUSIONS

Based on the model and the three scenarios developed for 2030, favorable development and an increase in the economically active population in rural municipalities based on the situation in 2020 and 2010 are assumed. This trend would be maintained if the repeatability of the environment is maintained and the goals set out in the Green Deal are met. The proposed realistic scenario has the highest probability of occurrence, which means that faster favorable changes in demographic and socio-economic aspects should be expected. In addition, the expected changes will affect the economically active population in rural than in non-rural municipalities more due to the restrictions set out in the Green Deal. It should not be forgotten that the model is proportional and extrapolated, which means that the trends are more reliable than the exact figures.

This trend has proven to be sustainable over time, especially after the crisis during the Covid-19 pandemic. Many young people have permanently left the large urban settlements and moved to ancestral houses in quiet and ecologically clean areas in the villages. If this business model continues to develop, it can be expected to increase the attractiveness and maintain the viability of rural areas, which is a positive sign for the implementation of the priority areas targeted in the Green Deal. The attraction of young married couples will influence the local administration to focus its efforts on policies and actions to improve infrastructure, employment opportunities and increase incomes. Naturally, this will be a good sign for the full absorption of EU structural funds. The question remains unresolved as to what is happening with the North-West region of Bulgaria, especially for the municipalities falling into Vidin region. The problems for the

population there are deepening, despite their favorable territorial location between two neighboring countries. At the local level, cross-border cooperation, investments in infrastructure projects, tourist attractiveness and the livelihood of the population must be strengthened. Naturally, the state must also take on the task of attracting more foreign investment and directing it to this region.

ACKNOWLEDGEMENTS

This publication is elaborated under the project "Stochastic analysis of the prospects and effects of the Green Deal in Bulgarian agriculture - GREENBASE", acknowledging the financing received by the National Scientific Fund, Contract № КП-06-Н 66/3 - 13.12.2022.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SUNFLOWER PRODUCTION AND EXPORT POTENTIAL OF THE REPUBLIC OF MOLDOVA: EVALUATION, VALORIFICATION

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Abstract

This paper analyzes and evaluates sunflower production and export potential of the Republic of Moldova. The article also provides a comparative analysis of sunflower production and export potential in relation to different countries, especially in EU countries. The following research methods were used in the presented work: economic analysis, logical, monographic, synthesis, comparative, etc. The research revealed the main producers, exporters and importers of sunflower in the world, EU, and Republic of Moldova. Based on national statistics, the main sunflower indicators in the country have been analyzed in terms of area, yield, and gross harvest for the period 2017-2023. In 2022, the EU received about 300,000 tones of sunflower seeds, while Ukraine, which is the world's largest producer of sunflower seeds, made a very insignificant contribution - less than 60,000 tones of EU imports. Strengthening trade agreements and improving export logistics can enhance market access and competitiveness of the Republic of Moldova.

Key words**:** *climate change**,** sunflower, production, export, evaluation, Republic of Moldova*

INTRODUCTION

Sunflower is among the most profitable and widely cultivated crops. As one of the world's leading oilseed plants and the primary crop grown for oil production, it attracts significant research interest from scientists worldwide, including those from the Republic of Moldova. As a result of the previous researches, many different theoretical and applied aspects related to this important crop have been revealed, and the knowledge gained is of great importance for further research of this crop in various fields: improvement of cultivation technologies, analysis of national self-sufficiency in this product [20], export of sunflower crops into global markets, especially EU markets, etc. From every 100 kilograms of crushed sunflower seeds, the processors obtain about 40 kilograms of oil, 35 kilograms of protein-rich sprouts and 25 kilograms of sub-products.

The structure of the production cost for sunflower crop, fertilizers and pesticides have a share of 32.1%, seeds 19.3%, petroleum products 12.2 %, 17.7 % CIP, 10.4% labour and 8.3 % others [21].

In recent years, about 35% of Moldovan sunflower exports are exported to Turkey, 20% to Ukraine, the same amount to Romania and about 6% to Great Britain [2]. In the world rating of producers and exporters of sunflower and sunflower oil [10], Moldova ranks quite high. Moldova have ranks 15-16th in the world

ranking of sunflower seed producers with about 1.5% of the world export of this product [9].

Due to the importance and value of this crop worldwide and especially UE, the main purpose of this research is to estimate the production and export potential of sunflower in the Republic of Moldova and to elaborate the recommendations to increase the production and export of this crop, as well as sunflower products for domestic consumption and for export to the world and EU markets [18], [22].

Since the mid-1980s, the sunflower has repeated year after year a regular participation of 9-10% in total grain production.With an annual average of 5.8 Mt harvested between 1996 and 1999, obtained on an average of 3.3 M ha per year (average yield of 1.72 t/ha), it confirms an unfailing presence in the Argentine agricultural panorama [4]. Argentina allows Mercosur (Common Market of the South between Argentina, Brazil, Paraguay and Uruguay) to be among the top producers in the world [5].

The countries of the former USSR and the European Union experience less consistent production. Argentina's production growth follows a pattern similar to that of the European Union. But, since the jump in 1995 (2.1 Mt against 1.4 in 1994), the advance of the old continent tends to fade.For 1996-2000, the average annual production respective of these two zones is 2.26 and 2.91 Mt. world production; Eastern Europe offers 12 to 13%.

Argentina in the world total export decreased between the beginning and the end of the 1990s. Data from Oil World, Argentina fell from 42% of the world market in 1990 to 25% in 1994 and 15% in 1998 (494,000 t out of 3.2 Mt). The countries of the former USSR (Eastern European countries) take over and flow increasingly substantial quantities, resulting from a sharp increase in production. Their participation increased from a rate of 8% of the world market, on average per year, between 1986 and 1990, 30% between 1990 and 1995, and 59% of the market between 1996 and 2000 (1.8 Mt in 1998). The attitude of the European Union, the world's largest importer, also explains the fluctuations in this market. The contraction and then the recovery of its demand is determined by the upheavals of its own production. Its imports vary from 79% of world imports in 1981 (its maximum rate) to 28% in 1989 (minimum rate), 53% in 1992 and 72% in 1998 (2.3 Mt). Major players in sunflower processing are Cargill, OL. Moreno-Glencore, Bunge and Born. The number of players in the global sunflower oil market is small. On the side of exporters, Argentina comes first. Its rate of coverage of global needs has increased regularly and rose from 44%, on average per year between 1981 and 1985, to 54%, on average per year between 1996 and 2000. In 1998, Argentina assumed 56% of world exports, or 1.56 Mt [1]. The United States, the European Union and Eastern European countries share the rest of the market. Of on the importers' side, dispersion is the rule. Turkey, Latin America (Mexico), Asia (India) and the European Union are among the main customers. These are the destinations, among others, of sunflower oil from Argentina: in 1998, India bought 277,000 t from it, the European Union 172 000 t, Egypt 121,000 t, South Africa 112,000 t, Iran 111,000 t, Turkey, etc. [11, 12, [17].

On the world sunflower meal market, Argentina is the undisputed exporter: it accounts for 75 to 80% of world trade. The European Union is, for its part, the area imports par excellence. With 1.98 Mt imported in 1998, it relegates the other importers to minor levels. In fact, over the past two decades, Argentina has asserted its role as world's leading supplier because it has found in the European Union the market to supply: in 1998, it sold 90% of its exports there (1.82 Mt out of 2 Mt). Other customers are South Africa (29,000 t), Thailand (27,000 t), Chile (26,000 t), Egypt (13,000 t), etc. This level of 2 Mt exported is acquired for the following years. Far behind, the countries of Europe from the East (Poland) complete the offer [16], [19].

In this context, this paper aims to evaluate the cultivated area, yield, production, export, and import of sunflower in the Republic of Moldova from 2017 to 2021 to identify key trends and forecast future performance.

MATERIALS AND METHODS

To analyze sunflower production in the Republic of Moldova we used indicators such as:

- Sunflower cultivated area in the Republic of Moldova (hectares).
- Yield per hectare (tons/ha) – influenced by climatic conditions, fertilizer use and applied technologies.
- Total production (tons) – calculated based on cultivated area and yield.
- Production cost (MDL/ton) – including agricultural inputs (seeds, pesticides, fuel, labor).
- Climate impact – drought and extreme temperatures influence crop productivity.

For export of sunflower and derived products we used:
- Total exported volume (tons/year) by main destination countries – Romania, Turkey, Bulgaria, Ukraine, EU.
-Average export price ($/ton) – depending on international demand and trade policy. Taxes and trade restrictions – legislative changes and trade agreements (DCFTA with EU).
-Export evolution – analysis of trends over the last years.
-Capacity of processing plants (tons/year) – data.

Descriptive statistical analysis (means, dispersion, standard deviations for production and exports) and time series analysis are main methods used to forecast production and exports based on historical data.

RESULTS AND DISCUSSIONS

The world's leading sunflower producers include Ukraine, Russia, the European Union, Argentina, and Turkey. In the 2021/22 season, the global sunflower harvest reached a record high of over 57 million tons, marking a 20% increase compared to the 2017/18 season.- more than 57 million tons, which is 20% higher than in 2017/18.The growth was achieved thanks to increase the oilseed harvests in key oilseed producing countries - Ukraine to 17.5 million tons – i.e. +28% compared to 2017 and Russia to 15.7 million tons – i.e. in 1.5 times [14]. These countries account for more than half of the sunflower cultivation in the world - 58% in 2021. In the EU, Romania contributes about a third of the total oilseed production in global harvest [1], [3], [19].

In 2021, less than 9% of the harvested sunflower crop was commercialized on the world market.In the period 2017-2021, the volumes of sunflower exports to the world market decreased by 5% to 5 million tons, taking into account the restrictions due to pandemic Covid-19 and the development of internal processing for vegetable oil. At the same time, the value of oilseed supplies increased by 30% to $4.7 billion due to higher world prices. The highest sunflower supplies were delivered to the global market in 2019.

Sunflower market in the EU

In 2021, the share of EU countries in the global sunflower market exceeded 60%. The leader from UE is Romania, which despite the ensuring its own needs, trades oilseed mainly to EU partner countries. At the same time, the most significant increase in the physical volume of supplies compared to 2017 was observed in France +33% to 4,000 tons by 505 million$ (+39%). The second place with a market share of 9% belongs to China, which exports sunflower to Turkey, Iraq, Egypt. EU countries are leading in terms of sunflower oilseed purchases mainly due to imports by Bulgaria, the Netherlands, Germany, Hungary - their share in 2021 accounted for 32% of the global market. Turkey accounts for 15% of sunflower supplies, which increased its imports to 742 thousand tons (+ 16% vs. 2017). Russia is among the five key importing countries in terms of the value of imported sunflower due to the purchase of oilseeds for sowing.

According to Eurostat data, in 2022 EU imports from Ukraine decreased for a number of agricultural products and this is due to military actions. From 2021 to 2022, the share of sunflower oil increased from 87.5% to 79.8%. Eurostat (2023) [8] analyzed trade between the European Union and Ukraine over the last year: while in 2021 the EU imported 87.5% of sunflower oil from Ukraine, in 2022 this share reached 79.8% [14], [19].

The EU produces about 30 million tons of oilseeds per year and has traditionally been a net importer. Most oilseeds are processed to obtain oil for food or biofuels and meal for animal feed. The EU produces about 5 million tons of protein crops per year. Protein crops are used for food and feed purposes.

Sunflower areas planted in the European Union in the current year 2023 amount to a record 5,153.57 thousand hectares - against 4,368.72 thousand hectares a year earlier. Due to this factor - increase in sown areas and possible favorable weather conditions, the gross yield of sunflower of the new crop could exceed the volume of the harvest compared to the previous year.

Historically, sunflower area in the European Union reached a maximum in 2014 at4,582.42 thousand hectares and a minimum in 2019 at 4,025.65 thousand hectares. In 2023, sunflower area was only 4.7 million ha [8].

Table 1. EU area cultivated with sunflower in period 2014-2023, thousands hectares.

№	Year	Area (ha)
1	2014	4,582.42
2	2015	4,266.05
3	2016	4,197.59
4	2017	4,133.13
5	2018	4,311.63
6	2019	4,025.65
7	2020	4,337.84
8	2021	4,396.74
9	2022	4,368.72
10	2023	4,700.00

Source: [8].

The leader in sunflower cultivation in the European Union is Romania, with the largest sunflower cultivation area of more than 1.2 million hectares. According to prior years' data, Bulgaria ranks second and France third.

According to latest updated Eurostat data, in 2022 the situation has changed slightly with EU countries in terms of area under sunflower cultivation. Today, in the European Union - Romania has also the largest area under sunflower cultivation - about 1.1 million hectares under cultivation, second place - Hungary, third place – Italy [8], [14].

In the period 2022/2021, the area under sunflower cultivation decreased compared to the previous year 2021 in the following EU countries: Romania - from 1,123.96 thousand ha to 1,081 thousand ha, i.e. by 42.17 thousand ha, Italy - from 116.99 thousand ha to 110.82 thousand ha, i.e. by 6.17 thousand ha, Slovakia - from 73.36 thousand ha to 73.13 thousand ha, Italy - from 116.99 thousand ha to 110.82 thousand ha, i.e. by 6.17 thousand ha, Slovakia - from 73.36 thousand ha to 73.13 thousand ha, i.e. by 0.23 thousand ha, Austria - from 24.68 thousand ha to 24.29 thousand ha, i.e. by 0.39 thousand ha, Netherland - from 0.74 thousand ha to 0.65 thousand ha, i.e. by 0.09 thousand ha. In Hungary the area of cultivated land with sunflower increased from 654.69 thousand ha. to 681.67 thousand ha. i.e. by 26.98 thousand ha. as compared to last year, and in the Czech Republic - from 17.98 thousand ha. to 22.49 thousand ha. i.e. by 4.51 thousand ha. and Portugal - from 5.59 thousand ha. to 6.80 thousand ha. i.e. by 1.21 thousand ha.

Totally, in 2022 in the EU, approximately 10.5 million of tonnes of sunflowers were produced. Approximately the same quantity was also consumed. About 450 thousand tonnes were imported from non-EU countries, but about 300 thousand tonnes were exported. These data do not include numbers for sunflower oil or for shives used in animal feed.

In 2021, around 10.5 million tonnes of sunflower were produced in EU countries. About the same quantity was consumed. Of the total tonnes consumed, about 450 thousand tonnes were imported from third countries and about 300 thousand tonnes were exported.

Table 2. EU volume of sunflower harvest in the main producing countries (2021)

№	Country	Volume of harvest Miilion tonnes
1	Romania	3.0
2	France	2.0
3	Bulgaria	2.0
4	Hungary	1.7
5	Spain	800
6	Greece	230
7	Slovakia	200
8	Croatia	120
9	Germany	100

Source: [8].

As a result of the war in Ukraine, sunflower prices have increased sharply to a record high of $1,100 per tonne, or more than 20 MDL per kilogram, almost twice as much as the previous year.

Sunflower market in the Republic of Moldova

The cultivated area with sunflower increased year by year from the minimum in 2010 accounting for 252 thousands ha to the peak of 359 thousands ha in the year 2019 [6].

The total seed production reached 811 thousand tons in 2019, being by 112% higher

than in 2010. It was noticed a trend of a constant gross seed production [6].

The yield level differs depending on the region. It was proved that in the Northern region, sunflower carried out higher seeds yields due to the favorable soil and climate conditions the average yield is usually higher in the Northern region due to more favourable climatic and relief conditions. But, sometimes it is not so, yield could be different, for example, in the central region has an average level and the peak yield is achieved in the south region. For instance, Domenco et al (2020) affirmed that in the year 2016, in the South area it was harvested 21.7 q/ha, in the Center 19.2 q/ha and in the North 18.6 q/ha [7, 6].

In 2023, sunflower was cultivated on 385 thousand ha, average production reached 2.4 tonnes/ha and total seed production accounted for 940 thousand tonnes.

Sunflower seeds balance reflected that in ten year 2021, internal production was 960 thousand tonnes, only 21 thousand tonnes were imported, the stock variation accounted for -360 tonns, so that the total resources reached 621 tonnes (Table 3)

Table 3. The level of sunflower seeds balance in the Republic of Moldova, 2016-2021

	2016	2017	2018	2019	2020	2021	2021/2016 %
Resources							
Production	677	804	789	811	493	960	141.82
Import	6	5	3	5	5	21	350.00
Change in stocks	-53	-118	33	83	112	-360	679.20
Total resources	630	691	825	900	610	621	98.57
Ulilizations							
Export	446	521	526	577	381	303	67.93
Seeds	2	2	2	4	3	2	100.00
Forages	3	3	3	5	4	3	100.00
Processing	170	155	282	301	211	300	176.47
Losses	4	5	8	8	6	9	2.25
Own consumption of the population	5	5	4	4	4	4	80.00
Total utilization	630	691	825	900	610	621	98.57
Level of self-supply, %	446	521	526	577	381	303	67.93

Source: National Bureau of Statistics of the Rep. of Moldova [13].

For the period 2023/2024, the sunflower balance was a little different from the previous years as shown in Table 4.

In 2023, it was cultivated an area of 434 thousand ha.

Table 4. Sunflower balance, 2023/2024

	Harvest Thou. tonnes	Average yield Tonnes/ha	Export Thou. tonnes	Import Thou. tonnes	Domestic consumption Thou. tonnes
2023	622	1.43	236	37	390
2021	960	2.21	303	21	309
Differences 2023 versus 2021	-338	-0.78	-67	+16	-81

Source: [15].

The total production was by 338 thousand tonnes lower than in the year 2021, reflecting the negative impact of climate change (higher temperatures and a long and severe drought).

Average yield was only 1.43 tonnes per ha, by 0.78 tonnes less.

While export declined by 67 thousand tonnes, import increased by 16 tonnes.

Consumption increased in 2023 versus 2021.

In the year 2023-2024, the sunflower seeds stocks stored represented 100 thousand tonnes [15].

The domestic market is not so much influence by sunflower export of Ukraine, because the Ukrainian farmers prefer to sell their seeds on the Romanian market where the price level is higher than in the Republic of Moldova [15].
In 2022, Republic of Moldova exported approximately $155 million worth of sunflower seeds to the European Union market, and 50% less vegetable oil and other fats.
As for sunflower oil, the price of which has risen sharply: Ukraine delivered about 1.4 million tonnes in 2021. This represents about 85% of total imports, while Moldova accounts for a very small amount.
Sunflower is an export-oriented crop, so its imports (excluding seed) are insignificant. The changes over 40 years such important indicators across the country as total sunflower area planted, production of sunflowers and average harvest reveals the total sunflower area was increased on +2.28 times, sunflower production – on +1.97 times and average sunflower harvest was decreased on -2 quintals/hectare.

CONCLUSIONS

Sunflower production plays a crucial role in Moldova's agricultural sector, being one of the main oilseed crops. The country benefits from favorable climatic conditions and fertile soils, making sunflower a key component of the national economy.
While sunflower production has remained relatively stable, but in the last years, yield was affected by weather conditions, such as droughts and high temperatures.
Improved irrigation systems and climate-resilient seed varieties are essential to sustain and increase productivity.
A large share of Moldova's sunflower production is exported, primarily as raw seeds or crude oil. Key markets include Romania, Turkey, Bulgaria, and Ukraine. Strengthening trade agreements and improving export logistics can enhance market access and competitiveness.
Moldova has a growing but underutilized processing industry for sunflower oil. Expanding local processing capacities would allow the country to export higher-value products rather than raw materials, increasing revenue and economic sustainability.
Despite its export potential, the sunflower sector faces challenges such as fluctuating global prices, dependency on foreign markets, and insufficient modernization of processing facilities. Encouraging investments in value-added production and adopting advanced processing technologies could improve sector performance. With strategic investments and policy support, Moldova can significantly increase its sunflower production efficiency and export competitiveness. The development of a well-integrated value chain, from cultivation to refined product export, will ensure long-term economic benefits for the country.
The positive result was achieved due to the growth of sunflower harvests on +20%. Sunflower accounts for about 9% of the global oilseed production structure.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CHANGING CONSUMER PREFERENCES TOWARDS POULTRY PRODUCTS (EGGS AND MEAT) IN THE PERIOD 2019-2024 IN ROMANIA

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Abstract

The Covid-19 pandemic has led to significant changes in many areas of activity, and food has suffered in terms of quantity, quality, price and logistics. The article focused on the livestock population, generated by the relocation of the population to the rural area and the self-production of some of the food, as well as the quality of poultry products in Romania (chicken meat and eggs). According to the Romanian Institute of Statistics, the number of chickens sharply decreased in 2020, by 5.55% compared to 2019, only to suddenly increase by about 10% in 2021-2023, and afterwards it remained constant. For Romania, the number of egg-laying birds is what makes the difference, being directly proportionally correlated with egg consumption per capita. By comparing the statistical data to the responses received in a questionnaire-based survey from 877 inhabitants throughout Romania, it can be stated that the rapid recovery of the poultry sector was due to the population's agri-food changes and their decision to produce part of their own food.

Key words**:** *consumer preference***,** *poultry, eggs, meat, quality, Covid-19 pandemic, Romania*

INTRODUCTION

According to a study conducted by Abouzid et al. (2021) [1] on 5,896 residents from 17 countries in the MENA region (including countries from Middle East and North Africa), the behaviour of the population, strongly related with the emergency state imposed by the Covid-19 pandemic, has radically changed. Parameters like logistics, cost of production and food quality influenced the entire economy, which also have had a great impact on final prices, both internationally [19, 22] and nationally [5, 18, 21].

Several studies from different parts of the world [6, 8, 9, 11, 12, 13] indicate that eating habits have begun to focus on egg consumption, while other products, more perishable and harder to procure, have been consumed less. Giving the fact that the attention for health has been in the attention of every human being, for the entire European Union and Romania it is estimated that the number of organic egg production will continue to increase until 2030 [7]. The same trend is expected for chicken meat production in Romania, until 2033 [10], but also worldwide [25].

According to data presented by Pirvutoiu & Popescu [17] and Buliga-Stefanescu & Radoi (2021) [4], from 1990 to 2019 the number of hens raised by the individual owners, in their households, was in a downward trend, which was different after the start of the pandemic. Meanwhile, during 2007-2019 the amount of chicken meat produced increased, while the number of eggs decreased.

With the year 2020 and the relocation of part of the Romanian population, through the migration phenomenon from cities to villages [16], the livestock population has increased, as has the production of eggs and chicken meat on its own. The number of animals raised in households is difficult to monitor accurately at the national level, as stated by Serban et al. (2015) [23].

Over the years, eggs have been the subject of much research, with various themes, being appreciated as one of the most complex agri-food products [8, 11, 18].

For example, following numerous discussions on how to raise birds in different housing options, eggs have been evaluated for

radioactive contamination with cesium, respectively with the isotopes 134 and 137 [2], and it has been noticed that the maximum values weren't exceeded in any of the breeding systems of laying hens. In the same time, in recent years, it has been necessary to adopt modern technologies in animal husbandry [20], which will lead to a decrease in CO_2 emissions and be environmentally friendly [3, 18]. Another problem is that of the waste generated by this industry and how it can be transformed into by-products, in order to reduce pollution [24]. The aim of this article is to explain some of the changes that were generated by the Covid-19 pandemic, in direct connection with the agri-food habits of the population and the quality of poultry products (meat and eggs). It is also of interest to clarify the way of obtaining poultry products – in an institutionalized system or on an individual basis, for the years 2019-2024.

MATERIALS AND METHODS

For presenting conclusive and concrete findings, which are about to correspond to the aim of this article, the data found in the network Tempo-Online of the Romania's National Institute of Statistics (NIS) were used. For data analysis, the parameter which follows the number of raised chickens was chosen, considering two branches:
(1) chickens for meat;
(2) egg-laying hens.
The number of chicken eggs per capita, that were produced in Romania is another indicator considered important, being correlated with the number of chickens. The data for the years 2019-2023 were processed in Excel, in tabular and graphical form. Regarding the quality of products preferred by consumers, the questionnaire method was preferred. The questions analysed are part of a larger analysis, with 47 questions, but for this paper only three of them were considered relevant, namely:
(1) Do you consider that there have been changes in your family's consumption of poultry products (chicken meat and eggs) during the pandemic and post-pandemic period (2020-2024)?
(2) Have you started producing your own food or have you changed the source of the poultry products you consume?
(3) In 2020-2024, compared to the pre-pandemic period, have you given a greater importance to the nutrition and quality of the poultry products you consumed?
The questionnaire from which the above questions were extracted was uploaded in Google Forms format and sent to a target group of 1200 respondents, between January 2022 and December 2024. The final number of respondents was 877 people, which were analysed in tabular and graphical form in Excel.

RESULTS AND DISCUSSIONS

The indicators extracted from the statistics compiled at the national level have extremely variable figures from one year to another, as it can be observed in Table 1. Comparing with the control version, namely the year 2019, it can be concluded that the total number of birds increases in the years 2021-2023, after a very significant decrease in 2020, the year of the beginning of the pandemic. The number of birds for meat remains relatively constant during the studied period, in 2023 being lower than in 2019, which indicates the first of the changes in population consumption.

Table 1. Analysis indicators for the poultry population in Romania, in the years 2019-2023

Indicator	The unit of measure	Year				
		2019	2020	2021	2022	2023
Total hens, of which:	heads	75,364,575	71,183,431	77,148,372	78,220,737	77,749,597
Chickens for meat		34,636,147	34,534,953	35,110,424	36,337,266	33,647,416
Egg-laying hens		40,728,428	36,648,478	42,037,948	41,883,471	44,102,181
Egg production/capita	pieces/capita	287	282	310	315	308

Source: own processing based on NIS data, 2019-2023 [14, 15].

The difference in the number of poultry in 2020 compared to 2019 (a decrease by 5.55%) is due to the sudden decrease in the number of laying birds. This is correlated with the per capita egg production, which decreases from 287 to 282 pieces/capita.

For the years 2021-2022, the increasing trend of average egg consumption among Romanian residents can be noted. The maximum is reached in 2022, even if it doesn't correlate with the number of laying hens, as happens in other years (Fig. 1). This parameter stabilizes around 308-310 eggs consumed annually by each inhabitant, indicating the population's preference for products that they can produce themselves, raising chickens in their own household, or can purchase from neighbours and/or acquaintances, knowing their provenance and having more confidence in consuming them.

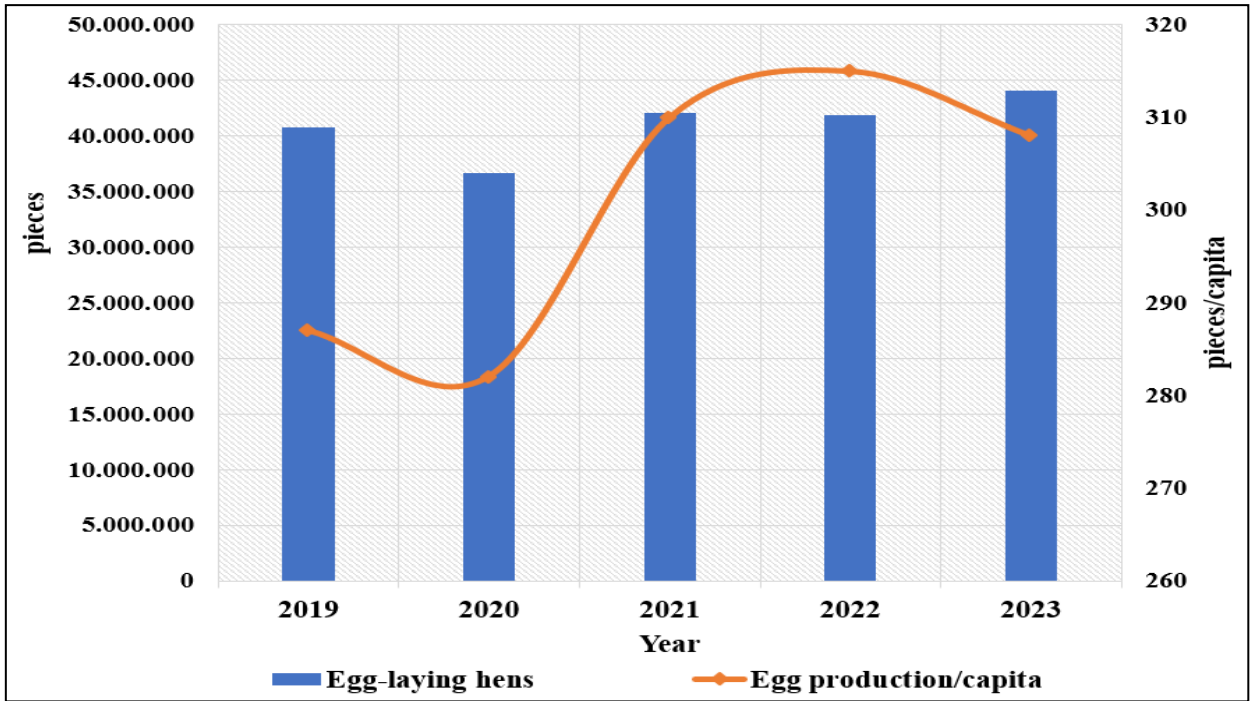


Fig.1. Correlation between the evolution of the number of laying birds and per capita egg consumption in 2019-2023
Source: Original graphic based on NIS data [14, 15].

In summary, what stands out is the sudden rebound in the number of laying birds starting in 2021 – an increase of 14.7%, compared to the year the pandemic began (2020). The trend is maintained, with minimal fluctuations, in 2022, so that in 2023 there will be a new significant increase. The only logical explanation is due to the increasing number of households that have started raising chickens, initially for egg production, and then for meat (in the case of roosters and hens that have reached maturity and are replaced by young laying birds).

Certainly, each of the inhabitants of Romania prefers to eat something produced in their own household, and poultry products are part of the category of those that can be obtained without special efforts, along with some vegetables and fruits.

In support of these theories comes the questionnaire addressed to a part of the population, with the aim of finding out how they manage to ensure a good quality and safety of life, through the lens of agri-food products, in this case poultry products (chicken meat and eggs). Since the study period overlaps with that of the pandemic, some of the questions are oriented towards this specific topic.

For the research contained in this article, the responses received from the 877 respondents, in the years 2022-2024, are detailed in Table 2.

Table 2. Number of responses and their percentage received from 877 residents of Romania, for three questions regarding their nutritional habits as a consequence of Covid-19

No. crt.	Questions in the questionnaire	Answer options				
		To a very large extent	To a large extent	Relatively	To a small extent	Not at all
1.	Do you consider that there have been changes in your family's consumption of poultry products (chicken meat and eggs) during the pandemic and post-pandemic period (2020-2024)?	317 (36.15%)	134 (15.28%)	283 (32.27%)	110 (12.54%)	33 (3.76%)
2.	Have you started producing your own food or have you changed the source of the poultry products you consume?	421 (48.00%)	178 (20.30%)	101 (11.52%)	85 (9.69%)	92 (10.49%)
3.	In 2020-2024, compared to the pre-pandemic period, have you given a greater importance to the nutrition and quality of the poultry products you consumed?	555 (63.28%)	59 (6.73%)	163 (18.59%)	48 (5.47%)	52 (5.93%)
Total answers		**1,293**	**371**	**547**	**243**	**177**

Source: original data.

Putting all these answers together, we see a small number of those who say they have changed their eating habits little or not at all – to be exact, only 15.2% of people. The difference, namely 84.8%, are those who have made changes from moderate to significant, generated by relocation to the rural area, working from home and the possibility of dedicating more time to the culinary sector.

These aspects also emerge from the structure of the answers to the three selected questions (Fig. 2), which suggest that people also felt the imposed changes through the prism of agri-food habits, which suffered and led to radical decisions regarding their lifestyle, which they chose to adapt to the new living conditions.

In fact, considering that based on these three questions, the majority of the answer options indicated drastic changes shows that the inhabitants of Romania took advantage of this new state of affairs to ensure a better, healthier and more sustainable life.

Question 1 has the most balanced structure of answers, indicating differences between respondents. However, only 33 people (3.76%) stated that they haven't changed anything related to the consumption of poultry products.

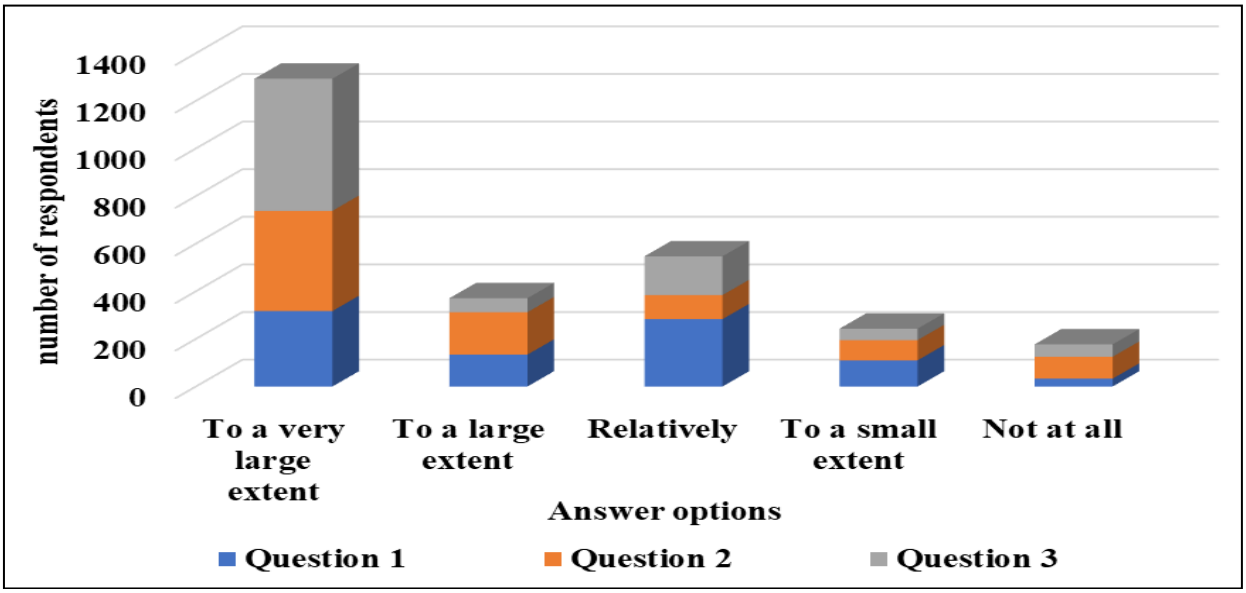


Fig. 2. Graphical representation of the answers received from the 877 respondents to the three questions, within the questionnaire during the period 2022-2024

Source: Original graph based on the respondents' answers.

Question 2 highlights that over 60% of the people interviewed have taken drastic measures regarding poultry products, which they either raise personally or buy from known sources, while Question 3 has the most concrete result – 555 of those interviewed (63.28%) are sure that they have done everything possible to purchase and consume poultry products of the best quality, unlike the pre-pandemic period.

CONCLUSIONS

By using the two research methods – evaluating statistical data and processing responses received in a questionnaire survey, it is possible to confirm the change in consumer perception regarding agri-food products during the pandemic and post-pandemic period (2020-2024).

The increase in the number of laying birds, correlated with the increasing consumption of eggs, can be inferred from people's preference for this miracle food, which they can easily produce in their own household. On the other hand, the decreasing number of birds for meat indicates a decrease in demand.

The three questions extracted from the questionnaire regarding the quality and food safety of the population revealed that the pandemic meant a reconfiguration of life for over 60% of those interviewed - in this case, through the change in eating habits and the way they produce or procure their poultry products.

However, the limitation of the study comes from three directions:

-it isn't possible to perform a highly accurate count of the poultry population in individual households;

-there is no clear classification of quality classes of poultry products (chicken meat and eggs), depending on the breeding and nutrition system;

-the impossibility of obtaining a higher number of responses to the questionnaire, for it to have statistical significance.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

AGRICULTURAL LABOR DYNAMICS IN PELAGONIA, NORTH MACEDONIA: A CASE STUDY THROUGH THE LENS OF AGRICULTURAL HOUSEHOLD AND LABOR TRANSITION MODELS

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Abstract

Agricultural labour dynamics in transition economies, particularly in the Balkans, have undergone significant shifts due to structural changes, migration trends, and evolving labour market conditions. Understanding how smallholders allocate their labour is crucial, as they form the backbone of agricultural production but face increasing challenges in sustaining their livelihoods. This study examines farm labour dynamics in the largest agriculture region in North Macedonia, the Pelagonia Region, exploring how smallholders allocate their labour amid broader labour market shifts and migration trends. Employing a synthesis approach, this study explores the interaction between agricultural households, migration patterns, and structural changes in the labour market. Findings reveal a reliance on family labour, with seasonal hiring filling gaps, though constraints on flexibility and productivity persist. Labour shortages, an aging workforce, and limited farm succession planning pose challenges to long-term sustainability. Slow structural transformation, low innovation uptake, and restricted diversification hinder adaptation to economic shifts. The policy recommendation framework focuses on three key areas: enhancing access to agricultural training, fostering modernisation through innovation, and increasing youth engagement to ensure a stable workforce. The study provides a contextualised analysis that can inform similar regions, demonstrating the applicability of established labour theories in agricultural contexts.

Key words**:** *labour trends, small-scale agriculture, survey-based analysis, Pelagonia case study, North Macedonia*

INTRODUCTION

Agricultural labour dynamics in transition economies, particularly in the Balkans, have undergone significant shifts due to structural changes, migration trends, and evolving labour market conditions. Understanding how smallholders allocate their labour is crucial, as these farmers form the backbone of agricultural production but face increasing challenges in sustaining their livelihoods.

One of the key issues is labour shortages, driven by rural-to-urban and international migration, as younger generations seek more stable and higher-paying jobs outside agriculture. This shift leaves aging smallholders with limited labour resources, affecting productivity, farm succession, and overall agricultural sustainability. The seasonal nature of agricultural work makes it difficult to secure a stable workforce, leading to further reliance on informal labour or mechanisation, which is not always accessible to small farms.

Smallholders in transition economies often engage in multi-activity strategies, balancing farm work with off-farm employment to secure household income. However, this dual engagement can reduce their long-term agricultural investment, weakening the sector's resilience. Additionally, the lack of institutional support, limited access to financial resources, and inadequate labour policies exacerbate the problem, creating long-term risks for agriculture and rural development.

Without targeted interventions, the viability of smallholder farming in the Balkans remains uncertain.

A deeper labour analysis is essential to inform policies that can sustain agricultural production

while addressing demographic and economic challenges in rural areas. Hence, drawing on survey-based data collected from smallholders in North Macedonia, this study aims to examine the labour dynamics in agriculture within the Pelagonia Region, focusing on how smallholders allocate their labour in the context of broader labour market shifts and migration trends. The analysis will be framed through key labour theories, including the Agricultural Household Models [9], the Structural Change [8] and Labour Transition theories [6].

This study addresses critical issues of labour shortages and migration in rural areas– challenges of increasing significance in many developing economies, particularly those undergoing long transitions.

There have been various studies on labour analysis conducted in the region. A recent study emphasises that land security can reduce labour outflow, while liberalised land transfers increase migration [4]. Smallholder adaptation strategies, including reliance on off-farm income, labour dependence, and migration-driven responses, are explored in different studies [1], [2], [3], [5], [7].

This study demonstrates how established labour theories can be applied to agricultural contexts, enriching existing literature with empirical evidence. By focusing on the Pelagonia Region, the study offers a detailed, contextualised analysis that can serve as a model for other regions facing similar challenges. Moreover, this study offers a recommendation framework to inform policies for agriculture and rural development in regions facing similar challenges.

The following section provides a concise overview of the research region, followed by applied methods and theoretical framework. It then describes the sample and key determinants. The results on labour dynamics are followed by a contemporary discussion grounded in relevant labour theories. Finally, the study concludes with key takeaways, setting a structured guide for formulating recommendations.

North Macedonia, a small, landlocked country in south-eastern Europe, experiences significant regional disparities in population distribution, economic development, and access to technological innovation. With a total area of 25,713 km² and a population of approximately 1.84 million people [12], the country is divided into eight statistical regions, each with distinct demographic and economic characteristics. Out of 80 municipalities in the country, 64 are rural, making up 80 % of the total [11]. Rural areas cover 88.7 % of the territory but are home to only 47.5 % of the population [10].

These rural communities face numerous challenges, including high unemployment, increasing migration, and limited economic growth. Agriculture remains the backbone of rural livelihoods but struggles with technological underdevelopment, hindering its potential for growth and innovation.

According to SSO [11], the Skopje Region is the most densely populated, with the highest share of the young population (0-14 years old), despite having the smallest area of 1,812 km². On the other hand, the Pelagonia Region spans the largest area (4,902.93 km^2, including water surface) but has the highest proportion of the elderly population (65+). These patterns reflect a trend where younger people are more likely to migrate from rural to more urbanised areas, where they can access better opportunities. The aging population in regions like Pelagonia may further exacerbate this issue, as older individuals tend to remain in rural areas, while younger generations migrate to urban centres.

The Pelagonia Region, located in the southwestern part of the country, is the most important agricultural region in North Macedonia. Itborders Greece and Albania. The region is composed of nine municipalities (Table 1), all classified as rural areas, despite having five towns. These cities cover an area of 80 km², which represents 1.6 % of the region's total area and is home to nearly 70 % of its population. The remaining area, 4,822.93 km², consists of 339 villages (rural settlements), accounting for 98.4 % of the region's total area [10]. Bitola serves as the main administrative centre of the region.

Table 5. A brief overview of the municipalities in the Pelagonia Region

No.	Municipa-lity	Area (km^2)	Population (numbers)	Density (people per km^2)
1	Bitola	787.95	85,164	110.0
2	Demir Hisar	480.13	7,260	15.0
3	Dolneni	412.43	13,126	32.0
4	Krivogashtani	93.57	5,167	55.0
5	Krushevo	190.68	8,385	44.0
6	Mogila	251.20	5,283	21.0
7	Novaci	753.53	2,648	3.5
8	Prilep	1,194.44	69,025	58.0
9	Resen	793.00	14,373	19.0
Total	**Pelagonia Region**	**4,902.93**	**210,431**	**44.6**

Source: SSO, Census, 2022 [10].

The Pelagonia Region, with a population of 210,431 (11.5 % of the national population) [12], is heavily dependent on agriculture, particularly in the Pelagonia and Prespa Valleys. Agriculture contributes 4 % of regional production and 5 % of employment [10]. The region's favourable geography, high-quality land, and climate support agricultural success, but challenges such as fragmented land and outdated machinery persist.

Bitola Municipality holds the largest share of agricultural land (34.5 %), followed by Prilep (28.4 %) and Resen (8.8 %) [11]. The region's agriculture is diverse, with households engaged in producing cereals (wheat, barley, and maize) and vegetables (red peppers, watermelons, melons, and more), with crop rotation as the main practice. Vegetables are of great commercial value for the farmers. Industrial red pepper production has gained increased attention since there is a high market demand for this product. Watermelons are commercially also valuable, with around 90 % of watermelon production being exported [10].Wheat is of good bread-making quality but offers a low-profit margin, while barley is mainly used for livestock feed or sold to breweries.

The Pelagonia Region accounts for 20.7 % of North Macedonia's agricultural land, covering 260,488 hectares, with 44.2 % cultivated and 55.8 % used for pasture. Cultivated land consists of 84.1 % arable land and gardens, 3.4 % orchards, 0.7 % vineyards, and 11.8 % meadows (Table 2). The region faces challenges with land consolidation, outdated technology, and a lack of storage facilities for cereals.

Livestock farming, including dairy and meat production, is a key activity in the region. Cattle farming is prominent, with a focus on milk production, though beef farming exists. Sheep, goats, and pigs are raised, but their numbers are decreasing. Poultry farming, mainly for meat and eggs, is increasing (Table 3).

Despite its agricultural significance, the region faces various challenges, including a lack of technological advancements in farming, high unemployment, and significant migration trends that contribute to labour shortages in the sector. The region's rural areas, which cover nearly the entire region, are particularly affected by these issues.

Agriculture in Pelagonia is heavily reliant on family labour, with 90 % of agricultural holdings managed by men, typically averaging 57 years old [10]. There is a shortage of agricultural labour, exacerbated by the increasing trend of rural-urban migration and limited access to modern labour-saving technology. This shortage often results in increased reliance on family members for labour and seasonal workers, leading to inefficiencies in labour allocation and farm management. Smallholders face difficulties finding adequate seasonal labour during peak production times, which can limit the overall productivity of agricultural activities.

The fragmentation of land holdings is a significant issue in Pelagonia, as in the rest of the country. While land consolidation efforts are underway to address this, the slow pace of these initiatives, combined with outdated machinery, further limits the efficiency of the labour force. This is particularly problematic for smallholders, who often lack the resources to invest in new technologies or hire skilled labour to increase productivity.

Certain municipalities within the region, have developed specialised agricultural activities. However, the labour force is often insufficient to meet the demands of these specialised sectors, leading to either underutilisation of resources or the hiring of temporary labour, often from outside the region.

Pelagonia has been impacted by rural-urban migration, like many rural areas in the Balkans, with younger individuals seeking better living opportunities in urban centres. This trend depletes the local labour pool, further exacerbating the shortage of workers in agriculture.

Table 6. Agricultural area in the Pelagonia Region, in hectares

Year	Agricultural area	Cultivated land	Arable land and gardens	Orchards	Vineyards	Meadows	Pastures
2007	267,018	115,667	96,100	3,907	1,250	14,410	150,869
2008	268,500	115,314	95,879	3,916	1,201	14,318	152,705
2009	273,786	113,832	94,160	3,875	1,202	14,595	159,473
2010	272,565	112,622	93,082	3,846	1,115	14,579	159,462
2011	272,010	112,078	92,839	3,821	942	14,476	159,451
2012	262,880	111,987	92,712	3,862	931	14,482	150,416
2013	266,072	115,191	95,858	3,865	980	14,488	150,404
2014	263,243	115,148	95,877	3,838	925	14,508	147,832
2015	262,630	114,528	95,460	3,927	986	14,155	147,839
2016	263,678	115,348	96,298	3,968	981	14,101	147,833
2017	263,978	115,628	96,383	3,969	956	14,320	147,850
2018	262,262	116,084	96,917	4,002	954	14,211	145,678
2019	261,061	115,233	95,999	3,992	873	14,369	145,328
2020	260,192	114,356	96,092	4,006	803	13,455	145,336
2021	260,488	115,220	96,888	3,974	788	13,570	145,002

Source: SSO, MakStat, 2022 [10].

Table 7. Livestock production in the Pelagonia Region, in heads

Year	Cattle	Pigs	Sheep	Goats	Horses	Poultry	Beehives
2007	42,768	33,568	242,293	7,651	4,259	372,222	3,416
2008	46,237	25,853	105,374	7,569	4,933	447,591	2,233
2009	51,445	25,846	228,984	7,322	6,919	399,813	2,424
2010	56,229	17,943	152,649	5,567	4,632	317,114	7,496
2011	55,211	18,639	171,650	5,358	4,753	369,176	6,038
2012	58,246	16,333	143,109	3,710	2,139	274,625	6,402
2013	56,988	8,246	133,788	2,006	3,082	312,466	974
2014	55,890	9,153	132,868	4,588	2,864	355,062	...
2015	57,492	9,694	130,270	4,957	2,940	301,901	1,835
2016	58,609	15,225	116,549	5,208	1,341	280,530	8,535
2017	59,340	21,997	90,712	3,866	2,455	396,071	6,681
2018	61,404	14,433	74,823	7,319	1,072	427,438	805
2019	49,835	16,418	73,259	4,238	647	405,666	11,453
2020	67,561	18,791	65,791	4,390	380	412,262	2,807
2021	40,810	25,143	102,171	3,189	453	492,428	15,523

Source: SSO, MakStat, 2022 [10].

MATERIALS AND METHODS

The labour analysis was based on survey data collected from smallholders in the Pelagonia region in March 2023. The survey employed a combination of online survey and in-person interviews conducted by skilled local interviewers–advisers from the head office of the National Extension Agency (NEA). The sample consisted of 60 agricultural households.

The questionnaire was carefully designed to structure the labour analysis and ensure comprehensive data collection. It was divided into three main sections.

The first section gathered demographic and structural information about agricultural households, including family composition, legal status, commercial production focus, and future expansion plans.

The second section examined labour dynamics, capturing details on the engagement of family members and hired workers, as well as assessing labour utilisation on farms.

The third section covered general data on respondents. The questionnaire primarily relied on closed-ended questions to facilitate quantitative analysis.

Data processing and analysis methods

The data processing employs fundamental statistical methods, including ratio analysis, descriptive statistics, and cross-tabulations. The study's key contribution lies in integrating theoretical frameworks to explain the underlying determinants of labour dynamics in the research area.

The research heavily depends on the analytical and integrative skills of the researchers to interpret the collected data. It focuses on how smallholders allocate their labour within the broader context of labour market shifts and migration trends. Using a synthesis approach, the study examines the interactions between agricultural households, migration patterns, and structural changes in the labour market. By identifying key trends and patterns, the research provides a framework of recommendations to address labour shortages in agriculture and mitigate the effects of migration on the agricultural workforce.

Theoretical framework

The theoretical framework for analysing labour in Pelagonia's agriculture is rooted in two main perspectives: the Agricultural Household Model, and Structural Change and Labour Transition Theories.

The Agricultural Household Model, developed by Singh, Squire, and Strauss, considers farm households as both producers and consumers of labour [9]. It emphasises the way family labour interacts with hired labour in small-scale farming while accounting for non-wage factors such as self-sufficiency and food security. This model highlights endogenous labour allocation, where households decide whether to use family labour, hire external workers, or engage in off-farm employment based on relative wages, production needs, and consumption priorities. It also considers non-wage factors affecting labour supply, including food security, risk aversion, and farmland sizes. Market imperfections and labour constraints play a crucial role, as rural labour markets often face seasonality, informal contracts, and credit limitations, influencing decisions on labour use. The model provides insights into why smallholders may be reluctant to commercialise their farms, emphasising the role of family labour and the challenges associated with hiring external workers.

Structural Change and Labour Transition Theories offer a broader perspective on how labour shifts from agriculture to other sectors as economies develop. The Lewis Model describes agriculture as having surplus labour, which gradually moves to industry due to higher wages [6]. This transition is seen as a driver of economic growth, with industrial profits further stimulating expansion and employment. However, the model has limitations, as it assumes an unlimited labour supply and does not fully account for migration barriers or the possibility of rural labour shortages. Rostow's Stages of Growth further elaborate on economic transitions, outlining how agriculture's role diminishes as economies industrialise [8]. In the early stages, agriculture dominates the economy, but as productivity improves and infrastructure develops, labour gradually shifts toward industry and services. Mechanisation reduces agricultural employment, leading to a stage where agriculture's share in GDP becomes minimal, with most workers engaged in non-agricultural sectors.

These studies collectively illustrate how labour in transition agriculture is shaped by structural reforms, institutional constraints, and smallholder adaptation strategies, particularly in the Balkans.

RESULTS AND DISCUSSIONS

Description of farms and households

The survey sample consists of rural households in the Pelagonia region, with the majority located in Bitola (43 %) and Prilep (32 %) (Fig. 1).

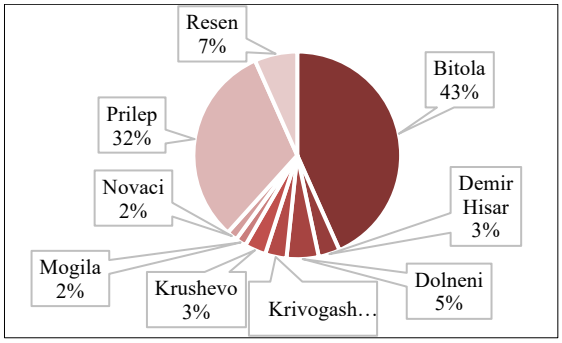


Fig. 2. Spatial distribution of the households in the sample
Source: Survey, 2023.

The remaining households are distributed across seven other municipalities. Household sizes vary, averaging 5.1 members, with the largest in Krushevo, Mogila, and Novaci (6.0) and the smallest in Krivogashtani (4.0).

Migration is limited, as 84 % of households reported no migrating family members. Among those that experienced migration (16 %), most relocated abroad, primarily from Bitola, Resen, Prilep, and Demir Hisar.

Agriculture is the main income source for over 40 % of households, though many also supplement their earnings with salaries, pensions, or income from renting out equipment. Agricultural holdings are mostly family farms (35 %)registered at the Ministry of Agriculture, Forestry and Water Economy, while 18 % operate as companies, 8 % as individual farmers, and 33 % are registered through the Pension and Disability Insurance Fund.

Income distribution among farms is diverse, with the majority earning between 25,000-49,000 EUR (Fig. 2).

Recordkeeping practices vary, with Prilep farms showing the highest consistency, whereas purely rural municipalities lag in this aspect. Advisory services from the National Extension Service (NEA) are widely used (95 %). Agricultural cooperatives are rare (7 %), limiting the benefits of collective market access and resource-sharing.

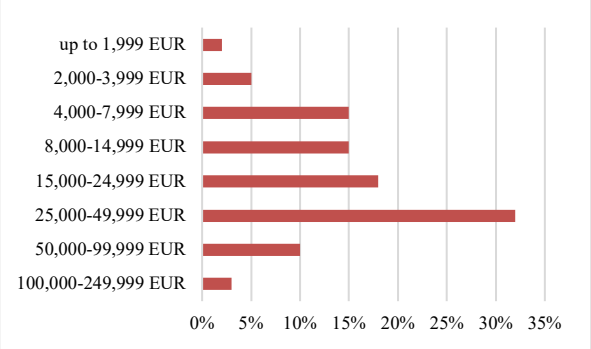


Fig. 3. Economic size of sample farms: Three-year average agricultural income
Source: Survey, 2023.

Farms display varied agricultural orientations. While many engage in mixed farming, specialisation in tillage (cereals) is common. Mixed farms and tillage farms report the highest incomes. However, diversification is low (5 %), with some farms engaging in on-farm processing or value-added activities. Farm ages vary widely, with most falling within the 10 to 30-year range, reflecting a mix of long-established farms and newer operations. The average farm age is 23 years. Regarding generational transfer, 49 % of households have identified a successor to continue farm operations, an uncommon trend in the country. Given the tendency of young people to leave rural areas and avoid farming, succession planning is essential for ensuring the long-term sustainability of farms by facilitating the transfer of knowledge, experience, and ownership across generations.

The aging farmer population is another key challenge. The average farm owner in Pelagonia is 47.6 years old, lower than the national average of 55 years but still relatively high. Attracting younger individuals to farm ownership and management remains crucial for the sector's sustainability. Farm ownership in the Pelagonia region follows the national trend, where men predominantly own and manage farms. While farm management can occasionally be handled by spouses, children, or siblings, decision-making largely remains in the hands of male owners. This gendered stereotype limits women's and youth's access to resources, training, and decision-making power, restricting their contributions to agriculture.

Typically, farms are associated with the location of the rural household. Farm investment intentions are high (83 %), with farmers prioritising machinery replacement, farm modernisation, and expansion. However, the adoption of innovation (2 %), digitalisation (3 %), and green agriculture practices (15 %) remains low, and over 60 % of farmers show no intent to adopt these changes. The lack of forward-thinking hinders the potential benefits that could be derived from embracing new ideas, technologies, and practices in agriculture. This reluctance limits the sector's ability to improve efficiency, sustainability, and competitiveness.

Labour determinants

Family labour is the dominant source of labour in the surveyed agricultural households, with an average of three family members engaged in farm work (Table 4). Educational attainment among farm family labour varies, but most members have completed high school. However, additional agricultural training is

rare, limiting opportunities for innovation and improved farm practices.

Table 8. Labour distribution across farms (in number of people)

	Internal labour	External labour	
Indicator	Family labour	Permanent employees	Seasonal labour
Mean	2.95	1	4.1
St. dev.	1.25	0	2.6
Mode	2	1	3
Range	5	0	14
Minimum	1	1	1
Maximum	6	1	15

Source: Survey, 2023.

Seasonal labour is also widely utilised (54 %), with farms typically employing three seasonal workers annually, though the average reaches 4.1 workers. Additional temporary labour is hired during peak periods, such as planting and harvest seasons. About 53 % of seasonal workers are local, while the remaining come from other regions. Foreign labour is rare, which is not typical for the country. Seasonal workers are typically employed for 30 days per year, and are paid daily, usually in cash. Hiring decisions are influenced by quality, expertise, cost, and availability.

In contrast, the presence of permanent employees is minimal, with only three farms reporting a full-time hired worker. This indicates a strong reliance on family and seasonal labour, with limited long-term employment in the sector. Permanent employees work an average of 9.7 hours per day, and receive a monthly salary, mostly via bank transfer. Permanent workers lack formal agricultural education, even though key hiring factors include quality, expertise, availability, and cost.

Farm capacity for employment refers to the potential or capability of a farm to provide employment opportunities. It represents the ability of a farm to accommodate and sustain a certain number of workers based on its size, resources, production activities, and labour requirements. In the region, farms cannot often employ permanent labour since farms are predominantly small-scale with limited economic power, minimal technological advancements, and a lack of diversification. However, there is a need for seasonal labour, as indicated by approximately half of the households surveyed. The main constraints in hiring seasonal labour include the scarcity of available workers, insufficient quality and expertise among potential workers, and the financial constraints faced by the farms, making it challenging to adequately compensate workers.

Farm labour dynamics

Farm labour dynamics in the Pelagonia Region illustrate how smallholders allocate their labour in response to broader labour market shifts and migration trends, framed through key economic theories (Table 5).

Table 9. Labour allocation by smallholders (in number of people)

Factor	Impact on labour choice
Farm size and profitability	Small-scale farms rely on family labour to reduce costs, while larger ones hire seasonal workers.
Seasonality of work	Farms avoid permanent employees and instead, hire workers only when needed.
Risk and uncertainty	Farmers hesitate to commit to permanent employees due to income variability and weather risks.
Labour availability	Family members provide a stable workforce, while seasonal workers fill temporary gaps.

Source: Own synthesis of findings, 2023.

Smallholder farms primarily operate within a subsistence and semi-commercial model, where household members supply most of the labour due to economic constraints and limited mechanisation. The reliance on seasonal rather than permanent labour reflects *a cost-minimisation strategy*, with hiring driven by necessity rather than long-term employment planning. The low rate of migration further suggests that most households do not replace family labour with remittance income. Instead, they prioritise on-farm work while supplementing their income through off-farm activities such as salaries, pensions, and renting equipment. This *mixed livelihood strategy aligns with the non-separability hypothesisin agricultural household models*, where household and farm labour decisions are

interdependent and shaped by market conditions and resource constraints.

The *limited focus on farm succession planning, combined with an aging farmer population, presents challenges for future labour availability*. Without a younger workforce willing to take over farm operations, reliance on family labour may decline, leading to an increased demand for hired workers. The predominance of family and seasonal labour suggests that *farms in Pelagonia remain in a traditional or pre-transition phase, consistent with theories of economic growth*. The absence of permanent employees further indicates that most farms are not yet fully commercialised and continue to operate on a semi-subsistence basis.

The *widespread use of seasonal workers supports labour transition theories*, which suggest that agriculture does not permanently absorb surplus labour but instead provides temporary employment before workers migrate to other sectors. *This dynamic reflects a slow structural transition*, where agriculture remains a key but temporary source of employment for rural populations.

The *Pelagonia Region exhibits partial evidence of structural transformation theories*, which suggest that as economies develop, labour shifts from agriculture to industry and services, driven by urbanisation and higher wages in non-agricultural sectors. Low levels of diversification indicate that *most farms limit alternative income streams that could support labour retention*. High reliance on seasonal labour reflects a shift towards more *flexible employment patterns, a characteristic of agricultural sectors undergoing transition*. Minimal foreign labour, with only one permanent foreign worker, reported, contrasts with broader migration trends in agriculture, where countries facing rural labour shortages often rely on migrant workers. Instead, farms in Pelagonia depend mostly on local seasonal labour and domestic workers from other regions.

The persistent role of family labour, coupled with limited technological adoption and digitalisation, suggests that *structural change is occurring at a slow pace*. While investment intentions are high, actual modernisation efforts remain limited, constraining productivity growth and reducing incentives for labour reallocation. The combination of these factors highlights the need for targeted policy measures.

Key labour challenges and implications

The labour dynamics in Pelagonia present several key challenges, structured in the following groups:

(i) labour market constraints;
(ii) gender and generational aspects, and
(iii) modernisation and innovation gaps.

Labour market constraints

The study identifies three main barriers to hiring external labour: *a*) labour shortages **-** a common issue in rural economies experiencing outmigration; *b*) lack of skilled workers - agricultural training is rare among both family and hired labourers, *c*) financial constraints - small-scale farms struggle to offer competitive wages.

These constraints reinforce household dependency on family labour and limit the potential for employment expansion.

Gender and generational Aspects

Farm ownership and management remain male-dominated, limiting opportunities for women and youth. Given that generational transfer is uncommon in the country, the relatively high succession rate in Pelagonia (49 %) is promising. However, encouraging young farmers to remain in agriculture remains a challenge, with limited access to training and resources further discouraging participation.

Modernisation and innovation gaps

Despite high investment intentions**,** actual adoption of new technologies remains low. Without modernisation, farms may struggle to transition from labour-intensive to more efficient, mechanised operations, which could reduce dependency on family and seasonal labour, improve working conditions attractive toa younger workforce, and enhance productivity and income stability, mitigating rural outmigration.

CONCLUSIONS

Following the aim of this research, the study investigates farm labour dynamics in Pelagonia

and illustrates how smallholders allocate their labour in response to broader labour market shifts and migration trends. Findings highlight key structural challenges. The region's labour structure reflects a mix of traditional agricultural household patterns and emerging structural pressures. While family labour remains dominant, labour shortages, an aging workforce, and weak succession planning threaten long-term sustainability. Seasonal hiring mitigates labour gaps but remains constrained by financial and structural limitations.

Slow structural transformation, low innovation uptake, and limited diversification restrict the sector's adaptability. Farms prioritise household labour due to income uncertainty, while the financial unsustainability of permanent employees reinforces dependence on informal labour arrangements. Limited youth involvement further signals challenges in modernisation and generational renewal.

Targeted policies are essential to ensuring long-term sustainability. Expanding agricultural training can enhance labour quality, mechanisation and innovation adoption can reduce reliance on manual labour, and strengthened succession planning can secure a stable workforce. Addressing these challenges will help Pelagonia's farms navigate labour market shifts, fostering a more resilient and productive agricultural sector. The study also provides a contextualised framework that can inform similar regions, demonstrating the relevance of established labour theories in agriculture and offering practical insights for policy and development.

ACKNOWLEDGEMENTS

We acknowledge the support from the RENAISSANCE project, funded through the INTERREG IPA CBC Greece–Republic of North Macedonia 2014–2020. This study is part of a broader research effort focused on the Pelagonia Region, and all views, analyses, and interpretations presented are solely those of the authors.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

BIOCHEMICAL AND ECONOMIC DIMENSIONS OF APILARNIL WITH A FOCUS ON ROMANIAN APICULTURE

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Abstract

Apilarnil is a beekeeping product obtained from drone larvae, recognized for its biochemical and therapeutic properties, but also for its economic potential. The present study explores both the biological dimensions and medical uses of apilarnil, as well as its economic and managerial implications in the context of Romanian beekeeping. The analysis includes the presentation of existing products on international markets, highlighting the diversity of pharmaceutical forms and therapeutic applications, from supporting reproductive and immune health to anti-aging and vitality-stimulating effects. In parallel, data on the structure and organization of the beekeeping sector in Romania are evaluated, with a focus on the number of beekeepers and the relevance of financial indicators. The results emphasize that apilarnil has a dual role: on the one hand as a biological resource with multiple health benefits, and on the other hand as an economic opportunity that can contribute to strengthening the competitiveness and sustainability of Romanian beekeeping in a European and international context.

Key words: *bee drone, beekeeping, Apilarnil, apiculture, added-value product*

INTRODUCTION

Apiculture constitutes a specialized sector within agriculture that utilises natural resources through managed bee colonies to produce honey and other apicultural products [21]. Beekeeping provides income and enjoyable outdoor work in both rural and urban areas [22]. Apilarnil is a bee-derived product obtained from homogenized drone larvae (*Apis mellifera*) collected on the seventh day of development, before the sealing of the brood cells [9]. Since its discovery, this product has attracted increasing interest due to its complex biochemical profile, which is comparable in some respects to royal jelly but enriched in specific sterols and hormone-like compounds. For this reason, apilarnil is considered both a functional food and a potential apitherapeutic agent [5].

The general composition of apilarnil includes approximately 65–70% water, 10–15% proteins, 15–20% carbohydrates, 3–6% lipids, and 1–3% vitamins and minerals [36]. This chemical heterogeneity underpins the wide spectrum of biological activities attributed to the product. Modern analyses (LC-MS/MS, GC-MS) have revealed fatty acids, peptides, flavonoids, glycerophospholipids, sugars, steroids, and volatile compounds such as esters and ketones [19]. Proteins are a major fraction, and they include both structural proteins and bioactive peptides. Essential amino acids such as lysine, methionine, and tryptophan are present in significant amounts, contributing to protein synthesis and tissue regeneration [5]. Moreover, antimicrobial peptides, analogous to those found in royal jelly, may support the immune system and exert protective effects against pathogens [36]. The lipid fraction, though smaller, is of special importance. It contains medium-chain and polyunsaturated fatty acids, as well as sterols such as cholesterol and testosterone-like derivatives [9]. These compounds are thought to contribute to the tonic and androgenic properties traditionally attributed to apilarnil. Experimental data suggest that sterols and fatty

acids from drone larvae may play a role in modulating endocrine activity and supporting reproductive function, though more controlled human studies are needed to validate these claims [5].

Carbohydrates, mainly glucose and fructose, represent a readily available source of energy. Their proportion is like that found in royal jelly, supporting the role of apilarnil as a stimulant and energy booster [10]. In addition, minor amounts of oligosaccharides may contribute to prebiotic effects, although this hypothesis remains insufficiently explored.

Vitamins and minerals, although quantitatively less abundant, are biologically significant. The B-complex vitamins (thiamine, riboflavin, pyridoxine, pantothenic acid) are particularly well represented and support enzymatic activity and cellular metabolism [36]. Provitamin A carotenoids and vitamin D precursors have also been identified in lower concentrations, suggesting potential antioxidant and regulatory effects. Among minerals, potassium, calcium, magnesium, iron, and zinc dominate the profile, playing crucial roles in enzymatic catalysis, neuromuscular function, and immune defense [10].

Another component of apilarnil is represented by nucleic acids (DNA and RNA) and enzymatic molecules derived from larval homogenates. These compounds may stimulate protein synthesis, cell division, and regenerative processes, although data on their specific bioactivity in humans are still limited [5]. The presence of enzymatic systems such as proteases and oxidoreductases further enriches the biochemical complexity of apilarnil.

Overall, the nutritional and biochemical composition of apilarnil explains the wide range of biological effects attributed to its consumption: anabolic and restorative actions due to amino acids and sterols, immunomodulatory potential from bioactive peptides, rapid energizing capacity from carbohydrates, and antioxidant and metabolic support from vitamins and minerals.

Due to its rich amino acid and micronutrient content, apilarnil is regarded as a promising nutritional supplement. Scientific studies indicate antioxidant and adaptogenic activities [19], while experimental models have shown androgenic and anabolic effects, including improvements in testosterone levels and reproductive parameters [2]. Other reported benefits include immunostimulatory, hepatoprotective, neuroprotective, and fertility-supportive actions [4].

Apilarnil represents an added-value product that allows beekeepers to diversify their income sources beyond honey and wax. This diversification can strengthen rural economies and contribute to local sustainability [32]. For human health, apilarnil's nutrient density makes it a potential natural remedy against micronutrient deficiencies and lifestyle-related diseases [4].

The sustainable production of apilarnil is closely connected to pollinator health. Climate-related stressors such as shifts in flowering times, extreme weather events, and increased pathogen pressure may negatively affect bee colonies, thereby reducing both honey and drone brood availability [38]. Consequently, climate-resilient apicultural practices are essential to preserve this resource and maintain its role in supporting rural economy and human health.

In recent years, global warming has been a cause of climate change, affecting both bee populations and melliferous flora [14]. These changes have negative consequences for nectar and pollen production in flowers, on pollination activity and on bee productivity. Pollination is essential for maintaining biodiversity and ecological balance, and it has a significant economic impact worldwide [29]. Environmental factors such as temperature, humidity and wind strongly affect the physiological processes of plants, as well as the development and behavior of bees. Among these, temperature is the most important, as it shapes both the activities carried out inside the hive and the foraging patterns and physiological responses of bees, having a direct effect on the health of the colony [1, 37]. Research has shown that low temperatures (below 7°C) negatively affect the bees' foraging capacity. Conversely, a positive correlation has been observed between temperature and foraging efficiency, due to

lower metabolic rates at higher temperatures [18].

Exposure to extreme temperatures during foraging significantly reduces the lifespan of honeybees. Brood development is highly sensitive to temperature, with both suboptimal low and high thermal conditions associated with increased risk of colony loss. Non-optimal temperatures during brood rearing have been shown to result in neural impairments and morphological abnormalities, particularly affecting wing structure [12].

The reduction in foraging activity has negative consequences on brood development by slowing down larval growth and maturation, as well as on food reserves for overwintering [16]. Food reserves, represented by nectar and pollen, are also influenced by external temperature, crucial for the development and survival of colonies. Prolonged cold periods during spring, when the colony is developing, hinder the bees' foraging activity, leading to a rapid depletion of food reserves in the hive and to colony weakening or even loss. The egg-laying rate, larval feeding with pollen, and the development of new generations of bees depend on changes in climatic conditions, which influence the distribution of plant species, the flowering period and the production of nectar and pollen [14].

Climate change reduces pollen availability, disrupting the honeybee's brood development cycle.

Humidity represents an additional climatic factor that influences not only plant physiology but also the behavior and physiology of honeybees. Within the hive, humidity levels play a critical role in processes such as honey ripening and egg hatching. Optimal relative humidity for successful egg hatching ranges between 90–95%; levels below 50% have been correlated with a significant reduction in hatch rates. To maintain optimal humidity within the hive, bees engage in various adaptive behaviors: to increase humidity, they evaporate water from nectar and actively seek external water sources; to reduce humidity, they ventilate the hive by fanning their wings to expel moist air [1].

Excessive precipitation interferes with foraging activity, thereby limiting access to nutritional resources. Moreover, ambient humidity affects nectar concentration in flowers and, consequently, bee foraging behavior. Bees respond to changes in climate by selecting more diluted nectar during hot and dry periods, or by visiting flowers where nectar has been concentrated due to dry winds.

Prolonged drought causes a decrease in nectar secretion and its quality, which, when combined with a pollen deficit characterized by low nutritional value, results in weakened immunity and incresead vulnerability of bee colonies to diseases and pests [14].

The goal of the research is to analyze the biochemical composition and therapeutic applications of apilarnil, while also evaluating its economic significance and potential for enhancing the competitiveness and sustainability of Romanian apiculture in the context of European and international markets.

MATERIALS AND METHODS

To carry out this research, a documentary and comparative analysis methodology was used, based on scientific sources, specialist reports and statistical data. Information regarding the biochemical composition and therapeutic uses of apilarnil was collected from national and international specialist literature, including articles published in academic databases, manuals and reference works in the field of beekeeping and beekeeping biotechnologies.

Data regarding commercial uses and products available on the international market were obtained by consulting official online sources, beekeeping product catalogues and specialist publications, allowing a comparative analysis between various countries (Romania, Russian Federation, Germany, Turkey, Canada, USA).

For the economic part, statistical data provided by the Romanian Beekeepers Association and other relevant indicators at sectoral level were analyzed. Correlating this information allowed highlighting the role of apilarnil from three perspectives: biochemical, commercial and economic-managerial.

RESULTS AND DISCUSSIONS

At the end of 20th century, Apilarnil yield in Romania was in early stages, given the market potential that was foreseen at the time within the Romanian context. Nevertheless, production progressed rapidly, with seasonal volumes starting at approximately 500 kg in 1981 and reaching up to 16,000 kg by 1984, reflecting both growing interest and the scalability of this novel bee-derived product (Fig.1). Despite many years of limited market uptake, estimates in Denmark suggest a potential yield of up to 80 tonnes per year [15] reflecting renewed interest in its integration across food, health, and feed industries.

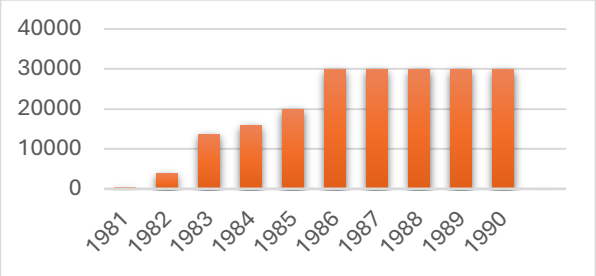


Fig. 1. Raw Apilarnil production in Romania 1981 -1990
Source: [8].

In Romania, Apilarnil production is directly influenced by market demand dynamics and its potential applications as well as by climatic factors with impact on size of colony, availability of food, colony microclimate [29]. In the last years, even the fact that production potential of Apilarnil is very high in Romania, Apilarnil aquired for application in medicinal or cosmetic formulations was very low (Fig. 2).

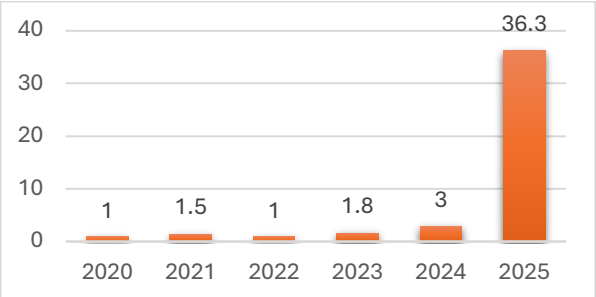


Fig. 2. Processed Apilarnil Quantity in Romania (Kg)
Source: Romanian Bekeepers Association [28].

One of the key factors influencing the development of the beekeeping sector is the diversification of the product range offered by beekeepers to consumers. In this context, identifying new opportunities to add value to hive-derived products, through innovative formulations developed either domestically or abroad, can generate export opportunities for the sector.

This becomes particularly relevant considering that only 33% of Romanian beekeepers are currently interested in foreign markets. Due to the very small quantities being processed or consumed fresh, Apilarnil is not among the bee products exported at present. Instead, export reports show high volumes for honey (93.1%), propolis (59.7%), beeswax (43.9%), and royal jelly (8.8%) [24]. Colony growth is constrained by pollen deficiency or inadequate nutrient intake, particulary as drone larvae require substantially larger quantities of food with a more diverse protein profile than worker bee larvae due to an extended developmental period involving spermatogenesis and organogenesis [31]. In this context, N. Hrassnigg and K. Crailsheim, (2005) estimated that daily pollen consumption is around 325-487,5 mg pollen to produce Apilarnil – more than three times the amount required for rearing worker bee larvae [7]. The European Commission has recently accelerated the integration of edible insects into mainstream European diets, recognizing them as a sustainable and efficient alternative protein source [27]. This process was facilitated primarily by their legal authorization for commercialization on European market through their inclusion in the Novel Foods list under Regulation (EU) 2015/2283 [26]. This development is largely driven by the urgent need to meet growing global food demand amid declining agricultural yields. In this context, drone brood, also known as Apilarnil, stands out as a valuable yet underutilized bee product. While relatively unknown in most of Europe, it has long been appreciated for its nutritional and therapeutic properties in countries such as Romania, China, Zambia, Senegal, and Ecuador [30]. Although bee brood is acknowledged by the local population and consumed in Thailand, where it remains a niche element of the culinary tradition [33] it is typically avoided in the Russian Federation due to cultural perceptions, [24]. In contrast, in country like Austria and Germany, bee brood is gaining popularity as food snacks

called ”Biennengramled” or ”bee crackle”, as well as in deserts such as chocolate mousse or ice creams, while in Turkey, Apilarnil, is primarily promoted as a functional food, being used as a meat substitute or as a protein concentrate similar to soy [35] identified in this way new potent source of high-quality protein in the context of global search for sustainable food ingredients [25].

International market analysis shows varied therapeutic uses of apilarnil. In the Russian Federation, the preparations *Bilara* and *Femo-Klim* are associated with maintaining the health of the microcirculatory system and alleviating menopausal symptoms, respectively, being formulated as powders and lyophilized tablets [13]. In Romania, the variety is much more pronounced, with the emergence of products such as *Apilarnil Potent*, intended for the treatment of male sexual dysfunction, *Activated Lyophilized Apilarnil*, used to increase vitality, support circulation, and combat physical and mental fatigue [17], or *Apicioco with Apilarnil*, with nutritional, biostimulatory, and skin-regenerating effects. Furthermore, *Apilarnil Forte* targets general fatigue, low immunity, and metabolic and digestive disorders, while *Apilarnilprop* acts as an energy stimulant and biological activator.

At the international level, the Canadian product *ApiDrohn* is aimed at maintaining hormonal balance and energy levels, while in Turkey, *Arbee Energy Apilarnil* is marketed as a general tonic, available both in powder and capsule form. Germany offers two distinct products: *Apilarnil frisch*, a fresh formulation with energizing effects, and *Apilarnil lyophilisate*, capsules intended for the same functional area. In the United States, *Drone Brood Homogenate* stands out for its broader therapeutic spectrum, including anti-aging, antioxidant, neuroprotective, and muscle-enhancing effects, being available in lyophilized capsule form.

The predominance of lyophilized formulations is primarily intended to preserve the product’s stability, as studies have shown that Apilarnil retains its quality characteristics for up to six months at 20°C when packaged either in glass containers or in hermetically sealed, triple-layer aluminum-based film under a nitrogen atmosphere [24]. Furthermore, the lyophilized form has demonstrated higher consumer acceptability compared to oven-dried alternatives, confirming its preferential use in both food and therapeutic formulations [3]. Other research has also indicated that honey enriched with lyophilized bee brood maintains a more stable formulation than honey supplemented with 4% frozen bee brood, the latter exhibiting visible darkening and consistency changes [31].

In parallel, it is important to note that *Varroa destructor* is widely recognized as the most harmful parasite affecting honeybee colonies [11, 34], with a strong reproductive preference for drone brood, where infestation levels can be up to twelve times higher than in worker brood [20]. As a response, some beekeepers have adopted strategic removal and utilization of drone brood to naturally regulate Varroa populations [30]. Nevertheless, the effective implementation of such biological control strategies requires adequate beekeeper training [6]. Beyond its role in pest management, the selective harvesting of drone brood also generates economic opportunities, both by reducing reliance on chemical treatments and by opening new avenues for marketing drone brood as a value-added hive product.

Overall, the analysis demonstrates that apilarnil represents a biological resource of major interest, with wide applicability across various therapeutic fields, while also offering complementary benefits in apicultural management and economic diversification.

The economic analysis of the Romanian beekeeping sector, with a focus on the production and exploitation of apilarnil, is essential for understanding the real potential of this product. Apilarnil not only offers biochemical and therapeutic benefits but also diversifies beekeepers’ incomes and supports sector growth. Its production and integration on the market depend on factors such as the structure and size of the holdings, the degree of professionalization of beekeepers and the organizational capacity of the entire sector. In this context, the analysis of the number of members of the Romanian Beekeepers Association, corroborated with the available

financial data, provides a relevant picture of the size and competitiveness of the industry.

These elements are fundamental for understanding the opportunities and constraints related to the integration of apilarnil on domestic and international markets and allow the identification of strategic directions aimed at strengthening the competitiveness, profitability and long-term sustainability of Romanian beekeeping.

The evolution of the number of beekeepers registered with the Romanian Beekeepers Association (ACA) during the period 2020–2024 highlights a constant downward trend, with a significant decline in recent years. While 12,380 beekeepers were reported in 2020, their number gradually decreased to 11,724 in 2021 and 10,250 in 2022, only to see a slight return to 10,503 members in 2023.

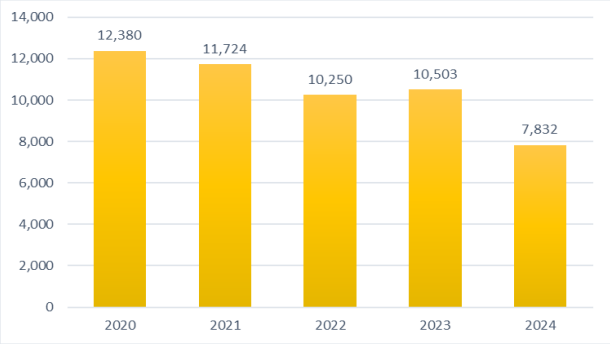


Fig. 3. Beekeeper Numbers in ACA Romania, 2020–2024
Source: Romanian Beekeepers' Association (ACA) [28].

However, the year 2024 marks a steep decline, reaching only 7,832 beekeepers, which represents a decrease of almost 37% compared to the 2020 level.

In the context of the economic analysis of apilarnil, this decrease in the number of beekeepers has direct implications: it reduces production potential and affects Romania's ability to competitively exploit its beekeeping resources, including niche products with added value, such as apilarnil. Therefore, supporting beekeepers and developing market stimulation policies has become essential to ensure long-term sustainability and competitiveness of the sector.

The evolution of the number of bee colonies in Romania, according to data provided by the National Institute of Statistics for the period 2021–2024, highlights moderate annual fluctuations. In 2021, 1,903 thousand colonies were registered, and in 2022 an increase was observed, reaching the maximum level of the analyzed interval, of 1,936 thousand colonies. Subsequently, in 2023, their number decreased to 1,898 thousand, with an increase again in 2024, up to 1,915 thousand colonies.

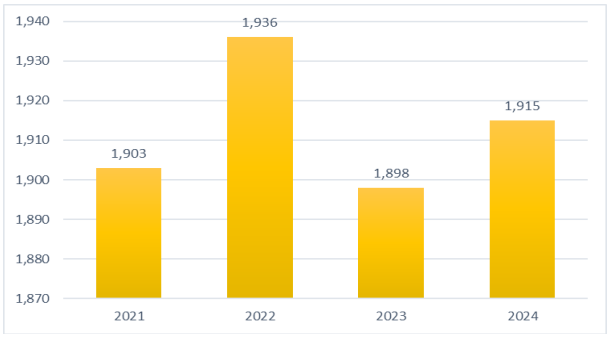


Fig. 4. Bee Colony Numbers in Romania ('000s)
Source: Romanian Beekeepers' Association (ACA) [28].

The amount of honey purchased by the Beekeeping Complex between 2017 and 2020 has registered significant variations, with a generally decreasing trend. If in 2017 approximately 854 tons were collected, and in 2018 the volume decreased to 660 tons, 2019 brought a drastic reduction, reaching only 179 tons. In 2020 the situation improved partially, with 487 tons reported, but the level remains well below that recorded at the beginning of the analyzed period. These fluctuations can be associated both with unfavorable climatic conditions and problems related to the health of bee colonies, as well as with economic difficulties that influenced the production and valorization of honey.

The data analysis shows a significant decrease in the volume of honey purchased in the period 2021–2023, from 533.2 tons to only 218.4 tons, which represents a reduction of over 50%. In 2024, a slight recovery is observed, up to 247.4 tons, but the level remains well below that of 2021. The distribution by counties highlights major disparities: areas such as Vaslui, Hunedoara, Caraș-Severin, Dâmbovița, Mehedinți and Bacău stand out for their high volumes, while many counties have almost zero values. These differences reflect both the

particularities of the honey resources and the degree of integration of beekeepers into the collection circuit organized by the ACA. The general decrease can be explained by factors such as unfavorable climatic conditions, economic pressures on beekeepers and the orientation towards other sales channels, which raises questions about the sustainability and competitiveness of the Romanian beekeeping sector.

Table 1. Honey Purchases by Commercial Companies within the Structure of the Romanian Beekeepers' Association (2021–2024)

No.	County	Total honey purchases (t)			
		2021	2022	2023	2024
1	ALBA	0.9	0.0	0.9	0.7
2	ARAD	9.0	0.0	24.0	2.0
3	ARGEŞ	31.0	22.9	0.0	5.0
4	BACĂU	21.0	14.8	70.0	1.0
5	BIHOR	8.3	4.0	0.0	0.0
6	BISTRIŢA N.	1.5	0.0	0.0	0.0
7	BOTOŞANI	12.2	0.0	0.0	0.0
8	BRAŞOV	0.0	0.0	0.0	0.0
9	BRĂILA	0.2	0.0	0.0	0.0
10	BUZĂU	0.0	1.4	1.0	0.0
11	CARAŞ SEV	30.0	93.7	0.0	32.0
12	CĂLĂRAŞI	6.0	3.0	0.0	0.0
13	CLUJ	0.0	0.0	0.4	0.0
14	CONSTANŢA	3.5	0.0	0.0	0.0
15	COVASNA	0.0	0.0	0.0	0.0
16	DAMBOVIŢA	80.0	22.5	0.0	3.0
17	DOLJ	2.8	3.0	1.5	0.0
18	GALAŢI	0.0	0.0	0.0	0.0
19	GORJ	45.0	1.5	2.0	1.0
20	HARGHITA	0.0	0.0	0.0	0.0
21	HUNEDOARA	50.0	30.0	20.0	40.0
22	IALOMIŢA	4.2	p	0.0	0.0
23	IAŞI	0.6	0.0	0.2	0.0
24	MARAMUREŞ	0.0	0.0	0.0	0.0
25	MEHEDINŢI	25.0	28.0	6.0	15.0
26	MUREŞ	11.0	3.0	0.7	0.0
27	NEAMŢ	0.2	0.0	0.0	0.4
28	OLT	0.4	0.2	0.8	0.0
29	PRAHOVA	0.0	0.0	0.0	0.0
30	SATU MARE	0.0	0.0	0.4	0.0
31	SĂLAJ	0.0	0.0	0.0	0.0
32	SIBIU	1.6	0.0	0.5	0.0
33	SUCEAVA	0.2	0.0	0.0	0.3
34	TELEORMAN	3.3	0.6	0.0	0.0
35	TIMIŞ	0.0	0.0	0.0	0.0
36	TULCEA	25.0	7.0	0.0	2.0
37	VASLUI	160.0	42.0	90.0	145.0
38	VALCEA	0.3	0.0	0.0	0.0
39	VRANCEA	0.0	0.0	0.0	0.0
40	BUCUREŞTI	0.0	0.0	0.0	0.0
TOTAL		**533.2**	**277.6**	**218.4**	**247.4**

Source: Romanian Beekeepers' Association (ACA) [28].

Data on the revenues of commercial companies in the beekeeping sector in the period 2021–2024 reveal an oscillating evolution, marked by decreases and partial recoveries.

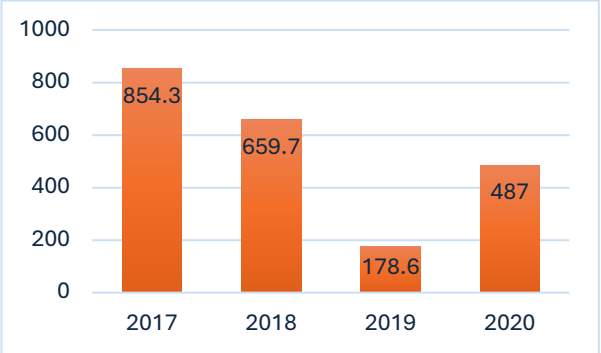


Fig. 5. Quantity of honey purchased by the Beekeeping Complex in the period 2017-2020 (t)
Source: Romanian Beekeepers' Association (ACA) [28].

Table 2. Revenues of Beeking Commercial Companies (2021-2024)

County	**Revenues**				**2024/ 2021 %**
Year	**2021**	**2022**	**2023**	**2024**	
Alba	375,168	484,025	446,293	624,563	166.48
Arad	353,324	349,314	621,266	389,406	110.21
Argeş	1,082,302	1,400,562	1,310,941	1,312,773	121.29
Bacău	1,029,004	943,526	945,577	934,321	90.80
Bihor	2,114,857	2,139,813	2,098,171	2,220,492	104.99
Bistriţa	537,969	777,264	756,581	782,146	145.39
Botoşani	947,385	1,090,577	1,148,126	1,014,234	107.06
Braşov	470,038	744,391	1,101,587	1,390,854	295.90
Brăila	400,147	453,672	474,641	434,668	108.63
Buzău	1,272,030	1,501,712	1,336,040	1,363,263	107.17
Caraş Severin	2,232,690	3,079,136	1,665,949	1,520,794	68.11
Călăraşi	250,328	291,724	250,624	257,298	102.78
Cluj	794,241	836,968	689,236	736,468	92.73
Constanţa	920,342	1,150,266	933,687	681,396	74.04
Covasna	255,113	415,123	505,813	560,824	219.83
Dâmboviţa	2,474,008	2,775,864	2,717,328	2,823,740	114.14
Dolj	1,419,925	1455650	1,336,530	1,296,749	91.33
Galaţi	388,406	540,629	547,069	517,011	133.11
Gorj	1,710,102	2,289,461	1,987,215	2,066,032	120.81
Harghita	488,005	460,798	443,252	431,821	88.49
Hunedoara	4,142,705	3,685,752	2,787,449	2,636,752	63.65
Ialomiţa	605,079	1,236,047	694,557	689,472	113.95
Iaşi	673,740	751,767	789,682	749,704	111.27
Maramureş	1,318,915	1,188,420	1,242,970	1,261,398	95.64
Mehedinţi	1,219,444	1,293,447	1,021,362	1,056,386	86.63
Mureş	1,685,649	2,024,921	1,874,797	1,859,462	110.31
Neamţ	1,021,990	1,195,947	1,184,280	1,261,595	123.44
Olt	623,020	736,144	688,658	734,092	117.83
Prahova	492,542	551,370	538,205	513,485	104.25
Satu Mare	753,115	840,585	886,200	880,450	116.91
Sălaj	1,154,369	1,165,748	1,018,247	1,064,121	92.18
Sibiu	928,516	1,125,426	1,017,368	1,225,070	131.94
Suceava	734,720	916,278	947,562	859,161	116.94
Teleorman	859,309	1,068,352	958,909	913,422	106.30
Timiş	595,652	614,228	531,070	462,539	77.65
Tulcea	366,665	408,192	463,400	499,213	136.15
Vaslui	4,784,878	2,093,033	2,497,537	3,595,769	75.15
Vâlcea	1,927,560	2,184,590	2,042,629	1,798,938	93.33
Vrancea	808,969	937,311	936,340	987,769	122.10
Mun. Bucureşti	570,400	665,352	595,004	617,357	108.23
Total	**44,782,921**	**47,863,385**	**44,032,152**	**45,025,008**	**100.54**
Editura Albina	168,146	121,003	97,005	107,994	64.23
Complex Apicol SA	15,278,116	16,653,446	14,329,316	14,420,867	94.39
ICDA SA	16,174,352	16,303,846	16,105,161	16,989,705	105.04
Total general	**76,403,535**	**80,941,680**	**74,563,634**	**76,543,574**	**100.18**

Source: Romanian Beekeepers' Association (ACA) [28].

At the national level, total revenues increased from 76.4 million lei in 2021 to 80.9 million lei in 2022, only to subsequently register a significant contraction in 2023 (74.5 million lei). The year 2024 brings stabilization, with an income level of 76.5 million lei, which practically represents a return to the reference value of 2021. The analysis by counties indicates considerable variations: significant increases are observed in counties such as Brașov (+195.9%), Covasna (+119.8%), Tulcea (+36.1%) or Sibiu (+31.9%), while sharp decreases are visible in Hunedoara (-36.3%), Caraș-Severin (-31.9%), Vaslui (-24.8%) and Mehedinți (-13.4%). Overall, these developments reflect a sector characterized by regional heterogeneity, influenced both by natural conditions and honey resources, as well as by the organizational and economic capacity of local commercial structures. At the same time, the dynamics of income shows the fragility of the beekeeping market to external factors, along with the existence of internal mechanisms for adjustment and maintenance of functionality.

CONCLUSIONS

The analysis highlights that apilarnil is located at the intersection of the biochemical and economic dimensions, having a dual role: as a biological product with remarkable nutritional and therapeutic properties and as a strategic economic resource for Romanian beekeeping. The study demonstrated that, internationally, apilarnil is recognized through a diversity of pharmaceutical forms and applications, from supporting reproductive and immune health to anti-aging and vitality-stimulating effects. At the same time, the analysis of data from Romania highlights the challenges of the beekeeping sector, reflected in the decrease in the number of beekeepers, fluctuations in the volume of honey purchased and the dynamics of commercial companies' income. These aspects highlight both the vulnerability of the sector to climate change and economic pressures, as well as its potential for adaptation through product diversification and integration into domestic and foreign markets. Strengthening competitiveness and long-term sustainability requires coherent support policies, the professionalization of beekeepers and the strategic valorization of niche products, such as apilarnil, in the context of European and global trends regarding functional foods and alternative protein resources.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

LOCAL GASTRONOMIC POINTS – A TOOL FOR SUSTAINABLE VALUE CHAIN IN RURAL TOURISM FROM ROMANIA

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Abstract

This study examines Local Gastronomic Points (LGPs) as instruments for sustainable rural development in Romania, with a focus on Sibiu County, using literature review, statistical processing of official data, field observations. The article analyze the rapid growth of LGPs—small, family-run dining units serving traditional dishes made from local ingredients. Since 2018, LGP numbers have increased by 282%, reflecting their popularity and economic impact. Concentrated in mountain regions with established tourism infrastructure, LGPs enhance destination image, preserve intangible culinary heritage, and support local producers. Findings show that LGPs stimulate rural economies, reduce depopulation, and contribute to sustainable food practices by linking agriculture with tourism. They also highlight the need for marketing strategies, digital engagement, and youth education to maximize their potential within Romania's rural development framework.

Key words: *rural gastronomic tourism, culinary tourism, food tourism, intangible cultural heritage, Local Gastronomic Points (LGP), tourism value chains, local development, Romania*

INTRODUCTION

The gastronomic specificity of each country and region represents a key socio-cultural factor contributing to sustainable tourism development [66]. Gastronomy plays a pivotal role in tourism, serving as an expression of local identity and a primary motivation for tourists to visit a destination [32, 34, 55].

Beyond its economic significance, gastronomy constitutes a medium through which local culture is expressed [25] and establishes a connection between culinary heritage and the surrounding environment [8]. Culinary heritage encompasses a region's gastronomic identity, including traditional recipes, preparation methods, dining customs, and social interactions arising from the production and sharing of food [59]. Local gastronomic identity not only reflects regional culture and culinary traditions [33] but also emphasizes the quality, authenticity, and uniqueness of local foods and dishes. This identity is reinforced through the organization of diverse gastronomic events, which over time fosters tourist loyalty to the destination.

The gastronomic identity of a region is largely shaped by its geographical and cultural characteristics [49] and is grounded in traditional culinary practices specific to each nation [61].

The image of a gastronomic tourism destination is closely associated with the taste and quality of food, its emotional and health-related value, authenticity, and diversity [16, 42, 55]. Moreover, destination image significantly influences tourists' behavioral intentions [48, 73], underscoring the importance of coordinated efforts among all stakeholders in cultivating and promoting a destination's gastronomic image. Consumer behavior in relation to gastronomic services emerges from the complex interplay of various factors, including individual personality traits, the uniqueness of the gastronomic experience, and social media influence [26]. Long et al. (2024) [38] identified 49 factors affecting the development of gastronomic tourism destinations, with destination marketing being the most significant. Fourteen of these factors are directly related to food sourcing, safety,

and quality, all of which contribute to local sustainable development through the interconnectedness of multiple elements.

According to [68] key trends shaping gastronomic tourism include the need to market authenticity, focus on local food, leverage artificial intelligence, prioritize sustainability, extend tourist stays, encourage travel to lesser-known destinations, promote gastronomic diversity, and support health and wellness tourism. Additionally, global warming is increasingly affecting the production of foods registered under quality schemes with protected designations.

García-Pérez et al (2024) [28] highlight that gastronomic tourism experiences are influenced by both personal factors and destination image. They emphasize that future research should consider the cultural context of each country and analyze these factors from the perspective of all stakeholders, with particular attention to service quality [36].

Literature Review: Gastronomic Tourism/ Culinary Tourism/ Food Tourism

Gastronomic, culinary, and food tourism encompass activities directly related to the primary production of food and its valorization [47]. These forms of tourism include serving traditional dishes directly at local producers' locations, product tastings, visits to local processors, cooking workshops, gastronomic tours, as well as classical or alternative gastronomic events such as brunches, local or traditional product fairs, and farmers' markets [29, 72]. Product tastings are closely associated with the emotions elicited in tourists, which in turn directly influence their behavioral intentions and attitudes [44]. Collectively, these activities contribute to the preservation of local identity [43] and the conservation of rural landscapes designed to meet human needs.

Gastronomic tourism is grounded in the production and consumption of local culinary dishes and is widely recognized as a component of heritage tourism [11]. Its impact on the local economy is significant, accounting for approximately 25% of economic activity in relevant areas [68].This form of tourism provides unique products, services, and experiences that are memorable for tourists, contributing to their well-being while integrating into local value chains [77].Food tourism can take different forms such as gastronomic tours, cooking workshops, tastings, visits to agricultural producers or local producers' markets [74].

Sustainable gastronomic tourism revitalizes local communities [47], operates within specific social, cultural, and psychological contexts [13], and fosters communication between residents and tourists. It also contributes to the preservation of cultural heritage and promotes intercultural exchanges [35, 75]. Culinary tourism emphasizes food sourcing and preparation methods [58], and tourism marketing strategies should promote local culinary activities, encourage the consumption of locally produced foods, and enhance service quality. These strategies are essential for sustainability while simultaneously valorizing local culinary traditions and producers [20]. Culinary tourism generates income for local residents and serves as an instrument for sustainable development. Policies supporting this sector should adopt a holistic approach to local gastronomy, integrating it into ecosystem services, with an emphasis on conserving agricultural and food genetic resources that contribute to regional food security [5]. Recent research indicates that tourists who prefer local gastronomy value the quality of service and the dining atmosphere. Positive correlations exist between the number of dining establishments, population size, and overnight stays at the destination level [39]. Additionally, some tourists seek one-day culinary experiences that provide a holistic engagement encompassing dining, learning, culture, and nature [40].

Entrepreneurs in Food Tourism

Successful management of restaurants and dining establishments in the context of food tourism requires a comprehensive set of knowledge, skills, and competencies [75]. Key priorities include understanding trends in tourists' culinary preferences, integrating local ingredients, and fostering collaboration with regional producers.

Restaurants capitalize on local knowledge embedded in recipes, dishes, and cooking techniques, which collectively reflect regional gastronomic culture. This approach

strengthens community ties and enhances the attractiveness of the destination, positioning local cuisine as an effective marketing tool [32, 69].

Entrepreneurs in gastronomy are encouraged to adopt online marketing strategies and collaborate with digital promotion and booking platforms, paying close attention to tourist reviews. Online reviews play a crucial role in promoting destinations, particularly in highlighting the authenticity, freshness, and local origin of culinary offerings [3, 53]. The integration of gastronomic offerings into social media platforms not only increases the destination's appeal but also supports the local economy [1].

Blanco-Moreno et al (2024) [9] suggest a novel research methodology that employs artificial intelligence to analyze tourist sentiment expressed through social media posts, hashtags, and comments, providing valuable insights for destination marketing. The Covid-19 pandemic highlighted the reliance of consumers on digital solutions for food procurement [17], underlining the need for HoReCa entrepreneurs to invest in enhancing employees' digital competencies and adopting mobile applications [70]. Furthermore, implementing sustainable practices in daily operations is essential, including selective waste collection, food waste reduction, and optimization of waste treatment processes [7, 79], thereby aligning gastronomy entrepreneurship with both environmental and economic sustainability.

Young People and Food Tourism

Educating and training rural youth in organic agriculture, traditional production methods, and their involvement in agritourism and gastronomic tourism can contribute to transforming current global food systems and addressing many of the challenges facing rural areas [54].

Young people's culinary preferences in the context of gastronomic tourism can be influenced through social media platforms. Several authors argue that young people themselves act as promoters of gastronomic tourism on these platforms, as they are digitally literate [67] and frequently post images of the dishes they consume or reviews of their culinary experiences on social networks. Understanding generational habits of content creation and sharing related to food tourism can be leveraged in marketing strategies targeting these audiences [52].

Food Sustainability and the Impact of Tourism Development on Communities

Globally, gastronomy is dynamic, with its evolution driven by societal changes, concerns regarding health and food safety [57], and technological advancements [78]. In this context, food must be approached holistically, with emphasis on biodiversity conservation and as an opportunity to create connections among people and foster social exchange [60]. Increasingly, there is a need to promote local products as fresh, flavorful, and seasonal, while encouraging education around smarter and more sustainable consumption [30].

Local gastronomic products form part of national cultural heritage [62] and are most often marketed through short food supply chains [12, 64]. Consumers are becoming increasingly knowledgeable about gastronomy, paying greater attention to food sustainability, preferring organic products, purchasing locally, and supporting small producers [56].

Currently, Romania has 15 food products registered under European quality schemes and 753 products nationally recognized as traditional foods [23]. At a regional level, the presence of foods or culinary products registered under various quality schemes is associated by tourists with the authenticity of local gastronomy and enhances the tourism experience, providing educational value [22] while also contributing to mitigating rural depopulation. According to producers and entrepreneurs involved in creating such products, these play an essential role in increasing the visibility of both a tourist destination and local producers [27].

Local gastronomy, specific to each country and region, represents part of the potential intangible heritage. Preserving and valorizing this heritage strengthens local identity and supports sustainable tourism [10]. Local gastronomy should be promoted as a resilient, competitive, and sustainable tourism product [73]. It creates local value chains [19] and can

be particularly effectively promoted through gastronomic events and investments in digital marketing [21].

Residents of rural areas are custodians of traditional knowledge related to local food culture [80], closely tied to traditional practices of producing fresh, flavorful, and healthy foods and dishes. Local food culture is increasingly being highlighted through tourism, with a strong connection observed between the registration of dishes under quality schemes and sales volumes [24].

Despite the significant influence of social and natural environments on a nation's culinary traditions [37], traditional knowledge of wild and cultivated medicinal and aromatic plants and their use in local cuisine remains particularly important. Integrating this knowledge into gastronomic tourism helps preserve cultural values, foster local development [4], and initiate sustainable forms of eco-tourism [50]. In multiethnic areas, local gastronomy is in constant evolution, with various ethnic groups transmitting their culinary knowledge to one another [61].

In this context, the present research aimed to assess Local Gastronomic Points (LGPs) as tools for a sustainable rural development in Romania, emphasizing the state in Sibiu County, based on literature review on the topic, statistical processing of the official empirical data and the observations collected from the field.

MATERIALS AND METHODS

The research work was based on documentary research, literature review, statistical analysis of secondary data, observations, content analysis, regarding the localities with Local gastronomic points from Sibiu County, Romania.

The methodology included at the beginning desk research methods and procedures to collect the primary data from official information sources and data bases regarding lodging and travel services provided. In this case it was used the site of The National Authority for Tourism. Also, the data were picked up from the National Agency of Mountain Area or from National Institute of Statistics. After setting up the data collection for this research article, there were calculated some tourist traffic indicators of rural tourism in different Sibiu villages (touristtrafficdensity, touristtrafficintensity,andtourist operation rate), using known methodology [36]. Excel, v. 365 Microsoft, was used for data processing.

Tourist traffic density (TD) is the indicator that directly links tourist traffic with the resident population (on January 1). It is calculated as the ratio between the number of tourists arriving in the area (TA) and the resident population of the area on January 1 (P).

TD = ...(1)

The intensity of tourist flow was determined dividing the number of overnight stays to the resident population in the village (on 1 January).

TI= .....(2)

where:

Ti = tourist traffic intensity Os = number of tourist overnight stays P = total population on 1 January

To assess the size of the tourist development in the studied area, it was evaluated the *tourist operation rate,* whose formula involves calculating the ratio between the total number of accommodation units and the resident population.

Tfr = Tacu/P……..... (3)

where:

Tfr = tourism function rate Tacu = total number of accommodation units P = total population on 1 January

The main research objectives are:

O1 Presentation of the Development of Gastronomic Points in Romania

O2 Review of the Literature on Gastronomic Points in Romania

O3 Establishing the link between the functioning of the PGLs and the stage of rural tourism development in villages in Sibiu County, Romania.

RESULTS AND DISCUSSIONS

The Concept of Local Gastronomic Points (PGLs) and their evolution in Romania according to Law 412/2023, Local Gastronomic Points are units for the utilization of locally sourced food products within rural communities. They may operate within private households, agricultural farms, or locations where activities related to primary production are carried out.

In 2024, the Gastro Local Association developed a best practices guide for the operation of local gastronomic points, according to which local producers may serve meals to groups of up to 15 people. The primary mission of the Gastro Local Association is to support local producers and promote traditional Romanian gastronomy [6].

Beginning in 2023, the association has organized an annual PGL conference aimed at highlighting the sector's contribution to sustainable rural development.

Between 2018 and the beginning of 2025, 516 such family-run food service units were registered [45], representing an approximate 282% increase compared to the 186 PGLs recorded in 2021 [51]. These units operate in rural areas, contributing to the direct valorization of products and increasing farmers' incomes.

Their national distribution is presented in Figure 1. The counties with the highest number of PGLs are Brașov (106), Tulcea (57), Cluj (38), Sibiu (33), Alba (30), Hunedoara (28), Bistrița-Năsăud (26), and Suceava (20). Thus, approximately 65.5% of all PGLs nationwide are concentrated within these eight counties.

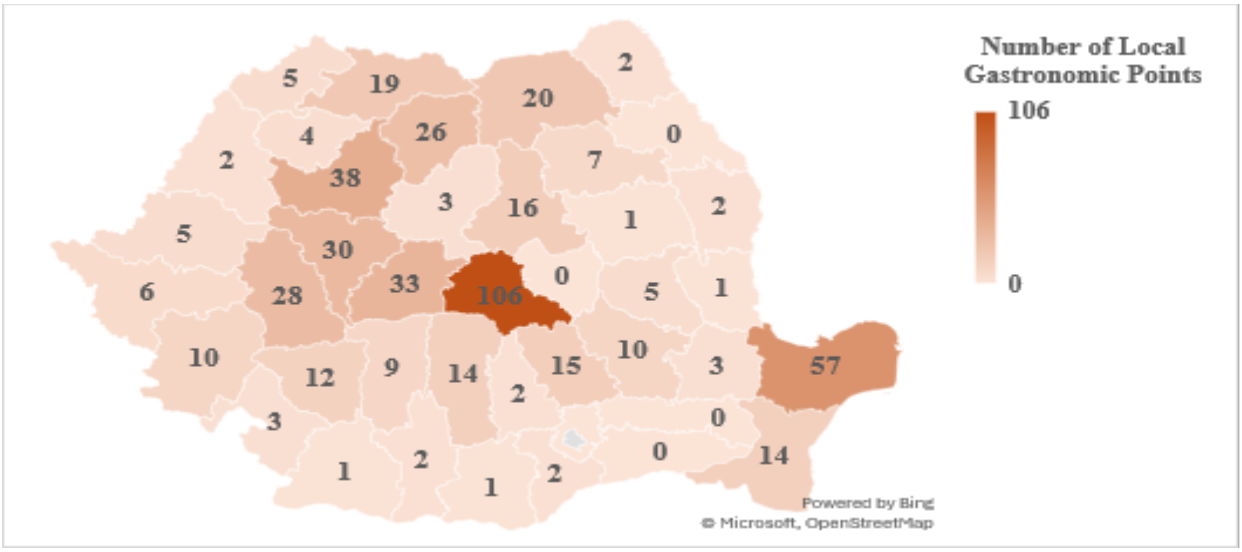


Fig. 1. National Distribution of Local Gastronomic Points in Romania
Source: own design based on [45].

Within the Central Region, 188 Local Gastronomic Points (PGLs) are registered, representing 36.43% of the total nationwide. Brașov County holds 106 PGLs, accounting for 20.5% of all PGLs at the national level.

Romanian Literature on PGLs

Local gastronomic points are located in rural areas and serve as a bridge between agriculture and tourism, contributing to the definition of a destination's image and the preservation of both local and national identity [65]. The establishment of PGLs as part of rural gastronomic tourism in Romania has experienced remarkable growth [15].

Tourists spending their holidays in rural areas and dining at PGLs are interested in consuming local dishes prepared according to traditional recipes, using locally sourced raw materials. They are informed and aware that menus offered at PGLs typically include only two types of soups and two main dishes, which they may choose from. Tourists associate local gastronomy with "a sense of place" and local culinary specialties with rural tourism destinations—an association that can be

promoted as part of local gastronomic culture [14]. Yang et al. (2024) [76] discuss the concept of rural gastronomic tourism, emphasizing that it integrates food, services, and environment, and highlighting that tourist preferences in the post-pandemic era have shifted toward greater attention to the quality of the rural environment.

Establishing the Link between the Functioning of PGLs in Sibiu County and Rural Tourism

The history of organizing alternative gastronomic events in Sibiu County dates back to around 2017, when, through the initiative of the "My Transylvania" Association, connections were forged between small producers from Sibiu's villages and visitors invited to attend weekend brunches [63]. Since the 2000s, the local gastronomy typical of Transylvanian villages has been showcased at festivals held in the mountain villages of the county. Among these are the Cheese and Plum Brandy Festival, organized in the commune of Răşinari, and the Peony Festival, held in Gura Râului commune.

By the end of 2024, Sibiu County had 33 registered Local Gastronomic Points operating in 22 communes, with the highest concentrations found in Biertan and Râu Sadului. The evolution of local gastronomic points from their establishment in 2018 to 2024 is presented in Figure 2. Notably, 10 of the 33 existing PGLs in Sibiu County were established in 2024 alone.

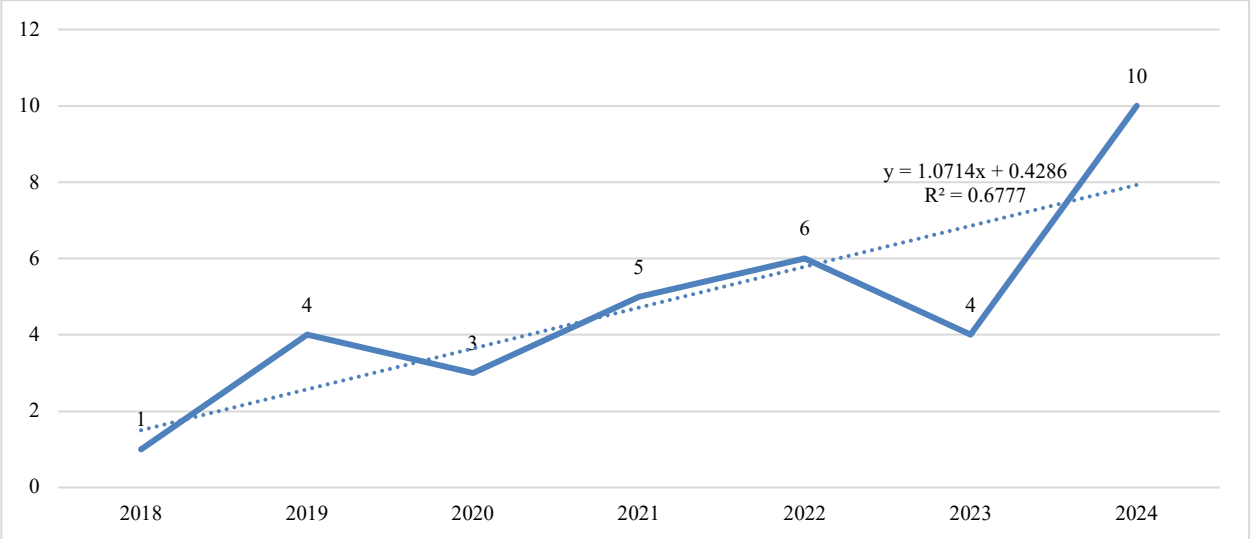


Fig. 2. Evolution of the Number of PGLs, in Sibiu County
Source: own calculation based on [45] .

In general, Local Gastronomic Points (PGLs) have been established in localities where tourist accommodation facilities are available. The communes hosting PGLs and having the highest number of accommodation structures in the county are: Cârţişoara (48), Porumbacu de Jos (35), and Gura Râului (34). Their creation reflects a local need to provide public food services (Table 1) and to capitalize on raw materials produced within peasant households. These communes are located in the mountainous area and are attractive due to their scenic landscapes and the way local traditions have been preserved. The mountainous area is subject to several natural and human constraints such as rugged relief, isolation, distance from administrative centers, population aging, and depopulation [71] yet it remains preferred by tourists seeking to spend their holidays in a natural, picturesque setting and to enjoy gastronomy based on fresh, flavorful, and healthy foods [51].

Agyeiwaah and Zhao (2024) [2] highlighted the relationship between rural residents' quality of life, their attachment to place, and their support for organizing tourism events and promoting tourism development. Local gastronomy integrates local agroecological practices with tourism and contributes to preserving knowledge related to agriculture

and food preparation among the local population [31].

The highest values of tourist traffic density for 2023 were recorded in the communes of Râu Sadului (9,312), Cârțișoara (7,919), and Arpașu de Jos (3,071). The highest values of tourist traffic intensity for the same year were also found in RâuSadului (21,679), Cârțișoara (12,924), and Arpașu de Jos (4,210). Values above 1.0 for tourist traffic density and intensity were also recorded in Gura Râului, Porumbacu de Jos, and Șura Mare. The highest tourist operation rates for 2023 were observed in Cârțișoara (0.035), Râu Sadului (0.022), and Porumbacu de Jos (0.011). The communes of Cârțișoara, Arpașu de Jos, and Porumbacu de Jos belong to the ethnogeographical area "Țara Oltului," located at the foot of the Făgăraș Mountains, while Râu Sadului belongs to "Mărginimea Sibiului," a nationally and internationally renowned tourist area [18].

Table 1. Localities in Sibiu County Where PGLs Have Been Established, Number and Capacity of Tourist Accommodation Structures, and Tourist Traffic Indicators

No.	Locality	Population at 1 January 2,023	Number of PGL	Number touristic structures	Number of rooms	Number of places	Number of arrivals (2023)	Number of overnight stays (2023)	Tourism traffic density	Tourism traffic intensity	Tourist operation rate
1	Loamneș, (Alămor village)	2,851	1	0	0	0	0	0	0.000	0.000	0.000
2	Alma Vii	1,812	1	1	5	10	0	0	0.000	0.000	0.000
3	Arpașu de Jos	2,805	2	13	69	146	8,614	11,809	3.071	4.210	0.005
4	Sat Bradu	932	2	2	13	27	0	0	0.000	0.000	0.000
5	Biertan	3,000	3	16	75	170	778	1,393	0.259	0.464	0.005
6	Bruiu	962	1	4	12	35	0	0	0.000	0.000	0.004
7	Chirpăr	1,895	1	2	6	16	375	824	0.198	0.435	0.001
8	Cisnădioara	25,931	2	13	128	336	8,724	17,343	0.336	0.669	0.001
9	Cisnădie		1	26	97	247					
10	Cârțișoara	1,376	1	48	444	1,035	10,896	17,784	7.919	12.924	0.035
11	Dârlos	3,500	1	1	2	4	0	0	0.000	0.000	0.000
12	Gura Râului	3,818	2	34	226	469	7,136	13,861	1.869	3.630	0.009
13	Hoghilag	2,538	1	2	8	17	672	998	0.265	0.393	0.001
14	Jina	3,559	1	6	76	152	750	1,202	0.211	0.338	0.002
15	Laslea	4,279	1	6	27	78	682	1,316	0.159	0.308	0.001
16	Moșna	3,715	2	6	15	38	139	294	0.037	0.079	0.002
17	Roșia (Nucet village)	6,296	1	8	27	63	0	0	0.000	0.000	0.000
18	Porumbacu de Jos	3,220	2	35	189	483	6,294	10,777	1.955	3.347	0.011
19	Râu Sadului	552	3	12	80	158	5,140	11,967	9.312	21.679	0.022
20	Sadu	2,724	2	7	39	89	214	425	0.079	0.156	0.003
21	Șeica Mare	4,567	1	2	12	24	271	419	0.059	0.092	0.000
22	Șura Mare	5,274	1	4	47	97	5,430	7,106	1.030	1.347	0.001
	TOTAL	**85,606**	**33**	**248**	**1,597**	**3,694**	**56,115**	**97,518**	**0.656**	**1.139**	**0.003**

Source: own calculation based on [41, 45, 46].

CONCLUSIONS

The gastronomic popularity of Sibiu County, located in central Romania, reached its peak in 2009, when it was awarded the title of "European Gastronomic Region," thereby highlighting the area's culinary potential shaped by centuries of coexistence among Romanians, Saxons, and Hungarians.

Entrepreneurs engaged in rural gastronomic tourism represent new rural actors who valorize the resources of agricultural holdings and local communities, thereby contributing to rural revitalization.

Educating and training rural youth and involving them in agritourism and gastronomic tourism can contribute to transforming current global food systems, addressing many of the

challenges facing rural areas, and stimulating local entrepreneurship.

Local Gastronomic Points (PGLs), established within peasant households in Romania, promote the pluriactivity of farming families, enabling them to earn additional income while preserving and showcasing traditional knowledge related to food production and preparation. This type of food service aligns with the "farm-to-fork" strategy, as most ingredients used in culinary preparations come from their own production or from other local producers, thereby adding value to agricultural raw materials. Families involved in operating a local gastronomic point share their stories with visitors, offering an authentic gastronomic experience rooted in a particular lifestyle and tradition of food production and processing. They actively participate in preserving local culinary heritage and traditions related to crop cultivation, animal husbandry, and agricultural processing. In this way, families become central to local rural tourism offerings, around which the entire community is strengthened.

Local Gastronomic Points are part of gastronomic tourism and have the potential to enhance the competitiveness of Romanian rural tourism. Entrepreneurs managing PGLs should consider creating one-day tourism packages that include visits to both natural and cultural attractions in and around their localities.

The entire community in the tourist villages where local gastronomic outlets and tourist accommodation facilities operate strengthens the tourism value chain and contributes to the development of the area.

Local public administrations must collaborate with county tourism associations and NGOs specializing in the organization of alternative gastronomic events. Hosting gastronomic events in villages promotes the area's natural and cultural potential and increases the tourist appeal of the locality.

ACKNOWLEDGEMENTS

This research was funded by the project Horizon Governance Project: Regional Inclusive Biobased Entrepreneurship Solutions (RIBES), 2024-2027, Identification no. 101134911, and it was realized under the Research Center for Agricultural Sciences and Environment Protection of the University Lucian Blaga of Sibiu.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STRATEGIES FOR PREVENTING AND REDUCING FOOD LOSS AND WASTE ACROSS THE AGRI-FOOD CHAIN: EVIDENCE FROM A MULTI-ANNUAL RESEARCH INITIATIVE

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Abstract

Ensuring food security and addressing poverty and hunger constitute critical challenges for humanity. The security and sustainability of our food can be achieved by eliminating the causes that lead to food loss and through measures that can be taken by all stakeholders in this phenomenon. The aim of the paper is to identify concrete measures to mitigate food loss in the agri-food chain. The study forms part of a multi-annual research initiative and employs both quantitative and qualitative methodologies to address the three objectives established. In addition to a comprehensive review of the relevant literature and the analysis of data from official sources, empirical evidence was gathered during a workshop conducted in person in June 2025. The resulting data were systematically synthesized, processed, and interpreted, and presented in tabular and graphical form. The findings highlight practical solutions for reducing food loss (FL) and food waste (FW) at the farm level, within processing and distribution, in the food service sector, and among households. Emphasis is placed on the role of public policies and social responsibility programs in supporting these efforts.

Key words**:** *food loss, food waste, reduction, consumers, supply chain*

INTRODUCTION

In 2024, approximately 32% of the global population could not afford a healthy diet, while 8.2% experienced hunger. In this context, food sustainability [16] and food security are universal concerns, encompassing equitable access to food, its availability, and its responsible utilization [17]. The food system plays a crucial role in achieving Sustainable Development Goals (SDGs) 2 and 12, adopted by the United Nations in 2015, various authors reporting the need to implement solutions to reduce food loss. [13, 35].

In Romania, the share of the total population facing moderate or severe food insecurity during the period 2022–2024 was 18.6% (Figure 1), one of the highest rates in Eastern Europe (compared to Albania 33%, Ukraine 32.5%, Republic of Moldova 25.1%, Hungary 15.6%, North Macedonia 15.2%, Bulgaria 11.6%, and the Czech Republic 10%) [18].

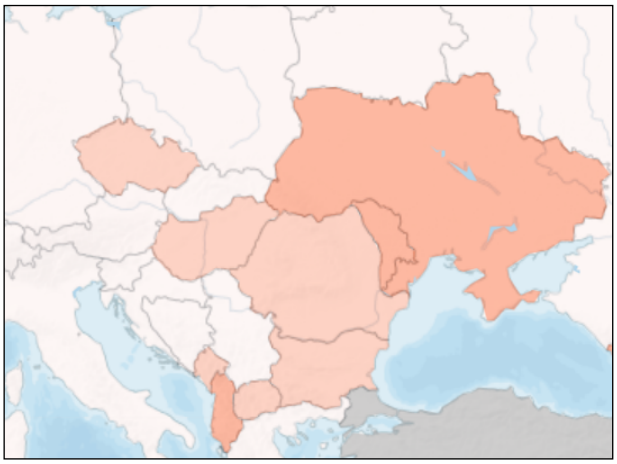


Fig. 1. Map of Moderate or Severe Food Insecurity in Eastern European Countries
Source: caption from [18] .

Against this backdrop, food waste represents a major and complex challenge [38]; its reduction can mitigate hunger, pollution, and biodiversity loss [3, 39], thereby serving as an integral component of ensuring food security and a shared responsibility among all stakeholders.

According to the United Nations Environment Program (UNEP), in 2022 food waste levels were particularly high in several European countries, reaching 168 kg/person in Portugal, 157 kg/person in Cyprus, 144 kg/person in Malta, and 132 kg/person in Italy, all of which exceeded the global average of 132 kg/person [37].

Various studies have shown that the amount of food waste generated at the household level depends on socio-demographic factors as well as on purchasing and food management practices [10, 24], which underscores the need for intervention measures tailored to different categories of consumers. Chereji (2023) [6] reported that younger populations generated larger quantities of food waste, regardless of their place of origin.

Food loss and food waste arise from multiple causes along the supply chain (Figure 2):

-Consumer-level causes: inadequate shopping and meal planning, impulse buying, poor inventory management, over-preparation of food, inappropriate handling of leftovers, and confusion over date labeling.



Fig. 2. The word cloud regarding the FL and FW
Source: created with [34].

-Supply chain causes (production, processing, distribution, retail): insufficient investment in efficient technologies, poor management, losses during preservation, overproduction and overcooking (HoReCa sector), spoilage, food preparation leftovers, and unfair commercial practices.

Good Practices for Preventing and Reducing Food Loss and Waste (Figure 3)

-Consumer-level practices: careful shopping and meal planning, avoidance of impulse purchases, effective inventory management, preparing appropriate portion sizes, creative use of leftovers, and accurate interpretation of date labels (e.g., "best before" vs. "use by") [5].

-Supply chain practices: investment in innovative technologies, efficient resource management, facilitation of food donations, price reductions for products nearing the end of their shelf life, improved packaging and transportation, adoption of digital and technological solutions, and the transition toward a circular economy [19, 20, 35]. These measures emphasize the continuous and efficient use of resources and the minimization of waste [1].



Fig. 3. The word cloud regarding the actions aimed at combating FW
Source: created with [34].

Addressing Food Waste Requires Coordinated Efforts from All Stakeholders

-Role of consumers: Everyone plays a crucial role by adopting responsible consumption habits.

-**Role of entrepreneurs and the food industry**: Through strategic investments, efficient management, price reductions, and food donations.
-**Role of policymakers**: By developing updated regulations, clarifying legislation, and providing financial support.
-**Collective responsibility**: Through the joint effort of all individuals to reduce FW, the food system can undergo transformative changes towards a circular economy.
The aim of this paper is to identify strategies to prevent and reduce FL and FW at various stages of the agri-food chain.

MATERIALS AND METHODS

Study Design

This study was conducted as part of a multi-year research project aimed at identifying concrete actions to reduce FL and FW in Romania.
A mixed-methods approach was employed, integrating a systematic content analysis of relevant literature with survey-based data collection during a workshop conducted in June 2025.
During the event, statistical data from different countries regarding FL and FW were presented, examined key legislative frameworks, and outlined the obligations of economic operators to minimize and valorize food waste in alignment with circular economy principles.
The second phase of the workshop involved structured open discussions, during which representatives from the food industry and agricultural sector presented concrete interventions implemented to mitigate food loss and waste and discussed the principal operational challenges encountered.
Data were collected through paper-based questionnaires, comprising primarily five-point Likert scale items, supplemented by open-ended questions to capture qualitative insights.
All participants were informed of the study's objectives and data protection procedures in accordance with GDPR requirements.
Collected data were systematically processed and analyzed using Microsoft Excel v.365 (Microsoft Corporation, Redmond, WA, United States).
Table 1 presents the primary objectives of the study.

Table 1. Objectives of the studies

Main objectives in the second study
O.1 Identification of measures to reduce FL to the farmers
O.2 Identification of actions to reduce FL at processors and wholesalers
O.3 Identification of actions to reduce FW at the end of the agri-food chain (in the HoReCa system and at the household consumption level) and social responsibility

Source: own design.

Study Participants

A total of 14 respondents completed the paper-based questionnaire administered during the workshop on 4 June 2025. The participants had a mean age of 29.5 years (range: 19–50), with equal representation of males and females. Most participants (57.1%) resided in urban areas. Half of the respondents were high school graduates, currently students from family farms or employed by food processors, while the other half held higher education degrees. By region, 85.7% were from Sibiu County, with the remainder from neighboring counties Alba and Vâlcea.

RESULTS AND DISCUSSIONS

O1 Identification of measures to reduce FL to the farmers

Workshop participants highlighted several strategies to mitigate food loss at the farm level (Table 2). The most important measure, according to the respondents, is the implementation of disease and pest monitoring systems in both the field and storage facilities, which received a mean score of 4.57. Equally important is the use of data collection, storage, and analysis systems, enabling timely and informed decision-making (mean score: 4.50).
The use of sensor systems connected to the Internet of Things (IoT) received the lowest rating (mean score: 3.79), reflecting the additional requirements for specific digital skills and adequate infrastructure.
These findings underscore the relative feasibility and perceived effectiveness of

different technological interventions for reducing farm-level food loss.

Table 2. Assessment of the Importance of Food Loss Reduction Measures at the Farm Level

Measure	Mean score	Rank
Use of disease and pest monitoring systems	4.57	1
Use of field data collection, storage, and analysis systems (Big Data) to generate actionable crop insights	4.5	2
Use of irrigation monitoring systems and smart irrigation technologies	4.14	3
Use of drones for crop monitoring	4.07	4
Use of IoT-connected sensor systems	3.79	5

Source: own calculation.

Use of Storage and Preservation Systems to Reduce On-Farm Crop Losses

Responses from the workshop indicate that among strategies to reduce on-farm crop losses, the most highly rated measure is the implementation of monitoring and control systems within storage facilities, which received a mean score of 4.36 (Figure 4).

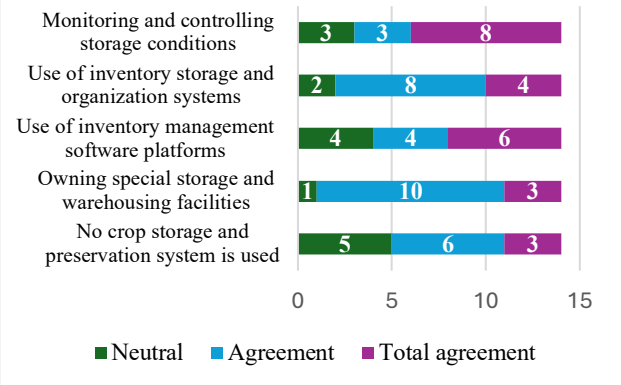


Fig. 4. The importance of using crop storage and preservation systems
Source: own design.

Such systems enable real-time tracking of storage conditions, early detection of spoilage, and prompt corrective actions, thereby minimizing post-harvest losses. These findings highlight the critical role of storage management in maintaining crop quality and reducing overall food loss at the farm level, complementing field-level interventions such as pest and disease monitoring.

Importance of Infrastructure Investments as Measures to Reduce FL at the Farm Level

In Romania, the platform "Solution4Farming" has been developed for mixed farms and tailored to the country's pedoclimatic conditions, serving as a direct link between digital agriculture solutions and sustainable production practices. The platform enables the measurement of greenhouse gas emissions, on-farm losses, and water consumption relative to the farm's livestock [31].

The primary infrastructure investments required to reduce agricultural production losses at the farm level (Figure 5) include the acquisition of automated harvesting and handling systems—such as GPS-equipped tractors, combines, and other machinery to enhance operational efficiency—which received a mean score of 4.43. The use of Blockchain technology for tracking the agricultural supply chain from farm to consumer was also highly rated, with a mean score of 4.21. All categories of infrastructure investments received mean scores above 4.0, indicating their perceived importance.

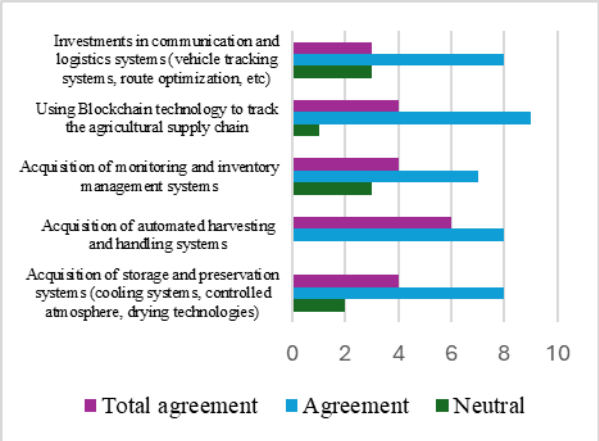


Fig. 5. The importance of investments in farm infrastructure as measures to reduce on-farm food loss
Source: own design.

Integrating Blockchain technology facilitates the application of sustainable agricultural practices and ensures the stability of the food supply chain [33]. Innovative smart agriculture

solutions further contribute to increased productivity, optimized resource use, and the traceability necessary to guarantee food safety [2].

Forms of Support to Assist Crop Management at the Farm Level, According to Workshop Participants

In response to an open-ended question regarding the types of support needed by farmers, workshop participants suggested the following measures, summarized in Figure 6:

-User-friendly smart devices;
-Comprehensive crop monitoring with alerts for potential issues;
-Establishment of associations or cooperatives to secure clients for products and provide adequate storage facilities;
-Promotional campaigns for small-scale producers;
-On-farm processing of raw materials;
-Investments in modern technologies, including advanced machinery, GPS systems, and drones;
-Provision of financial support and subsidies for farmers;
-Implementation of agricultural insurance;
-Direct contractual agreements with buyers.



Fig. 6 The word cloud of resulted from open question regarding to the forms of support needed for farmers
Source: created with [34].

These suggestions highlight the multifaceted support required to enhance farm management, improve efficiency, and reduce

O2 Identification of actions to reduce FL at processors and wholesalers

Measures to Reduce Food Waste at Processors

The most important and effective measure identified in this sector is the establishment of a legal framework and infrastructure for the formal management of food waste, which received a mean score of 4.5. This is followed by the creation of start-ups aimed at developing solutions to optimize the management of food loss (mean score: 4.43) (Table 3).

Previous studies indicate that food processors often implement their own solutions to recover and reuse by-products, thereby minimizing waste [9, 15].

Table 3. Preferences for Measures to Improve Food Waste Management at Processors

Measure	Mean score	Rank
Legal framework and infrastructure for formal food waste management	4.50	1
Funding for start-ups developing solutions to optimize food waste management	4.43	2
Tax incentives for staying within a defined food waste threshold	4.07	3
Penalties for exceeding the established food waste threshold	3.57	4
Don't know	3.14	5

Source: own calculation.

Measures to Reduce Food Loss at Distributors

Most participants believe that distributors must have intelligent inventory monitoring systems that monitor consumption, product spoilage, and expiration dates.

O3 Identification of actions to reduce FW at the end of the Agri-Food Chain (HoReCa and Household Level) and Social Responsibility

Importance of a Digital Support System for Food Waste Management in HoReCa

More than 90% of workshop participants emphasized the importance of a digital platform to manage food waste in the HoReCa sector. Devaraj and Balasubramanian (2025) [12] report that the service sector generates approximately 28% of total annual food waste, highlighting the need for tailored avoidance strategies. Managerial practices in this sector often prioritize customer satisfaction, with insufficient attention to food waste reduction [26]. Various authors have reported as

identified measures to reduce FW in public catering the redistribution of food, the use of leftovers from plates for animals, and the use of various technical equipment and mobile phone applications. [14, 29].

The importance of collaboration within the food chain

Over 90% of the workshop participants positively assessed the need for collaboration between all stakeholders in reducing FL and FW.

Measures to Reduce FW in the family

Kalogiannidis (2025) [22] shows that FW at the household consumer level exceeds 50% of its total at the food chain level. Any intervention aimed at reducing household waste positively contributes to food security [23]. According to the workshop participants, the most effective measure at the household level is proper inventory management, including checking and prioritizing food consumption depending on the expiration date (average score: 4.43). All the actions they scored over 4 points, all of which were important from the participants' perspective.

Table 4. Measures to Reduce Food Waste at the Household Level

Measure	Mean score	Rank
Checking and prioritizing the use of food according to expiration dates	4.43	1
Reusing leftovers from the refrigerator	4.21	2
Menu planning with the preparation of a shopping list	4.07	3
Purchasing smaller quantities and cooking smaller portions	4.07	4
Buying food at discounted prices near the end of its shelf life	4.00	5

Source: own calculation.

Study participants emphasized the need for national awareness and education campaigns on this topic, which received a mean score of 4.71. The second preference (average score 4.50) referred to the need for investments in re-technologies and innovation. (Table 5)

Several studies [4, 28] indicate that education and awareness remain essential for young consumers to develop responsible and sustainable behaviours that contribute to the reduction of food loss. Universities have a critical role in this process through formal education, supporting the use of mobile applications, smart packaging based on nanotechnology, and promoting ecological awareness [27]. Consumer education on food waste reduction should begin at home and continue throughout the school curriculum [40], informed by research on ecological, moral, financial, and social motivations related to minimizing food waste [32].

Table 5. Additional Measures Contributing to the Reduction of Food Waste

Measure	Mean score	Rank
Awareness and education	4.71	1
Investments in technology and innovation	4.50	2
Recovery, reuse, and recycling of food waste (e.g., for animal feed, biochemical processing, anaerobic co-digestion, composting/aerobic processes, controlled combustion, or integration into the circular economy)	4.36	3
Correct understanding of food labeling (distinguishing “best before” vs. “use by” to reduce consumer-level waste)	4.29	4
Price reductions on products nearing expiration (e.g., sale with discount labels)	4.29	4

Source: own calculation.

Workplace-Applied Solutions Identified by Participants

In response to an open-ended question, participants suggested several practical measures applicable in their work settings, including: efficient management of raw material stocks using the FIFO (“First-In-First-Out”) method; delivery of food products following FIFO principles; production planning and manufacturing of smaller batches; strategic planning of raw material procurement; correct portion sizing; creation of short-term inventories; discounting products nearing expiration; utilization of food waste for animal feed; use of modern training methods on food waste reduction; and effective communication strategies regarding FW.

Importance of Social Responsibility Policies and Programs

Approximately 86% of respondents emphasized the importance of policies and programs enabling the donation of surplus food to vulnerable populations through food banks, charitable organizations, or local communities. Other studies support the need for national policies promoting responsible consumption, public education campaigns [7, 8, 10, 14, 30, 36], and collaboration among all stakeholders to diminish FW [11, 21, 25].

CONCLUSIONS

During the workshop, several concrete actions aimed at avoiding food waste were prioritized:

Farm Level:

-Implementation of crop and storage monitoring systems for diseases and pests;

-Investments in storage facilities equipped with temperature, humidity, and gas sensors;

-Acquisition of modern automated harvesting and handling systems;

-Provision of various forms of support for farmers to reduce raw material losses.

Processors and Distributors:

-Establishment of a legal framework and infrastructure for monitoring and managing FL and FW;

-Application of measures to improve food waste management;

-Implementation of inventory management systems to monitor consumption, spoilage rates, and expiration dates.

HoReCa Sector:

-Support for the creation and acquisition of digital platforms to manage FW;

-Establishment of partnerships between farmers and food service units for the valorization of FW.

Household Level:

-Improved management and verification of food stocks, prioritizing consumption based on expiration dates;

- Organizing non-formal education actions and population awareness campaigns to demonstrate the long-term effects of FW on food sustainability.

Social Responsibility Policies and Programs:

Awareness of stakeholders regarding policies and programs for donating surplus food to vulnerable populations.

The study also identified gaps in knowledge and skills regarding composting of household FW. Major barriers to effective FW reduction include the lack of a globally accepted definition, absence of standardized reference levels, inconsistent interpretations of legislation, issues related to value-added tax on food, and unfair commercial practices.

Reducing FW, community involvement, implementation of high-performance, innovative technologies, and collaboration are essential.

ACKNOWLEDGEMENTS

The authors express their gratitude to all individuals who took the time to participate to the workshop and respond to the questionnaire developed in this research study. This research was conducted as part of a national project ADER 17.1.1 „Research on the evolution of the phenomenon of food waste at the national level, from the perspective of Romania's commitment to achieving the objective of sustainable development", funded by the Ministry of Agriculture and Rural Development.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

COOPERATIVIZATION IN ROMANIAN AGRICULTURE: EVOLUTION AND CURRENT PERSPECTIVES

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Abstract

Organizing small agricultural producers into cooperatives can improve production value, operational efficiency, and access to European funds.The study analyzes the evolution of collectivization in Romanian agriculture using open-access literature and official data from theMinistry of Agriculture and Rural Development. Data were statistically processed and graphically represented to examine geographic distribution, cooperative status, and economic performance, while identifying challenges faced by Romanian agricultural cooperatives.Principal component analysis (PCA), heat maps, and volatility coefficient analysis were employed to uncover territorial patterns and assess the stability of cooperative development across Romania, providing a comprehensive understanding of the factors influencing cooperative dynamics at the county and regional levels. Findings reveal a concentration of cooperatives in certain counties, reflecting infrastructure differences, cooperative traditions, and institutional support levels. Many cooperatives struggle beyond initial stages, with financial performance remaining fragile due to governance difficulties, limited market access, and funding challenges. Access to European funds and external support could greatly enhance cooperative sustainability.The study underscores the critical role of agricultural cooperatives in rural development and suggests policies for increased durability, including ongoing fiscal support, member professionalization, and short supply chain development.

Key words**:** *agricultural cooperatives, rural development, Romania, sustainability*

INTRODUCTION

Cooperativization remains a current issue for Romanian agriculture, given that the sector is characterized by significant disparities.
Thus, there is a very large number of small agricultural holdings engaged in subsistence activities, alongside very large farms spread over tens of thousands of hectares.
According to the agricultural census, Romania has a total of 2.9 million farms (31.8% of the 9.1 million agricultural holdings in the EU Member States). Around 63.8% of European farms have an area smaller than 5 hectares. In Romania, 90.3% (approximately 2.6 million farms) fall into this category, and over half of these small holdings are located in the country. The average size of a Romanian farm is 4.42 hectares, compared to the European average of 17.4 hectares, according to Eurostat statistics [3].
The Romanian agricultural sector ranks among the top 10 at the European Union level. As of 2023, the sector's share in Romania's gross domestic product reached approximately 3.9%, according to data fromthe World Bank [11].
Agriculture provides employment for about 20.9% of Romania's labor force, placing the country first in the EU in this regard [4].
The association of farmers is an unpopular phenomenon in Romania, and this can be understood when correlated with the forced collectivization of peasants during the communist regime—an era marked by abuses from the authorities, excesses committed by party activists, and forced adhesion or donation of agricultural land [6].
The belief that joining a cooperative leads to the loss of land ownership is so deeply rooted that farmers must be reassured on this matter, requiring both entrepreneurial training programs and promotion of the agricultural cooperative model [9].
The transition from a centralized system, in which property rights had virtually lost their meaning, to the privatization of agricultural

land brought about a sense of euphoria that lasted for decades. However, today, land owners face difficulties in exploiting their holdings [1].

An aging rural population, possessing small and highly fragmented plots of agricultural land, often relies on leasing to specialized entities, usually being dependent on a limited number of offers available on the market. At the same time, leasing is correlated with the expansion of farm sizes, often through rental, and sometimes through sale [2].

Cooperativization of small farmers could represent a means of reviving national agricultural production by increasing productivity and economic efficiency. Through this form of association, farm infrastructure can be improved, including the construction and modernization of storage facilities. Primary processing units may be established, enabling the production of higher value-added finished products, the diversification of distribution channels, and better capitalization of available resources [12].

A focus on digitalization, increased economic efficiency, the adoption of circular economy systems, and the development of short supply chains are additional advantages linked to modernization (Florea et al., 2023) [5].

In this context, the paper analyzes the evolution of collectivization in Romanian agriculture based on the open-access literature and official data from the Ministry of Agriculture and Rural Development, regarding teh following aspects: geographic distribution, cooperative status, economic performance, and challenges faced by Romanian agricultural cooperatives

MATERIALS AND METHODS

Scientific data bases such as Clarivate, Research Gate, and Google Scholar were used to gather bibliographic references, primarily through open-access articles. These sources were complemented by reports from the European Commission and national agricultural statistics. The research relied on data provided by the Ministry of Agriculture and Rural Development (MADR) regarding agricultural cooperatives, supplemented within formation from Eurostat and the National Institute of Statistics (NIS). These data were statistically processed, graphically represented, and interpreted.

Artificial intelligence (AI) tools, including ChatGPT, were used to correct language and formatting errors and ensure the accuracy of terminology in English. AI-supported statistical tools were also employed for the processing of several data series. These tools enabled the generation of the heatmap (year–countymatrix), a biplot chart based on principal component analysis (PCA), as well as the volatility index analysis regarding the cooperative phenomenon across Romania's regions.

AI-assisted statistical processing facilitated more efficient identification of patterns and the extraction of territorial typologies from complex, multiannual data sets provided by MADR. The results obtained were compared with other scientific sources in the literature for validation purposes.

RESULTS AND DISCUSSIONS

The public data provided by theMinistry of Agriculture and Rural Development (MADR) regarding agricultural cooperatives in Romania includes functional data series for the 2018–2023 period. These data sets contain identification details, legal and operational status, and, in somecases, economic indicators, NACE codes, the number of cooperative members, submitted financial statements, and the current status of the cooperative (active or dissolved). The institution's website hosts 11,360 records [7].

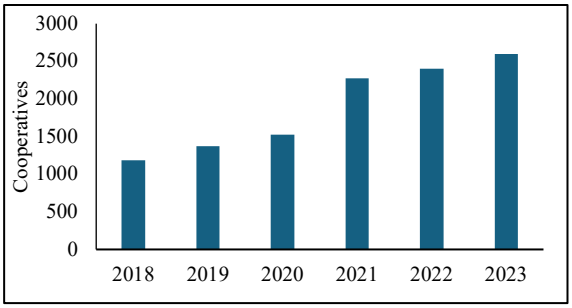


Fig. 1. Evolution of cooperatives in Romania
Source: Author's elaboration based on [7].

The evolution of the number of cooperatives duringthe 2018–2023 period is illustrated in Figure 1.

According to Figure 1, the period 2018–2023 saw a steady increase in the number of active agricultural cooperatives in Romania, rising from 1,186 units in 2018 to 2,600 units in 2023, with an average annual growth of approximately 235 units per year. This upward trend is likely associated with a growing interest among Romanian farmers in joining associative structures, driven by a better understanding of the cooperative model, the availability of European support measures, and the possible maturation of the cooperative sector in Romania. The county-level evolution of these associative forms is presented in Table 1.

Table 1. Agricultural cooperatives by county

County	2018	2019	2020	2021	2022	2023
Alba	31	38	42	61	64	72
Arad	29	35	39	64	70	82
Argeș	18	23	25	32	36	36
Bacău	14	22	33	33	34	38
Bihor	29	34	39	65	73	88
Bistrița Năsăud	41	49	51	73	77	83
Botoșani	125	127	129	137	138	143
Brașov	35	36	42	57	57	57
Brăila	12	13	13	31	37	38
București	11	12	12	15	16	17
Buzău	28	34	37	61	65	67
Caraș Severin	20	21	22	30	30	30
Cluj	44	46	67	83	95	108
Constanța	42	51	52	76	84	100
Covasna	16	18	18	56	63	62
Călărași	33	40	43	56	55	56
Dolj	64	76	82	136	143	152
Dâmbovița	31	38	41	59	63	68
Galați	16	18	20	38	44	46
Giurgiu	12	18	20	34	36	41
Gorj	11	20	21	23	26	27
Harghita	26	27	34	60	63	67
Hunedoara	7	9	16	31	35	39
Ialomița	22	28	29	52	57	61
Iași	29	31	33	56	54	57
Ilfov	14	12	12	13	16	17
Maramureș	24	36	40	61	63	66
Mehedinți	9	12	17	30	29	28
Mureș	13	16	17	53	58	66
Neamț	9	16	21	31	32	33
Olt	51	58	66	87	91	95
Prahova	14	15	17	19	24	27
Satu Mare	29	44	46	82	85	94
Sibiu	4	6	11	25	29	36
Suceava	43	48	56	67	65	65
Sălaj	24	28	33	42	42	48
Teleorman	82	82	83	107	106	108
Timiș	44	52	56	87	92	102
Tulcea	10	11	13	53	57	73
Vaslui	23	21	23	34	34	41
Vrancea	33	34	34	43	44	44
Vâlcea	14	18	19	21	21	22

Source: Author's elaboration based on [7].

The analysis of the data presented in Table 1 shows that the highest absolute growth rates were recorded in the counties of Dolj (+88), Cluj (+64), Bihor (+59), Satu Mare (+65), Timiș (+58), and Constanța (+58). These counties are characterized by a predominance of small and medium-sized farms, active agricultural activity, and a functional support infrastructure (including APIA centers, active LAGs, agricultural universities, etc.). While many counties in Transylvania recorded significant increases (Cluj, Timiș, Arad, Satu Mare), supported by a dynamic entrepreneurial environment, in the Moldavia region, only Botoșani and Suceava show visible progress.

At the regional level (Table 2), the evolution reflects a growing interest in associative structures in agriculture, likely driven by public policies, financing opportunities (including EU funds), and the farmers' need to access markets more efficiently. All development regions in Romania recorded positive trends, with the most visible momentum occurring in Transylvania. The North-West (+296) and Center (+235) regions had the highest absolute growth rates. The Western and Bucharest–Ilfov regions (with limited agricultural activity) had the lowest growth rates.

The accelerated development recorded in 2021 and continued thereafter is likely the result of new support mechanisms introduced at the European level, the expansion of agricultural advisory networks, and the promotion of good practice models.

Table 2. Agricultural cooperatives by region

Region	2018	2019	2020	2021	2022	2023
Bucuresti-Ilfov	25	24	24	28	32	34
Center	125	141	164	312	334	360
North-East	243	265	295	358	357	377
North-West	191	237	276	406	435	487
South-East	141	161	169	302	331	368
South-Muntenia	212	244	258	359	377	397
South-West Oltenia	149	184	205	297	310	324
West	100	117	133	212	227	253

Source: Author'selaborationbased on [7].

The evolution of the closure of agricultural production cooperatives in Romania during the analyzed period is presented in Figure 2.

The number of agricultural cooperatives that closed in Romania followed an upward trend, particularly after 2020, reaching a peak of 40 units in 2023. This development may be the result of structural challenges or management-

related issues, which can occur even though the national trend shows the continuous establishment of new cooperatives. The top five counties in terms of the number of cooperative closures are Dolj (23), Satu Mare (19), Vrancea (14), Constanța (12), and Mehedinți (12).

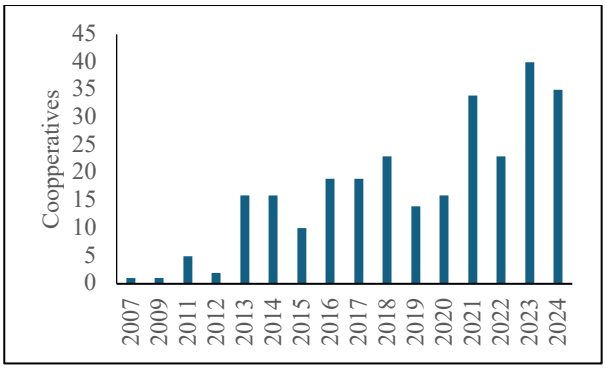


Fig. 2. Closed Agricultural Cooperatives
Source: Author's elaboration based on [7].

The evolution of the agricultural cooperative phenomenon in Romania can be further analyzed through principal component analysis (PCA), using AI tools [8]. PCA allows the identification of dominant axes of variation among Romanian counties, considering the annual evolution in the number of cooperatives (2018–2023), the frequency of closures, and optionally, their affiliation with development regions or NACE activity codes. The resulting biplot (Figure 3) provides a two-dimensional representation of both counties and variables, enabling the identification of natural groupings, correlations, and the direction of influence of the main factors.

For simplification, counties were labeled using the official Romanian administrative codes, according to legal regulations [10].

The PCA biplot in Figure 3 illustrates the existence of similarities between counties based on the evolution of the number of agricultural cooperatives during the analyzed period. Counties positioned on the right side of the graph (such as Olt, Dolj, and Teleorman) stand out due to a consistently high number of cooperatives through out all years. Counties located on the left side (e.g., Ilfov, Giurgiu, or Tulcea) exhibit a lower and more unstable level of cooperative activity. The redarrows indicate the influence of each year on the distribution, and their proximity (particularly in 2022 and 2023) suggests a shared recent growth trend. The graphical representation generated by PCA allows for the identification of distinct territorial patterns and counties with similar behavior in the development of agricultural cooperatives.

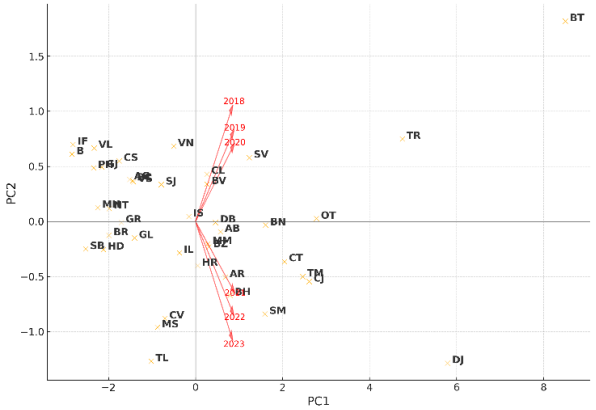


Fig. 3. PCA biplot – County-level typologies in cooperative development
Source: Author's elaboration based on [7] and [8].

The annual distribution of functional agricultural cooperatives in Romania, by county (2018–2023), represented using official county administrative codes, is shown in Figure 4.

The value of each cell corresponds to the number of cooperatives registered in the respective year.

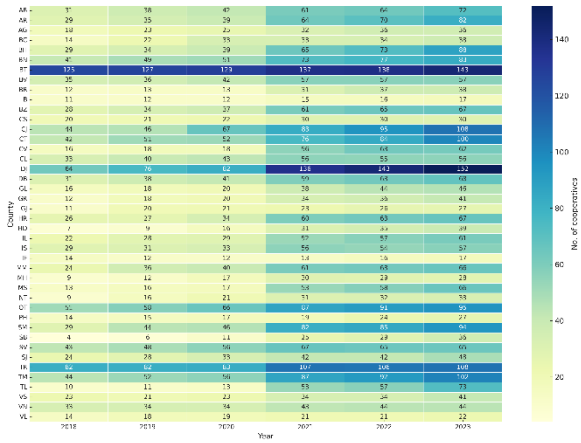


Fig. 4. Heat map of agri cooperatives, by county
Source: Author's elaboration based on [7] and [8].

The heatmap highlights the intensity of the cooperative phenomenon at the county level across Romania. Darker shades on the map indicate a higher number of cooperatives.

According to the graphical representation, counties such as Botoșani, Dolj, Olt, and Teleorman consistently record high values, indicating a mature and active cooperative environment. At the opposite end, counties like Ilfov, Tulcea, and Giurgiu exhibit persistently low levels of cooperative activity throughout the entire period, signaling slow or volatile development.

The increasing trend in the number of cooperatives is visible in most counties during the analyzed period, suggesting a national shift toward cooperative organization—likely influenced by EU agricultural policies and the availability of European funding instruments. The heat map provides a comparative visual perspective on the territorial dynamics of cooperatives, allowing the identification of highly dynamic areas and regions with weaker development.

To better assess the development of agricultural cooperatives in the 2018–2023 period from the perspective of stability, a volatility coefficient was calculated at the county level. This indicator is expressed as the ratio between the standard deviation and the average number of functional cooperatives. It is useful for identifying counties with unstable dynamics, characterized in the short term either by a rapid influx of newly created cooperatives or by numerous closures within a short period. The calculated data are presented in Table 3.

Counties with a high volatility coefficient (above 0.5)—such as Giurgiu, Ilfov, Tulcea, Caraș-Severin, and Gorj—are characterized by a low number of agricultural cooperatives and frequent fluctuations, or by a late and uneven development of the cooperative sector. In such cases, the volatility index may reflect a possible institutional fragility within the associative framework. To address this situation, public support should be targeted specifically toward the consolidation and stabilization of cooperatives in these counties.

Conversely, counties such as Dolj, Botoșani, Buzău, and Vaslui display low volatility, which indicates a predictable local environment with viable mechanisms for supporting cooperative development.

This complementary approach, based on volatility, allows for an analysis not only of the intensity of the cooperative phenomenon but also of its territorial resilience. From this perspective, volatility analysis serves as a useful diagnostic tool for the design of differentiated public policies tailored to the sensitivity of specific regions or counties.

Table 3. Average number of cooperatives by county, standard deviation and volatility coefficient

County	2018	2019	2020	2021	2022	2023	Aver.	Standard dev.	Volatility coeff.
Alba	31	38	42	61	64	72	51.33	15.05	0.29
Arad	29	35	39	64	70	82	53.17	19.78	0.37
Argeş	18	23	25	32	36	36	28.33	6.80	0.24
Bacău	14	22	33	33	34	38	29.00	8.29	0.29
Bihor	29	34	39	65	73	88	54.67	21.93	0.4
Bistriţa-Năsăud	41	49	51	73	77	83	62.33	15.90	0.26
Botoşani	125	127	129	137	138	143	133.17	6.54	0.05
Braşov	35	36	42	57	57	57	47.33	9.91	0.21
Brăila	12	13	13	31	37	38	24.00	11.55	0.48
Bucureşti	11	12	12	15	16	17	13.83	2.27	0.16
Buzău	28	34	37	61	65	67	48.67	15.99	0.33
Caraş-Severin	20	21	22	30	30	30	25.50	4.54	0.18
Cluj	44	46	67	83	95	108	73.83	23.84	0.32
Constanţa	42	51	52	76	84	100	67.50	20.67	0.31
Covasna	16	18	18	56	63	62	38.83	21.62	0.56
Călăraşi	33	40	43	56	55	56	47.17	9.01	0.19
Dolj	64	76	82	136	143	152	108.83	35.54	0.33
Dâmbov.	31	38	41	59	63	68	50.00	13.90	0.28
Galaţi	16	18	20	38	44	46	30.33	12.62	0.42
Giurgiu	12	18	20	34	36	41	26.83	10.65	0.4
Gorj	11	20	21	23	26	27	21.33	5.25	0.25
Harghita	26	27	34	60	63	67	46.17	17.47	0.38
Hunedoara	7	9	16	31	35	39	22.83	12.68	0.56
Ialomiţa	22	28	29	52	57	61	41.50	15.54	0.37
Iaşi	29	31	33	56	54	57	43.33	12.42	0.29
Ilfov	14	12	12	13	16	17	14.00	1.91	0.14
Maram.	24	36	40	61	63	66	48.33	15.82	0.33
Mehedinţi	9	12	17	30	29	28	20.83	8.51	0.41
Mureş	13	16	17	53	58	66	37.17	22.19	0.6
Neamţ	9	16	21	31	32	33	23.67	9.05	0.38
Olt	51	58	66	87	91	95	74.67	17.06	0.23
Prahova	14	15	17	19	24	27	19.33	4.71	0.24
Satu Mare	29	44	46	82	85	94	63.33	24.53	0.39
Sibiu	4	6	11	25	29	36	18.50	12.12	0.66
Suceava	43	48	56	67	65	65	57.33	9.18	0.16
Sălaj	24	28	33	42	42	48	36.17	8.49	0.23
Teleorman	82	82	83	107	106	108	94.67	12.35	0.13
Timiş	44	52	56	87	92	102	72.17	22.23	0.31
Tulcea	10	11	13	53	57	73	36.17	25.59	0.71
Vaslui	23	21	23	34	34	41	29.33	7.41	0.25
Vrancea	33	34	34	43	44	44	38.67	5.02	0.13
Vâlcea	14	18	19	21	21	22	19.17	2.67	0.14

Source: Author's elaboration based on [7] and [8].

CONCLUSIONS

The evolution of agriculturalcooperatives in Romania during the 2018–2023 period reveals a growing interest in associative structures, particularly in regions with active agricultural sectors and functional support infrastructure. The total number of functional cooperatives

has nearly tripled, with the most significant increases observed in counties such as Dolj, Cluj, and Bihor. This expansion reflects both the incentives provided by public policies and farmers' adaptation to market demands and resource constraints.

The territorial analysis revealed major disparities in the development of the cooperative sector. Counties such as Olt, Dolj, and Teleorman consistently recorded high cooperative density, while others, such as Ilfov and Tulcea, remained at low and unstable levels. The PCA biplot confirmed the existence of distinct county-level typologies, with a notable upward trend in 2022–2023. The heatmap clearly illustrated the intensification of the cooperative phenomenon, along with the widening of territorial disparities. The volatility coefficient analysis highlighted areas where cooperative development is unstable and vulnerable to failure.

Overall, the findings indicate that the development of agricultural cooperatives in Romania is not only expanding but also undergoing territorial divergence. This calls for differentiated support mechanisms, including fiscal stability, technical assistance, and structured access to European funding. AI-assisted statistical processing has significantly contributed to uncovering hidden patterns and extracting relevant territorial typologies, enhancing the analytical value of the study.

The results obtained can assist policy makers in designing tailored public policies aligned with the local cooperative profile, contributing to the strengthening of associative structures in agriculture and the reduction of territorial disparities.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ENHANCING THE COMPETITIVENESS OF AGRICULTURAL VALUE CHAINS IN MOLDOVA: NATIONAL STRATEGIC DIRECTIONS

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Abstract

Moldova's agricultural sector is a key economic pillar, yet its potential remains underutilized due to technological gaps, infrastructure deficits, market fragmentation, and financial constraints. This study examines strategies to enhance four key value chains—vegetable production, soft fruits, apiculture, and sheep/goat farming—through improved infrastructure, policy reforms, cooperative strengthening, and expanded financial access. The research integrates an extensive literature review, statistical analysis, and primary data from 100+ respondents via surveys, guided interviews, and participatory consultations. Sources include reports from the National Bureau of Statistics, FAO- Food and Agriculture Organization, GIZ- Deutsche Gesellschaft für Internationale Zusammenarbeit, IFAD- International Fund for Agricultural Development and others. Additionally, consultations with policymakers and industry leaders provided critical insights into investment needs and regulatory barriers. The study employs a mixed-methods approach, combining thematic qualitative analysis with quantitative statistical interpretation. By triangulating data from multiple sources, this research offers a comprehensive assessment of Moldova's value chains, delivering evidence-based recommendations for stakeholders, policymakers, and development partners to drive competitiveness, sustainability, and market expansion.

Key words: *value chains, cooperation, competitiveness, policy, Republic of Moldova*

INTRODUCTION

Agriculture holds a central position in Moldova's economy, contributing substantially to GDP and employment. Despite this, the sector faces persistent challenges that restrict its capacity for growth and market competitiveness. These include outdated agricultural practices, inadequate infrastructure, limited financial resources, and disjointed cooperative efforts among small and medium-sized farms. No less important, lack of trust and cooperation between smallholders and other categories of farmers hinders the development of the sector.

Studies highlight the importance of aligning national agricultural policies with global standards to ensure competitiveness in the face of crises and trade fluctuations [20]. To address these challenges, this study identifies critical agricultural value chains with high potential for the Republic of Moldova and highlights the macroeconomic interventions that would positively impact these value chains and the sector as a whole.

Research indicates that improving infrastructure, enhancing production quality, and establishing robust market linkages are key to achieving sustainability in agricultural value chains [15]. These elements align with the objectives of this study, which seeks to identify strategic measures to strengthen Moldova's agricultural sector through improved policies, financial support, and cooperative structures.

A fundamental aspect of enhancing agricultural value chains is the need for transformative interventions. Value chain transformation requires re-engineering traditional approaches and integrating innovative solutions to increase efficiency, inclusivity, and environmental sustainability [13]. Moldova's agricultural sector can benefit from adopting such an approach by investing in modern farming techniques and expanding access to markets.

In addition, the role of competitiveness and product quality in market expansion cannot be

overlooked. Research on agrifood products emphasizes that competitiveness is driven by both quality improvements and compliance with international standards, which enhances the success of export promotion initiatives [12]. Moldova's agricultural products must therefore meet stringent quality benchmarks to gain access to high-value markets and increase their share in global trade.

The potential of Moldova's agricultural products in international markets has been recognized, but harnessing this potential requires targeted interventions. Studies suggest that focusing on specific value chains and developing tailored strategies can significantly enhance agricultural exports and economic returns [2]. By prioritizing value chains with high growth potential, Moldova can strengthen its agricultural competitiveness and foster rural economic development.

The focus on vegetable production, soft fruits, apiculture, and sheep/goat farming stems from their economic promise, employment potential, and the current lack of comprehensive support. Enhancing these value chains can catalyze broader agricultural improvements, drive rural development, and foster sustainable practices that align with global environmental and social standards.

In this context, the purpose of the paper is to highlight the most important measures and regulatory directions that would ensure the development of the analyzed value chains and, at the same time, facilitate the replication of best practices to other sectors with growth potential.

MATERIALS AND METHODS

To set up this research work, there were used various information sources and secondary data which include reports from the National Bureau of Statistics [16], FAO [5, 6, 7], GIZ [8], USAID [21], IFAD [11], scientific articles and national policy documents.

The study employs a mixed-methods approach, combining qualitative and quantitative research techniques.

Also, primary data were gathered through structured questionnaires (100+ respondents), guided interviews, and two participatory consultation sessions with at least 20 participants representing the selected value chains.

Discussions covered sector challenges, policy tools, donor support mechanisms, integration into value chains, optimal business models, and the government's role.

The questionnaire disseminated to four value chain associations covered key topics, including production constraints, financial access, policy impact, export potential, market dynamics, and technological adoption. The specific questions have been:

(Q1)What are the key barriers to production growth in your value chain?

(Q2)How accessible are financial instruments for your business operations?

(Q3)What policy measures would best support sectoral development?

(Q4)What are the main obstacles to expanding exports and entering international markets?

(Q5)How does your business integrate into value chains, and what challenges do you face?

The guided interviews with decision-makers in the agri-food sector were focused on policy frameworks, regulatory challenges, and investment priorities. The key questions have been:

(Q1)What are the most pressing policy gaps in Moldova's agrifood sector?

(Q2)What government initiatives exist to support value chain integration?

(Q3)How can donor funding be more effectively allocated to strengthen the sector?

(Q4)What role do cooperatives and producer groups play in improving competitiveness?

The consultation sessions with stakeholders, including farmers, processors, traders, and exporters, explored practical challenges and opportunities. The discussions addressed:

(i)Key factors limiting sectoral growth and value chain integration

(ii)Policy interventions needed to enhance competitiveness

(iii)Potential donor-supported mechanisms to facilitate value chain development

(iv)The most effective business models for sector expansion

(v)The role of public-private partnerships in strengthening market access.

A sampling method ensured sectoral representation in the data collection. The respondents of the questionnaires and the participants to the consultation sessions have been selected using a stratified method. The respondents and participants are members of the 4 value chains and also are geographically representative, including women and youth participation. Statistical analysis included descriptive statistics to interpret the survey results. Qualitative data was processed through content analysis. Findings were validated through expert consultations, including academy and policy makers, ensuring relevance for policy framework.

RESULTS AND DISCUSSIONS

The study's results indicate that targeted investments in key agricultural value chains can significantly enhance Moldova's competitiveness.

The findings align with similar studies conducted in Central and Eastern Europe, where investments in infrastructure, technology adoption, and cooperative structures have led to increased efficiency and profitability [18], [4].

The study emphasized the selection of four key agricultural value chains that show significant potential for enhancing Moldova's competitiveness. These are:

-Vegetable Production (in open fields and protected environments).

-Soft Fruits (including strawberries, raspberries, and currants).

-Apiculture.

-Sheep and Goat Farming.

These chains were chosen based on their economic feasibility, market potential, and the active participation of small and medium-sized farms as mentioned by [22], [17]. The selection was made after a thorough pre-selection process involving 18 potential sectors, from which these four were highlighted as most promising for sustainable development. Table 1 presents a comparative analysis of the four selected agricultural value chains, highlighting key indicators such as productivity, profitability, and market potential.

Table 1. Key Performance Indicators of selected value chains

Value Chain	Productivity (tons/ha)	Profitability (%)	Market Potential
Vegetables	25	35	High
Soft Fruits	15	45	High
Apiculture	N/A	50	Medium
Sheep/Goat Farming	N/A	40	Medium

Source: Own calculation.

The results show that soft fruits and apiculture have the highest profitability, while vegetable production demonstrates significant market potential.

Survey and Interview Responses

To gain deeper insights, structured questionnaires and interviews were conducted with key stakeholders, including farmers, agribusiness representatives, and policymakers. The findings from these methods are summarized in Table 2.

Table 2. Summary responses from surveys and interviews

Question	Stakeholder Responses	% of Respondents
What are the main challenges faced in the selected value chains that you operate?	Limited technology adoption, lack of modern storage facilities, financial constraints, and poor cooperative structures.	82%
What are the key factors driving profitability?	Access to markets, investment in modern farming techniques, cooperation and partnership among farmers and government support.	95%
What are the best model that would help the small scale farmers integrate into a value chain?	Integration through regional clusters and hubs; integration with the support of driving verticals of the sector	75%
What policies would improve your sector's competitiveness?	Incentives for sustainable practices, streamlined regulations, financial incentives like VAT and taxes revision, and enhanced financial support programs.	100%

Source: Own results.

Challenges Identified during the surveys and interviews

-***Technological Barriers*:** Limited adoption of modern farming practices and insufficient access to advanced agricultural tools.

-***Infrastructure Deficits:*** Lack of facilities such as cold storage, sorting centers, and pre-cooling tunnels.

-***Financial Access Issues*:** Significant hurdles in securing affordable funding for necessary investments.

-***Cooperative Weaknesses*:** Poor organization among farmers reduces their market power and efficiency.

-***Market and Quality Constraints*:** Issues related to product quality and outdated varieties affect market access.

Opportunities Identified:

-Increasing competitiveness through targeted investments in infrastructure and technology.

-Strengthening cooperative and partnership models.

-Leveraging Moldova's natural resources to develop value-added agricultural products.

Innovation

The article proposes innovative solutions for transforming Moldova's agricultural sector into a more competitive, sustainable, and profitable industry.

The innovation lies in the integrated approach that combines modern technology, cooperative models, policy advocacy, and sustainable practices, tailored to the specific needs of priority value chains such as vegetables, soft fruits, apiculture, and sheep/goat farming [5], [19], [1].

The key answers and conclusions have been selected during the 2 consultation sessions organized with the representatives of the selected value chains. The opened discussions allowed to identify key drivers that would improve sectoral competitiveness and value chains development. Here are key aspects of innovation:

(a)Technological Advancement in Farming:

Precision Agriculture: Introduction of GPS-guided equipment, automated irrigation systems, and advanced crop monitoring sensors represents a leap forward for Moldovan farmers. These tools optimize the use of inputs, reduce labor costs, and improve overall productivity.

Digital Platforms for Market Access: Utilizing e-commerce and digital marketing platforms to bridge the gap between farmers and consumers. This digital shift allows farmers to sell products directly, enhancing profit margins by minimizing intermediaries.

(b)Sustainable Agricultural Practices:

Integrated Farming Models: The article recommends blending traditional farming with new practices such as intercropping with medicinal plants that support biodiversity and soil health.

Renewable Energy Initiatives: Encouragement of solar-powered irrigation systems and energy-efficient cold storage facilities contributes to the sustainability of these innovations.

(c)Enhanced Cooperative Frameworks:

Cluster Development: Creating agricultural clusters connects farmers, processors, and logistics providers, fostering innovation and ensuring efficient product movement. This integrated approach reduces individual farmer risk and promotes shared investment in technology and infrastructure [14].

(d)Training and Knowledge Transfer: Establishing partnerships with universities and research institutions supports continuous education and exposure to international best practices [10].

(e)Policy and Legislative Support:

Eco-Friendly Policy Incentives: The adoption of laws that provide tax breaks or subsidies for farmers implementing sustainable methods can accelerate the shift toward eco-friendly farming practices.

Simplified Regulatory Processes: By streamlining bureaucracy, farmers can adopt modern practices and access necessary certifications more swiftly.

Key recommendations

(i)Investing in Infrastructure and Technology

Expanding Cold Storage and Post-Harvest Facilities*:* One of the most immediate needs is the development of regional cold storage facilities and packaging centers. Shared-use facilities can lower individual costs for farmers and ensure that products maintain quality and freshness longer, opening doors to higher-value markets.

Upgrading Irrigation Systems*:* Only a small portion of Moldova's farmers currently benefit from efficient irrigation. Investments in modern, climate-resilient irrigation systems will help stabilize yields, especially under conditions of climate variability. Simplified processes for obtaining irrigation permits and

incentives for water-efficient technologies are essential [3].

***Promoting Advanced Farming Tools**:* The adoption of precision agriculture technologies, such as automated irrigation, crop sensors, and GPS-guided machinery, can optimize input use, boost yields, and reduce labor costs. The government should pilot these technologies through subsidies and partnerships with private tech companies to demonstrate their benefits.

(ii)Enhancing Human Capital

Developing Comprehensive Training Programs: Nationwide training programs are needed to improve farmers' technical and managerial skills. Workshops on sustainable farming practices, integrated pest management, crop rotation, and organic methods should be core components. This training can help farmers enhance productivity while reducing environmental impact.

***Knowledge Transfer through Partnerships**:* Partnerships with agricultural universities and international research institutions can facilitate knowledge exchange, bringing global best practices to Moldovan farms. This collaborative approach ensures that farmers can learn the latest techniques and apply them effectively.

(iii)Strengthening Cooperative Structures

Encouraging Cooperative Formation: Supporting the establishment and operation of cooperatives will empower farmers to pool resources, share knowledge, and collectively market their products. Initial financial support for the first few years of cooperative formation is essential to build momentum and achieve sustainable operations.

***Developing Integrated Agricultural Clusters**:* Creating agricultural clusters that connect farmers, processors, and logistics providers fosters a more cohesive supply chain. Clusters can drive innovation and facilitate the movement of products from farms to markets more efficiently.

(iv)Policy and Legislative Reforms

***Streamlining Regulations**:* Reducing bureaucratic hurdles related to permits and certifications will enable farmers to adopt modern practices faster and more efficiently. Streamlined processes for securing water rights and agricultural permits will also support more widespread use of intensive and innovative farming practices [9].

***Promoting Eco-Friendly Practices through Legislation**:* Incorporating incentives such as tax breaks and subsidies for adopting sustainable farming methods (e.g., renewable energy, organic fertilizers) will encourage farmers to implement environmentally friendly practices that preserve soil health and biodiversity.

(v)Expanding Access to Finance

Creating Tailored Financial Solutions: Developing financial instruments tailored to the specific needs of small and medium-sized farms is crucial. These could include government-backed loans at lower interest rates and flexible repayment options. Expanding microfinance initiatives with reduced collateral requirements can also address the needs of smaller farms that lack conventional assets.

***Strengthening Guarantee Funds**:* Expanding existing guarantee funds to support a broader range of financial institutions can make credit more accessible to farmers. This approach reduces the perceived risk for lenders, encouraging them to offer loans for equipment and infrastructure upgrades.

(vi) Marketing and Value Addition

***-Developing a National Agricultural Brand**:* Moldova should create a cohesive branding strategy, such as "Authentic Moldova," to market high-quality products like medicinal honey and soft fruits. This will enhance the visibility of Moldovan goods in international markets, building consumer recognition and trust.

-Diversifying Product Offerings: Encouraging farmers to engage in value-added production, such as making preserves, essential oils, and herbal products, can diversify income sources and increase profitability. Training on processing techniques and providing access to processing equipment can support these efforts.

-Utilizing Digital Market Platforms: Digitalization offers opportunities to expand market access. The development of e-commerce platforms for direct sales to consumers and wholesalers can increase profit margins by cutting out intermediaries. Training

farmers on digital marketing and the use of such platforms can maximize their impact.

CONCLUSIONS

The research reveals that Moldova's agricultural sector possesses untapped potential that, with strategic intervention, can be realized.

Strengthening value chains through targeted investments, cooperative development, policy support, and training will enable Moldova to boost competitiveness, ensure sustainability, and increase profitability across priority agricultural sectors. These findings are in accordance with [6], [7].

Strategic Insights:

-Prioritizing infrastructure investments, such as cold storage and advanced irrigation, is crucial for enhancing product quality and market access.

-Cooperatives and clusters should be supported to enable collective action and shared resource use, improving farmers' market power and access to economies of scale.

-Expanding tailored financial solutions, including microfinance and government-backed loans, will help farmers invest in modernization and innovation.

Training and educational programs, alongside partnerships with research institutions, will empower farmers with the knowledge to adopt sustainable and efficient farming practices

AKNOWLEDGEMENTS

This article is realized as a result of a 5 months project since 2024, entitled *Pre-selection and analysis of 4 value chains for Republic of Moldova*, supported by UCIP IFAD Moldova.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DIAGNOSIS OF OPERATIONAL RISK IN RELATION TO BREAK-EVEN POINT AND FINANCIAL STRUCTURE OF THE ENTITY OF TWO AGRICULTURAL COMPANIES IN THE REPUBLIC OF MOLDOVA

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Abstract

The purpose of this research is to comparatively analyze the results of diagnosing the operational risk using the break-even method for agricultural enterprises in the Republic of Moldova. Our investigations have shown that the increased share of constant costs and expenses did not generate a high operational risk, given the fact that in the vicinity of the break-even point the elasticity of the operating result is low. The comparisons of the dynamics of rates of return and leverage showed the following: - the decrease of debt degree caused the attenuation of the downward trends of return on assets and return on equity, which indicates the reducing of capital capacity to generate profit; - the growth of debt degree within reasonable limits conditioned the positive difference between return on assets and interest rate, showing a major trend of increasing financial performance.

Key words**:** *operational risk, break-even, financial structure, diagnostics, performance.*

INTRODUCTION

The specialized literature discusses the idea that the financial equilibrium of the entity is respected if the profitability compensates the assumed risk, a risk that depends on the economic factors and the financial policy of the enterprise [1; 3; 8; 10; 14].
The diagnostic approach envisages the following forms of operational (or economic) risk, financial risk, and bankruptcy (or insolvency) risk.
Operational risk is the inability of the enterprise to adapt to environmental changes in time and at the lowest possible cost [3]. The results of the enterprise are influenced by several factors, such as: price increases in energy, fuel, natural gas, technical equipment, and technical equipment, increases in wages, which consequently determine the structure of costs and their behaviour in relation to sales volume.
According to [11; 12; 15], the most appropriate method of assessing the economic and financial risk is the break-even method.
The literature reflects important studies on break-even point [5] and its use for establishing the value of a firm [7], for assessing the leverage effect [4], its role in the firm management [6], its role in investing [13], and its level in the small sized-farms dealing with organic farming [2].
In this context, this research aimed to make a comparison analysis concerning the financial structure and stability of two agricultural companies.

MATERIALS AND METHODS

The research was focused basing on the data of agricultural enterprises from the Northern region of the Republic of Moldova. The information sources were Annual financial statements and The cost register.
The distribution of the total amount of constant costs and expenses was carried out on the basis of the volume of sales, using for this purpose the annual statistical survey 21-Sales "Sales of agricultural production".
In the research frame were utilized: break-even method, some traditional methods of economic analysis, such as: comparison, dividening and disintegration, the method of chain substitutions.
In this case was calculated the break-even point and debt degree for two agricultural enterprises

from the northern region: ACP „Taduran Agro" and LLC „Şipca - Spicuşor" in the years 2022-2023.

RESULTS AND DISCUSSIONS

This method is applied both at the product level (in physical units) and at the enterprise level (in value units). In our opinion, the indicators that estimate the break-even point at the enterprise level are: contribution margin, contribution margin rate, revenue from critical sales, safety margin, efficiency gain, result (profit, loss) from operating activity.

The economic content and calculation formulas of these indicators are presented below [17]:

1)*The total contribution margin* (MCt) expresses the excess of sales revenue (VV) over variable costs and expenses (CCV):

$$\mathbf{MC_t = VV - CCV} \quad (1)$$

2)*The contribution margin rate* (R_{MC}) characterizes the share of the total contribution margin in the sales revenue component according to the formula:

$$\boldsymbol{R_{MC} = \frac{MC_t}{VV} \times 100\%} \quad (2)$$

3)*The break-even in value units* reflects the critical size of sales revenue (VVcr) that exactly covers all costs and expenses, with zero profit:

$$\boldsymbol{VV_{cr} = \frac{CCC}{R_{mc} \div 100}} \quad (3)$$

where: CCC – total constant costs and expenditure.

4) *Safety Margin*, also called security index (M_S), reflects the position of sales revenue in relation to break-even and shows by how many value units sales revenue can be reduced without the risk of incurring losses:

$$\mathbf{M_S = VV - VV_{cr}} \quad (4)$$

5) *The efficiency gain* (Se), also referred to as the position (flexibility) indicator, expresses the percentage by which the enterprise can reduce its sales revenue in order to avoid losses and adapt to market requirements. It is calculated according to the formula:

$$\boldsymbol{S_e = \frac{M_s}{VV} \times 100} \quad (5)$$

The following safety indicator ratings are recommended in the literature [1; 8; 11]:

- if Se<10%, the situation of the enterprise is unstable;
- if Se<20%, the enterprise is relatively stable;
- if Se>20%, the breakeven situation of the enterprise is comfortable.

6)The result (profit, loss) from operating activities (Rop) is the difference between the total contribution margin and total constant costs and expenses:

$$\mathbf{Rop = MC_t - CCC} \quad (6)$$

In the table 1 were calculated these indicators in the dynamics for two agricultural enterprises that differ in their level of economy but also in the structure of costs and expenditures.

The results obtained which are presented in Table 1 show that the sales revenues of the agricultural production cooperative (ACP) "Taduran Agro" exceed those of the LLC "Sipca - Spicușor" 7.4 times in the reporting year, not taking into account the fact that both entities are producers of cereals and oilseeds, but they have different production capacities. For example, ACP "Taduran Agro" is equipped with state-of-the-art agricultural machinery, while LLC "Șipca-Spicușor" has outdated and morally obsolete equipment. This factor within the low capacity to pay the bills of LLC 'Șipca-Spicușor' has made impossible the implementation of innovative cultivation technologies and to obtain higher income.

Also the ratio between variable and constant costs is different. At ACP "Taduran Agro" the share of constant costs and expenses is 76.8%, while at LLC "Șipca-Spicușor" - 45.4%.

The increased share of constant costs and expenses did not generate a high operational risk, given the fact that in the vicinity of the break-even point the elasticity of the operating result at ACP "Taduran Agro" is low. As a result, sales income outruns the break-even

point in the current year by 32.06%, which means that the enterprise can reduce sales income by 32.06% without the risk to support the losses. At the same time, it is necessary to add the fact that the ACP "Taduran Agro" shows a dynamic increase in the break-even point by MDL 12.9 million or 14.1%. This situation resulted in a negative elasticity coefficient (-0.857), reduction of all profit indicators and profitability ratios, as well as a decrease in the safety margin by 4.12 percentage points.

Table 1. Comparative situation of the two entities performance in relation to break-even point and financial structure

Indicators	ACP „Taduran Agro”		LLC „Șipca - Spicușor”	
	2022	2023	2022	2023
1. Sales revenues, thousand lei	143,471.6	153,763.6	11,326.2	18,318.4
2. Variable costs and expenses, thousand lei	23,188.4	26,185.4	6,090.1	9,067.3
3. Constant costs and expenditure, thousand lei	76,771.4	86,682.9	4,991.4	7,539.4
4. Contribution margin, thousand lei	120,283.2	127,578.2	5,236.1	9,251.1
5. Break-even, thousand lei	91,559.6	104,474.5	10,796.9	14,929.0
6. Result of operational activity, thousand lei	43,521.8	40,895.3	244.7	1,711.7
7. Safety margin:				
- in absolute values, thousand lei	+51,912	+49,289.1	+529.3	+3,389.4
- in relative values, %	+36.18	+32.06	+4.67	+18.5
8. Interest-bearing debts, thousand lei	110,637.0	119,406.5	4,815.0	5,850.5
9. Interest paid, thousand lei	4,571.3	6,287.5	129.6	355.9
10. Average interest rate, %	4.13	5.27	2.69	6.08
11. Profit before tax, thousand lei	42,103.2	38,695.9	2,127.6	3,204.7
12. Net profit for the reporting period, thousand lei	34,819.2	30,921.7	2,088.9	3,000.3
13. Financial leverage ratio, coefficient	1.5161	1.4108	1.8723	2.00
14. Total assets turnover rate, coefficient	0.3375	0.3675	1.031	1.193
15. Return on sales revenue, %	29.35	25.17	18.78	17.49
16. Return on assets, %	9.9	9.25	19.37	20.87
17. Return on equity, %	15.02	13.05	36.27	41.74

Source: Author's calculations based on Annual financial statements, cost registers and annual statistical surveys 21-Sales "Sales of agricultural production" of ACP “Taduran Agro” and LLC “Sipca-Spicușor”

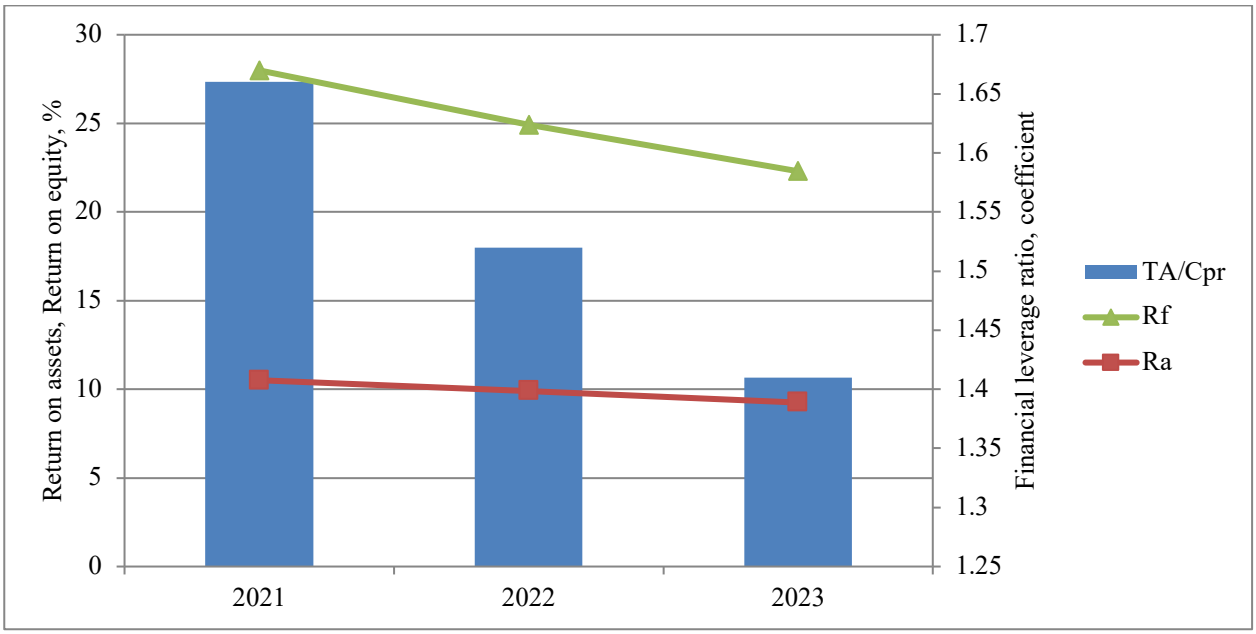
At ACP "Taduran Agro", interest-bearing debts increased by 8.8 million lei or 7.93%. The data presented in Table 1 allow us to note a reduced operational flexibility at LLC "Șipca-Spicușor". This entity is in a much more comfortable situation than PCA "Taduran Agro" in terms of operational risk. Having a lower level of activity with a share of constant costs and expenses of 45.4% LLC "Șipca-Spicușor" has recorded an increase in performance indicators. Thus, the operating profit and net profit increased by 6.0 times and 43.63% respectively. There is also an increase in the safety margin from 4.67% to 18.5%.

The data in Table 1 shows that the increase of the leverage ratio (financial leverage ratio) of LLC "Șipca-Spicușor" by 12.71 percentage points had a positive impact on the increase of the efficiency of the utilization of assets and equity. Thus, the financial profitability increased from 36.27% to 41.74% or by 5.47 percentage points.

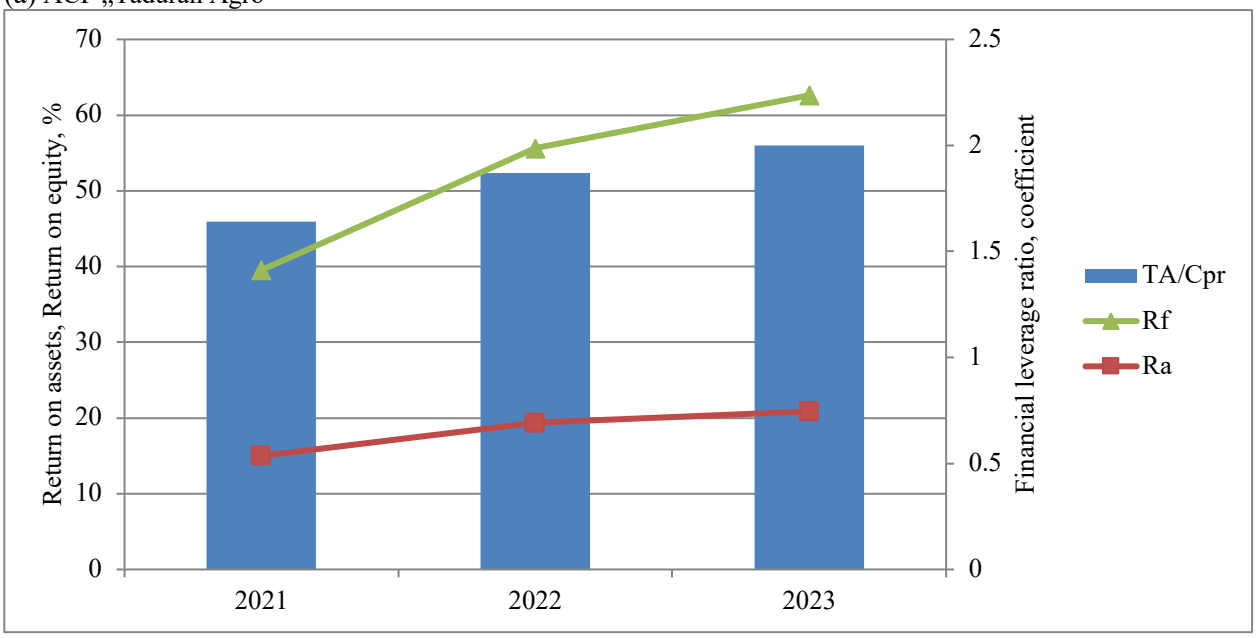
Comparing the evolutionary nature of the rates of return and leverage (financial leverage) of the analyzed entities (Fig. 1), we found contradictory situations. The reduction of the debt ratio in the dynamics of PCA "Taduran Agro" had negative effects that led to the attenuation of the trends of continuous decrease in the rates of return (Fig.1). Thus, in the last year of the analyzed period, the financial leverage decreased by 15.06%, respectively, it is also noted the decrease of return on assets by 1.26 percentage points and financial return by 4.43 percentage points. This situation characterizes the decrease in the capacity of the entity's capital to generate profit. At the same time, at LLC "Șipca-Spicușor", the dynamic increase in the degree of indebtedness had positive effects, showing a trend of a major increase in both the return on assets and the financial return (Fig.1).

This trend is due to the increase in the turnover rate of total assets and equity. At the same time,

the positive effect of leverage occurred against the background of the excess of return on assets over interest rate (Table 1). This means that the increase of indebtedness by 36% in the last year at LLC "Șipca-Spicușor" has created premises for the increase of return on assets and return on equity by 5.87 and 17.21 percentage points respectively, which indicates to the efficient use of the enterprise's patrimony.



(a) ACP „Taduran Agro"



b) LLC „Șipca-Spicușor"

Fig. 1. The correlations between return on equity, return on assets and leverage (financial leverage ratio) in grain and oilseed producing entities

Source: Author's calculations based on Annual financial statements, cost registers and annual statistical surveys 21-Sales "Sales of agricultural production" of ACP "Taduran Agro" and LLC "Sipca-Spicușor"

In this context, it is necessary to quantify the factors and their quantitative influence on the change in financial profitability. It is well known that financial profitability expresses the ratio between net profit or profit before tax and the average value of equity, according to the formula:

$$R_{cpr} = \frac{Pn\ sau\ Pimp}{\overline{Cpr}} \times 100\% \quad (7)$$

To decompose the factor model, first of all we multiply the numerator and denominator of formula 7 by the average value of assets:

$$R_{Cpr} = \frac{Pimp}{\overline{Cpr}} \times \frac{\overline{A}}{\overline{A}} = \frac{Pimp}{\overline{A}} \times \frac{\overline{A}}{\overline{Cpr}} \quad (8)$$

According to this factor model, return on equity changes under the influence of the following factors:

-economic profitability ($\frac{Pimp}{\overline{A}}$);

-the debt degree or leverage ($\frac{\overline{A}}{\overline{Cpr}}$).

In the theoretical mode, the influence of these factors is calculated:

8.1. $\Delta R_{Cpr}^{\frac{Pimp}{\overline{A}}} = \Delta \frac{Pimp}{\overline{A}} \times \frac{\overline{A}}{\overline{Cpr}}(0)$.....(9)

8.2. $\Delta R_{Cpr}^{\frac{\overline{A}}{\overline{Cpr}}} = \frac{Pimp}{\overline{A}}(1) \times \Delta \frac{\overline{A}}{\overline{Cpr}}$ .....(10)

The second stage of the diagnosis breaks down the return on assets by influencing factors which can be seen in the Figure 2.

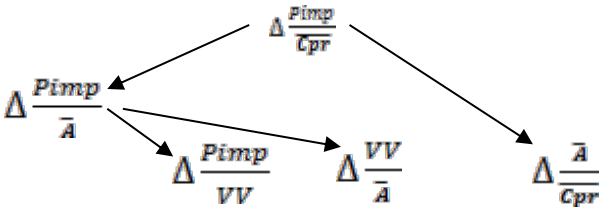


Fig. 2. Return on equity decomposition scheme
Source: Elaborated by the author.

Figure 2 shows the factorial model of the financial rate of return.

$R_{Cpr} = \frac{Pimp}{VV} \times \frac{VV}{\overline{A}} \times \frac{\overline{A}}{\overline{Cpr}}$ factorial model II .....(11)

According to factor model II, the factors influencing the change in financial profitability are:

- return on sales (Pimp/VV);
- asset turnover rate (VV/A);
- leverage (A/Cpr).

Thus, factor model II expresses the dependence of financial profitability on business efficiency, asset utilization and financial structure of the entity.

Table 2 presents the calculation of the influence of factors according to factor model II, applying the chain substitution method.

From the calculations in Table 2 we deduce the following:

1) the increase in financial profitability at LLC "Șipca-Spicușor" is due to the positive influence of the following factors:

- the increment of the asset rotations number from 1.031 to 1.193 points led to the growth of financial rate by 5.31 percentage points, this being the decisive factor;
- the increase in the entity's leverage ratio from 187.23% to 200% conditioned the increase in financial profitability by 2.67 percentage points.

2) A negative influence was exerted by the decrease in the return on sales from 18.78% to 17.49%, which caused a decrement in the financial profitability by 2.51 p.p. This value is considered as own reserve for the enterprise.

Concerning to the factor A/Cpr, it deserves to mention that the growth in the financial structure does not always lead to an increase in return on equity. In economic practice, there is a maximum limit for leverage. The ratio of total debt to total sources must not exceed 70%. Exceeding this limit entails higher interest rates for the entity and additional guarantees required by the banks, because the financial risk is higher (in such a situation the multiplication factor (A/Cpr) cannot exceed 1+70/30=3.33 units). This means that debt-raising must be done with caution, as the return on assets must exceed the interest rate.

At LLC "Șipca-Spicușor" according to the data in Table 1 the return on assets exceeds the interest rate in both periods.

Thus, in the year of management, this excess is 14.79 p.p., a situation that favoured the excess of the financial return over the economic return (Rf>Ra) by 2 times.

In this context, the fundamental issue addressed by the authors [9; 10; 14, 16] is to determine whether unfavourable economic conditions can influence the decrease in economic profitability and financial profitability, so as to cause the correlation (Rf<Ra) based on the following clarifications:

- in the case of stable or growing economic conditions, leverage is less dangerous and can be utilized at high levels if the difference between economic return and interest rate is stimulating such that Rf is higher than Ra;

- if there is economic instability, there is a high risk that business activity will decline, leading to a situation where leverage becomes dangerous, causing the correlation to exist Rf < Ra.

Table 2. Calculation of the influence of factors on changes in financial profitability in LLC "Șipca-Spicușor"

No.	No.	Correlated factors			$R_f = \frac{Pimp}{Cpr} \times 100$	Calculation of the influence of factors	The results	Causes of deviation
		Pimp/VV	VV/A	A/Cpr				
1	0	18.78	1.031	1.8723	36.27	-	-	-
2	1	**17.49**	1.031	1.8723	33.76	33.76 – 36.27	-2.51	↓ Pimp/VV
3	2	17.49	**1.193**	1.8723	39.07	39.07 – 33.76	+5.31	↑ VV/A
4	3	17.49	1.193	**2.00**	41.74	41.74 – 39.07	+2.67	↑ A/Cpr
Total		X	X	**X**	X	X	+5.47	X

Source: Author's calculations based on the data from Table 1.
Verification: 41.74 – 36.27 = 5.47 p.p.

CONCLUSIONS

The results of our investigations show that the relatively large share of constant costs and expenses (76.8%) did not generate a high operational risk in the ACP enterprise "Taduran Agro", given the fact that in the vicinity of the break-even point the elasticity of the operating result is low. The negative value of the elasticity coefficient (-0.857) shows that the operating result of this entity is very sensitive to the change in sales revenues, registering a decrease of 2.6 million lei. At the same time, LLC "Șipca-Spicușor" has a lower operational risk, which is confirmed by the positive elasticity coefficient (9.716), the relatively low share of constant costs and expenses (45.4%), which consequently registers an increase in all performance indicators.

The factorial diagnosis revealed that the factors influencing the increase in financial profitability are:

-Increasing asset turnover by 15.7%;

-Increase in the entity's leverage ratio by 6.82%.

The positive influence of the indebtedness ratio was manifested against the background of exceeding the return on assets compared to the average interest rate by 14.79 percentage points, also confirming the existence of correlation Rf>Ra.

3. Improving financial performance and reducing operational risk require an increase in return on sales, which can contribute to an increase in return on assets by 1.33 percentage points and financial return by 2.51 percentage points based on the improvement of the assortment structure to meet consumer requirements and the penetration of the entity's products on new markets.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STUDY ON THE TRADE PERFORMANCE OF THE EUROPEAN UNION ON THE INTERNATIONAL PLUM MARKET

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Abstract

This research aims to analyze the trade performance of the European Union in fresh plum trade, through an integrated approach that combines evolutionary, structural and quantitative analysis of official statistical data. The main objective is to assess the trade position of EU Member States on the international plum market, in terms of trade volume, dependence on trading partners, sensitivity to price variations and strategic export orientation. The methodology applied involved the analysis of the dynamics of plum trade in the period 2014–2024, differentiated by intra- and extra-community flows, both for imports and exports, using quantitative and value indicators, as well as synthetic variation indices, such as the Herfindahl–Hirschman index for trade concentration or the coefficient of variation for price volatility. The analysis started from the premise that plums represent an important category of fruit in the agricultural economy of several European countries, and the trade behavior of the European Union reflects not only its positioning in relation to other global actors, but also its vulnerabilities or competitive advantages within the international flows of fresh fruit. The results obtained highlight that exports of fresh plums from the EU have registered significant increases in some Member States such as Spain, Italy and Romania, while others have shown high volatility and lower contributions to the Union's trade performance. The evolution of selling prices has been marked by significant fluctuations, and the application of the Herfindahl–Hirschman index has confirmed a trend of increasing import concentration, indicating dependence on a small number of trading partners. The conclusions drawn indicate that, despite the progress made, the EU plum market remains exposed to trade imbalances and requires sustained policies to stabilise and consolidate competitive advantages.

Key words: *performance, plums, import, export, trade flows, competitiveness*

INTRODUCTION

Fresh fruit trade is a strategic segment of global agriculture, at the intersection of food security, international trade and rural development. Among the fruit species that are increasingly attracting research and trade policy attention is the plum (Prunus domestica), a species that plays a major role not only in terms of agronomics but also in terms of commercial value and position in the fruit market [2, 5, 7]. Plums are widely cultivated in many regions of the world, especially in temperate zones, and international trade in plums reflects the general trends of globalization of fresh fruit production and consumption [4, 12].

Worldwide, the plum occupies one of the first positions in the ranking of fruit species according to the cultivated area, being present in over 70 countries. According to FAOSTAT data, global plum production has exceeded 12 million tons annually in the last decade, with China, Serbia, India, Iran and the European Union being among the main producers [3]. The European Union plays an essential role in world production, not only through the quantities obtained, but also through the quality of the cultivated varieties, adapted both to fresh consumption and industrial processing [1, 11].

On the fruit market, plums occupy an important niche, with significant seasonal consumption, but also being used in multiple forms of processing: juices, jams, prunes or the entire agri-food chain. For this reason, the commercial performance of this crop has broad implications, influencing the trade balances of producing and consuming countries, farmers' incomes, the structure of supply chains and,

last but not least, the Common Agricultural Policy [6].

The European Union, through its Member States, is a major player in both the export and import of plums. Due to the seasonal nature of production and the continuous demand from consumers, many European countries import plums outside their own production season, thus contributing to a volatile but dynamic commercial market. At the same time, countries with surplus production, such as France, Spain or Bulgaria, direct significant volumes towards exports, strengthening trade relations with external markets, especially outside the Community area.

The commercial performance of a region or a country cannot be assessed solely in terms of exported or imported volumes but must be analysed in the context of the structure of trade, trading partners, prices and, above all, the added value obtained. Trade in fresh plums is therefore a relevant indicator for assessing the competitiveness of a horticultural sector, the efficiency of trade chains and the geographical position in international flows [8].

Determining trade performance thus becomes essential, as it allows the identification of strengths and vulnerabilities of plum trade, including the risks associated with excessive dependence on certain markets or a structural imbalance between exports and imports. The analysis of the trade balance, expressed in value and quantitative terms, represents only the first stage, being complemented by trade orientation indicators, such as the export-import ratio, concentration indicators, but also by correlations between prices and trade flows. More and more scientific research and statistical approaches have been applied to evaluate the trade performance of agri-food products, including fruits. For example, studies conducted by [10, 13] have highlighted the fact that the dynamics of fruit exports are closely correlated with innovation in the logistics chain, product quality and the ability to access high-value-added markets. Regarding marketing, the specialized literature emphasizes the seasonal and volatile nature of the market, as well as the increasing influence of phytosanitary standards from the production phase onwards [9].

At European level, analyzing trade performance is important as the CAP promotes external competitiveness, sustainability and adaptability of agricultural markets. The fruit sector is supported by dedicated schemes, and fruits such as plums benefit from financial support and promotion policies on third markets. However, faced with increasing competition from third countries, such as Turkey, Chile or South Africa, the European Union needs to better understand its own trade flows to adapt trade policies adapted to global realities.

Trade performance is therefore an essential component of diagnosing horticultural potential, but also a strategic decision-making tool in defining the development directions of the plum sector. This involves not only measuring trade flows, but also an integrated analysis of the structure of partners, price sensitivity, import dependencies or the capacity to capitalize on external trade opportunities. In this context, this research attempts to contribute to understanding the place occupied by the E.U. in the international trade in fresh plums, by analyzing a series of official statistical data, corroborated with commercial performance indicators.

MATERIALS AND METHODS

This analysis is based on a complex set of statistical data on trade in fresh plums in the European Union, collected from the official Eurostat database. The data were downloaded in July 2025, covering the period 2014–2024.

The methodological approach followed a multi-level approach, focused both on the analysis of evolution over time and on the structure, namely dependence, orientation, concentration of partners, in order to evaluate the trade behavior of the EU with regard to fresh plums, through the prism of quantitative, value and structural dimensions. For this, the analysis followed: the annual dynamics of the volume of imports, with extra-EU and intra-EU imports being analyzed separately, and subsequently aggregated to provide a complete view of the evolution of the total volumes of plums imported by the European Union; the evolution of exports, which were also divided

into extra-EU and intra-EU flows; the evolution of sales prices, using the average annual sales prices expressed in euros/100 kg, which allowed the calculation of variation indices and the calculation of the coefficient of variation for estimating price volatility at community level; the analysis of trade orientation which was carried out starting from the ratio between exported and imported volumes, calculating trade orientation indicators at the level of each member state; the analysis of import and trading partner dependence, which allowed the estimation of risks related to potential trade vulnerability, by calculating the Herfindahl–Hirschman index, an indicator measuring the degree of concentration, which was applied to both imports and exports; the integrated analysis of the price–trade relationship, which assessed the correlation between the average selling price and imported/exported volumes, in order to identify the extent to which trade movements are sensitive to price variations.

The HH indicator was calculated based on the share of each partner country, of origin or destination, in the total value traded, as follows:

$$HH = \sum_{i=1}^{n} (si)^2 \quad (1)$$

where:

s_i - represents the market share of country i in total trade.

A value close to 0 indicates a fragmented market, characterized by diversification of trading partners, while an increased value shows potential dependence on certain suppliers, with implications for market resilience and food security.

RESULTS AND DISCUSSIONS

By analysing trade flows, price variations and the degree of concentration towards certain partner markets of the fresh plum trade, the study aims to identify the main trends and vulnerabilities of this agricultural segment. The ultimate goal is to assess the EU's trade performance to adopt strategic decisions in the field of agri-food trade.

Only EU Member States for which complete data were available for the entire period analysed were included in the analysis. Countries that presented lack of reporting or statistical inconsistencies for one or more years between 2015–2024 were removed from the sample, to ensure comparability and substantiation of interpretations.

During the period under review, extra-EU trade in fresh plums reflected high volatility, driven by structural and cyclical factors of an economic, climatic and commercial nature. At the aggregate level, the EU showed an evolution with different amplitudes from one year to the next, indicating a moderate reactivity to the dynamics of domestic demand and to the supply from third countries. Although the arithmetic mean of the annual variations shows a relatively positive trend, the high dispersion of the values signals an unstable trade climate.

Disaggregation at the level of the Member States highlights heterogeneous trade behaviors. Thus, some Central European economies such as the Czech Republic, Slovakia and Hungary presented episodes of intense imports followed by severe contractions, which highlights an irregular adaptation to seasonal variations in domestic production and to changes on the world market. Similarly, countries such as Poland and Lithuania recorded short-term increases, which can be attributed to transitory factors.

On the other hand, in the case of countries with a favorable geographical or economic position, such as Germany, Italy and France, the annual percentage variations indicate a more stable procurement regime and better correlated with domestic consumption coverage strategies.

This stability demonstrates both the logistical efficiency of supply chains and a better capacity to integrate imports into agricultural and food distribution cycles. Some smaller Member States, such as Estonia, Bulgaria and Latvia, have experienced disproportionate fluctuations compared to the European average, which may indicate vulnerability to changes in international prices (Table 1).

Table 1. Evolution of fresh plum imports, Extra – EU, in the period 2015-2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
European Union	14.44	27.44	5.59	0.96	-18.42	11.13	25.71	-5.45	7.76	24.08
Austria	28.68	61.53	24.7	-32.79	15.13	101.09	15.25	-9.36	97.37	34.06
Belgium	16.32	-37.93	-36.54	-33.81	-25.02	-14.72	5.56	13.79	-51.38	14.00
Bulgaria	776.97	-64.48	-50.99	163.4	-20.18	-84.08	61.23	673.53	-84.33	-29.62
Croatia	104.49	1.6	24.13	39.6	-41.71	343.13	27.47	-10.24	89.62	-2.25
Czechia	251.85	19.91	17.8	-62.45	62.8	72.34	19.17	-48.15	101.68	19.83
Denmark	-72.97	159.58	6.25	-7.99	-39.61	-33.99	-19.68	-42.68	74.39	122.18
Estonia	2,3314.41	-25.71	131.65	-30.85	-78.69	182.46	-62.69	-32.28	754.66	10.39
France	68.82	-10.22	-42.54	88.99	-35.35	18.54	19.95	3.54	17.25	7.82
Germany	146.23	-14.26	85.2	-40.52	30.94	83.2	-6.7	-5.26	-20.78	-28.42
Greece	12.33	103.11	-30.99	42.37	9.63	-20.38	-39.2	-38.83	32.05	58.46
Hungary	163.73	277.27	493.78	-65.06	-64.17	489.57	-41.3	-63.09	664.37	179.89
Ireland	47.18	-30.65	55.58	-28.56	-21.5	-33.78	-11.42	41.74	7.95	-27.14
Italy	127.79	17.58	8.48	27.62	-2.38	-8.01	16.87	-47.71	95.83	-30.49
Latvia	93.31	41.75	453.38	-70.48	76.19	89.35	1.68	-46.01	218.74	-0.64
Lithuania	-83.37	-93.52	3897.92	-37.61	172.67	475.86	-18.39	-29.99	296.6	-49.86
Netherlands	-0.45	29.11	-18.57	29.17	-26.66	-3.06	40.09	-0.48	-22.07	37.3
Poland	-49.49	370.41	5335.53	-89.5	38.97	156.44	-1.09	-9.87	193.74	28.64
Portugal	361.36	89.79	-10.08	-51.1	-18.24	-3.13	101.32	-47.98	-29.07	1.17
Romania	233.81	29.67	64.8	-23.08	28.14	35.31	-10.14	39.46	33.76	15.35
Slovakia	-11.22	202.29	25.09	-85.52	174.58	109.37	-54.6	50.29	162.79	22
Slovenia	172.13	239.63	64.14	-49.34	20.38	52.48	46.46	-52.93	-29.2	60.76
Spain	19.07	43.85	-3.08	29.72	-23.4	-77.18	6.78	-0.34	60	-6.7
Sweden	273.65	-25.85	6.4	-6.99	18.83	122.69	-4.52	19.92	40.12	10.09

Source: own processing [14].

In particular, extreme values in certain periods indicate the existence of episodic phenomena, such as regional poor harvests, fluctuations in transport costs, or temporary barriers to market access.

Trade fluctuations were correlated with macroeconomic factors, such as the depreciation of the euro against the currencies of the main exporting countries, but also with severe climatic factors that affected plum yields in the intra-community space. At the same time, in the post-pandemic context and the conflict in Ukraine, some trade routes were redirected and some markets recalibrated, indirectly affecting import flows.

These findings confirm that, in the absence of stable trade partnerships with third countries producing plums, the EU remains exposed to high volatility in supply, and common trade policies must aim to reduce this dependence by diversifying external sources and strengthening domestic production.

Intra-EU trade in fresh plums within the EU has registered a significant consolidation during the period under review, reflecting a dual trend: on the one hand, an intensification of agricultural exchanges within the single market and, on the other hand, an increase in geographical specialization in the production and distribution of seasonal fruits.

The aggregate growth of over 60% at EU27 level is due not only to the expansion of demand, but also to the increased functionality of internal logistics and trade networks.

The growth recorded in most Member States is due to the more efficient distribution of seasonal crops, as well as the growing preference of consumers for products originating within the European area, in the context of new guidelines on food safety, traceability and sustainability.

Table 2. Evolution of fresh plum imports, Intra-EU, during 2015-2024 (%)

Country	2014 (EUR)	2024 (EUR)	2014–2024 (%)
European Union – 27	145,317,728	233,051,712	60.37
Austria	4,184,103	7,474,178	78.63
Belgium	15,388,914	18,091,724	17.56
Bulgaria	175,936	464,980	164.29
Croatia	479,610	1,346,162	180.68
Cyprus	583,793	1,244,278	113.14
Czechia	3,312,364	9,152,809	176.32
Denmark	5,707,300	5,544,045	-2.86
Estonia	1,006,968	1,280,444	27.16
Finland	3,268,003	4,096,929	25.36
France	15,447,793	11,468,290	-25.76
Germany	41,474,787	77,333,842	86.46
Greece	955,801	1,239,946	29.73
Hungary	594,389	1,737,673	192.35
Ireland	1,980,023	3,196,116	61.42
Italy	8,258,077	19,624,509	137.64
Latvia	1,653,856	1,307,718	-20.93
Lithuania	8,424,815	2,868,832	-65.95
Luxembourg	844,900	1,605,127	89.98
Malta	729,912	1,043,526	42.97
Netherlands	8,750,439	13,966,203	59.61
Poland	8,154,436	19,521,767	139.4
Portugal	3,564,059	9,505,685	166.71
Romania	775,854	2,298,991	196.32
Slovakia	1,000,684	3,111,894	210.98
Slovenia	664,796	2,454,960	269.28
Spain	3,123,696	6,836,145	118.85
Sweden	4,812,420	5,234,939	8.78

Source: own processing [14]

Countries such as Slovakia, Slovenia and Romania have shown an increase in intra-EU imports, which reflects an accelerated integration into European supply chains, but also a reduction in the domestic capacity to satisfy seasonal demand. On the other hand, the decrease in volumes recorded in countries such as France, Lithuania or Latvia indicates a process of substitution of imports with local production, but also a repositioning of these economies in the regional trade network (Table 2).

These developments are due both to more efficient domestic agricultural policies and to price dynamics that made domestic supply more advantageous in certain periods. The position of Germany is also noteworthy, whose absolute volume of intra-community imports of plums almost doubled in the analyzed period. Given the size of the German market and its role as a redistribution center in Central Europe, this trend is an indication of the intensification of trade ties in the region, but also of increased pressures on the logistics infrastructure for managing perishable products. Countries in Central and South-Eastern Europe, such as Hungary, Poland, Croatia and the Czech Republic, recorded growth rates of over 150%, which demonstrates both the increase in domestic consumption and an untapped potential in developing their own production or storage capacities. At the same time, these results highlight a pattern of increased

interdependence between new and old Member States, in which trade in plums plays an increasingly clear economic role.

Thus, the intensification of intra-Community trade reflects not only the functional integration of the European single market, but also the adaptive dynamics of the horticultural sector to the modern demands of European consumers. In this context, fresh plums, although an apparently seasonal and quantitatively limited product, emerge as relevant indicators of internal trade performance and of the level of agricultural cohesion of the EU.

Table 3. Evolution of total imports of fresh plums into the EU from all countries of the world (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	37.61	26.88	8.62	-17.72	-5.14	41.71	2.02	-0.91	79.78	19.19
Belgium	17.93	10.44	-5.4	-12.32	-16.66	9.67	4.71	2.67	1.72	5.94
Bulgaria	163.04	-29.77	-27.41	55.89	8.74	-45.42	25.44	135.92	-21.56	-26.31
Croatia	46.58	-2.11	13.47	32.59	-19.65	163.62	34.14	-6.61	88.41	-6.45
Cyprus	-14.85	0.31	14.19	15.31	29.06	-30.91	45.34	-23.56	33.07	39.92
Czechia	11.41	21.03	5.53	-23.86	-1.62	15.08	29.79	-10.64	39.38	60.01
Denmark	4.65	-1.26	-7.8	5.7	-17.03	6.91	-7.5	20.56	-2.59	-4.06
Estonia	38.81	-10.16	3.38	-13.01	-2.89	4.29	23.27	10.7	2.12	-11.34
Finland	8.54	-11.6	11.6	18.81	-12.02	4.63	4.25	-7.11	0.25	18
France	22.32	1.24	-15.25	10.69	-36.98	36.91	51.07	-23.14	-15.74	-19.85
Germany	17.79	19.75	11.83	-19.44	-7.83	40.4	-1.3	-6.22	10.08	12.98
Greece	-24.65	19.1	-22.69	11.63	17.46	-9.11	32.13	-7.87	-0.52	33.04
Hungary	15.54	43.75	60.38	-34.24	45.44	-2.76	10.98	0.09	19.74	56.69
Ireland	29.7	-9.35	12.42	-12.14	-17.11	-18.22	18.98	40.4	-7.4	-6.06
Italy	43.88	-8.43	9.19	0.03	-11.84	19.61	42.13	-21.6	37.95	3.78
Latvia	-6.32	13.64	4.26	-10.62	3.78	29.98	4.62	14.4	15.99	-11.49
Lithuania	-62.93	-40.63	46.57	-20.65	37.46	6.2	31.94	-5.93	6.75	-19.9
Luxembourg	34.95	17.33	-1.45	1.64	4.52	1.55	2.16	5.88	-5.85	10.82
Malta	-9.66	28.88	-9.75	-2.13	-11.28	-12.89	28.74	-17.87	35	26.05
Netherlands	1.05	28.74	-18.22	24.53	-23.65	2.35	31.14	-0.15	-17.27	29.97
Poland	17.51	8.94	162.89	-58.67	33.65	17.26	6.15	-9.39	42.35	28.76
Portugal	34.52	56	-21.2	44.63	-42.62	51.5	-15.24	40.03	-13.53	24.23
Romania	100.45	31.48	55.57	-15.09	21.48	24.94	1.42	27.46	19.53	13.76
Slovakia	3.95	64.07	4.22	-10.46	6.27	26.67	10.09	0.61	33.24	1.59
Slovenia	41.61	141.19	48.49	-43.98	15.91	39.39	51.03	-43.09	-0.2	43.31
Spain	15.8	36.4	-6.73	21.84	-28.21	-36.57	29.13	4.01	21.02	0.43
Sweden	25.45	-7.26	-3.21	-4.38	-12.22	29.3	23.48	-10.67	4.47	-8.06

Source: own processing [14]

In the dynamic context of the international fruit market, trade in fresh plums in the EU reflects a complex sequence of fluctuations determined by climatic factors, changes in consumer preferences, seasonality, reorganisation of supply chains and imbalances between supply and demand. The analysis of the evolution of total imports reflects significant volatility in the case of many Member States, without a unitary trend at the level of the Community block (Table 3). In some cases, such as Austria, Poland or Slovenia, an alternation of significant increases and corrections is observed, which indicates a heightened sensitivity of bilateral trade to seasonality, but also to trade policies and reorientations of supply sources. High values, followed by declines or vice versa, demonstrate the existence of temporary imbalances or transitions to alternative trade partnerships,

depending on the regional availability of the product. For large importing countries, such as Germany, Italy and France, the trajectories differ visibly. Thus, Germany presents a relative stability of flows, with a recent recovery. In contrast, France has recorded a steady decline in imports in the last years of the period under review, an aspect that is due to the resizing of domestic plum consumption as a result of changes in consumer preferences. The Baltic countries, such as Latvia, Lithuania, Estonia, present contradictory developments, due on the one hand to instability in supply, and on the other hand to the fragmentation of national markets. In countries such as Greece, Portugal or Romania, a sharp increase in imports is observed, with clear episodes of consolidation, but also of withdrawal. Romania had a relatively constant increase trend, due to the structural deficit of domestic production correlated with an increase in demand. On the other hand, certain Nordic countries, such as Sweden, show stagnation or even a gradual reduction in imports, signaling a reorientation of consumption towards other categories of fruit. Denmark and Finland are mature markets, where the level of imports is already stabilized and adapted to a constant level of demand (Table 3).

It is important to note that, in many cases, import dynamics follow a cyclical or periodic adjustment pattern rather than a clear trend of expansion or contraction. Thus, the plum market in the European Union proves to be extremely sensitive to external disturbances, such as climatic phenomena in exporting countries, transport costs or phytosanitary restrictions, but also to structural transformations within national markets.

Table 4. Evolution of extra-EU27 fresh plum exports in the period 2014–2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	4,777.70	102.35	-13.04	-57.38	-49.9	-35.89	-42.04	382.35	-91.34	1,233.85
Belgium	-68.08	4.42	32.51	181	-33.64	24.81	-19.36	-6.37	15.07	-13.41
Bulgaria	-90.89	608.34	14.27	-85.7	514.25	-22.4	-31.25	31.91	-45.52	-2.53
Denmark	10.58	3.06	1.59	-9.92	24.14	-21.61	5.95	-2.79	4.26	45.11
Germany	124.00	19.98	32.81	-78.88	187.76	-1.66	157.34	-66.61	190.73	-79.06

Source: own processing [14, 15].

The choice of a limited sample of countries to analyze the evolution of the value of fresh plum exports from EU Member States to third countries, during the period 2014–2024, is not accidental (Table 4).

On the one hand, it reflects the reality of a market in which only a few EU Member States have a significant export capacity to countries outside the EU, and on the other hand, it is based on the criterion of the availability of continuous and comparable data for the entire period analyzed.

The percentage approach highlights trade phenomena with high explanatory potential, such as external shocks, changes in global demand for fresh fruit, the competitiveness of European products, tariff and non-tariff barriers or the strategic redirection of trade flows depending on market opportunities.

What can be observed is a high volatility and a lack of structural coherence in the trade behavior of most of the analyzed Member States. With the exception of a few episodes of growth, these developments are marked by a conjunctural nature rather than a consolidated and predictable export strategy. The significant fluctuations recorded in the case of Germany or Bulgaria, for example, demonstrate a high degree of vulnerability to external factors, such as seasonal demand, tariff changes or changes in logistics networks.

The analyzed data highlight a heterogeneous configuration of trade performance between EU Member States. Domestic plum exports, carried out between countries, reflect not only seasonal demand fluctuations and national production capacities, but also the degree of integration into regional fresh fruit supply chains, essential elements for assessing the

functionality of the single agri-food market. Countries such as Romania, Bulgaria and Croatia record high percentage variations, which are due to low initial volumes, but also to the lack of a constant trade infrastructure (Table 5).

Table 5. Evolution of intra-EU27 fresh plum exports in the period 2014–2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	19.62	65.21	50.65	-36.33	23.47	57.93	-5.97	-6.75	104.83	45.36
Belgium	16.17	-3.91	16.46	-72.36	1.17	24.95	-1.59	0.40	6.78	-2.35
Bulgaria	-20.97	73.82	367.08	-69.57	-1.49	22.69	160.30	-86.80	-25.15	906.31
Croatia	100.71	18.88	146.24	-60.15	-10.75	332.02	46.36	-24.59	135.56	-10.82
France	27.30	8.61	1.00	-33.28	-19.00	15.59	-33.08	17.24	14.24	18.72
Germany	35.21	20.18	3.56	23.37	-18.32	9.85	27.69	5.38	-29.86	2.77
Italy	12.65	8.98	12.27	-16.59	-14.72	-30.05	51.33	15.15	-1.62	39.76
Netherlands	24.88	20.83	8.50	10.48	-19.11	11.36	23.58	-2.65	-13.47	18.44
Romania	2,012.54	17.09	42.81	-80.25	-20.23	27.82	338.54	253.73	116.65	-43.04
Spain	15.91	1.38	-4.79	-10.16	-7.59	61.43	6.85	-20.48	22.89	-4.57

Source: own processing [14].

Cumulative increases of over 2000% in Romania in 2015 or over 900% in the case of Bulgaria in 2024, do not reflect a consolidation of competitiveness, but a structural fragility of the presence of these countries on the domestic plum market, which is still in its early stages of development. On the other hand, countries with a tradition in fruit production and marketing, such as Germany, France, Italy or Spain, demonstrate a more stable dynamic, but not without disruptions. Although these economies have a mature agricultural infrastructure, the data show an inability to maintain a constant upward trend, which is due not only to changes in consumer preferences, but also to strong competition from products imported from outside the EU or from neighboring countries. Italy and France in particular show recurrent episodes of export contraction, indicating a reassessment of the positioning on the European internal market for fresh plums. The case of Germany is significant from the perspective of a major economic actor: although it records a high degree of stability, the relatively constant evolution and moderate variations indicate a saturation of export capacity in the region, associated with an increase in domestic consumption, but also a redirection of flows to extra-EU markets. As for the Netherlands and Spain, the data show an efficient functioning of trade channels, but also a sensitivity to economic and agricultural cycles, which determine variations in exports.

Overall, intra-EU trade does not show a uniform pattern of growth or consolidation. Instead, we are witnessing a fragmented dynamic, influenced by multiple factors, from storage and transport capacities to access to large consumer markets and the influence of phytosanitary regulations. This reality justifies the need for constant monitoring of trade performance, through aggregated and seasonally adjusted indicators, in order to be able to substantiate coherent strategies for the development of the European internal market for plums.

It is also necessary to stimulate interstate cooperation and common trade platforms, which would facilitate the predictability of flows and reduce the trade imbalances reported.

The data analysed highlight the significant differences in the export capacity of fresh plums between the Member States, highlighting a clear concentration around three major exporters: Spain, the Netherlands and Italy, which dominate the intra- and extra-EU market, indicating the existence of consolidated competitive advantages, based on specialized production, logistics infrastructure and access to markets (Table 6).

Table 6. Evolution of EU fresh plum exports in the period 2014–2024

An	Spain	Netherlands	Italy	France	Romania	Austria	Germany	Poland
2014	99,801,991	36,607,708	44,782,146	16,417,987	121,808	1,799,600	3,312,422	6,119,868
2015	107,381,999	48,285,081	48,318,971	20,694,812	305,533	2,179,503	4,908,967	4,449,122
2016	111,952,407	55,340,642	51,104,421	22,431,062	358,137	3,610,920	5,897,492	4,759,422
2017	99,883,897	60,599,159	53,873,370	22,488,257	547,202	5,404,237	6,488,110	3,213,683
2018	88,266,995	62,019,710	49,067,028	15,070,046	101,505	3,430,455	6,236,144	4,594,419
2019	92,205,842	51,470,378	45,229,874	13,675,266	83,372	4,220,471	5,846,295	4,472,742
2020	107,899,289	57,266,215	30,382,226	15,074,829	132,107	6,655,701	6,301,277	6,557,548
2021	135,706,347	68,042,515	45,683,761	12,473,966	470,657	6,256,062	9,385,844	6,356,098
2022	125,425,833	68,672,892	54,523,180	13,873,489	1,587,744	5,848,751	7,976,120	8,580,030
2023	140,683,333	60,614,072	51,195,282	14,905,711	3,447,366	11,943,796	7,553,252	7,434,056
2024	127,258,394	71,627,918	68,924,299	17,398,313	1,981,465	17,380,833	5,650,123	3,927,246

Source: own processing [14, 15]

Spain consistently remains the European leader in the export of fresh plums, with annual values that frequently exceed 100 million euros, a performance that is due not only to high production, but also to logistical capacity, favorable seasonal synchronization and superior product valorization.

Modern agricultural practices, integration into commercial chains and the active role of cooperatives contribute significantly to consolidating this position.

The Netherlands is not distinguished by extensive agricultural production of plums, but export values reflect a dominant role as a commercial and logistical intermediary.

With a developed port network and a tradition in re-exports, the Netherlands acts as a redistribution hub for products originating from other member states, which justifies the high value of exports compared to its productive capacity.

Italy ranks third in the ranking of European plum exporters, registering moderate fluctuations until 2020 and an increase in recent years, reaching 68 million euros in 2024, as a result of the diversification of varieties, adaptation to foreign market requirements and the strategic reorientation of exports to more profitable regions.

Among the countries with an average share in exports, France presents constant values, ranging between 13 and 22 million euros. French exports are oriented towards regional markets, given that a considerable part of production is directed towards processing.

A special case is Romania, which, although starting from a low level in 2014, manages to reach a maximum of over 3.4 million euros in 2023, as a result of the emergence of competitive commercial initiatives.

Poland had an oscillating evolution, marked by unstable agricultural and commercial factors, in turn being affected by climatic problems.

Based on the data in Table 7, we analyzed the volatility of the selling price of plums in the EU Member States during the period 2015–2024, which highlights a market marked by instability. Most states record significant price oscillations, without a clear upward or downward trend in the long term.

Prominent examples are Germany and Poland, which experience years of sharp increases (over +60%) followed by decreases due to the rapid adaptation of the domestic market to the level of supply.

Countries such as Hungary, Lithuania and Malta show the greatest fluctuations, including extreme variations of +586% in Hungary in 2018 or +230% in Lithuania in 2024, indicating small, vulnerable and highly reactive markets to annual variations in production.

Central and Southeastern European countries, such as Romania, Bulgaria, Slovenia, are characterized by a moderate and relatively constant price increase in most years, signaling a gradual consolidation of demand.

Table 7. Evolution of the selling price of plums in the EU, 2015–2024 (%)

Country	2016	2017	2018	2019	2020	2021	2022	2023	2024
Austria	4.55	9.46	32.66	-4.74	13.98	1.95	8.98	16.51	-9.67
Belgium	-2.15	13.08	18.97	-22.9	173.18	-18.07	-12.8	-	-
Bulgaria	-15.25	-0.34	9.78	-4.5	-0.47	0.47	14.09	2.45	1.64
Croatia	-11.65	42.86	6.99	-7.81	17.59	7.34	10.53	25.83	-13.25
Cyprus	-16.96	16.81	-9.54	26.77	-8.01	5.63	3.13	2.39	7.98
Czechia	-3.79	37.33	-37.24	14.82	6.14	21.02	7.01	12.73	11.53
Denmark	-11.12	16.53	-25.84	3.51	0	68.54	-8.24	26.17	3.71
Germany	5.88	63.39	-52.3	30.91	25.94	-4.95	2.00	-17.42	9.86
Hungary	-9.96	-84.16	586.23	11.72	66.01	-13.87	7.56	22.76	-10.85
Latvia	7.35	19.05	8.74	3.74	9.31	-1.45	8.83	-10.1	21.98
Lithuania	7.64	-	-23.65	31.83	-13.64	-	11.76	-39.54	230.12
Luxembourg	13.64	4.00	-3.85	4.00	11.54	1.72	-	1.69	66.67
Malta	76.25	-6.51	15.15	-17.59	-8.99	0	-20.55	96.73	28.48
Poland	-25.17	110.36	-64.91	68.78	10.84	10.62	-12.54	68.22	18.64
Portugal	-3.33	-34.13	75.06	23.47	-0.46	4.79	6.57	6.51	21.04
Romania	-10.19	33.94	-23.94	20.97	0.53	17.48	17.26	-12.43	-3.65
Slovakia	4.30	18.05	2.30	1.27	17.55	0.17	9.74	45.22	-9.10
Slovenia	-4.52	-14.14	6.46	-8.81	9.25	41.52	-15.66	36.38	5.18
Spain	-10.57	-10.79	26.58	-30.10	9.20	2.48	15.31	14.77	9.56

Source: own processing [15].

However, these developments are often interrupted by episodes of regression.

In Western Europe, countries such as Spain and France have a more stable but still volatile model, in which price fluctuations are less pronounced compared to the rest of the countries, as a result of the larger size of the internal market, the integration into efficient distribution chains and the capacity to absorb production in variable contexts.

Therefore, the price of plums in the EU proves unstable and heterogeneous between countries, without a clear convergence, reflecting national specificities, market structure and exogenous influences.

This high variability requires increased attention from producers and traders to market risk management tools, as well as the need for agricultural policies that mitigate the impact of annual imbalances.

The data in Table 8 highlight a pronounced structural diversity in the evolution and volatility of plum prices at EU level over the period 2015–2024.

Countries with small or isolated markets, such as Malta, Lithuania and Luxembourg, have recorded price increases accompanied by high volatility, which signals imbalances between supply and demand and increased exposure to external shocks.

On the other hand, countries such as Bulgaria, Spain and Romania show a lower degree of price instability, but also a low average annual growth rate, indicating a mature market with slow adjustments.

The highest average values are found in economies with constant demand and high income levels, such as Austria and Denmark.

To assess the degree of concentration of the fresh plum import market in the EU, we used the Herfindahl–Hirschman index, an indicator established in competitive analysis and market structure studies, which allows quantifying the relative distribution of import values between partner countries, reflecting the level of market dominance by a small number of suppliers (Table 9).

The application of the index is justified in this context because imports of fresh plums are influenced by seasonal, geographical and economic factors, which can lead to an

excessive concentration of supply from a limited number of external sources.

Table 8. Evolution and volatility of plum prices in the European Union, 2015–2024

Country	Average price (€/100kg)	Average annual growth rate (%)	Volatility (€/100kg)	Index (2015=100)
Austria	217.58	8.19	54.22	192.76
Belgium	138.63	16.59	61.83	-
Bulgaria	22.67	0.88	1.93	105.21
Croatia	50.1	8.72	13.77	189.6
Cyprus	108.9	3.13	12.94	123.24
Czechia	51.72	7.73	11.63	164.56
Denmark	220.41	8.14	60.92	160.89
Germany	87.62	7.04	18.22	119.67
Hungary	37.97	63.94	17.01	184.02
Latvia	152.23	7.49	27.96	185.34
Lithuania	85.83	22.72	34.21	208.7
Luxembourg	146	11.05	38.77	227.27
Malta	181.62	18.11	59.69	285.77
Poland	41.65	20.54	15.97	199.52
Portugal	109.23	11.06	32.07	197.24
Romania	62.44	4.44	10.83	129.34
Slovakia	57.32	9.95	17.6	217.59
Slovenia	102.7	6.18	24.25	148.86
Spain	55.43	2.94	8.64	114.53

Source: own processing [15].

Table 9. Evolution of the concentration index of plum imports in the EU in the period 2020–2024

Year	HHI Index Imports (E.U.)	HHI Index Exports (E.U.)
2020	0.198	0.103
2021	0.205	0.112
2022	0.217	0.127
2023	0.228	0.135
2024	0.235	0.143

Source: own processing

In the case of EU plum exports, the HH index recorded values between 0.10 and 0.14 during the analyzed period, oscillating slightly from one year to another, indicating a moderately diversified distribution of sales markets, without a critical dependence on 1–2 destinations. The values close to 0.14 are due to the countries that absorbed a significant share of total exports, indicating an incipient trend of concentration. This slight vulnerability is due to the trade dynamics with traditional partners, such as Germany, but also countries in Central Europe, which have a constant demand and a well-connected trade infrastructure with producers in southern Europe. As for plum imports, the HH index is at significantly higher values, between 0.18 and 0.27. This level of concentration reflects a strong dependence of the EU on a few major external suppliers. Countries with significant shares of imported volumes face commercial and logistical risk in the event of supply disruptions, political tensions or tariff barriers. The E.U. market is thus in a position of relative vulnerability in relation to supplies from outside the E.U.

Comparing the two sets of HH values highlights a strategic asymmetry between export orientation and import dependence. While the EU benefits from greater diversification in its exports, the dependence on a few key suppliers for plum imports represents a weak point in the supply chain.

CONCLUSIONS

The integrated analysis of data on trade in fresh plums in the EU for the period 2014–2024 highlights a complex evolution, marked by significant structural transformations and a diversity of trade behaviours between Member States. In the context of constantly changing

markets, the dynamics of exports and imports, both intra- and extra-EU, reflect not only economic and logistical pressures, but also the differentiated capacity of countries to adapt to international market requirements. The significant fluctuations in sales prices, together with the heightened volatility identified in many Member States, prove the existence of vulnerabilities in terms of the stability of supply chains, the level of competitiveness and the efficiency of the adopted trade strategies.

Against this backdrop, synthetic indicators such as the HH index provide an additional picture of the degree of market concentration, highlighting a slight but constant trend of increasing dependence on a small number of suppliers or trade destinations. This increased concentration may raise questions about trade resilience and competitive balance within the EU. At the same time, the data highlight the fact that Member States do not react uniformly to market changes, and national policies play a significant role in shaping trade performance. Thus, the results obtained confirm the need for an integrated approach to the development of the European fresh fruit market, combining rigorous statistical analysis with coherent trade, agricultural and logistics policies, adapted to both global challenges and regional specificities. This direction is essential to ensure the economic sustainability of the sector, the diversification of trade sources and the competitiveness of European players on international markets.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

WHO IS COVERING THE MOST PART OF THE MEAT IMPORTING DEMAND IN CENTRAL AND EASTERN EUROPE IN THE CONTEXT OF THEIR OVERALL DECLINING LIVESTOCK?

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Abstract

The decline in livestock numbers in the Central and Eastern European Countries (CEECs) in the last decade has affected not only the regional meat production but also the trade flows. This paper examines the evolution of livestock and meat imports in the CEECs over the past decade, a period marked by a significant rise in meat imports across most of these countries. The method is quantitative based on data sourced from ITC and Eurostat. Findings reveal that the leading livestock producing countries in the region are also major importers. Additionally, countries such as Spain, Germany, and the Netherlands — which hold a large share of the EU's livestock — play a key role in meeting the meat import demand of the CEECs. Romania and Poland, which account for the largest share of livestock within the CEECs, along with the Czech Republic, also rank among the top meat-importing countries in the region. Excepting poultry meat sector, all the other sectors are depending on the imports from the Western Europe.

Key words: *livestock, trade, meat, import flows, Central and Eastern Europe, Romania, Poland*

INTRODUCTION

Covering the demand for meat has been examined by some authors through the evolution of trade flows, especially during significant political events that disrupted international trade [16]. The dynamic of meat imports in the group of countries defined by The Organisation for Economic Co-operation and Development (OECD) as Central and Eastern European Countries (CEECs) [13] – comprising the Baltic States (Estonia, Latvia and Lithuania), the Visegrad Group: Czech Republic, Hungary, Poland and Slovakia, as well as Bulgaria, Romania, Slovenia, and Albania (although geographically located in the Southeastern Europe) can be analysed from multiple perspectives. However, recent trends are particularly relevant for the development of future national and regional strategies, as they offer a valuable basis for further analysis and policy evaluation. Several years after their accession to the European Union, the CEECs were assessed in the context of agricultural trade. This accession was generally seen as having a positive impact, supported by comprehensive studies on their roles in the EU poultry meat production and foreign trade [14]. Studies on livestock development in some of these countries are also pertinent [2, 7], as livestock dynamics directly affect agricultural output and significantly influence meat trade flows in the CEECs. These should be considered in the context of the scientific debates concerning sectoral competitiveness [5]. An assessment of self-sufficiency in beef and pork across the CEECs revealed significant disparities between countries, which have in turn shaped regional meat trade flows [11]. Furthermore, livestock health crises—such as outbreaks of African Swine Fever, particularly in Romania [15, 3, 4] and Poland [17, 10] - must be taken into account when analysing the evolution of meat trade in the region, given their substantial impact on domestic production and meat prices. A recent study highlighted that Poland, a key meat exporter in the region, recorded one of the lowest meat price levels, followed by Romania. Both countries had an internal market meat price index below 62% of the EU average. However, it is important to note that

Polish consumers benefit from higher average annual salaries compared to Romanian consumers [12]. Each CEEC is characterized by a specific context in terms of meat trade. For instance, Romania is recognized as a net importer of meat, particularly pork and poultry [8]. Germany remains the primary exporter of meat to CEECs. Paradoxically, the competitiveness of Germany's meat industry relies heavily on low-paid labour from CEECs, which contributes to its ability to maintain low export prices [1].

MATERIALS AND METHODS

The paper analyses individual and aggregate data related with the livestock and meat trade in the Central and Eastern Europe. We focused first on the evolution of the livestock, then on identifying the main meat trade importers in this region and we analysed data related with the main meat exporters. In order to evaluate the dependence on the meat imports for the CEECs we insisted more on the import flows and we also considered the trade balance, because some countries, as Poland and Romania are also important meat exporters, and the trade balance reflect better the overall trade context. The free access data were offered in relation with trade by International Trade Centre – ITC through its official web site [9] and for livestock by Eurostat [6].

RESULTS AND DISCUSSIONS

The evolution of livestock in CEECs

As in the EU, the livestock in the CEECs is held in only some countries. The pig population decreased in CEECs by 16.42% from 23,204.97 thousand heads in 2015 to 19,394.57 thousand heads in 2023. In 2015 the main livestock of swine of CEECs was recorded in Poland - 10,590.20 thousand heads, followed by Romania - 4,926.90 thousand heads, Hungary - 3,124 thousand heads and Czechia -1,555.40 thousand heads. In 2023, Eurostat centralized a decrease of swine livestock in all these countries: Poland -9,769.70 thousand heads (-7.75%), Romania - 3,154.10 thousand heads (-7.34%), Hungary -2,607.70 thousand heads (-6.6%) and Czechia 1,362.28 thousand heads (-12.4%). The bovine population also decreased in CEECs between 2015 and 2023, but only by 1.3% from 13,448.57 thousand heads in 2015 to 13,277.85 thousand heads in 2023. The number of bovines is almost at the same level because some of the main countries specialised from CEECs has increased the production and covered the decreased of bovine livestock from the other countries. While Poland recorded 6,267.46 thousand live bovines in 2023, compared to only 5,762.50 thousand bovines in 2015, Romania declared 1,817 thousand heads in 2023, versus 2,092.40 thousand in 2015. Czech Republic, the third producer in terms of bovines' livestock from CEECs has slightly increased the bovine's livestock from 1,366.33 thousand live bovines in 2015 to 1,369.59 thousand in 2023.

The sheep population also decreased in CEECs from 15,429.25 thousand live animals in 2015 to 13,691.76 thousand live animals in 2023. Romania, which is by far the main sheep-breading country in this region, increased its sheep livestock from 9,809.50 thousand animals in 2015 to 10,299.50 thousand animals in 2023. Instead, Bulgaria and Hungary, which are the second and the third sheep breeders in the region, decreased the sheep livestock from 1,331,89 thousand animals in 2015 to 1,072.77 thousand animals in 2023 when it comes to Bulgaria, respectively from 1,190 thousand animals to 907.10 thousand animals in 2023 for Hungary.

The same decreasing trend can be noticed related with the goat livestock in the CEECs. The goat's population decreased in CEECs from 2,898.01 thousand live animals in 2015 to 2,292.51 thousand live animals in 2023. The main goat breeders from CEECs recorded a decrease of the live goats from 2015 to 2023: Romania, from 1,440.20 thousand goats in 2015 to 1,421.70 thousand goats in 2023, Albania from 932 thousand goats in 2015 to 640.24 thousand goats in 2023, and Bulgaria from 276.92 thousand goats in 2015 to 174.95 thousand goats in 2023.

Being complicated to estimate the evolution of the poultry population, we can only mention that the main poultry farming countries from CEECs, Poland, Hungary and Romania

increased their poultry meat production in the last decade, based on use of advanced technology and high consumption demand.

Main importing meat countries in the CEECs

From 2015 to 2024 the meat imports in the CEECs became more than doubled, from 4,916 million Euro to 10,129 million Euro (Fig.1).

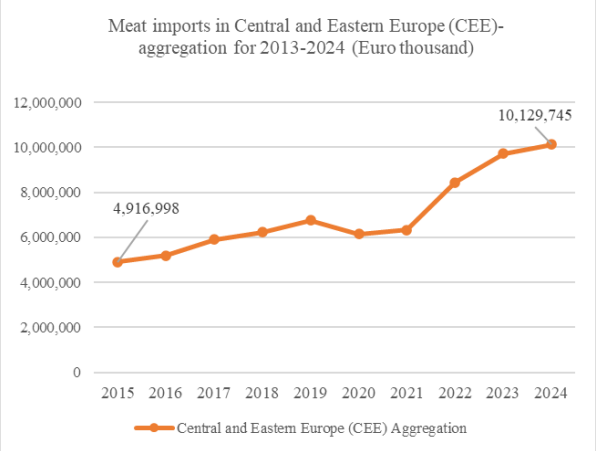


Fig. 1. Meat imports in Central and Eastern Europe (CEE) aggregation from 2015 to 2024 (Euro thousands)
Source: Eurostat [6].

After a steady upward trend up to 2019, the COVID – 19 pandemics made its decline impact, but from 2021 until 2024 the imports increased considerably, reaching the highest level in 2023 and 2024, based on some states decline in domestic meat production, collaborated with the need to cover the internal consumption by imports and, on impacting economic aspects as changes in purchasing power in some ECE countries or strengthened intra-European meat trade, especially within the EU. Poland faced the highest meat imports within this period in value terms, from 1,371,043 thousand Euro in 2015 to 2,201,619 thousand Euro in 2024 (Table 1), corresponding to an increase of 60.57%. Czech Republic recorded the second highest increase value of meat imports for the same period in this region, from 943,627 thousand Euro in 2015 to 1,714,388 thousand Euro in 2024, corresponding of an increase of around 82%. Romania, the third in this chart, also increased significant its meat imports, from 568,661 thousand Euro in 2015 to 1,600,147 thousand Euro in 2024, which correspond to the highest percentage increase from the region in this period, of 181%.

Table 1. Top importers of meat in CEECs between 2015 and 2024 (Euro thousand)

Year	Imports value by country		
2015	Poland	Czech Republic	Romania
	1,371,043	943,627	568,661
2016	Poland	Czech Republic	Romania
	1,369,960	984,712	643,710
2017	Poland	Czech Republic	Romania
	1,546,016	1,068,564	766,528
2018	Poland	Czech Republic	Romania
	1,687,389	1,093,051	817,588
2019	Poland	Czech Republic	Romania
	1,748,237	1,177,175	940,316
2020	Poland	Czech Republic	Romania
	1,563,524	1,082,694	912,484
2021	Poland	Czech Republic	Romania
	1,533,083	1,096,799	973,613
2022	Poland	Czech Republic	Romania
	2,004,689	1,461,312	1,300,729
2023	Poland	Czech Republic	Romania
	2,219,794	1,672,886	1,534,539
2024	Poland	Czech Republic	Romania
	2,201,619	1,714,388	1,600,147

Source: ITC [9].

Main meat suppliers for the CEECs

Only four countries could take a place in the top meat suppliers of CEECs between 2014 and 2023: Germany, Spain, Netherlands and Belgium. Germany was between 2014 and 2023 the main supplying meat market for the CCE countries. The value of the meat exported by Germany in CEECs, increased from the 1,100,781 thousand Euro in 2014 to 1,710,504 million Euro in 2024. Belgium, which was the second main meat supplier in the CEECs in 2015 with a value of 424,782 thousand Euro increased its export in this region up to 639,505 thousand Euro in 2024 but left the top 3 of the main CEE meat exporters in 2023 and 2024. Spain consolidates its role of supplier in the region, increasing deliveries from 423,682 thousand Euro in 2015 up to 1,636,599 thousand Euro in 2024. Also, Netherlands re-entered in the top 3 suppliers in 2023 and 2024. As regarding the meat suppliers within CEECs, can be noticed, based on the ITC statistic, that Poland is the main provider in the region, and

increased its meat exports value from 667,595 thousand Euro in 2015 to 1,478,912 thousand Euro in 2024. Hungary, which was the second main meat exporter in the region in this period, increased its meat exports from 257,382 thousand Euro in 2015 to 602,277 thousand Euro in 2024. Romania increased its meat deliveries in the CEECs but with a value of only 108,585 thousand Euro in 2024.

Table 2. Top suppliers of meat in CEECs between 2015 and 2023 (thousand Euro)

Year	Exports value by country		
2015	Germany	Belgium	Spain
	1,100,781	424,782	423,682
2016	Germany	Spain	Belgium
	1,117,862	572,054	421,540
2017	Germany	Spain	Netherlands
	1,283,328	704,297	488,227
2018	Germany	Spain	Belgium
	1,279,869	772,212	518,915
2019	Germany	Spain	Belgium
	1,338,892	891,202	594,143
2020	Germany	Spain	Belgium
	1,255,359	757,776	591,860
2021	Germany	Spain	Belgium
	1,346,041	775,757	562,426
2022	Germany	Spain	Belgium
	1,554,355	1,138,629	666,615
2023	Germany	Spain	Netherlands
	1,668,304	1,625,267	846,864
2024	Germany	Spain	Netherlands
	1,710,504	1,636,599	849,920

Source: ITC [9].

While at CEECs level the trade balance increased from a positive sold of 1,077,794 thousand Euro in 2015 to 1,484,955 thousand Euro in 2024 (Fig.2), only Poland and Hungary had a positive sold, of 5,984,000 thousand Euro, respectively 517,690 thousand Euro in 2024 (Table 3). The ITC data indicates that only Poland recorded a positive balance trend from 2015 to 2024. While Czech Republic recorded a negative trade balance for meat of 1,438,810 thousand Euro in 2024, which was more than double related with the one recorded in 2015 and is the CEE country with the highest deficit balance for the meat trade, Romania, ranked in the second place in this negative top, having a meat balance trade deficit in 2024 of 1,202,964 thousand Euro, which is almost 4 times higher than in 2015.

Table 3. The CEECs with the highest positive and negative meat trade balance between 2015 and 2024 (Euro thousand)

Year	Trade balance by country			
2015	Poland	Hungary	Romania	Czech Republic
	2,447,953	598,356	-320,798	-706,507
2016	Poland	Hungary	Romania	Czech Republic
	2,501,055	579,658	-406,632	-761,249
2017	Poland	Hungary	Romania	Czech Republic
	2,959,896	426,823	-485,849	-872,173
2018	Poland	Hungary	Romania	Czech Republic
	3,388,128	451,555	-553,576	-907,806
2019	Poland	Hungary	Romania	Czech Republic
	3,458,042	422,183	-699,758	-996,834
2020	Poland	Hungary	Romania	Czech Republic
	3,266,636	361,891	-717,287	-905,716
2021	Poland	Hungary	Romania	Czech Republic
	3,835,523	549,214	-733,921	-915,091
2022	Poland	Hungary	Romania	Czech Republic
	5,606,285	514,572	-978,721	-1,195,157
2023	Poland	Hungary	Romania	Czech Republic
	5,307,417	516,340	-1,211,945	-1,393,176
2024	Poland	Hungary	Romania	Czech Republic
	5,984,000	517,690	-1,202,964	-1,438,810

Source: ITC [9].

Slovakia was the third country in terms of deficit of meat trade balance, with 784,718 thousand Euro in 2024, in a high increase compared with 2015 when the deficit was only 247,964 thousand Euro (Fig. 3).
From 2015 to 2024 only one country (Lithuania) switched from positive to negative meat trade balance.

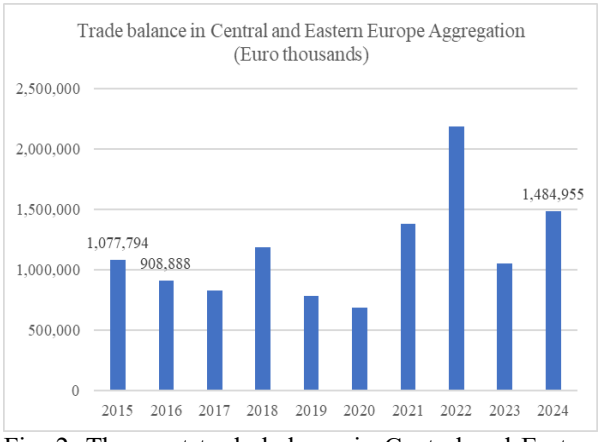


Fig. 2. The meat trade balance in Central and Eastern Europe (CEE) build-up between 2015 and 2024 (Euro thousands)
Source: ITC [9].

The positive meat trade balance of Poland is based on a value of exports of 8,185,619 thousand euro, comparative with only 2,201,619 thousand euro imports.

As for Romania, the meat import value is 4 time higher than the meat export value: 397,182 thousand euro exported meat value in 2024, comparative with 1,600,147 thousand euro imported meat value in 2024.

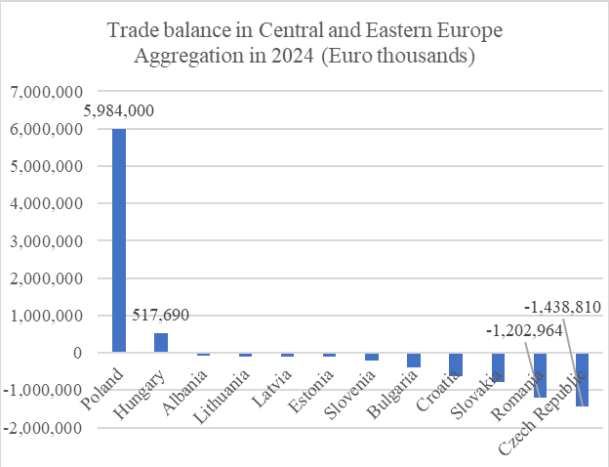


Fig. 3. The meat trade balance in Central and Eastern Europe (CEE) aggregation in 2024 (Euro thousands)
Source: ITC [9].

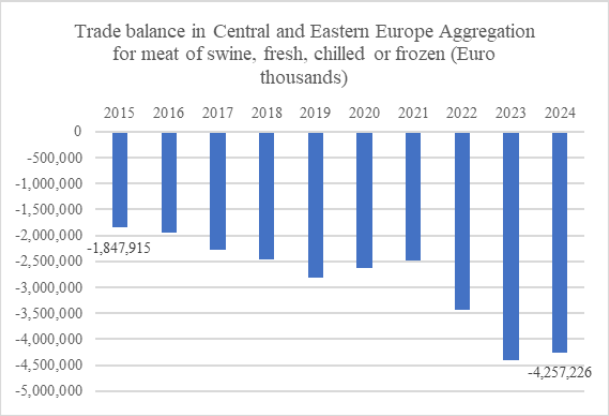


Fig. 4. Trade balance in Central and Eastern Europe build-up for meat of swine, either fresh, chilled or frozen (Euro thousands)
Source: ITC [9].

In 2024 Spain (436,820 thousand euro), Germany (278,667 thousand euro), Hungary (277,329 thousand euro), Netherlands (160,929 thousand euro) and Poland (152,429 thousand euro) covered most part of the meat import demand from Romania. The trade balance for swine meat in the CEECs show an increased deficit from 1,847,915 thousand euro in 2015 to 4,257,226 thousand euro in 2024.

Romania had the highest swine meat trade balance deficit in 2024, of 1,073,764 thousand Euro, followed by Poland with 945,679 thousand Euro and Czech Republic with 810,366 thousand Euro (Fig. 4, Fig. 5).

The same countries mentioned for Romania's total meat imports are also among the top exporters of swine meat to Romania.

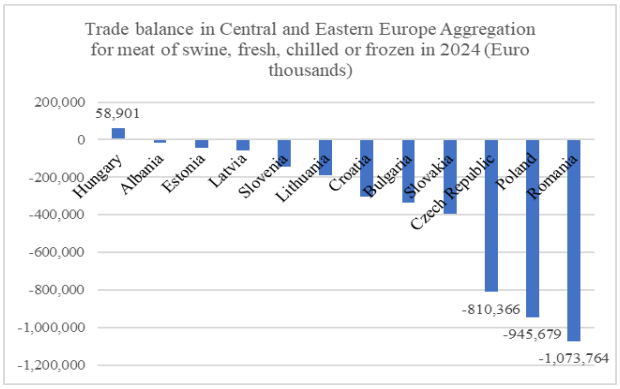


Fig. 5. Trade balance in Central and Eastern Europe build-up for meat of swine, either fresh, chilled or frozen in 2024 (Euro thousands)
Source: ITC [9].

Poland imported in 2024 swine meat mainly from Denmark, Germany, Belgium, Spain and Netherland, while Czeck Republic imported in the same year most part of the swine meat from Spain, Germany, Poland, Belgium and Netherland.

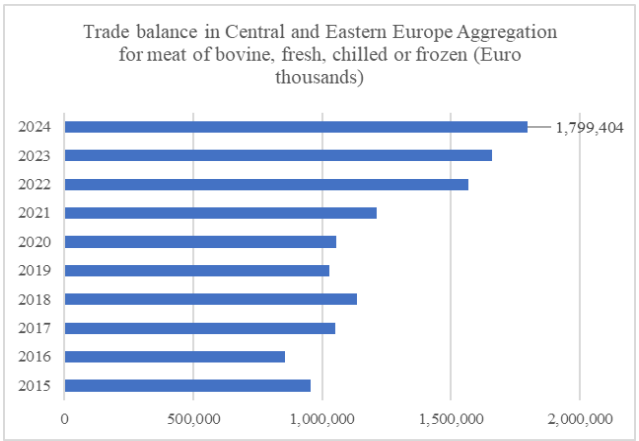


Fig. 6. Trade balance in Central and Eastern Europe build-up for meat of swine, either fresh, chilled or frozen in 2024 (Euro thousands)
Source: ITC [9].

In the frozen bovine meat category, the trade balance of the CEECs in 2024 showed a surplus of 314,939 thousand euros.

The CEECs region recorded in 2024 a positive trade balance for meat of bovine either fresh, chilled or frozen. While CEECs recorded a positive balance of 1,484,465 thousand euro for fresh and chilled meat bovine, Romania had in 2024 a negative trade balance for this category of 21,832 thousand euro.

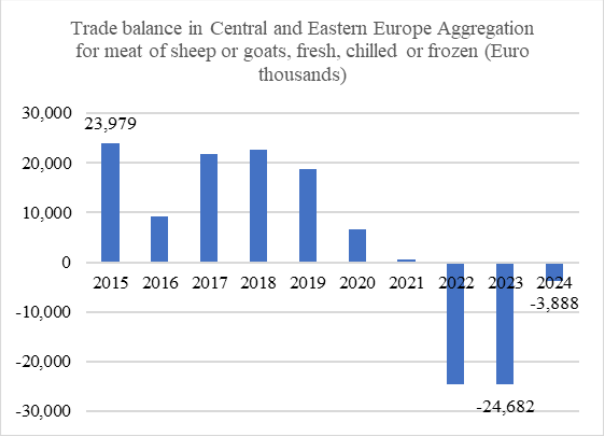


Fig. 7. Trade balance in Central and Eastern Europe build-up for meat of sheep or goats, fresh, chilled or frozen (Euro thousands)
Source: ITC [9].

Poland and Romania are in opposing positions, the first, in the top, with a positive trade balance for this category of 314,939 thousand euro, and the second, the last, with a negative balance of 48,526 thousand Euro.
The trade balance for sheep and goat meat, fresh, chilled, or frozen, was slightly negative in 2024, whereas in 2015 it recorded a positive value.

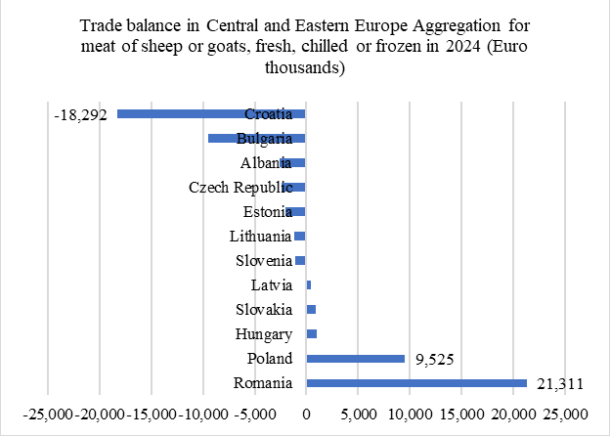


Fig. 8. Trade balance in Central and Eastern Europe build-up for meat of sheep or goats, fresh, chilled or frozen in 2024 (Euro thousands)
Source: ITC [9].

The trade balance of the meat from the poultry sector recorded a positive value of 3,999,406 thousand Euro in 2024 comparative with only 1,761,801 in 2015. Only Poland, Hungary and Slovenia recorded a positive trade balance for poultry meat in 2024. Romania that imported poultry meat worth 245, 840 thousand euro in 2024, recorded a negative balance of 1,442 thousand euro in euro in 2024.

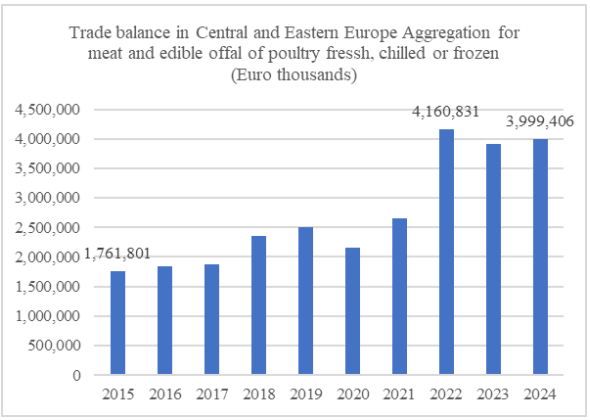


Fig. 9. Trade balance in Central and Eastern Europe aggregation for meat and edible offal of poultry, fresh, chilled or frozen in 2024 (Euro thousands)
Source: ITC [9].

CONCLUSIONS

The CEECs increased their dependence for meat imports in the last decade due to the decrease of their livestock, which manifest with few exceptions. The meat consumption is depending heavily from the huge imports from Germany, Spain, Netherlands or Belgium. The main deficit for meat trade in the CEECs is related with the swine meat, associated with the huge pig livestock decline. The poultry meat is the only sector that brings a significant contribution to the trade balance for meat in the CEECs, assuring its overall positive value and having Poland as the main engine in the region. Two aspects can be related with the importing countries: the distance between countries implied in trade and the the robustness of each category of livestock production and level of development of processing sector of the exporting country. Taking into account the inclusion of Romania and Bulgaria in the Schengen space and the switch to Euro of Bulgaria, in the context of improving infrastructure in these two countries, an

increase of meat trade can be seen in the next years in this region of CEE.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

FOOD SYSTEM SUSTAINABILITY AND SAFETY IN ROMANIA: BETWEEN CONSUMER EXPECTATIONS AND STRATEGIC CHALLENGES

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Abstract

This paper analyses a series of relevant aspects regarding food security as an integral part of sustainable development, with a particular focus on Romania in 2024, as well as the factors influencing food security both nationally and globally. All these elements are addressed to identify future steps, perspectives, and specific challenges for regional and global food security in the coming years. Currently, Romania faces a range of emerging risks, while global issues increasingly impact sustainable development and food security. It is crucial to approach food security as an essential aspect of social stability, capable of preventing significant imbalances within communities. Sustainable development, in this context, involves finding a balance between the current needs of the region and the preservation of resources for future generations. This process includes short- and long-term objectives, addressing economic and environmental challenges, and leveraging local agri-food potential, all of which are closely interconnected. The methodology employed in this study focuses on a SWOT analysis, examining the strengths, weaknesses, opportunities, and threats related to food and nutritional security in Romania. This analysis is grounded in the four essential dimensions of food security: availability, stability, economic access, and utilization. Additionally, the study examined the Global Food Security Index (GFSI) in Europe, reflecting levels of food access and the population's ability to secure adequate, safe, and nutritious food. The aim was to identify the most precise and statistically valid forecasting method.

Key words: *food security, food sustainability, availability, stability, consumption*

INTRODUCTION

In recent years, an increasing number of people have begun to focus on food security, particularly on the quality of products consumed daily, from the perspective of food safety. It must be acknowledged that, in many cases, there is confusion between the two concepts, food sustainability and food safety, which are often considered synonymous. However, food sustainability is just one of the key components of food security. Essentially, food sustainability encompasses all indicators related to how food reaches the population [1], while food security focuses more on aspects concerning product quality, hygiene, and safety. With the domestic market increasingly exposed to the dynamics of international food chains and recent inflationary pressures, Romanian consumers have become more aware of the importance of quality, traceability, and the origin of agri-food products. Consumption choices are influenced not only by price, but also by perceptions of health risks, environmental impact, and support for the local economy. Thus, food security is now perceived as a right, not just a necessity, and agri-food systems must be rethought to meet these multiple expectations [7]. Based on this definition provided by the FAO, four dimensions of food security can be identified: food availability, economic and physical access to food, food utilization, and stability (vulnerability and shocks) over time (FAO) [16]. It is true that without ensuring a minimum level of product quality, discussions

about the economic aspect of ensuring access to food become futile. Food security, on the other hand, revolves around generating food production at a productivity level sufficient to sustain the human population.

Food sustainability, food security, and food safety are three critical concepts related to the production, distribution, and consumption of food. In summary, food sustainability emphasizes the long-term environmental impact of food production, food security underlines access to food for all, and food safety addresses protecting consumers from foodborne illnesses. Together, these concepts are essential for creating a healthy, equitable, and resilient food system capable of meeting the needs of present and future generations [3]. Food safety and security are two complementary elements of a sustainable future. This paper argues that, in the long term, the goals of food safety and security must be aligned to achieve sustainability, and trade-offs between these three objectives must be carefully managed and evidence based.

Exploring the similarities and differences between the three terms—food sustainability, food security, and food safety—we observe that food sustainability focuses on the environmental impact of food production, promoting sustainable agriculture, reducing waste, and conserving natural resources. It encompasses practices that are environmentally responsible, socially equitable, and economically viable. On the other hand, food security seeks to ensure that all individuals have access to sufficient, safe, and nutritious food to meet their dietary needs and lead a healthy life. It addresses issues of hunger, malnutrition, and poverty, involving efforts to improve food availability, access, utilization, and stability. Finally, food safety deals with preventing contamination and foodborne illnesses throughout the food supply chain. It involves maintaining strict standards, proper handling and storage practices, and regular inspections to protect consumers from harmful substances and ensure safe food consumption. The idea of sustainable farming is based on increasing production alongside safe and consistent yields with minimal environmental impact while ensuring the population's food security [3]. Sustainable food production fundamentally relies on the availability of fertile land, water, nutrients, and a suitable climate to produce enough high-quality food. Unfortunately, in recent years, a trend has emerged, both among the civilian population and Romanian institutions, to underestimate the importance of other factors contributing to food security. This situation has arisen from the belief that a normal level of food sustainability [2] has long been achieved and cannot decrease once reached. Consequently, all efforts are directed toward increasing the quality of consumed products.

In Romania, there have been constant concerns regarding food security, including during the Covid-19 pandemic, due to worries about increasing trade deficits in certain product categories, under the pressure of rising consumption of high-nutritional-value products (animal-based products, vegetables, fruits, fish), against the backdrop of policies to increase household incomes. Today, an agri-food product must not only guarantee safety for consumption but also have a minimal ecological footprint; it must meet the producer's expectations and contribute to social and human development [4]. Since agricultural production is responsible for food security, safety, and environmental protection, the consumption of organic food based on ecological behaviours can enhance the commercial opportunities of organic agriculture for production, processing, and trade, bringing significant benefits to society [5]. In this context, the paper analyses a series of relevant aspects regarding food security as an integral part of sustainable development, with a particular focus on Romania in 2024, as well as the factors influencing food security both nationally. The SWOT analysis emphasizes the strengths, weaknesses, opportunities, and threats related to food and nutritional security being grounded in its four essential dimensions: availability, stability, economic access, and utilization.

MATERIALS AND METHODS

The study relies on data gathered manually from the Eurostat European Statistics Institute

[14], the National Institute of Statistics [20], World Bank [22, 23, 24], FAO [15, 16], European Commission [12, 13] and reports published on indicators related to agricultural sustainability, food security, and environmental sustainability over six years (2016-2024). The methodology employed includes a SWOT analysis of food security and nutrition in Romania, highlighting the vulnerabilities that impact the population. Among the most significant deficiencies is the lack of self-sufficiency in the production of certain staple foods, such as meat, fruits, sugar, and fish, where systematic deficits are compensated through imports. This aspect indicates a significant economic dependency on external markets. The paper provides a detailed overview of the strengths, weaknesses, opportunities, and threats associated with Romania's food security, considering key factors influencing the availability, accessibility, and quality of food. The SWOT analysis highlights both competitive advantages, such as the extensive and fertile agricultural land, and major challenges, such as dependency on imports for essential products and vulnerability to climate change. By identifying development opportunities, such as accessing European funds for modernization, and potential threats, such as international market fluctuations, the study proposes solutions to enhance the resilience of the agri-food sector and ensure sustainable food security [13].

RESULTS AND DISCUSSIONS

The cultivated area and production of main crops play a pivotal role in ensuring food security. In Romania, leveraging fertile agricultural land and improving crop productivity contribute to stable food supplies and economic resilience. Policymakers must prioritize sustainable agricultural practices and crop diversification to address future challenges and ensure long-term food security. Sustainable agricultural practices play a vital role in ensuring a secure and consistent food supply, contributing to global food security and safeguarding food safety. [21] These practices aim not only to produce sufficient food to meet the needs of a growing global population but also to guarantee its quality and safety [18].

Table 1. The cultivated area and production of main crops

No.	Crops	Cultivated area		Total production		Differences 2023 compared to 2022 (±)	
		thousand ha	thousand ha	thousand tons	thousand tons	thousand ha	thousand tons
		2022	2023	2022	2023	2022	2023
1	Grains for grains	5,184	5,238	18,861	20,571	54	1,710
3	Wheat	2,169	2,208	8,684	9,635	39	951
4	Barley and two-row barley	426	501	1,707	2,001	75	294
5	Oats	78	76	172	155	-2	-17
6	Corn for grains	2,431	2,373	8,037	8,522	-58	485
7	Leguminous crops for grains	76	102	119	164	26	45
8	Oilseed crops, including:	1,701	1,859	3,584	4,122	158	538
10	Sunflower	1,093	1,089	2,107	2,028	-4	-79
11	Soybeans	136	141	244	300	5	56
12	Rapeseed	469	625	1,230	1,787	156	557
13	Potatoes	81	77	1,346	1,085	-4	-261
14	Vegetables	178	179	2,426	2,466	1	40

Sources: National Institute of Statistics (INS) 2022-2023 [20], Eurostat 2022-2023 [14].

The table provides a comparative analysis of cultivated areas and total production of major crops in Romania for 2022 and 2023, highlighting changes in both the areas cultivated and the resulting yields. These differences are crucial for understanding agricultural trends and identifying factors influencing crop production.

- The total cultivated area for cereals increased by 54 thousand ha in 2023, resulting in a

significant rise in total production by 1,710 thousand tons. This trend indicates improved agricultural practices, favourable climatic conditions, or increased investments in cereal production.

- Wheat cultivation expanded by 39 thousand ha, leading to a production increase of 951 thousand tons. This suggests enhanced productivity, possibly due to improved seed varieties, better soil management, or favourable market demand.
- Barley exhibited a notable expansion in the cultivated area (75 thousand ha), accompanied by a production growth of 294 thousand tons. This increase reflects growing demand and the crop's adaptability to diverse climatic conditions.
- Oats showed a slight reduction in both cultivated area (-2 thousand ha) and production (-17 thousand tons). This decline may be attributed to shifting farmer preferences toward more profitable crops or less favourable market conditions.
- Despite a reduction in the cultivated area (-58 thousand ha), corn production increased by 485 thousand tons, indicating significant yield improvements. This could result from advancements in hybrid corn varieties, better irrigation, or optimal planting conditions.
- The cultivated area for legumes expanded by 26 thousand ha, resulting in a production increase of 45 thousand tons. This growth highlights the increasing importance of legumes in crop rotations due to their nitrogen-fixing properties and their role in enhancing soil fertility.
- The total area for oilseeds increased by 158 thousand ha, with a corresponding production rise of 538 thousand tons. This growth underscores the economic value of oilseeds in both local and international markets.
- Sunflower: A slight decrease in cultivated area (4 thousand ha) and production (-79 thousand tons) may indicate challenges in sunflower cultivation, such as adverse weather conditions or pests.
- Soybeans: Both area and production increased by 5 thousand ha and 56 thousand tons, respectively, reflecting growing interest in soybeans due to their high protein content and market demand.
- Rapeseed: Rapeseed showed the most significant expansion, with an increase of 156 thousand ha and 557 thousand tons in production. This highlights rapeseed's growing importance as a biofuel feedstock and an oil crop.
- Both the cultivated area (-4 thousand ha) and production (-261 thousand tons) declined, likely due to reduced profitability or competition from imported potatoes. This trend raises concerns about domestic potato self-sufficiency.
- Vegetables showed a marginal increase in both cultivated area (1 thousand ha) and production (40 thousand tons). This modest growth suggests stability in vegetable demand and supply, supported by local consumption trends.
- Expanding crops: Wheat, barley, legumes, and rapeseed are experiencing notable growth, likely due to favourable economic and environmental factors.
- Declining crops: Oats, potatoes, and sunflower have faced declines, possibly due to market shifts, competition, or environmental stressors.
- Yield improvements: Increases in production despite reductions in cultivated areas for certain crops (e.g., corn) highlight advancements in agricultural technologies and farming practices.
- Sustainability implications: The expansion of oilseed and cereal crops reflects a potential shift toward crops with higher market value and export potential, but this must be balanced with environmental sustainability and soil health considerations [8]. Gentilini (2002) highlights that food aid should not be perceived only as an emergency intervention, but as a strategic tool for development, capable of contributing to poverty reduction and strengthening food security [17].

Food security, defined by the availability, accessibility, and utilization of safe and nutritious food, is a critical component of Romania’s development strategy. In a possible scenario of a global food security crisis, characterized by sharp increases in agricultural prices and restricted access to basic goods, the balance of power in international trade could be reversed: exporters become the dominant

actors, capable of influencing the flow of essential food supplies. According to DG Agri (2020), the Member States factsheets provide relevant insights into European agricultural policies. [9]. This imbalance disproportionately affects developing countries, where poverty levels intensify, but also developed nations, where vulnerable groups – including the middle class – directly feel the impact [6]. The annual consumption of agri-food products per capita is a key indicator that reflects not only the food supply but also consumer preferences, economic conditions, and public health trends. This study examines the evolution of this indicator and its implications for national food security (Table 2).

Table 2. Evolution of annual consumption of agri-food products/per capita in Romania

No.	Product	2014	2023	2024	Slope (m)	Intercept (b)	Calculated Y (2025)	Calculated Y (2026)
1	Cereals	172.8	199.8	213.7	4.54	-8,966.98	222.66	231.06
2	Potatoes	59.4	73.5	97.7	3.98	-7,965.48	100.77	98
3	Sugar	24.7	26.6	24.5	0.03	-27.61	25.42	33.17
4	Vegetable oil	12.6	10	13	-0.02	59.94	11.72	19.42
5	Vegetables	124.9	140	147.7	2.53	-4,972.46	152.72	153.32
6	Fruit	56.7	55.8	45.4	-1.1	2,268.73	46.05	40.13
7	Wine	20.6	26.1	27	0.74	-1,470.45	29.01	28.79
8	Meat	73.8	50.5	54.3	-2.41	4,929.17	45.06	46.51
9	Milk	99.4	195.3	215	13.29	-26,668.4	249.66	257.16
10	Fish and seafood	5.6	2.3	3.2	-0.31	623.82	1.86	-4.24

Source: Own calculations based on National Institute of Statistics (INS) 2014-2024 [20].

In 2026, cereal consumption is estimated to reach 231.06 kg per capita, maintaining a steady upward trend (m=4.54). This growth can be attributed to a consistent demand for staple products and the diversification of cereal-derived products, supported by improvements in the agricultural sector.

For potatoes, consumption is projected to reach 98 kg per capita, showing a slight decline compared to 2025. This indicates market stabilization after significant growth between 2014 and 2024 (m=3.98). This trend reflects market maturity and diversification of carbohydrate sources in the population's diet.

Sugar consumption is estimated at 33.17 kg per capita in 2026, showing moderate growth (m=0.03) compared to previous years. This increase reflects steady demand but raises public health concerns, given the potential impact on obesity and metabolic disorders.

For vegetable oil, the projected consumption of 19.42 kg per capita represents a recovery following earlier declines (m=-0.02). This increase indicates market adaptation to consumer preferences for healthier fats and the diversification of available products.

Vegetable consumption continues to grow, with an estimated 153.32 kg per capita in 2026 (m=2.53). This growth can be associated with increased awareness of the importance of vegetables in daily diets and greater market availability.

In contrast, fruit consumption shows a continued decline, reaching 40.13 kg per capita in 2026 (m=-1.10). This decrease could be explained by high costs, low availability, or shifting consumer preferences toward other food categories. Wine consumption remains relatively stable, with an estimated 28.79 litres per capita (m=0.74). This stability reflects a strong tradition of wine consumption and producers' ability to adapt to market demands.

Meat consumption is estimated at 46.51 kg per capita (m=-2.41), indicating a slight recovery after recent declines. This growth may be driven by higher availability and household income recovery but remains below earlier levels. Milk and dairy products show accelerated growth, with projected consumption reaching 257.16 litres per capita in 2026 (m=13.29). This trend reflects increased preferences for dairy products and

effective promotion campaigns highlighting their benefits. Fish and seafood consumption is estimated to decline drastically to a negative value of -4.24 kg per capita (m=-0.31). While this value is unrealistic in practice, it highlights a clear downward trend due to high prices, limited access, and reduced interest in these products.

The paper presents a comprehensive evaluation based on a SWOT analysis of Romania's food security and safety, providing a structured framework to examine the strengths, weaknesses, opportunities, and threats that influence the national food security and safety landscape. By delving into these dimensions, the study aims to offer a clearer understanding of Romania's position in ensuring consistent access to safe and nutritious food for its population, in alignment with domestic needs and European Union standards. According to the European Commission (2018), the Common Agricultural Policy for 2020 was designed to respond to future challenges related to food security, sustainable management of natural resources and balanced development of rural territories [12].

Table 3. The Internal Factor Evaluation (IFE) Matrix-2024

No.	Internal factors	Weight	Rating	Total Weight
	Strengths			
1	Existence of local agrifood market networks	0.09	4	0.36
2	High production capacity and fertile agricultural land suitable for various crops and livestock farming	0.08	4	0.32
3	Favourable climatic conditions for agricultural activities in certain regions	0.07	4	0.28
4	Longstanding tradition and expertise in agricultural practices	0.06	3	0.18
5	Experienced agricultural workforce	0.06	3	0.18
6	Improved food safety standards due to EU regulations	0.06	4	0.24
7	Access to European funds for modernization and rural development	0.08	4	0.32
8	Diversified production capacity for crops and livestock	0.05	3	0.15
	Subtotal	0.55		1.67
	Weaknesses			
1	Dependence on imports for staple foods such as meat, sugar, and fish	0.08	4	0.32
2	Systematic deficits in certain food categories. impacting self-sufficiency	0.06	3	0.18
3	Instability of domestic agricultural production due to weather and technological conditions	0.08	4	0.32
4	Low-income levels, particularly in rural areas	0.07	3	0.21
5	Significant regional disparities in economic development	0,05	3	0,15
6	Food consumption heavily reliant on inexpensive, calorie dense foods such as cereals and potatoes	0.06	3	0.18
7	Insufficient intake of animal protein and essential nutrients	0.05	3	
	Subtotal	0.45		1.36
	Total	1,0000		3.03

Source: Own calculations based on National Institute of Statistics (INS) 2022-2024 [20].

Strengths:

1. Existence of local agri-food market networks:

Local agri-food markets play an essential role in reducing the distribution chain, minimizing food waste, shortening storage times, and maintaining food freshness. These markets strengthen the local economy by providing direct access for local producers to consumers. Additionally, they support biodiversity by promoting native products, including local varieties and breeds.

Impact on food security: Reducing dependence on imports and ensuring access to fresh and safe food for the population.

2. High production capacity and fertile agricultural land:

Romania boasts over 9 million hectares of arable land, offering a competitive advantage for producing cereals, legumes, and industrial crops.

The soil fertility and diversity of pedoclimatic conditions allow crop adaptation to various regions.

Impact on food security: Increased domestic production reduces supply vulnerabilities and

strengthens exports, supporting both food and economic security.

3. Favourable climatic conditions for agricultural activities in certain regions:

Romania's temperate-continental climate supports favourable vegetation cycles for crops such as wheat, corn, sunflower, and vineyards. Moreover, available water resources for irrigation in lowland areas provide an additional advantage.

Impact on food security: Leveraging these favourable climatic conditions ensures stable agricultural production and consistent supply for domestic and international markets.

4. Long-standing tradition and expertise in agricultural practices:

Accumulated experience and traditional farming methods contribute to maintaining sustainable practices and adapting to local conditions. Traditions also encourage the use of local resources and cultivation of traditional varieties.

Impact on food security: Traditions can be integrated with modern technologies to ensure sustainable and efficient agriculture.

5. Experienced agricultural workforce:

Romania's rural population represents a vital resource for the agricultural sector. While mechanization is increasing, farmers' experience in manual labour and traditional techniques remains an advantage.

Impact on food security: Maintaining traditional agriculture and adopting new technologies contribute to increased efficiency and productivity.

6. Improved food safety standards due to EU regulations:

EU integration required Romania to adopt strict food safety standards, leading to enhanced control over production and distribution chains.

Impact on food security: Adhering to these standards improves product quality and protects public health.

7. Access to European funds for modernization and rural development:

EU funds are utilized for modernizing agricultural equipment, building new infrastructure (irrigation, storage, rural roads), and supporting farmers transitioning to sustainable practices.

Impact on food security: Increased production capacity and diversification of crops reduce import dependency and strengthen the agricultural sector's resilience.

Recommendation: Creating an efficient mechanism for accessing and implementing funds can maximize the benefits.

Weaknesses:

1. Dependence on imports for staple foods (Weight: 0.08, Rating: 4, Total Weight: 0.32):

Romania relies on imports for essential products like meat, sugar, and fish, which increases food security vulnerabilities to international price fluctuations.

Recommendation: Stimulating domestic production for these food categories is crucial to reduce dependency.

2. Agricultural production instability due to weather conditions (Weight: 0.08, Rating: 4, Total Weight: 0.32):

Climate change and the lack of modern irrigation infrastructure negatively affect the stability of agricultural production.

3. Low-income levels, especially in rural areas (Weight: 0.07, Rating: 3, Total Weight: 0.21):

At the same time, most forward-looking analyses highlight the complex and often contradictory global dynamics expected to influence food security in the coming years. On one hand, the rapid economic growth observed in emerging markets is projected to lead to a significant increase in per capita food consumption. This growth is accompanied by a major shift in dietary patterns, moving from diets traditionally dominated by cereals and other starchy foods to those that include a higher proportion of animal-based products, fruits, vegetables, and processed foods.

Low incomes limit access to diverse and nutritious foods [19].

Recommendation: Social policies to support vulnerable families, alongside educational programs on nutrition, are necessary.

This paper analyses the influence of external factors on food security in Romania, emphasizing both opportunities and threats that shape the country's ability to ensure a stable and safe food supply. By evaluating key factors and their weighted impact, strategic priorities and actionable directions are identified to

strengthen food security and mitigate vulnerabilities.

Key Opportunities:

1. High-quality agri-food products on the market (0.28): Reflects adherence to EU food safety and quality standards, increasing consumer trust and reducing import dependency. Promoting these products internationally could enhance economic growth.
2. Households offering high-quality food at low prices (0.21): Rural households provide fresh, affordable food, crucial for vulnerable communities. Supporting these households through subsidies and market access could boost local development.
3. Growing interest in organic products (0.18): Rising demand for eco-friendly food highlights a shift toward sustainable consumption. Investments in organic farming and consumer education are essential.
4. Potential for sustainable agriculture (0.30): Romania's natural resources position it for sustainable farming practices, essential for food security and environmental protection. Investments in precision agriculture and climate adaptation are recommended.
5. Improved logistics and supply chains (0.40): Enhancing storage and transportation infrastructure can reduce food waste, improve access to fresh products, and stabilize food availability.

Key Threats:

1. Climate change (0.40): The most significant risk, affecting crop yields and increasing resource pressure. Solutions include developing resilient crop varieties and modern irrigation systems.
2. Economic inequalities (0.21): Low incomes in rural areas limit access to nutritious food. Social policies and subsidies are needed to support equitable access.
3. Global market fluctuations (0.15): Price volatility impacts food affordability, necessitating stronger local production capacities.
4. Geopolitical tensions (0.12): Disruptions in supply chains due to global conflicts stress the need for diversification and local production.
5. Legislative instability (0.08): Policy unpredictability hinders investment in the agri-food sector. Long-term strategies are essential for stability.

Recommendations:

- Integrated policies: Address opportunities and threats holistically to strengthen food security.
- Investments in innovation: Modern technologies, such as precision agriculture, can improve productivity and sustainability [23].
- Climate resilience: Promote sustainable practices and adaptive infrastructure to mitigate climate risks.
- Reduction of inequalities: Implement social policies to ensure equal access to food resources.
- Logistics enhancement: Improve supply chains to reduce food losses and support vulnerable communities.

Romania's food security requires a balanced approach, leveraging opportunities such as improved logistics and sustainable agriculture while addressing major threats like climate change and economic disparities. Strategic investments and policies can enhance the country's resilience and ensure long-term food security [22].

By categorizing these factors distinctly, the SWOT analysis provides a clear and actionable framework for understanding and addressing the multifaceted challenges of food security and safety in Romania.

At the same time, external opportunities, including access to EU funding and increasing demand for traceable, high-quality food products, contrast with looming threats like geopolitical instability and volatile market conditions.

Through this structured SWOT perspective, policymakers, stakeholders, and agricultural entrepreneurs are better equipped to prioritize interventions, promote sustainable food systems, and strengthen consumer trust. Ultimately, aligning strategic development with the principles of sustainability, innovation, and equity is essential for securing Romania's food future in an increasingly complex global context.

Table 4. The Internal Factor Evaluation (IFE) Matrix-2024

No	External factors	Weight	Rating	Total Weight
Opportunities				
1	Quality food available on the agri-food market and in trade	0.07	4	0.28
2	Existence of households offering higher quality food at relatively low prices	0.07	3	0.21
3	Increasing interest in organic products and development of organic farms	0.06	3	0.18
4	High potential for sustainable agriculture	0.10	3	0.3
5	Investments in agricultural innovation	0.06	4	0.24
6	Access to European funds for modernization	0.08	4	0.32
7	Development of sustainable agricultural practices	0.06	3	0.18
8	Promotion of food education	0.05	3	0.15
9	Improvement of logistics and distribution chains	0.10	4	0.4
Subtotal		0.65		1.29
Threats				
1	Climate change	0.1	4	0.4
2	Global market fluctuations	0.05	3	0.15
3	Geopolitical tensions	0.04	3	0.12
4	Economic inequalities	0.07	3	0.21
5	Legislative instability	0.04	2	0.08
6	Food safety risks	0.05	3	0.15
	Subtotal	0.35		1.11
	Total	1.00		2.4

Source: Own calculations based on National Institute of Statistics (INS) 2022-2024 [20].

Another important indicator is Global Food Security Index (GFSI) [7], which plays a key role in analysing food security by providing a structured framework for evaluating the accessibility, availability, quality, and safety of food, as well as the sustainability of Romania's food systems in the context of global standards. Romania ranks 36th globally in food security, excelling in food standards and GDP per capita (1st place globally), while facing challenges in availability (17th place) and production sufficiency (47th place). This study evaluates Romania's performance in food security, focusing on accessibility, availability, and quality & safety, based on the Global Food Security Index (GFSI) 2024. Romania's accessibility score increased to 69.80 (+1.30 from 2023), reflecting improved affordability and economic support for food access, with notable progress in household purchasing power (GDP per capita: 102) and robust food safety standards [10].

Table 5. Determinant factors for food security

	Category of FSI	Score 2024	Score 2021	Change in 2024 versus 2023	RO place worldwide	Global score
1	Overall	72.3	69.11	+3.19	36	61.2
2	Access	69.8	67.5	+1.30	42	59.5
3	Food expenses	46.2	43.33	+2.10	72	57.8
4	Poverty rate	82.5	82.15	-0.50	31	77.5
5	GDP per capita	102	100	+2.00	1	68
6	Food standards	101	100	+1.00	1	64
7	Safety programs	73.5	69.01	+3.00	34	62.8
8	Farmer funding	68.4	65.86	+1.70	19	59.2
9	Availability	27.5	25.08	+1.40	17	18.4
10	Supply adequacy	54.5	52.06	+1.50	59	60.5
11	Sustainability	71.8	69.41	+1.80	101	88.8
12	Agri infrastructure	67.2	64.89	+1.20	23	50
13	Production sufficiency	88.5	85.6	+1.50	47	40
14	Political risk	101	100	+1.00	100	102
15	Corruption	97.2	95.59	+1.20	14	88
16	Urban capacity	75.4	72.82	+1.40	31	60.5
17	Food waste	96.5	94.5	+1.50	54	59
18	Quality & Safety	101	100	+1.00	1	84
19	Production volatility	58	56.07	-0.90	36	47
20	Nutrition standards	67.8	65.9	+1.30	30	51.5
21	Protein quality	77.5	74.7	+1.50	12	39.5

Source: Own calculations based on INSSE-Romania 2022-2024 [20].

However, challenges persist in addressing socio-economic disparities, with the poverty rate declining slightly to 82.50.

Table 5 highlights Romania's progress in terms of food security, based on 21 indicators included in the FSI (Food Security Index). Overall, Romania is recording significant

progress, with an increase of +3.19 points in the overall score and a position in 36th place worldwide, above the global average score (72.3 compared to 61.2) (Table 5). In terms of availability, the score rose to 27.50 (+1.40), driven by enhanced supply adequacy (54.50) and investments in agricultural infrastructure (67.20) and sustainability (71.80). Despite these gains, production sufficiency (88.50) remains vulnerable to climate risks and fluctuating crop yields.

Romania achieved a perfect score of 101 in quality and safety, underlining its strong adherence to food safety and nutrition standards. Improvements in nutrition standards (67.80) and protein quality (77.50) reflect diversification efforts, though production volatility (58.00) highlights the need for greater resilience.

The 2024 GFSI data underscores Romania's significant progress in strengthening food security. Improvements in accessibility, quality, and sustainability reflect effective policy measures and investments in agricultural infrastructure. However, addressing production volatility and regional disparities remains critical for ensuring long-term resilience and equitable access to safe and nutritious food for all citizens [11].

The figure effectively illustrates Romania's trajectory in food security, showcasing notable progress across various dimensions while also highlighting areas requiring further strategic focus. The overall trend suggests a positive trajectory, but ongoing challenges related to production stability and socio-economic disparities remain critical for achieving sustainable food security [15].

The chart compares Romania's performance in food security between 2021 and 2024, based on scores derived from the Global Food Security Index (GFSI) [11]. The data provides insights into the country's progress across key dimensions such as accessibility, availability, and quality & safety.

Romania's overall GFSI score increased from 69.11 in 2021 to 72.30 in 2024, indicating a strengthened food security environment driven by economic growth and improved policies.

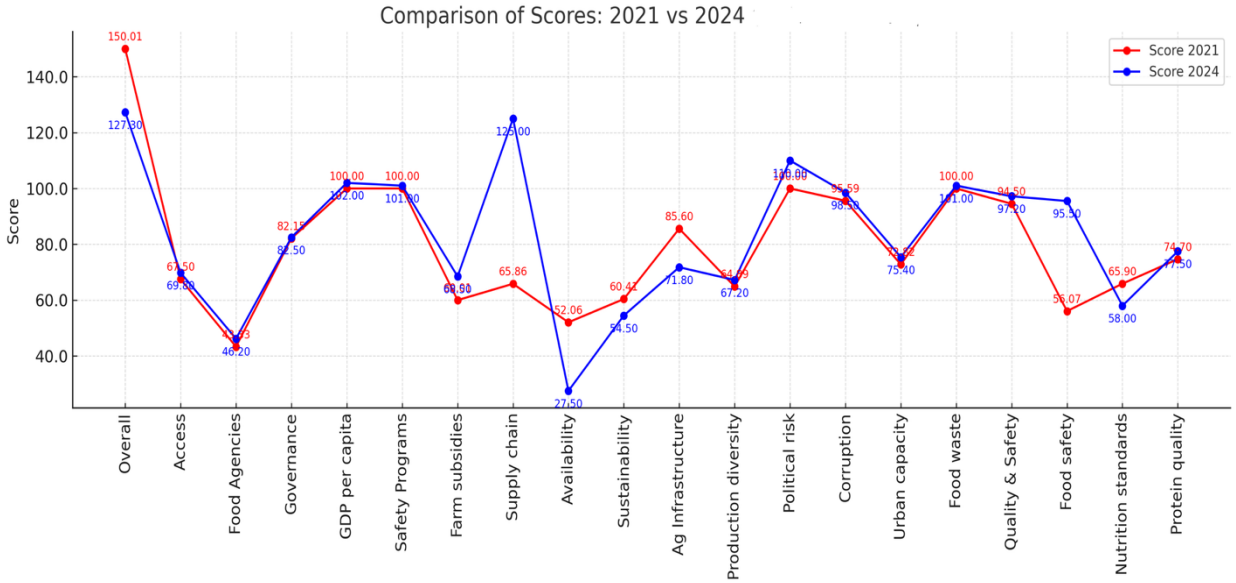


Fig. 1. Comparative analysis of Romania's food security performance in 2021 and 2024 based on GFSI dimensions
Source: Global Food Security Index (GFSI), Economist Impact – 2021 & 2024 reports

Accessibility. Scores for food access (67.5 to 69.8) and food expenses (43.33 to 46.2) reflect modest improvements in affordability, while a slight rise in GDP per capita (100 to 102) highlights increased purchasing power. However, poverty rate saw minimal change, signalling persistent socio-economic.

Quality and Safety. Romania maintained a perfect score of 101, highlighting robust food safety standards.

Improvements in nutrition standards (65.9 to 67.8) and protein quality (74.7 to 77.5) reflect enhanced dietary diversification. Production volatility remains a concern, with a slight decline (56.07 to 58.00), underscoring climate-related risks.

CONCLUSIONS

Having the intention of analyzing the agricultural sustainability of Romania, in comparison with European countries in economic, environmental, social, and political terms, by analyzing the central agricultural food policies related to food sustainability worldwide, the authors started from the assumption that food security policies are indeed an integral part of agriculture-food policies. We observed that the inclusion of food security measures within broader agricultural and food policies is crucial to ensure the production, processing, distribution, and consumption of safe and wholesome food. These policies aim to protect public health, prevent foodborne illnesses, and maintain consumer confidence in the food system.

Given Romania's fluctuating position in the Global Food Security Index and the identified indicators related to food security improvements, it is advisable to implement comprehensive educational campaigns and awareness initiatives targeting consumers, producers, and stakeholders.

Romania’s food security is on a positive trajectory, supported by targeted investments and policy reforms. However, achieving long-term resilience requires addressing climate risks, economic disparities, and production inefficiencies while capitalizing on opportunities like sustainable agriculture and organic product development. Romania’s food security landscape is improving steadily, supported by robust food safety standards, economic growth, and investments in infrastructure and sustainability.

1. Food Security as a Pillar of Sustainability

Food security is integral to sustainable development, requiring balanced efforts to meet current needs while preserving resources for future generations. Romania's progress reflects a growing alignment with global sustainability goals.

2. Improvements in Production and Consumption Trends

Significant progress in key crops like wheat, barley, and rapeseed highlights Romania's agricultural potential, while rising consumption of cereals and dairy indicates increased demand for staple and nutritious products. However, declining fruit consumption and import dependency on staples like meat and fish underline persistent vulnerabilities.

3. Key Challenges

Climate change, economic disparities, and production volatility remain critical threats to food security, affecting self-sufficiency and resilience [24]. These challenges emphasize the need for adaptive strategies and stronger support for rural and vulnerable communities.

4. Opportunities for Development

Investments in sustainable agriculture, enhanced logistics, and European funding offer avenues to improve food production, reduce waste, and enhance resilience. Promoting organic farming and modernizing agricultural practices can further strengthen the agri-food sector.

5. Strategic Recommendations

Policies should prioritize sustainable practices, socio-economic equity, and climate adaptation. Leveraging innovation, improving local production, and reducing import dependency are essential for ensuring long-term food security and stability.

Romania has made progress in food security, but addressing climate risks, import reliance, and social disparities is vital for sustainable growth. With targeted policies and investments, Romania can achieve a resilient, equitable, and secure food system.

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Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

TECHNOLOGY TRANSFER IN ROMANIA`S AGRO-FOOD SECTOR. AN OVERVIEW

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Abstract

Technology transfer represents a strategic domain for enhancing the competitiveness and economic sustainability of Romania`s agro-food sector. The adoption of modern technologies in production, processing, and distribution can optimize resources, reduce costs, and support sustainable development. This paper analyzes technology transfer in Romania`sagro-food value chain. The research results indicate an underdeveloped infrastructure for processing, such as facilities for sorting, packaging, and freezing, which limits the added value of products. Technological integration, whether through precision agriculture or short supply chains, supports farmers by reducing intermediaries and logistical costs. Public policy documents highlight the need for financial support, collaboration between farmers and academia, and the implementation of successful models. To leverage the potential of technology transfer, integrated policies are necessary to support farmers' associations, modernize infrastructure and promote innovation. These measures can transform Romania`s agro-food value chain into a competitive and sustainable sector, capable of meeting both domestic and international market demands.

Key words: *technology transfer, agrifood chain, challenges, research units*

INTRODUCTION

An applied research that addresses major societal issues is a priority on the agenda of the European Union (EU). The main directions targeted by funding through the multi-annual research and innovation framework programmes are the development of European research, aiming to be more competitive at international level; strengthening industrial innovation, investments in key technologies; easier access to funds and support for SMEs; technological progress aimed at achieving viable products with market commercialization potential; development of mutually beneficial partnerships between the public and private sectors [6].

Research and technological developmentis a priority of EU policy, as reflected in European regulations. Since 1980, a framework programme dedicated to research has been launched. During the period 2014–2020, the main method of financing European research was the Horizon 2020 programme, which aimed primarily at maintaining the EU's international competitiveness. Currently, the financing of these objectives is carried out through Horizon Europe funds, active for the period 2021–2027 [8].

An analysis of the competitiveness of European agro-food chains and of the key factors influencing their activity is carried out within the COMPETE project. Innovation is essential for competitiveness and is based on the interaction of main actors: farmers, industry, research centres, public authorities, universities, and consumers. The report recommends the development of networks and interdisciplinary collaborations to facilitate technology transfer and adapt knowledge to market needs. Open innovation involves cooperation between companies and external actors (research entities, universities, clusters, etc.) for a faster innovation process. The food industry is particularly dependent on this form of innovation, as companies require greater external resources and technological expertise. Although the EU has developed several tools to support innovation (Horizon 2020, EIP-AGRI, structural and cohesion funds), there is no coherence between policies on education, research, agriculture, and rural development.

Experts from Wageningen University recommend integrating these policies into a functional system (Agricultural Knowledge and Innovation System) that can support innovation in all links of the agro-food chain. The report mentions that Romania is classified among European countries with a weak national innovation system, characterized by poor links between stakeholders (farmer–industry–research–government). From the perspective of RDI (research, development, and innovation) expenditures, Romania's system records the lowest public and private investments [11].

The same recommendation regarding a coherent framework of public policies to support innovation in the "from farm to fork" process — essential for supporting the competitiveness of the agro-foodindustry — is also found in the European Commission (2009) report [16]. Technology transfer must be based on public-private partnerships, with simplified access to funding for SMEs and support for RDI initiatives targeting the agro-food chain [7].

For emerging economies, the development and modernization of agriculture requires public agricultural extension services that can mediate the relationship between research and farmers. The lack of public investments and diffusion mechanisms leads to the isolation of innovations within academia, without impact on the business environment. Agricultural research technology transfer is not available to farmers due to institutional separation between universities, research institutes, and R&D units, significantly reducing the practical applicability of innovations. Reforming the system must aim at integrating these actors into a coherent national technology transfer system [5].

The application of transferred technologies in practice is conditioned by economic factors, namely the capacity of the agricultural extension system to support farmers in integrating innovations into production. The absence of a standardized technology transfer system in the agro-food sector may lead to isolated and uncoordinated actions [3].

Academic institutions with well-developed research centres can act as promoters of technology transfer, through pre-acceleration programs and academic entrepreneurship. Entrepreneurial skills and market-oriented research are necessary. The main barriers to technology transfer in the agrifood sector are research directions misaligned with business needs and limited business competencies among researchers. The development of regional innovation ecosystems can stimulate cross-sector collaboration [3].

Research conducted under the auspices of FAO by Duczmal (2001) shows that technology transfer activities are key components in modernizing and increasing the competitiveness of the agro-food sector, especially in transition economies such as Romania. To ensure successful TT, efficient knowledge transfer systems in agriculture are required to support accessible production practices based on applied research. Otherwise, scientific research results remain in academic centres, with limited economic or social impact. The lack of correlation between research entities, academic institutions, and agricultural production units is the main weakness of TT. These entities often operate independently, without common objectives, leading to duplication of activities and low practical applicability of scientific results. System reform should include the strengthening of connections between stakeholders, development of collaborative platforms, and applied research aligned with the real needs of agricultural production and food processing [5].

At EU level, there are strategic initiatives promoting artificial intelligence along the agro-food chain (e.g., Digital Innovation HubsTesting and Experimentation Facilities and the Data Act), with the main goal of creating a community-wide database in the agricultural domain. Fair access to AI-based technologies, avoiding monopolies in data usage, and support measures for small farms in the digital transition are key actions. AI can have a major impact on European agro-food chains, through massive data collection and automated decision algorithms. AI tools can optimize agricultural resources (water, fertilizers, inputs) and enhance precision agriculture. The main challenges in the sector

concern data privacy, ethical principles, and the lack of digital skills among farmers [4].

Technology transfer in horticulture can bring several benefits to Romanian farmers. EU funds can be used to create specialized TT units (e.g., the Advanced Institute for Horticultural Research in Transylvania), which can offer an integrated framework for all segments of horticulture, promoting collaboration between research units, industrial processing, and administrative departments [19].

A study on TT in the agro-food sector, carried out by multinational companies in agro-food processing, evaluates three main channels: contract farming, internal collaboration for innovation, and spillover effects of foreign direct investments. Although FDIs may have some technological benefits, in many cases the overall impact on the innovation system of the host economy is limited or selective. The author recommends cautious approaches in public policy formulation and proper integration of multinationals into the local economy to enhance technology transfer [15].

The digitalization of the agro-food system is a European-level priority, with the potential to improve its efficiency and sustainability.

The application of computerized data management systems and modern technologies associated with precision agriculture contributes to the efficiency of agricultural production, food processing, as well as marketing and consumption activities. The large-scale integration of IoT and ICT supports the development of food products tailored to individual needs and better synchronization among economic actors along the agri-food value chain [14].

The import of high-performance technology, namely modern agricultural machinery, can represent a model of good practice in technology transfer. The example of Uzbekistan, which has achieved technological progress and improved sesame export capacity due to the import of specialized agricultural equipment from Turkey, can also be applied to other emerging economies. Econometric models used to assess the impact of technology transfer show that exchange rates and domestic demand can have a significant effect on Uzbekistan's sesame exports [1].

Agricultural consultancy activities and the involvement of specialized educational institutions in agricultural education have a positive impact on achieving technology transfer in Russia. Modernizing infrastructure and improving innovative support methods for agro-industrial production, along with strengthening collaboration among science, education, and industry, can support the continuous development of the agricultural sector [21].

The use of digitalization in agro-food production has been boosted by Industry 4.0, and the implementation of these modern solutions was accelerated by COVID-19. The integration of advanced digital technologies — including AI, big data, IoT, blockchain, smart sensors, robotics, digital twins, and immersive tools like virtual or augmented reality — offers viable solutions to counter the disruptive effects of global crises such as pandemics and climate shifts on food systems. Although digital transformation and the adoption of Industry 4.0 approaches in agri-food chains have begun, these efforts remain at an early stage and demand long-term commitment to enable efficient knowledge and technology transfer [10].

Technology transfer and technological adoption remain major challenges in Romania. Technologies transferred from universities or national research entities can be considered in an early stage of development, compared to market-ready technologies, which leads to specific challenges in this field. The research sector in Romania differs relatively from that of other European states. Romanian universities have only recently started to benefit from research funding, with most research historically carried out by public research institutes, under the coordination of the National Research Authority (ANC) or the Romanian Academy. The ANC (formerly the Ministry of Research, Innovation and Digitalization – MCID) coordinates the development of research and innovation policies, while the Ministry of Education and the executive agency UEFISCDI have key roles in project implementation and in the

management of European funding. The public research system is chronically underfunded, characterized by weak institutional capacity, the lack of clear regulations, limited human resources and skills, negative cultural factors, and lack of legislative clarity regarding the commercialization of research results. The system includes 263 public organizations in the RDI field, and a number of private entities (including private incubators, accelerators, and science parks). Public entities include 56 public universities, 46 national research and development institutes, and 65 institutions and research centres under the Romanian Academy. The 34 accredited private universities generally do not benefit from public funds, and some do not carry out any research activities [2].

The research conducted by Stanciu (2018) on innovation and technology transfer in Romania addressed the need to develop these elements to support SMEs and the national economy. The findings highlighted that Romania ranks at the bottom of European innovation indices and that technology transfer is underdeveloped. The study recommended the creation of specialized TT networks and the development of government policies for the sustainable growth of the national economy [17].

In this context, the paper aimed to analyze technology transfer in Romania`s agro-food value chain regarding infrastructure for processing, such as facilities for sorting, packaging and freezing.

MATERIALS AND METHODS

Open-access articles from scientific data bases (Clarivate Analytics, Research Gate, and Google Scholar) were used for bibliographic documentation. Where needed, these sources were complemented by reports from public institutions, research institutes, or professional associations.

The research was based on statistical data provided by Eurostat, the National Institute of Statistics (NIS), and the National Research Authority. The selected information was processed statistically, graphically represented, and interpreted. Artificial intelligence tools (ChatGPT) were used to correct possible language and formatting errors and to ensure the accuracy of English terminology. AI-assisted statistical processing facilitated more efficient identification of patterns and extraction of territorial typologies from complex multi-annual data sets. The results obtained were graphically represented and interpreted. The research conclusions were compared with scientific sources from the literature for validation.

RESULTS AND DISCUSSIONS

In Romania, information related to technology transfer activities is systematized by the National Authority for Scientific Research (ANCS), which has developed a national registry of the entities involved, in the form of the Network of Innovation and Technology Transfer Infrastructures (ReNITT). ReNITT, an initiative of the Ministry of Research and Innovation, aims to increase the visibility of national research and development units, to capitalize on scientific research results, and to enhance the competitiveness of small and medium-sized enterprises through the transfer of technology and knowledge. ReNITT does not have legal personality and lacks the capacity to directly finance technology transfer units. The network has been actively involved in the establishment of the Romanian Association for Technology Transfer and Innovation (ARoTT), which is a legal entity capable of entering international partnerships and participating in international projects [12].

In accordance with legal provisions, the infrastructure is composed of several categories of accredited entities specializing in innovation and technology transfer: Technology Transfer Center (TTC), Technology Information Center (TIC), Technology and Business Incubator Center (TBIC), and ResearchLiaison Office (RLO) [9]. The distribution of technology transfer entities within ReNITT, by category, is presented in Figure 1. The majority of entities fall into the TTC category (36), followed by TIC (6) and TBIC (4). The number of entities specialized in technology transfer is limited. In practice, an analysis of the 46 accredited entities shows that 15 belong to academic

institutions in Romania. Considering that there are 97 accredited universities, only about 15% have an accredited specialized structure. Moreover, these structures are often small in size, generally composed of only 1–2 staff members. By comparison, in Europe, TT entities are usually much larger: 24% of the m employbetween 5 and 10 full-time equivalent (FTE) staff, while 29% employ between 10 and 25 FTEs.

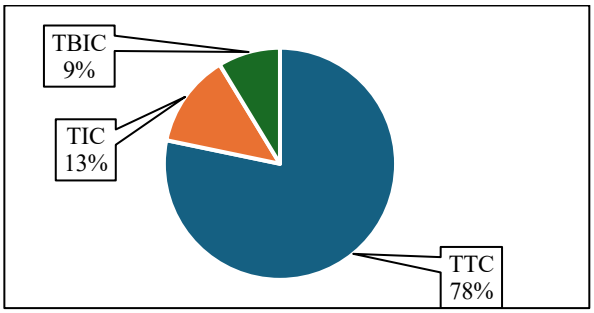


Fig. 1. TT Entities in Romania (by Category)
Source: Author's elaboration based on [12].

The Polytech Technological Transfer and Business Centre, affiliated with the "Gheorghe Asachi" Technical University of Iași, operates with a staff of 20, although a significant number of these employees are also engaged in activities unrelated to technology transfer. Among the 46 identified entities, 23 have specific functions linked to the agro-food sector or associated domains, such as bioeconomy, biotechnology, agriculture, the food industry, or precision farming (Figure 2).

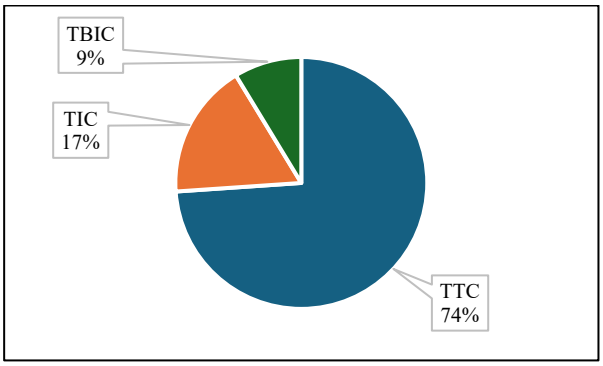


Fig. 2. TT Entities in the Agro-Food Sector (by Category)
Source: Author's elaboration based on [12].

Most of the units withr esponsibilities in this domain are Technology Transfer Centers (TTCs) – 17 in total, followed by Technology Information Centers (TICs) – 4, and Technology and Business Incubator Centers (TBICs) – 2.Of these, 11 are affiliated with universities:
CTT USAMVBT – Banat University of Agricultural Sciences andVeterinary Medicine, Timișoara;
CTT-USAMV AGROBIOLIFE – University of Agronomic Sciences andVeterinary Medicine, Bucharest;
CTT UGAL – "Dunărea de Jos" University of Galați:
CTT UOC – "Ovidius" University of Constanța;
CTT POLITEHNICA 2020 – Politehnica University of Timișoara;
CTT UCB – "Constantin Brâncuși" University of Târgu Jiu;
CTT CENTI – ICIA (Research Institute for Analytical Instrumentation), affiliated with INOE 2000, with university collaboration in Cluj;
CTT INCDTIM – National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca – collaborates with local universities, e.g., Technical University of Cluj-Napoca;
CTTC Cluj – Technical University of Cluj-Napoca;
CTT-UBB-TechTransfer – "Babeș-Bolyai" University of Cluj-Napoca;
CTT UMC – Maritime University of Constanța.
Examples of involved entities include those affiliated with research institutes, chambers of commerce, or private commercial companies. Among them are:IT IND-AGRO-POL – IND-AGRO-POL Association (an independent legal entity); INMA-ITA – National Institute for Research and Development of Machinery and Installations for Agriculture and the Food Industry, based in Bucharest; CTT-ICCF – National Institute for Research and Development in the Chemical and Pharmaceutical Industry, Bucharest; CTT IBA – National Institute for Research and Development of Food Bioresources, Bucharest; CTT BINNOTEH – National Institute for Research and Development in Biological Sciences, Bucharest; CTT ICECHIM – National Institute for Research and Development in Chemistry and

Petrochemistry, Bucharest; CIT ALBATECH – Alba Chamber of Commerce and Industry; IPA CIFATT – ITA Craiova – IPA SA (Research and Design Institute for Automation), Entrepreneurship and Technology Transfer Center, Craiova Branch;
The county-level distribution of these entities is presented in Figure 3.

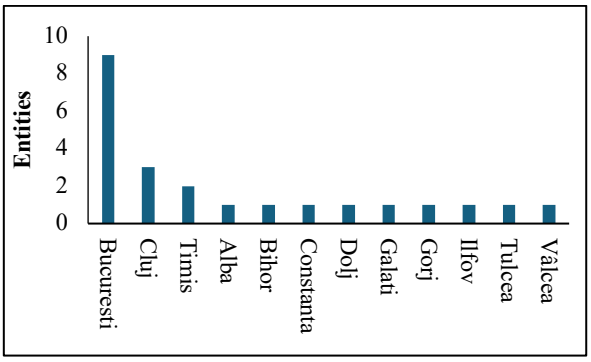


Fig. 3. TT Agrofood Entities (by Counties)
Source: Author's elaboration based on [12].

Romania's capital city, which hosts the largest number of universities and research institutes, holds the top position in this distribution. With 39% of all technology transfer entities specialized in agrofood, Bucharest ranks first among Romanian counties. Cluj (3) and Timiș (2) occupy the next positions, while the remaining counties host only one such entity each.
There is nonational-level data available on the number of spin-offs generated by research institutes or universities. No statistics are collected by the State Office for Inventions and Trademarks (OSIM), ReNITT, the Romanian Association for Technology Transfer and Innovation (ARoTT), or by the relevant ministries. Data from third-party commercial providers (such as Pitchbook) is also limited.
Although the commercial database Dealroom does not report any spin-outs directly from Romanian universities, it does record:
238 start-ups founded by alumni of the Bucharest University of Economic Studies (e.g., Napers, Adevinta, Adversity, Tandem, FintechOS);
120 start-ups founded by alumni of Babeș-Bolyai University of Cluj-Napoca (e.g., Modern Meadow, Pangea, Typing DNA, LiveRail, Frisbo);
107 start-ups founded by alumni of the University of Bucharest (e.g., UiPath, CapsidaBiotherapeutics, BotsAndUs, SkinVision), and several hundred others founded by alumni of other universities across the country.
In Romania, there are approximately 20 business accelerators, along with 6 incubators and 33 coworking spaces. As in other countries, the distinctions between these organizational types are often blurred, which makes strict classification difficult. From the perspective of technology transfer, there is no evidence that these are actively involved in TT activities [2].
To improve technology transfer in Romania, the former Ministry of Research, Innovation and Digitalization (now the National Research Authority – ANC) launched the project call "Transfer Projectstothe Economic Operator (PTE)", which proposed funding of 53,000,000 lei (approximately €10.6 million) to increase the competitiveness of the national economy by capitalizing on the results of research units and transferring them to the market.
The deadline for submitting project proposals was February 16, 2024, at 4:00 p.m. The duration of the projects was to be a minimum of 12 months and a maximum of 24 months, with funding of 1,500,000 lei per project, according to the approved state aid scheme.
Participating enterprises were required to contribute at least 50% of the total publicly funded project value from the irown budget. Each proposal had to be submitted by a research and development enterprise, coordinating the project, in partnership with at least one public or private research organization. Other enterprises could also be part of the partnership structure [13].
In March 2024, the ministry announced the funding of 35 projects, each with a 1.5 million lei grant (approx. €300,000). According to information available on the UEFISCDI website, the evaluation process was ongoing throughout 2024.
Their county-level distribution within Romania is presented in Figure 4.

The vast majority of funding applications were submitted in Bucharest, Ilfov, and Cluj, which together account for over 70% of all submitted projects.Out of the 42 counties in Romania (including Bucharest), no application was submitted by entities from Botoșani, Brăila, Caraș-Severin, or Covasna. As of October 21, 2024, it was announced that the individual evaluation stage had been completed for part of the projects, and intermediate consensus reports were made available to project directors. The final list of the 35 projects accepted for funding is available on the UEFISCDI website [18].

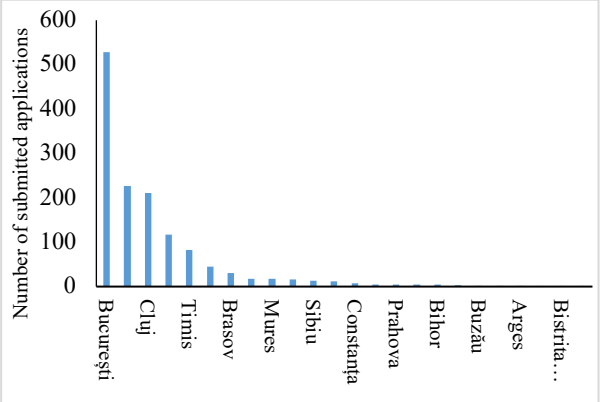


Fig. 4. TT Applications submitted, bycounty of the coordinating institution
Source: Author's elaboration based on [13].

An analysis of these projects shows that 6 of them (approximately 17%) are related to the agro-food, food, or agriculture sectors.
The list of these projects, with the following elements:Project title; Coordinating institution; Academic / R&D partner, is presented below:
1.Optimized Processing Model for a Traditional Product with the Certification of Uniqueness Markers at European Level (PDO Label); Coordinating institution: SICILIANA SRL; Academic / R&D partner: USAMV Cluj-Napoca; INCDTIM Cluj-Napoca
2.Intelligent IoTSystem for GreenhouseAutomation; Coordinating institution: Beia Consult International S.R.L.Academic/R&D partner: INMA; Politehnica University of Bucharest;
3.Exploring Climate Opportunities and Assessing Romania's Territorial Suitability for Optimized and High-Performance Agriculture; Coordinating institution: Indeco Soft SRL; Academic / R&D partner: USAMV Cluj-Napoca; Babeș-Bolyai University; CCDCPN
4.Advanced Technology-Based System for Implementing Agriculture 4.0 in Beef Cattle Farms; Coordinating institution: Beam Innovation SRL; Academic / R&D partner: USAMV Bucharest
5.High-Performance Equipment for Ecological Water Disinfection; Coordinating institution: I.C.P.E. Bistrița S.A.; Academic / R&D partner: Politehnica University of Bucharest
6. Innovative Solutions for Obtaining a Range of Products with Applications in Regenerative Cosmetics; Coordinating institution: Pure Life S.R.L.; Academic / R&D partner: National Institute of Chemical and Pharmaceutical Research – ICCF Bucharest.
Among the research topics, 4 projects targeted agricultural production or food processing (traditional foods, greenhouse digitalization, precision and climate-smart agriculture, Agriculture 4.0), while 2 projects addressed fields connected to the food industry (ecological water disinfection – relevant to the food industry, and regenerative cosmetics based on biological inputs, partially linked to food bioresources).

CONCLUSIONS

Technology transfer represents a strategic direction for the modernization and increased competitiveness of Romania'sagro-food sector.
Romania is taking its first steps in thefield of technology transfer, with progress currently reflected by the low number of TTOs per university and limited investments in RDI. To improve these aspects, it is essential to strengthen the technology transfer infrastructure, increase research and development funding, and encourage collaboration between academia and industry.
Although there is a formal technology transfer infrastructure—represented by 46 accredited entities nation wide—only 23 have direct or related responsibilities in the agro-food sector, and just 15 are affiliated with universities. These figures highlight the low level of

academic involvement in leveraging research results for the productive sector.

Romanian TT entities are generally understaffed and underfunded, which limits their operational capacity. The lack of national databases on spin-offs and the lack of coordination between universities, research institutes, and the business environment are major obstacles in analyzing a functional innovation ecosystem.

Technology transfer activity in Romania is not yet based on a significant mechanism for commercializing academic knowledge. To fully harness the existing potential, systemic reform is needed, ensuring the coherent integration of research, education, industry, and government sectors.

Supporting TT in the agro-food sector requires: investment in processing infrastructure, the development of functional regional TT centers, stimulation of applied research; development of entrepreneurial competencies, and facilitating SME access to innovation.

International examples—such as the German model or European initiatives on agricultural digitalization—canprovide concrete directions for action.

In the context of new global challenges—including health crises, climate change, and pressure on supply chains—the digital transformation of Romania'sagro-food system, supported by effective technology transfer, becomes a strategic priority.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the T3N-BSB Transnational Technology Transfer Network for the Black Sea Basin project for their valuable support in conducting the research and disseminating the findings.

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