Global warming and its impact on the production activities of Ukrainian agricultural enterprises

Serhii Demianenko[1*], *Iryna* Sas[2], and *Maksym* Fomichov[1]

[1] Kyiv National Economic University named after Vadym Hetman, 54/1, Beresteiskii Avenue, 03057 Kyiv, Ukraine
[2] SPE firm Eridon, 54, Geroiv Nebesnoi Sotni, 08150 Boyarka, Kyiv oblast, Ukraine

Abstract. The study is devoted to the problems of global warming and its impact on the production activity of agricultural enterprises in Ukraine. The influence of the average monthly and annual air temperature and precipitation over the last eighteen years on the yield of the main crops in all climatic zones characteristic of Ukraine and all regions of Ukraine was analyzed. It is shown that despite the increase in the average annual air temperature of 1,11 °C and the decrease of precipitation by month of the year on 454,18 mm and its instability, as well as the negative impact on the production activity of agricultural enterprises of Ukraine of the military aggression of Russia, there is an increase in the yield of the main crops in 2023 in comparison with 2005 - winter wheat on 56,1 %, oilseeds on 68 %, corn on 96,5 %, and vegetables of the open ground on 22,7 %. A conclusion was made about the expediency of expanding irrigation in all regions of Ukraine, particularly drip irrigation, to increase the yield rate, ultimately leading to an increase in revenue and, thus, the profit of agricultural enterprises. The project's cost for introducing a drip irrigation system was calculated using the example of an agricultural enterprise, and the efficiency of growing corn for grain with and without irrigation was compared.

1 Introduction

The task of the study is to analyze climatic changes as the main factor in the development of the use of irrigation systems by Ukrainian agricultural enterprises as a factor in reducing the level of agricultural risks and increasing the efficiency of their production activities. For this the climate changes observed during the last decade as a factor that directly affect the production activity of agricultural enterprises of Ukraine. A special sign of climate change is an increase in the average monthly and annual temperature (air, soil, water). At the same time, the temperature in Ukraine rises even more than in other countries. Such an increase in the average annual air temperature was approximately 1.1 °C, which had a negative impact on the production of agricultural products due to a decrease in the harvest of

* Corresponding author: serhii.demianenko@kneu.ua

agricultural crops and livestock products according to the conclusions of some researchers from different countries [1, 2]. There is an opinion that if this trend continues, the situation in the agricultural sector will worsen. According to scientists' calculations, one degree increase in the average annual air temperature leads to a 10% decrease in the production of agricultural products, and the predicted increase in temperature by 2-3 degrees in the near future will have the greatest impact on the production of grain crops [3]. However, agriculture also contributes to global warming through greenhouse gas emissions, as a result of the industry's production activities, especially in dairy farming. Agriculture accounts for almost half of the global emissions of the two most dangerous non-carbon dioxide greenhouse gases – nitrous oxide and methane. Nitrogen oxide emissions from the soil (as a result of the use of mineral and organic fertilizers) and methane emissions from animal husbandry make up more than 60% of the total volume of non-carbon dioxide greenhouse gas emissions, and, according to forecasts, this indicator will increase. Emissions of the remaining greenhouse gases (except carbon dioxide) occur from biomass burning, rice production and compost harvesting. Agriculture also significantly affects the accumulation (sequestration) of carbon in the soil and emissions of carbon dioxide as a result of changes in land use (in particular, when the proportion of humus in the soil decreases due to irrational use of land, when the level of plowed land increases, when shifting forest. Therefore, the relevance of this topic is gaining considerable scope, and the result of an in-depth consideration and research of this problem will be the confirmation or refutation of the declared impact of global warming on the production activity of agricultural enterprises.

In turn, in Ukraine, not taking into account the obvious adverse climatic changes, as well as the military aggression of Russia, there is a constant increase in the production of agricultural products, in particular grains and legumes. Thus, the production of grain crops increased to 75.1 million tons in 2019 compared to 38.0 million tons in 2005. The cultivation of oil crops in general is growing at a frantic pace - up to 21.6 million tons in 2023 compared to 4.7 million tons in 2005. Growth is also observed for potatoes, vegetables, and fruit and berry crops, respectively by 2.1%, 66.3%, and 46.2% [4]. As a result of global warming, in addition to an increase in the average annual air temperature, agriculture is affected by other factors - more frequent droughts, floods, temperature changes, storms, the spread of pests of agricultural crops and animal diseases, which also significantly complicate the process of agricultural production and cause diseases, losses and decline livestock productivity.

A factor that allows climate change to be mitigated to a certain extent is the widespread introduction of irrigation systems, in particular drip irrigation. A number of agricultural enterprises of Ukraine actively implement irrigation and thus increase their efficiency [6].
According to the National Meteorological Service of Great Britain, in the continental territories of Ukraine in the 21st century summer drought periods will increase (doubled compared to the previous period), and river flows will decrease significantly (also doubled). The consequence of this will be an increase in the salinity of the water in the Black Sea. In general, there will be a greater shortage of water in Ukraine. Meanwhile, the warming of the climate in Ukraine will positively affect the yield of crop production, and the increase in the concentration of carbon dioxide in the atmosphere will contribute to the acceleration of the photosynthesis process by 30–100% [7].

It should be noted that, in general, plants react differently to an increase in the amount of carbon dioxide in the atmosphere, and, as a rule, according to this feature, agricultural plants are divided into two groups: plants with a high sensitivity to an increase in the concentration of carbon dioxide (wheat, barley, sunflower, rice, soy); plants with low sensitivity to an increase in the concentration of carbon dioxide (corn, sorghum, sugar beets, millet).

It is expected that with an increase in the concentration of carbon dioxide in the atmosphere, the plants of the first group will grow better, their ripening period will accelerate, and the yield will increase by 20–30%, while the yield of plants of the second group will decrease significantly [2].

In general, an increase in the yield of winter wheat for all natural climatic zones of Ukraine should be expected from global warming (in particular, by 10% for the Forest Steppe, by 20–30% for the Steppe, and by 20–40% for the Polissia), and in favorable years, the yield of this crop may to grow 2-2.5 times throughout the territory of Ukraine. Thus, it is expected that climate changes will increase the production of winter wheat grain on the territory of Ukraine by 3.8–6.1 million tons, and the zone of guaranteed production of this agricultural crop will shift to higher latitudes [8].

2 Methodology

The information base of research consists of the scientific works of domestic and foreign scientists in the field of climate change and its effects on agricultural production and global warming effects on irrigation development and crop production [1, 9- 11]. In addition to the specified sources, this includes data of the State Statistics Service of Ukraine [9].

The survey was carried out in the period 2005-2023, covering questions regarding the dynamic of average monthly and annual air temperature and precipitation in Ukraine. Average monthly indicators of air temperature and precipitation testify to their unevenness and change according to growing seasons, and average annual indicators demonstrate their dynamics over the last decade. The correlation dependence is built on average annual indicators in order to show the dynamics and relationship of yield of the main agricultural crops with the level of air temperature and precipitation.

The structure of irrigated lands was studied for the period 2010-2021, information for 2022-2023 was not used, which is connected with Russian military aggression in 2022 and the occupation of significant territories in the south part of Ukraine, where the main array of irrigated lands is located.

The project cost of works and materials for the development and launch of the drip irrigation system has been calculated. The effectiveness of growing corn for grain without the use of drip irrigation and with its use on the basis of which investors make a decision on the feasibility of introducing drip irrigation is compared [12-15].

3 Results and discussion

The economic activity of agricultural enterprises depends not only on the level of qualification of the personnel, but also on a number of other factors. In particular, the territorial location of plots, agronomic indicators of the soil, local features of flora and fauna, and the natural and climatic conditions under which agricultural production is carried out. Global warming makes considerable adjustments to the activities of agricultural enterprises. Instead, the latter have to adapt and build such a model of activity that allows them not to reduce the level of crop yield and, accordingly, not to lose the level of profitability that they have, but on the contrary - to increase it in any conditions.

It is worth noting that the very fact of climatic changes, namely the global tendency towards a constant increase in temperature and changes in the amount of precipitation by region, is already generally recognized, which has caused a number of discussions about the causes of this phenomenon. Thus, the study of the impact of warming on production processes, technological effectiveness and financial and economic efficiency of agricultural enterprises is relevant and timely.

An indicative result of the activity of an agricultural enterprise, in the context of the analysis of the impact of global warming, is the indicator of the yield level of agricultural crops. Let's consider the general dynamics of yield of the main crops in Ukraine over the past 18 years and reveal the relationship between the change in this indicator and the level of the average annual air temperature and amount of precipitation in Ukraine (Table 1).

In order to obtain correct data regarding the average annual temperature and precipitation, it is worth considering that the climate of Ukraine is quite diverse. Therefore, it was analyzed the average monthly indicators of temperature and amount of precipitation from 2005 to 2023 for all climatic zones characteristic of Ukraine [5]. Most of Ukraine is characterized by a continental climate, represented by its three types: humid with warm summer (for example, Kyiv, Lviv, Kharkiv regions); humid with hot summer (for example, Dnipropetrovsk, Luhansk and Kherson regions); subarctic (most of the Carpathians). Also, part of the territory of Ukraine is characterized by a humid subtropical climate, which was investigated by weather stations in the village of Vylkove (Odesa region) and the city of Feodosia (Autonomous Republic of Crimea), but the cold steppe climate is characterized by data from the weather station in the village of Chorles. We note that the two main climatic indicators - the average annual precipitation and the average annual air temperature - were studied by us in all regions of Ukraine.

Table 1. Average annual air temperature and precipitation and yield of the main agricultural crops in Ukraine, 2005-2023 [4].

Years	Yield, centners per hectare				Average annual weather conditions	
	Winter wheat	Sunflower	Corn	Vegetables open soil	Temperature, °C	Precipitation, mm
2005	28,5	12,8	43,2	152,0	8,8	582,4
2006	36,7	15,3	46,9	165,9	8,4	576,0
2007	30,9	15,2	50,2	146,8	10,0	582,8
2008	26,8	15,0	45,1	168,5	9,6	658,9
2009	33,5	18,4	64,4	175,7	9,4	564,2
2010	28,0	16,5	47,9	166,6	9,3	764,8
2011	33,9	21,7	64,1	188,3	8,9	479,1
2012	28,5	12,8	43,2	192,0	9,3	626,7
2013	36,7	15,3	46,9	190,7	9,5	613,7
2014	40,1	19,4	61,6	199,4	9,6	590,6
2015	38,8	21,6	57,1	195,6	9,9	539,9
2016	42,1	22,4	66,0	201,0	9,5	644,9
2017	41,1	20,2	55,1	198,0	9,6	551,8
2018	37,3	23,0	78,4	204,7	9,7	622,2
2019	42,4	25,6	58,4	205,9	10,6	570,8
2020	38,0	20,2	56,2	199,0	10,7	464,1
2021	46,0	25,0	71,0	206,0	9,2	525,2
2022	35,9	21,6	63,5	195,5	9,7	594,0
2023	44,5	21,5	84,9	200,6	10,8	556,5

This research revealed that over the past 18 years, the average annual air temperature in Ukraine has a clear tendency to increase, with slight deviations in individual years. The highest average annual temperature index was reached in 2023 +10.8 °C, which indicates that this year had a hot summer and warm winter, but the lowest index was reached in 2006, when the average annual temperature was 8.4 °C. In general, during the studied years, the average annual temperature in Ukraine increased by of 2 °C (10.8 °C - 8.8 °C), which is 22.7% higher than the base year (Table 1, Fig. 1).

Thus, we confirm the opinion that there is a gradual increasing increase in air temperature, which has signs of global warming.

Regarding the indicator of the level of the average annual amount of precipitation in Ukraine, there is a tendency towards its gradual decrease. The highest rainfall was in 2000 at 764.8 mm, indicating that the year had a snowy winter and wet summer, while the lowest was in 2011 at 479.1 mm. In general, during the years of observation, the level of the average annual amount of precipitation in Ukraine decreased by 11.7 mm, which is 2.0% lower than the base year (Table 1, Fig. 1), which confirms the opinion about a gradual annual decrease in the amount of precipitation.

Thus, based on these statistics, in the last eighteen years, the correlation equation shows an annual increase in air temperature in Ukraine by 0.0618°C, and if calculated over 18 years, it is 1.11°C (0.0618*18). The indicator of the amount of precipitation has a tendency to decrease - by 3.01 mm annually (Fig. 1), which in the calculation for 18 years is 454.18 mm. (3.01 * 18). At the same time, the yield index of the main crops has a clear tendency to increase (Table 1), which requires additional research. However, it can already be stated that the main factors that influenced the growth of yield are the positive consequences of the implemented agrarian reform in Ukraine, in particular, the privatization of agricultural land, which stimulated investments in the agricultural sector.

In order to carry out a deeper analysis of the impact of climate changes on the yield of agricultural crops, we built correlation models of the dependence of the yield indicator of the main agricultural crops on the temperature indicator (Fig. 2).

According to the results of the correlation-regression analysis, it was established that there is not a significant relationship between the yield and the temperature indicator - the highest level of its coefficient of determination according to the selected statistics was for sunflower and corn, namely 0.3747 and 0.3599, respectively. The closeness of the linear relationship indicates an extremely low level of dependence of the analyzed indicators, in particular, the variation in the yield of sunflower and vegetables in the open soil depends on the variation of the temperature indicator by 37.47% and 38.99%, respectively.

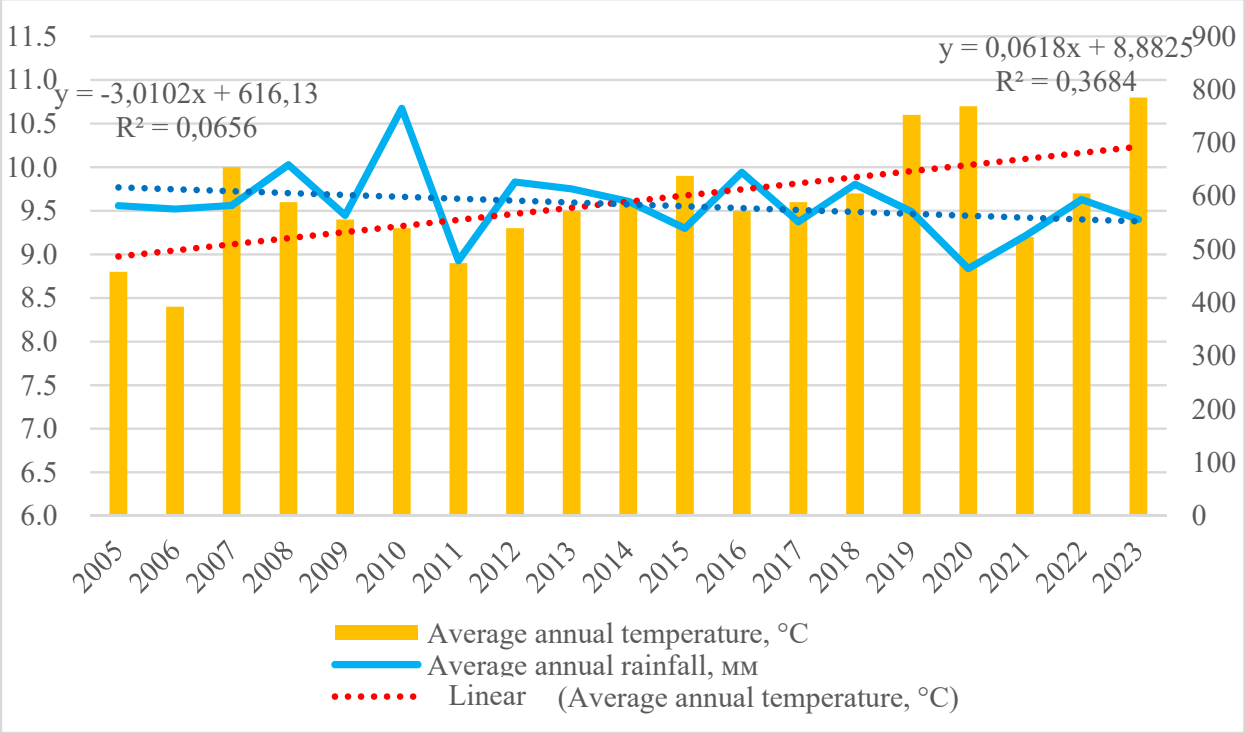

Fig. 1. Dynamics of average annual air temperature and precipitation in Ukraine, 2005-2023 [4].

Thus, it can be seen from the obtained results that with an increase in the temperature indicator, the crop yield indicators increase accordingly. According to the results of the correlation-regression analysis, the dependence of the yield of winter wheat on the increase in the temperature index was established - by 5.3 t/ha and sunflower – by 4.2 t/ha. The lowest level of influence is observed when growing sunflowers - with an increase in the temperature index, the yield of the crop increases by 4.2 tons/ha. The highest increase in yield is observed when growing vegetables in open ground - with an increase in the temperature index, the yield indicator increases annually by 20.2 t/ha.

Thus, from the data in fig. 2 we can conclude: with an increase in the temperature index of the air, which acquires signs of global warming, agricultural enterprises should choose such a set of crops in the structure of crops, which would be maximally adapted to all climatic and natural conditions and, at the same time, ensure obtaining the maximum yield, the highest level marginal rate from one hectare, and, accordingly, better payback indicators.

The correlation model of the dependence of the yield index of the main agricultural crops on the average annual rainfall shows a slightly different trend (Fig. 3).

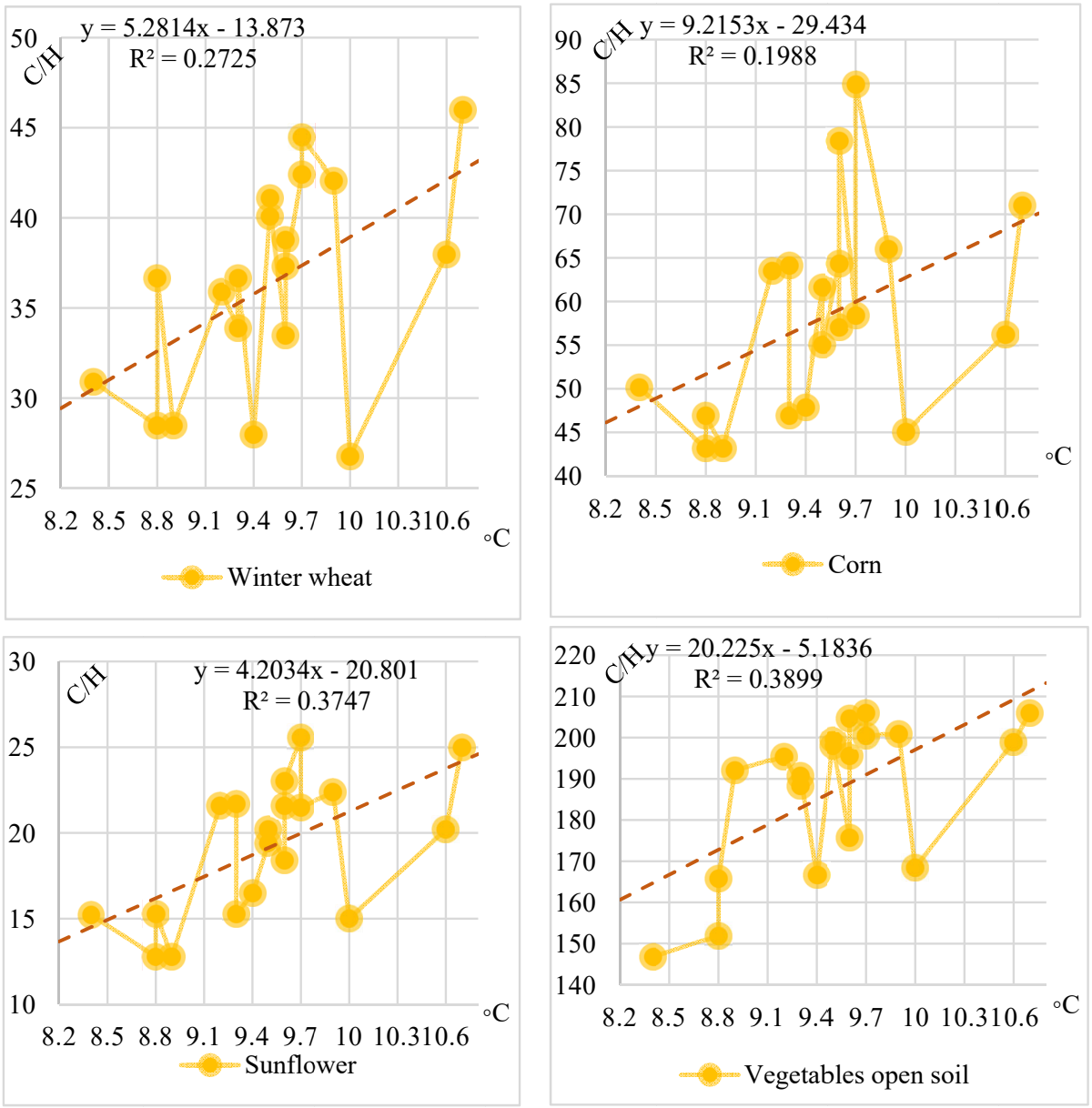

Fig. 2. The dependence of the yield of the main agricultural crops on the average annual air temperature in Ukraine for the years 2005-2023.

It was established that there is not a significant relationship between yield and the indicator of the amount of precipitation - the highest level of the coefficient of determination according to the selected statistics was 2.7 for sunflower. The closeness of the linear relationship indicates an extremely low level of dependence of the analyzed indicators, in particular, the variation of sunflower and corn yield by 2.7% and 0.5%, respectively, depends on the variation of the rainfall indicator.

Some researchers note that over the past 23 years, climate changes have been quite noticeable and are not changing for the better. In recent years, distinct periods of drought and rain have been observed. In a certain period there may be no rain, and in some periods there are showers, after which the drought comes again [1]. Thus, an increase in the temperature of the earth's surface leads to the formation of a greenhouse effect. The amount of moisture loss increases, but not in those periods when it is needed for growing plants. That is, there is no rain in the heat of the summer, and it falls in the early spring in the winter and autumn months. Therefore, the average annual temperature rises due to a warm winter and a critically hot summer, and in return, agricultural crops do not receive moisture when it is needed.

It is generally accepted that every missing millimeter of average annual precipitation reduces the yield of agricultural crops [3]. It is worth noting that the annual distribution of precipitation changes monthly in general, such months as April, May, June and July became an example of this. It was investigated that the deviation of the average amount of precipitation from the average long-term level in April is lower by 16-20 mm, in May it is higher by 5-9 mm, and in June it is lower by 17-21 mm. Note that July is characterized by a slight increase in the amount of precipitation, which amounted to only 3-5 mm. As you know, during these months the need for water for plants is the greatest, which lays the foundation for the yield of agricultural crops.

On average, during the period of active development of most crops (April-July), agricultural crops do not retain about 25-27 mm of moisture, and the precipitation that falls is often unproductive (evaporation of water exceeds its intake), which negatively affects the yield of crops. In general, we can say that in recent years the amount of precipitation has significantly decreased and its unevenness has increased.

Based on the analysis carried out, it can be stated that the climatic conditions in Ukraine are relatively favorable for the cultivation of the cult, however, the gradual climate change observed in recent decades (increase in the average daily temperature) worsens the temperature regime of the soil, and the decrease in precipitation leads to the deterioration of the water regime, which also allows us to draw a conclusion about the expediency of building an irrigation system in the fields that suffer the most from these problems.

The question of the feasibility of using irrigation systems as the main technical and technological method for reducing the risks of insufficient moisture in the cultivation of agricultural crops is worthy of attention.

To assess the current general state of irrigated lands in Ukraine in terms of the main agricultural crops, let's consider the change in irrigated acreage for the period 2010-2021 (Table 2).

This table shows a clear trend towards the growth of cultivated areas under irrigation during the studied period. In general, in 2021, the area of irrigated land amounted to 379.2 thousand hectares, which is 36.4% more than in 2010. This indicator was achieved thanks to the reconstruction of state irrigation systems (+16 thousand hectares), which was reported during the report on the results of the State Agency of Water Resources of Ukraine in 2017 [3].

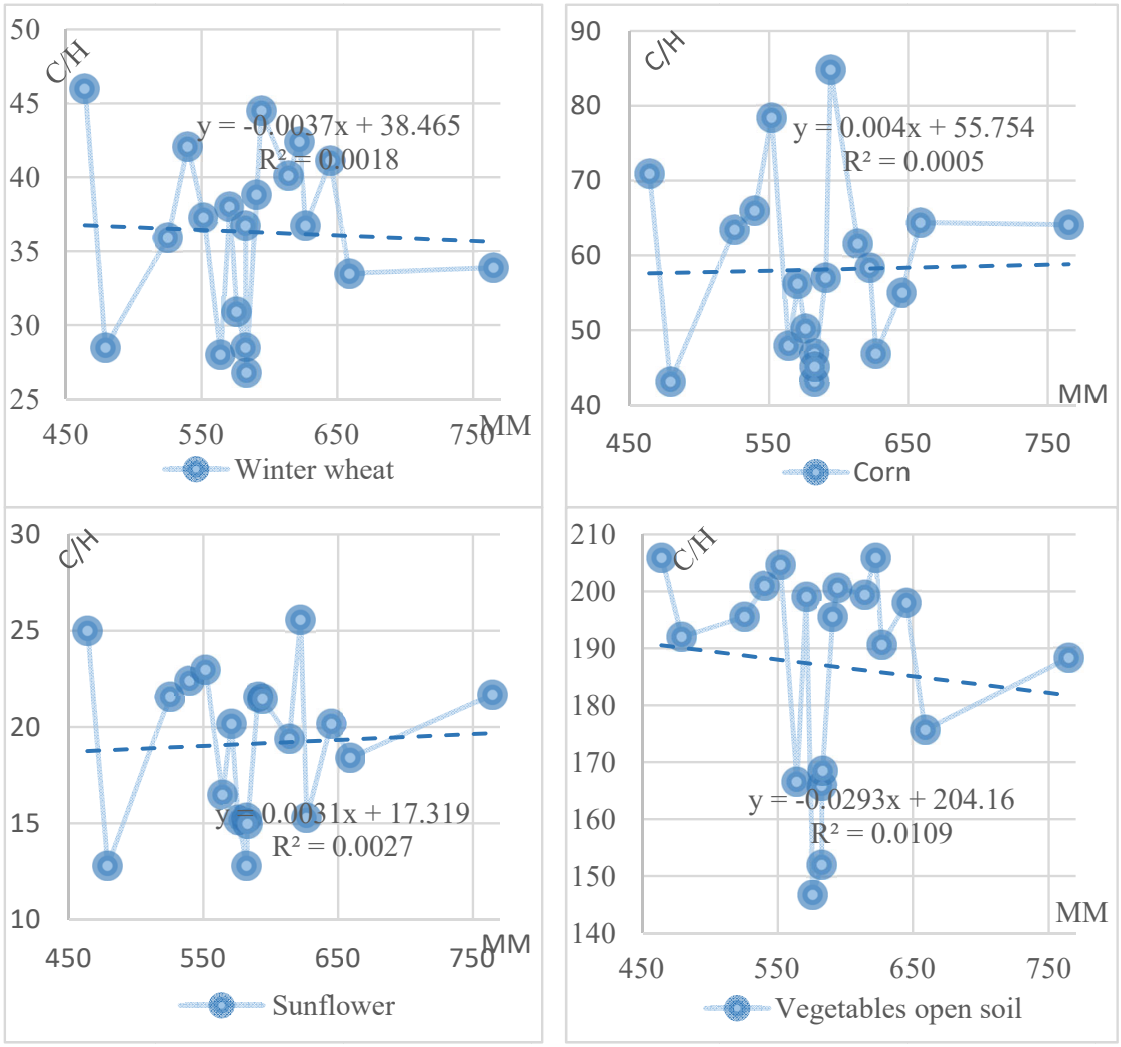

Fig. 3. Dependence of the yield of the main agricultural crops on the average annual rainfall in Ukraine for the years 2005-2023.

Such a change in area indicates the growing demand for irrigated land by agricultural enterprises of Ukraine. A significant increase is observed in sunflower **(**+144%) and cereals (+60.8%). As for sugar beet, taking into account the fact that the data in the statistical reports are reflected until 2017, we observe a significant increase, which amounted to from 0.3 to 4.2 thousand hectares, which is 7 times higher compared to 2010. And this is obvious, because these crops are more profitable compared to other agricultural crops, and therefore agricultural producers choose them in order to obtain higher results of their activities.

As for open ground vegetables, the situation remained almost within the limits that demonstrate stable irrigation in separately delineated territories. It is also worth noting that irrigated areas are used the most for vegetables (61% of all sown areas), so this is the most massive use of irrigation in agricultural enterprises of Ukraine [3].

Taking into account a number of factors of the external environment and the operating conditions of each individual enterprise, making a decision about the feasibility or impracticality of implementing an irrigation system can be different. Investments in drip irrigation are becoming relevant and agricultural enterprises are using it more and more often. After calculating the project cost of such an irrigation system, the enterprise makes a decision on the feasibility of implementing such an irrigation system [13-15].

Table 2. The structure of irrigated areas on the main agricultural crops of Ukraine, 2010-2021 [4].

Year	**Cultures**						
	Cereals and legumes, thousand ha	**Soy-been, thousand ha**	**Sunflower, thousand ha**	**Open soil vegetables, thousand ha**	**Potatoes, thousand ha**	**Sugar beet, thousand ha**	**Total irrigated land, thousand ha**
2010	125	99	25	23	6,3	0,3	278
2013	119	90	33	18	5,0	2,6	267
2014	98	109	39	21	3,9	0,1	272
2015	109	108	48	19	3,8	1,5	290
2016	102	116	45	20	4,5	4,6	292
2017	121	134	45	19	4,2	4,2	327
2018	136	126	62	21	4,1	-	349
2019	163	96,1	63	22	3,6	-	348
2020	188	87	72	23	4,5	-	374,5
2021	201	91	61	20,4	5,8	-	379,2
2021 to 2010, %	60,8	- 8,1	144	-11,3	-7,9	-	36,4

It is worth calculating the cost estimate of investments in the irrigation system. As an example, we have taken the private agricultural enterprise "Yana Plus", which has leased agricultural land within the boundaries of the Snovsky district of the Chernihiv region and for several years in a row has not been able to harvest agricultural crops due to unfavorable weather conditions. First of all, this situation is characterized by a decrease in the amount of precipitation in critical periods for plants in certain areas, i.e., uneven precipitation, as well as the spread of drought phenomena, especially in the summer and spring periods.

Based on the analysis, it was found that, on average, during the period of active development of most crops (April-July), the land of the enterprise does not receive about 25 mm of precipitation, and those that do fall are often unproductive (evaporation of water exceeds the intake of water), which negatively affects the yield of crops. In general, we can say that in recent years the amount of precipitation has decreased significantly and there is practically no uniformity.

Based on the analysis carried out, it can be stated that the climatic conditions in the territory of the Snovsky district are relatively favorable for the cultivation of the cult, however, a gradual change in the climate is felt, an increase in the average daily temperature worsens the temperature regime of the soil, and a decrease in precipitation leads to a deterioration of the water regime, which allows us to conclude about the expediency of building an irrigation system in the fields that suffer the most from these problems. The project's cost for introducing a drip irrigation system at an enterprise has been calculated, including three main groups of work. The groups were conventionally divided into preparatory work, design and costs for the irrigation system and its start-up (Table 3).

After the calculation, it follows that a significant share of costs falls on engineering systems and resource provision, which is 51.42% of all costs for investing in such a project. This value share includes significant costs for the development of the reservoir, which amounted to almost UAH 24,000/ha, and costs for equipment to provide the electricity system – 17.17% (UAH 13,700/ha).

Table 3. The project cost of works and materials for the development and launch of the drip irrigation system.

№	The name of the group of works	%	Cost UAH/ha
1	**Preparatory works**	**12,25**	**9 759**
1.1	Irrigation area assessment and analysis services	9,11	7 279
1.2	Works on the development of forested areas	0,12	94
1.3	Primary and basic tillage	3,02	2 386
2	**Primary and basic tillage**	**51,42**	**41 037**
2.1	Works on reservoir development and water supply	30,07	23 991
2.2	Works and equipment for providing the system with electricity	17,17	13 708
2.3	Engineering and technical block	4,18	3 338
3	**Irrigation system and work on its start-up**	**36,33**	**29 010**
3.1	Project works	6,57	5 243
3.2	Pump station	11,82	9 437
3.3	Filter station	5,69	4 544
3.4	Pipelines	8,75	6 990
3.5	Construction works	3,50	2 796
Total investments		**100,00**	**79 806**

The cost component included the construction of an artificial reservoir with a volume of 116,000 m^3 and the number of necessary wells, since the source of power can only be underground water, which must settle for a certain time in the reservoir itself before use.

Having calculated the investment investments in the launch of the drip irrigation system, investors make a decision on its implementation after comparing the efficiency of growing a separate crop without the use of drip irrigation and with its use. Therefore, we compared this efficiency using the example of corn cultivation. As we can see from Table 4, by investing in the irrigation system, we got an increase in yield of 5.5 t/ha, which at a price of 3,500 UAH/t will allow us to get an additional 19,250 UAH in revenue per hectare of irrigated area. Taking into account the amount of expenses, we get an additional UAH 3,097 profit from one hectare.

It should be noted that the implementation of irrigation systems requires changes in the management structure of the enterprise. As a rule, at the same time, an irrigation system is implemented, which requires a separate engineer and maintenance crew for this system. That is, when the enterprise begins to grow niche crops, vegetables or gardens, there is a need for new structural divisions that will be responsible for this, since one agronomist is no longer enough for 2000-2500 hectares.

Table 4. Comparison of the efficiency of growing corn for grain with and without irrigation.

Indicator	*With irrigation*	*Without irrigation*	Δ
Yield, t/ha	12,5	7,0	5,5
Revenue, hryvnias/ha	**43 750**	**24 500**	**19 250**
Direct expenses, hryvnias/ha	14 964	14 710	X
Irrigation costs, hryvnias/ha	15 899	X	15 899
Distributed costs, hryvnias/ha	7 147	7 147	X
Total costs, hryvnias/ha	**38 010**	**21 857**	**16 153**
Profit, hryvnias/ha	**5 740**	**2 643**	**3 097**
Profitability of production, %	15,1%	12,1%	3,0%
Margin, UAH/ha (%)	**11 423**	**3 848**	**7 576**
	30,1%	**17,6%**	**12,4%**

For an in-depth economic analysis of the selected drip irrigation implementation project, we calculated the classic indicators of investment analysis, which are shown in Table 5.

Table 5. General performance indicators of the drip irrigation project.

Indicaor	Value	Indicator	Value
WACC (коефіцієнт)	6,7	NPV (Net present value)	1 137 977
PP (Payback period)	5,08	IRR (Internal Rate Of Return)	8,7%
DPP (Discounted payback period)	6,43	PI (Profitability Index)	1,377

The weighted average cost of capital (WACC) is 6,7 for which the accumulated net cash flow of the project for seven years is UAH 6,001 thousand, while the accumulated discounted net cash flow is UAH 1,989 thousand. According to undiscounted cash flows, the project pays for itself in the sixth year of its operation, according to discounted ones - in the seventh year. Thus, investing in a drip irrigation system, under these conditions, the return on investment will have a positive result after six years of its operation.

4 Conclusion

Thus, after conducting a study of climatic changes observed during the last decade and its impact on the production activity of agricultural enterprises of Ukraine, we can make the following generalizations:

- ✓ over the past 18 years, the average annual air temperature in Ukraine has a clear tendency to increase, with minor deviations in individual years;
- ✓ correlation equation shows an annual increase in air temperature in Ukraine by 0.0618°C, and if calculated over 18 years – 1.11°C;

- ✓ the amount of precipitation tends to decrease - by 1.0766 mm annually, which is 454.18 mm over 18 years;
- ✓ with an increase in the temperature indicator, the yield indicators increase, in particular, when growing vegetables in the open ground - the yield indicator increases annually by 20.25 centners/ha;
- ✓ investing in an irrigation system for growing corn, it is possible to get an increase in yield of 5.5 t/ha, which will make it possible to get an additional 19,250 UAH in revenue per hectare of irrigated area;
- ✓ investing in a drip irrigation system, under the given conditions, the return on invested funds will have a positive result after six years of its operation.
- ✓ In conclusion, we note that Ukraine's place in the international market and its competitiveness depends to a greater extent on how it will be able to use its potential in conditions of water shortage, because today the shortage of this resource is one of the world trends.

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