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 Călăraşi and Timiş, 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***:** *productivity, 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 $x_1, x_2, ... x_N$ 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
Dolj	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%
Dolj	17%	73%	64%	65%	75%	57%	70%	77%	82%	83%	111%	111%	111%	81%	115%	96%	98%
Gorj	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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