Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 4, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EFFICIENCY ANALYSIS OF THE DRIP IRRIGATION SYSTEM ON THE CORN CROP

Cătălina POPOVICI[1] , Alexandru – Dragoș ROBU[1], Valentin BOBOC[2]

[1]Iasi University of Life Sciences "Ion Ionescu de la Brad", 3, Mihail Sadoveanu Alley, Iasi, Romania, E-mail: catalina.popovici@iuls.ro, dragos.robu@iuls.ro
[2]Technical University "Gheorghe Asachi" Iasi, 67, Prof. Dimitrie Manjeron Blvd., Iasi, Romania, E-mail: valentin.boboc@academic.tuiasi.ro

Corresponding author: dragos.robu@iuls.ro

Abstract

The field research was carried out in the North-East development region of Romania, during 2020-2023, on a cambic chernozem type soil, with a high humus content of 7%. The data were obtained from plots cultivated with corn, analyzed according to the irrigation rate, in order to verify the differences that appear in the crop within the plots. The drip irrigation method was applied using a system where the drip line is buried below the soil surface. In the growing seasons, when irrigation was applied, the increase in production was 63.41% higher than the average non-irrigated production. This method also had an influence in the valorization of water use. With water availability inside the soil, for plants of 1.1 mm/cm depth and with annual deviations of the precipitation with values between -51 and +27 mm, an average application of watering of maximum 4.25 l/m^2/day was reached. The purpose of the research was to highlight and quantify the effects of drip irrigation in corn, on the significant increase in production, by improving the operating yields of irrigation facilities, by reducing water and energy consumption and the effective application of fertilizers, with results beneficial in increasing agricultural production. The present research demonstrated a significant average production increase of 63.41% during 2020 – 2023, the studied period. Also, during the same period, the share of irrigation in covering the total water requirement was between 29.6% and 48.7% as it will be detailed.

Key words**:** *irrigation, drip, corn, efficiency, climate*

INTRODUCTION

Currently, obtaining a competitive cereal production in the North-East of Romania is influenced by high temperatures and low periodic precipitation. These factors lead to pedological droughts. Maize is a particularly important crop in the economy, and the quality of the production significantly depends on the irrigation in the first phases of vegetation. The occurrence of drought decreases the yield, both in terms of the quantity of production and its quality. As many researchers have reported, the application of irrigation in optimal conditions ensures the correct rate of plant growth and development, by intensifying physiological processes [1].

Irrigation systems are very important for sustaining yield performance for any agricultural crop, and in Romania this was proved in many areas affected by drought [6].

Applying various types of irrigation system in Egypt it was shown their influence on maize production for silage [7].

In Ukraine, it was experimented the effect of new technologies based on tillage and irrigation for corn culture for grains [3].

For farmers' associations, the irrigation systems improve the infrastructure level in agriculture and helps the producers to increase production [11].

the technological and economic effect of irrigation in the context of climate change was emphasized by [9].

The physical properties of the soil determine, together with the hydrophysical properties, the amount of water that is stored in the soil, the water accessible to plants, the rate of infiltration and the supply of nutrients to plants. These properties of the soil are taken into account when choosing the type of arrangement, the method and the technical elements of watering [12, 5, 2, 4].

Consequently, irrigation is effective for the success and sustainability of agricultural activities.

The analyzes regarding the irrigation regime for the corn crop were carried out during 2020-2023, within the Water User's Association "Spiridonești", Neamț county, on a cambic chernozem, on the active depth interval of H = 0.80 m, with a capacity of field for water CC = 70%. During the four-year study, the KWS KAMELIAS maize variety, which is part of the FAO 340 group, a hybrid with a vegetation period of 107-112 days, was used. The required seeding density is expressed in plants/m^2, related to the desired plant density in case of 99% emergence. The irrigation method used was drip irrigation.

MATERIALS AND METHODS

To determine the water consumption for the corn crop, using the drip irrigation method, the climatic conditions in the studied area were analyzed and the elements of the irrigation regime were decided, which differ according to the pedoclimatic and the characteristics of the area rainfall regime.

Table 1 presents the main indices studied in this experiment.

Table 1. Water regime/soil water balance

XIndices	stock
f	239.5 mm (0-100 cm depth)
countries	155.9 mm (0-100 cm depth)
p	231.06 mm (4-year average)
m	44.88 m^3/ha
Ouch	≃ 20 m
S	being a soil with a very low slope, surface runoff is insignificant
E	15-30% of evaporation at the soil surface
T	75-92%
Yaf	15-23% of precipitation
R_{CC}	17.4% w/w
R_{PM}	50%

Source: own compilation using own equipment.

For these elements the following weredetermined: soil water regime Rf-Ri=(P+m+Aaf+S)-(E+T+Iaf), Rf (final water reserve after harvesting) and Ri (initial water reserve which is in the soil in the spring), P-precipitation, m-sum of watering norms, Aaf-water supply, S-runoffsupply, E-evaporation, T-transpiration, Iaf-percolation, net watering norm $m_n = R_{CC} - R_{PM}$, R_{CC} -the reserve corresponding to the field capacity, R_{PM} -the reserve of the minimum ceiling and waterings during the vegetation periods, starting to be applied when the corn reaches the 6-8 leaf phase, requiring 12-14% of the total water requirement for the entire vegetation period.

For the analyzed soil texture, a water storage capacity of 3.6 (mm/cm depth) and a plant water availability of 1.1 (mm/cm depth) resulted.

RESULTS AND DISCUSSIONS

Following the analysis of the multiannual average temperatures over the years of study, it turned out that in the months of July and August, of each year, the temperatures were much higher in relation to the other months of vegetation.This finding is also confirmed by the entire science of agronomy and meteorology.

Moreover, the last following years were the warmest in the history of temperature measurement. Specifically, during 2012-2021, the positive thermal anomalies were between 0.69°C (2021) and 1.92°C (2019), this being the warmest period of 10 consecutive years inthe history of meteorological measurements, a fact attributed to climate warming [8].

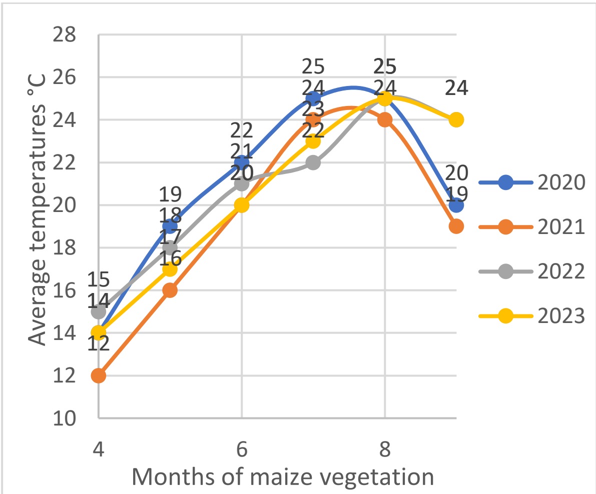

Fig. 1 Average temperatures in the growing months for the 4 years analyzed
Source: own determination using own equipment.

As can be seen, on the abscissa in the previous figure, the months of the calendar year are represented. According to specialized literature, the fourth month represents the period of the first stage of corn development (Figure 1).

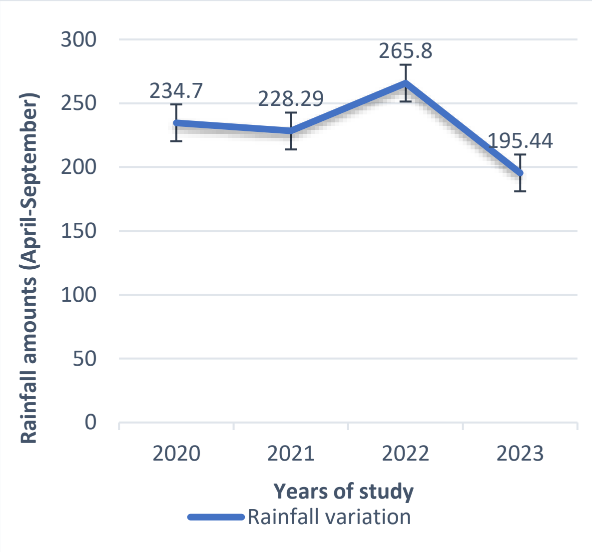

Fig. 2. Average amounts of precipitations in the studied period
Source: own determination using own equipment.

The average amounts of precipitation in the studied period, presented in Figure 2, were insufficient, or uneven, for the water requirement of the crop, during the development periods.

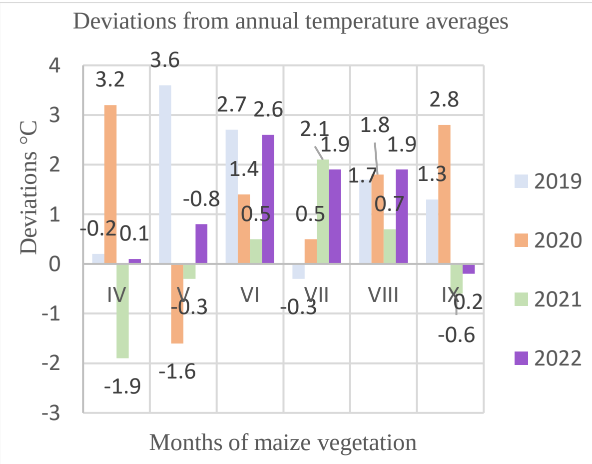

Fig. 3. Average annual temperature deviations for the 4 years analyzed
Source: own determination using own equipment.

The average annual temperature deviations of the four analyzed years (Figure 3) varied a lot throughout the vegetation period, but more pronounced values were recorded in the first month of development, in which corn has a water absorption of 27- 33% of the weight of the seed, being in the germination/emergence stage.

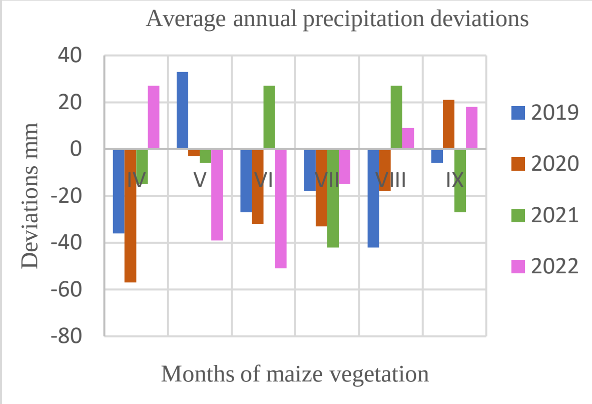

Fig. 4. Mean annual precipitations deviations for the 4 years analyzed
Source: own determination using own equipment.

The amounts of precipitation shown in figure 4, for the studied area, varied quite a lot in relation to the multi-year averages. Thus, in April 2020 a deviation of -36 mm was recorded, in August 2021 of -18 mm, values above the average were recorded in June and August 2022 (+27 mm), and in May2023 there was a deviation of -39 mm and in June of -51 mm.

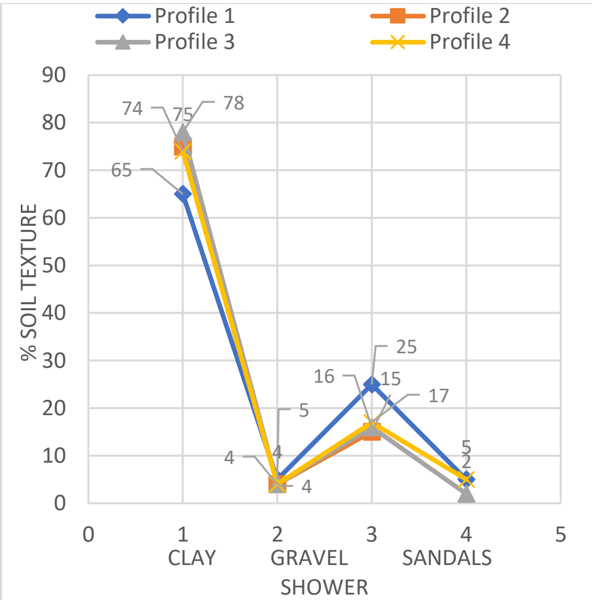

Fig. 5. Texture of the soil cultivated with maize
Source: Research Institute for Agriculture and Environment-ICAM, Iasi University of Life Sciences "Ion Ionescu de la Brad" [10].

Soil texture, shown in Figure 5, is important in the process of water and air retention. Important in the process of silification, drainage and stability or erosion. According to the analyzed texture, it results in a water storage capacity of 3.6 (mm/cm depth) and a plant water availability of 1.1 (mm/cm depth).

Knowing the bulk density of the soil (Table 2) is important in calculating the water reserve, nutrients, salts and fertilizer requirements.

Table 2 Apparent densities for the studied soil

Sample	Density values (g/ cm^3)
S1 (0-25 cm)	1.68
S2 (25-50cm)	1.80
S3 (50-75cm)	1.65
S4 (75-100cm)	1.70

Source: own determination using own equipment.

Following the analysis of the aspects presented above, the degree of water supply of the soil at a depth of 0-100 cm was within satisfactory limits only in 2021 (65%), because the amounts of precipitation were higher compared to the other years for study.

Table 3 shows the technical parameters of the drip irrigation system.

The amount of water required to irrigate the entire arable surface of the experimental fields is provided by pumping from the existing river in the northern part of the land, at a distance of approximately 1.15 km. According to the soil type, the distance between the drippers is 0.5 m, the distance between the drip lines is 1 m, with a required flow rate of 88.77 m ^{3}/h (Table 3).

Table 3. Technical parameters of the drip irrigation system

Description	**UM**	**Details (medium values)**
Crop	-	maize
Irrigated area	Ha	31.07
Spacing between rows	m	0.70
Distance between plants in a row	m	0.20
Max. working pressure of the drip line	bar	1.6 – 2.0
Flow distributed through the dropper	l/h	0.8 – 1.2
Distance between droppers	m	0.50
Distance between drip lines	m	1.00
The hourly rate of application of irrigates	mm/h	2.00
Maximum daily water consumption	mm/day	6.00
Irrigation cycle	days	1.0
Duration of an irrigation operation	h/day	3.0
The number of watering operations	no.	8.00
Maximum daily duration of irrigation operations	h	21.00
Maximum required flow rate	m^3/h	88.77

Source: own centralization of the experiment features.

Figure 6 shows the experimental field, with the surfaces related to each plot.

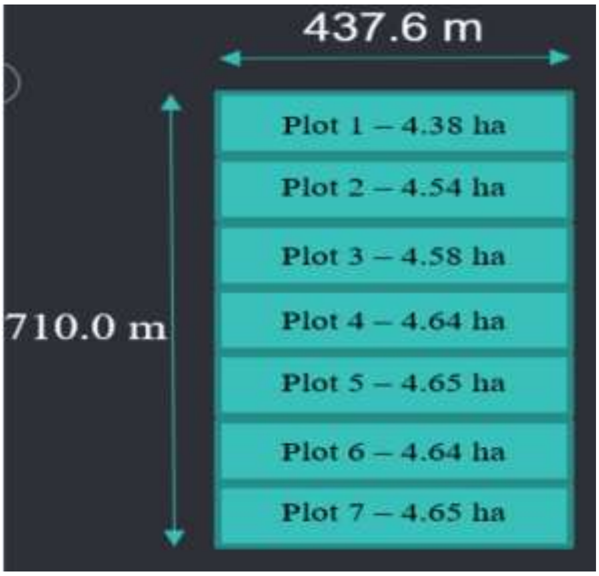

Fig. 6. Experimental field plan
Source: author graphic render of the dedicated experimental field.

The analyzed area was irrigated with the help of a pumping station provided by the farmer, which ensures a total flow of 187 m^3/hour.

The drip line chosen for researching drip irrigation techniques has an inner diameter of 20 – 24 mm, with a wall thickness of 0.3 – 0.5 mm.

The irrigation variants on the specified research areas recorded in 2020 average values of 2.31 l/m^2 /day for the month of May, 2.15 l/m^2/day for the month of June, 4.74 l/m^2/day for the month of July and 3.28 l/m^2/day for the month of August with variations between plots depending on the watering characteristics established initially.

In 2021, the watering options on the research areas recorded average values of 2.21 l/m^2/day for May, 1.07 l/m^2 /day for June, 3.83 l/m^2/day for July and 0.74 l/m^2 /day for the month of August.

The irrigation variants on the specified research areas recorded in 2022 average values of 2.50 l/m^2 /day for the month of May, 1.97 l/m^2 /day for the month of June, 4.42 l/m^2/day for the month of July and 3.94 l/m^2/day for the month of August with variations between plots depending on the watering characteristics established initially.

And in 2023, the irrigation options recorded average values of: 2.27 l/m^2/day for May, 1.75 l/m^2 /day for June, 4.25 l/m^2/day for July and August 3.45 l/m^2/day.

Irrigation of corn during 2020 and 2021 led to higher total water consumption values than in non-irrigated conditions by 56% and 58%. In the variants with interruption of irrigation, the values of total water consumption decreased compared to the variant optimally supplied with water.

Table 4. Irrigation regime of corn culturein different water supply options, 2020-2023

Alternative	April		May		June		July		August		April-August	
	ΣM m^3/ha	n	ΣM m^3/ha	n	ΣM m^3/ha	n	ΣM m^3 /ha	n	ΣM m^3/ha	n	ΣM m^3/ha	n
1	2	3	4	5	6	7	8	9	10	11	12	13
2020												
V_1	-	-	-	-	12.46	2	20.00	3	20.00	3	32.46	5
V_2	-	-	14.75	2	12.46	2	20.00	3	20.00	3	32.46	5
V_3	-	-	14.75	2	12.46	2	-	-	-	-	12.46	2
V_4	-	-	14.75	2	-	-	20.00	3	20.00	3	20.00	3
V_5	-	-	-	-	12.46	2	20.00	3	20.00	3	32.46	5
2021												
V_1	6.10	1	14.75	2	57.50	3	14.37	6	88.45	4	31.05	16
V_2	6.10	1	14.75	2	-	-	14.37	6	88.45	4	25.30	13
V_3	6.10	1	-	-	57.50	3	-	-	88.45	4	15.21	8
V_4	6.10	1	-	-	57.50	3	14.37	6	88.45	4	29.60	14
V_5	6.10	1	14.75	2	57.50	3	14.37	6	-	-	22.20	12
2022												
V_1	-	-	12.99	1	58.20	3	18.32	7	21.00	2	27.53	13
V_2	-	-	-	-	58.20	3	18.32	7	21.00	2	62.33	12
1	2	3	4	5	6	7	8.00	9	10.00	11	12	13
V_3	-	-	12.99	1	-	-	18.32	7	21.00	2	50.63	10
V_4	-	-	12.99	1	58.20	3	-	-	21.00	2	45.70	6
V_5	-	-	12.99	1	58.20	3	18.32	7	-	-	47.83	11
2023												
V_1	6.10	1	14.75	2	57.50	3	14.37	6	88.45	4	31.05	16
V_2	6.10	1	14.75	2	-	-	14.37	6	88.45	4	25.30	13
V_3	6.10	1	-	-	57.50	3	-	-	88.45	4	15.21	8
V_4	6.10	1	-	-	57.50	3	14.37	6	88.45	4	29.57	14
V_5	6.10	1	14.75	2	57.50	3	14.37	6	-	-	22.20	12

Source: own determination and centralization within the present research.

The share of irrigation in covering total water consumption was between 29.6 and 43.9% in 2020, 37.9 and 47.8% in 2021, in 2022 values between 35.8% and 46.7%, and in 2023 values between 39.8% and 48.7%.

From the soil reserve, non-irrigated corn consumed the largest amounts of water: in the variant without interruption of irrigation, corn consumed the smallest amount of water from the soil reserve, and in the variants with interruption of irrigation, the values were higher, without exceeding the amount of water consumed from the soil reserve by non-irrigated corn. "ΣM m^3/ha" represents the sum of the amount of water administered at a certain number of waterings, denoted by "n" for each proposed "V" variant (Table 4).

According to Figure 7, the average production recorded in 2020 for the experimental lots was 15,915.11 kg/ha (compared to 7,564.76 kg/ha in the non-irrigated version), in 2021 it was 8,012.17 kg/ha (compared to 5,998.8 kg/ha in non-irrigated version), in 2022 it was 8,241.73 kg/ha (compared to 6,556.87 kg/ha in the non-irrigated version) and in 2023 it was 9,403.99 kg/ha (compared to 6,242.49 kg/ha in the non-irrigated version).

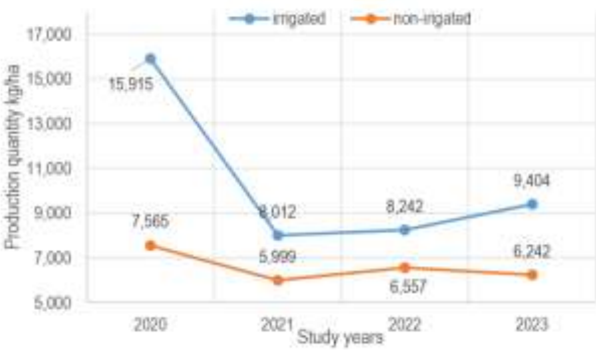

Fig. 7. Production over the years of study under irrigated and non-irrigated conditions
Source: own determination and centralization within the present research.

Next, the authors centralized the results of the determinations in the following Table 5. According to it:

-total water consumption was 309.7 l/m^2 in 2020, with a cost of 0.075 lei/m^2 related to one m^2 of cultivated land, of 184.7 l/m^2;

-in 2021 with a cost of 0.045 lei/m^2;

-in 2022 at a total water cost of 0.079 lei/m^2 to 0.326 m^3/m^2;

-and in 2023 at a total water consumption of 286.9 l/m^2 with a cost of 0.075 lei/m^2.

Table 5. Analysis of the economic efficiency of using the drip irrigation system

Feature	2020	2021	2022	2023
Total water consumption - l/m^2	309.7	184.7	326.8	286.9
Water cost - lei/m^3	0.243	0.243	0.243	0.243
Water cost - lei/m^2	0.075	0.045	0.079	0.075
Maize yield- kg/ha	5,648.86	3,505.85	8,857.14	7,995.87
Sale price for maize- lei/kg	1.11	1.2	1.2	1.2
Income related to increased yield- lei/m^2	0.607	0.421	0.687	0.677
Added economic value - lei/m^2	0.532	0.376	0.589	0.498

Source: own determination and centralization within the present research.

The added economic value was 0.532 lei/m^2 for 2020, 0.376 lei/m^2 in 2021, 0.589 lei/m^2 in 2022 and 0.498 lei/m^2 in 2023, which highlights the contribution of the system of value-added irrigation.

The importance of crop irrigation and especially its substantial and decisive influence on increasing the competitiveness of the economic unit are recognized throughout the European Union. Thus, in Romania, starting with the multi-annual financial year 2007 – 2014 (the first since Romania's accession), non-reimbursable funds were made available for the rehabilitation of the

irrigation infrastructure in Romania built during the communist period. Romania is currently in the third multi-year financial envelope since accession which provides substantial non-reimbursable grants to rehabilitate pumping stations, pipelines and irrigation plots.
The financier recognizes the particular importance of this strategic sector. Consequently, as an exception to the funds granted to other links in the agricultural production sector, for the modernization of these irrigation systems the financier grants 1.5 million Euros, a much higher amount than for other links in agricultural production and, in addition, a financial intensity of the support of 100%. This contrasts with other funding where between 40% and 80% non-reimbursable financial assistance is awarded.
For the calendar period 2023 – 2027, the European Union, through the National Strategic Program, made available to Romania the amount of 400 million Euros, an amount much higher than all the financial allocations for the irrigation sector since Romania's accession. It is expected that this non-reimbursable value of 400 million Euros will cover the modernization and rehabilitation of a number of about 270 Water User's Associations at national level, which serve on average about 600-800 ha each.
Therefore, the major positive influence of crop irrigation is found at the European level, not only at the Romanian level. Moreover, in addition to the modernization of the secondary irrigation infrastructure, Romania also benefits of funds for the rehabilitation of the primary infrastructure, which supplies Water User's Associations throughout the country. These are pumping stations located on the banks of large water courses that provide the water needed for secondary pumping stations owned by farmers

CONCLUSIONS

The results presented, obtained during 2020 - 2023, varied depending on the level of humidity maintained in the soil.
The share of irrigation in covering the total water requirement was between 29.6 and 43.9% in 2020, 37.9 and 47.8% in 2021, in 2022 values between 35.8% and 46.7%, and in 2023 values between 39.8% and 48.7%.
Optimum water supply of maize with the help of irrigation determined in 2020 and 2021 values of the total water consumption higher than in the other years by 56% and 58%, because the temperatures recorded values above the average and the precipitation was uneven.
Irrigation led to a significant increase of 63.41% in production and its stability in the following period.
Regarding the economic impact of the investment represented by the drip irrigation system on the analyzed Water User's Association, this consists in the operating yields improvement of the irrigation facilities in the area, by reducing water and energy consumption and the effective application of fertilizers, with effects in increasing agricultural production.
Therefore, the investment represented by the drip irrigation system has a significant positive impact on the economic performance of the Water Users' Association.
The special importance that irrigation has on crops is recognized internationally, with the European Union granting Romania, as a Member State, non-reimbursable financing of approximately 1 billion Euros since its accession in 2007 until now.
The financing intensity is 100% non-refundable and the maximum value of a project, within the PNS 2024-2027 envelope, is 1.5 million Euros.

REFERENCES

[1]Băcanu, C., Stoica, C., Ion, I.M., Stanciu, S., 2019, Aspects regarding the areas and conditions for wheat seed multiplication in Romania and in Braila County, Proceedings of The 33rd IBIMA International Conference: Innovation Management and Education Excellence Vision 2020; From Regional Development Sustainability to Global Economic Growth (Granada, Spain, 10 -11.04.2019), Khalid Soliman Editor.
[2]Cococeanu, A.L., Pelea, G.N., Cojocinescu, M.I., Man, T.E., Crețan, I.A., 2017, Study of surface water resources availability for irrigation arrangements. Case study: Bega river, Timis county, Romania", 17th International Multidisciplinary Scientific GeoConference SGEM 2017, www.sgem.org, SGEM2017 Conference Proceedings, 29 June - 5 July, 2017, Vol. 17(31), 633-640, DOI: 10.5593/sgem2017/31/S12.079.
[3]Didenko, N., Lavrenko, S., Lavrenko, N., Sardak, A., Didenko, S., Mrynskii, I., 2022, economic efficiency of corn grain cultivation with the new technologies of tillage and irrigation. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(3), 187-194.https://managementjournal.usamv.ro/pdf/vol.22_3/Art19.pdf, Accessed on May 1st, 2024.
[4]Grumeza, N., Dascălescu, O., 1983, Drip irrigation, Ceres Publishing House, Bucharest, pp. 33-34.
[5]Łabędzki, L., 2009, Przewidywane zmiany klimatyczne a przemyśl nawodnień w Polsce(Predicted

climate chnages and the irrigation industry in Poland). Infrastructure and Ecology Terenów Wiejskich3, 7–18.
[6]Miron, L., Lup, 1., 2020, The influence of irrigation on the structure of crops on arable land, under the conditions of Romania's planned economy and free market. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 20(2), 309-314.https://managementjournal.usamv.ro/pdf/vol.20_2/Art41.pdf, Accessed on May 1st, 2024.
[7]Mostafa, H., Derbala, A., 2013, Performance of maize crop for silage production using three different irrigation systems, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.13(2), 261-267.https://managementjournal.usamv.ro/pdf/vol.XIII_2/Art44.pdf, Accessed on May 1st, 2024.
[8]National Agency of Meteorology, Release on 07.01.2022, https://www.meteoromania.ro/wp-content/uploads/comunicate/comunicat-07.01.2022.pdf, Accessed on 16.01.2024.
[9]Prepelita (Popovici), C.I., Coada (Nenciu), D., Bucur, D., 2021, Analytical study on the technical-economic impact of irrigation systems: review on recent development and future perspectives, Research Journal of Agricultural Science, 53 (1), 152-161.
[10]Research Institute for Agriculture and Environment-ICAM, Iasi University of Life Sciences "Ion Ionescu de la Brad".
[11]Robu, A.-D., Costuleanu, C.L., Ungureanu, G., Borza, M., Brezuleanu, S.,2020, Secondary irrigation infrastructure in Romania: influence of the water user`s associations modernization on the performance of their member farms, Lucrări Ştiinţifice – Vol. 63(2)/2020, Series Agronomy, Iasi.
[12]Żarski, J., Dudek, S., Kuśmierek-Tomaszewska, R., Żarski, W., 2017, Effects of agricultural droughts in the province of Kujawsko-Pomorskie and possibilities of minimizing their impact. Infrastructure and Ecology of Rural Areas , Vol. II(2), 813–824.