AGRICULTURAL DEVELOPMENT UNDER A CHANGING CLIMATE IN UKRAINE: TRENDS AND CHALLENGES

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Abstract. *The last century was characterized by noticeable climatic changes. The whole world, including Ukraine has been significantly impacted. Such changes are characterized by increased average annual temperature on the planet surface, increased level of the water in the oceans, increased number of natural disasters and cataclysms, such as desertification, landslides, hurricanes, etc. Furthermore, the climate change coincides with the period of increasing food shortages in the world. The aim of the article is to study the dependence of agricultural efficiency on the changes in agro-climatic conditions of production in the long term and the impact of these changes on the cultivation of agricultural crops and their productivity. Research methods are general scientific and special, qualitative and quantitative, theoretical and empirical, comparative analysis. Agriculture is the sector of the Ukrainian economy that is the most vulnerable to fluctuations and climate changes. Given its inertial nature and the dependence on weather conditions, it is essential to make timely and adequate decisions regarding the problems caused by climate changes. Taken the expected increase of the air temperature in the Northern Hemisphere, Ukraine's food security will largely depend on the efficient adaptation to upcoming climate changes. The consequences and risks of the climate change for the food production vary from region to region, however the negative impact of climate trends outweighs the positive one. Thus, the research of the impact of climate change on the efficiency of agro-food production is crucial for the development of policies that would help to adapt to the consequences of these changes.*
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Introduction. Climate change has now become one of the biggest risks for the development of society, the environment and the economy both in the world and in Ukraine. Its influence is felt by all regions of the world and all strata of the population. Studies show that without adaptation measures, climate change could reduce global agricultural growth by up to 30% by 2050 (Munich Security Report, 2020). 500 million small farms worldwide will be critically affected.

Global climate changes, caused primarily by the active economic activities of mankind, lead to profound changes in the cycle of substances in the biosphere, which was formed over millennia. A global anthropogenic change in vegetation

functioning is observed, soil erosion is increasing, the Earth's climate is changing, and global warming is occurring (Stepanenko & Pol'ovyj, 2018).

Agriculture depends significantly on the weather, and therefore on long-term trends and changes in climatic conditions. Since agriculture is a key sector of the economy that ensures food security, climate change becomes an important factor in shaping food security because it can disrupt food production and cause uncertainty and instability in food prices. It is clearly impossible to determine how much climate change will affect the global food supply compared to other drivers. However, it is safe to say that the frequency and intensity of extreme events (heat waves, droughts and floods) may increase and this will lead to lower yields and production disruptions. Rising temperatures and changes in the timing, amount, and distribution of precipitation are likely to increase moisture and heat stress on crops and livestock, and agricultural systems will face increasing risks of soil erosion, runoff, landslides, and the spread of pests.

Currently, the climate of Ukraine is in the trend of global warming, it has covered the entire territory of our country, and the rate of increase in air temperature is even slightly ahead of the world average. Historical climate data indicate an increase in the annual temperature on the territory of Ukraine, and climate forecasts suggest further warming, especially in the south of Ukraine (NAS of Ukraine, 2021). Climatic zones are shifting to the north and west, heat and droughts are becoming more and more catastrophic, many extreme weather events that were rare before are often repeated in unusual seasons and in unusual areas. All these phenomena critically affect the production of agricultural crops, the condition of forests and water bodies, animal husbandry and fisheries, etc.

Literature review. Recently, many in-depth and large-scale studies have been conducted to study the impact of climate change on agricultural activity. The problem of global climate change is so complex and significant for humanity that large scientific teams in many countries of the world, international organizations and specially created creative groups are engaged in its research. Scientists of the world have developed dozens of different scenarios of possible changes in the Earth's climate under the influence of anthropogenic factors - growing human economic activity, as well as military conflicts of various scales. Common to all scenarios of future climate evolution is its warming. According to the World Meteorological Organization, the five-year period 2015–2019 was the warmest of any equivalent period globally, with a 1.1°C increase in global temperature over pre-industrial levels and a 0.2°C increase from the previous five-year period (World Meteorological Organization, 2019).

Scientists have proven that the consequence of global warming for agriculture is a reduction in the production of agricultural products due to a decrease in the yield of agricultural crops. In particular, this was emphasized by Adamenko (2019), Dem'yanenko (2012), El-Mansoury & Saleh (2017), Schönhart, Schauppenlehner et al. (2016) and others.

The problem of the influence of temperature on the yield of agricultural crops, and therefore the efficiency of the production of plant products, is considered

in the publications of many domestic and foreign authors. The assessment of the influence of weather factors on the yield of winter wheat in Ukraine was carried out in the work of Kryvoshein, Odnolietok, Dziuba (2016). The work of Gritsyuk & Bachishina (2016) is devoted to the impact of climate change on the yield of grain crops. Abrol & Ingram (1996) analyzed the dependence of productivity of major agricultural crops on high night and day temperatures. The effect of high temperatures on the physiology and phenology of plants is analyzed in the work of Hatfield & Prueger (2015).

The aim of the article is to study the dependence of agricultural efficiency on the changes in agroclimatic conditions of production in the long term and the impact of these changes on the cultivation of agricultural crops and their productivity.

Main results. The change in productivity and, as a result, the change in the efficiency of production of various agricultural crops, as well as the shift of their production to other agroclimatic zones, is considered in the context of the study of transformational processes under the influence of climatic changes occurring in the agricultural sector of Ukraine. Agriculture as a component of the economy depends to the greatest extent on the influence of natural factors, the main of which is the transformation of agroclimatic conditions caused by global climate changes.

The impact of climate change on the agricultural sector in Ukraine is already manifested in the reduction of productivity in the long term, the shift of agroclimatic zones to the north (northwest), a decrease in the level of soil moisture and intensification of erosion, an increase in the risk of the spread of pests and diseases, and an increase in the frequency of extreme weather conditions.

According to studies of changes in the average annual air temperature of the lower atmosphere, conducted for a long period by agrometeorologists of Ukraine, the modern climate of Ukraine is characterized by uneven warming over the territory, which is pronounced in the winter and summer months (Adamenko, 2019). Over the past 30 years, the average annual air temperature in Ukraine has increased by more than 1 C. The positive anomaly (deviation of air temperature from the norm) throughout the country in the period 1989-2019 was the largest in the entire history of instrumental weather observations. As these data show, since 1991, each subsequent decade has been warmer than the previous one: 1991-2000 – by 0.5 °C, 2001-2010 – by 1.2 °C, 2011-2019 – by 1.7 °C.

The change in the temperature regime in the warm period of the year affected the thermal resources of Ukraine, which are evaluated using the indicator of the sum of active (positive) air temperatures above +10 ºC accumulated during the warm period. A comparison of these amounts for different periods shows their significant increase, especially in the Polyssia zone (Table 1).

Table 1. **The sums of active air temperatures above + 10 ºC in the agroclimatic zones of Ukraine**

Agroclimatic zone	Periods		
	1961–1990	1991–2019	Change in the sum
Steppe	3145	3400	+255
Forest steppe	2705	2950	+245
Polyssia	2500	2770	+270

Source: calculated for (Adamenko, 2019*).*

Ukraine consists of three main agroclimatic zones: Steppe, Forest-Steppe, Polyssia and Precarpathia. This classification was carried out according to the ratio of the amount of precipitation to the amount of accumulated heat. Now, with the change in the average annual temperature and the amount of accumulated heat, these agroclimatic zones are shifting. According to forecasters, climatic zones are gradually migrating to the north. An increase in temperature by 1°C shifts the boundary of agroclimatic zones by an average of 100 km to the north. As the temperature increased by almost 2°C, the boundary of the climatic zones shifted by 200 km.

Currently, the Polyssia zone, which used to be a zone of sufficient moisture and not such high temperatures, is practically disappearing.

As a result of intense warming in recent decades, there have been changes in the structure of agricultural production, the area of field crops and their yield level. The data show that the Steppe zone, in which 44% of grain crops are concentrated, currently provides only 35% of total grain production, compared to 46% in 1990 (Table 2).

Table 2. **Changes in the structure of grain production in the agroclimatic zones of Ukraine, %**

Agroclimatic zone	Harvested area		Production	
	1990	2021	1990	2021
Cereal and leguminous crops - in total				
Steppe	44,9	44,2	45,8	34,8
Forest-Steppe	41,2	41,5	42,6	49,0
Polyssia	12,4	12,8	9,9	14,6
Precarpathia	1,5	1,5	1,7	1,6
Wheat				
Steppe	51,9	56,1	52,0	51,1
Forest-Steppe	36,7	34,0	38,6	38,8
Polyssia	10,0	8,9	8,0	9,1
Precarpathia	1,4	1,0	1,4	1,0
Corn				
Steppe	45,6	20,5	43,7	16,0
Forest-Steppe	48,3	59,0	50,2	61,9
Polyssia	4,3	18,2	3,8	20,0
Precarpathia	1,8	2,3	2,3	2,1

Source: calculated for data of the State Statistics Service of Ukraine.

There were no changes in the distribution of wheat production during the researched period, although it should be noted that the gross harvest in Ukraine as a whole increased by 6% compared to 1990, mainly due to the yield (12.7%), since the area under this crop generally decreased. Over 30 years, the placement of corn production, which requires higher temperatures and sufficient humidity, has changed significantly. The share of production in the Steppe zone decreased from 43.7 to 16%, and the area under this culture decreased accordingly. The production in the Polyssia zone increased very significantly, where previously corn was practically not grown, as it did not have time to ripen. Corn production in the forest-steppe zone is also increasing. Such trends are explained by climate changes, namely warming and the spread of arid zones in the Steppe.

The average grain yield in the Steppe zone during this period, despite its growth by 50% on a national scale, increased from 35.7 centners/ha in 1990 to 42 centners/ha in 2021. In Polyssia and in the Forest Steppe, an increase in yield was recorded from 29 to 58 and from 36 to 64 centners/ha, respectively. Thanks to this, 64% of grain is produced in these zones, although the share of crops of this group of crops here is only 54%.

Significant shifts caused by both technological and climatic changes occurred in the production of industrial crops. Over 30 years, Ukraine has significantly increased the production of sunflower, soybeans and rapeseed, while at the same time significantly reducing the production of sugar beet. The main factor behind such changes was the globalization of agricultural production and the entry of domestic producers into global markets. Compared to 1990, the production of sunflower seeds has increased by 6.4 times, rapeseed - by 22.5 times, and soybeans - by 35.2 times, so the production of the last two crops has turned from a niche to a main one. This radically affected the overall structure of production. At the same time, changes in accommodation occurred under the influence of climatic changes. Warming made it possible to move sunflower production from the Steppe zone to the Forest-Steppe and Polyssia zones. According to the table 3, in 1990 more than three quarters of all volumes were produced in the Steppe zone, and in 2021 produced 51.7%.

Table 3. **Changes in the structure of production of industrial crops in the agroclimatic zones of Ukraine, %**

Agroclimatic zone	Harvested area		Production	
	1990	2021	1990	2021
Sunflower seeds				
Steppe	79,4	57,5	75,9	51,7
Forest-Steppe	20,4	34,8	23,9	39,9
Polyssia	0,1	7,2	0,1	7,8
Precarpathia	0,1	0,5	0,1	0,6
Rapeseed				
Steppe	4,0	46,2	3,6	39,6
Forest-Steppe	61,1	36,3	64,6	42,3
Polyssia	29,2	15,3	24,6	15,7
Precarpathia	5,7	2,2	7,2	2,4
Soybeans				

Steppe	59,7	13,2	61,4	14,2
Forest-Steppe	38,9	63,9	37,4	62,7
Polyssia	0,4	18,9	0,2	18,9
Precarpathia	1,0	4,0	1,0	4,2
Sugar beet				
Steppe	14,5	5,1	11,5	4,6
Forest-Steppe	73,1	76,7	75,4	77,8
Polyssia	11,1	17,5	11,6	17,3
Precarpathia	1,3	0,2	1,5	0,3

Source: calculated for data of the State Statistics Service of Ukraine.

The data show that compared to 1990, soybean production from the Steppe zone, where 61.4% of soybeans were produced, moved to the Forest Steppe and Polyssia (due to the climatic conditions in Polyssia, soybeans were practically not grown), where currently, it is concentrated 82.8% of soybeans areas, which provides 81.6% of total production.

There were also changes in the distribution of rapeseed production during the research period, namely, the planting of this crop increased in the Steppe zone and decreased in Polyssia. Over 30 years, sugar beet production has decreased by 75% and is practically disappearing from the Steppe zone. This is due to both climate change and general market conditions.

The location of vegetable production in Ukraine has also changed significantly due to the increase in temperature and lack of moisture in the main growing area - the Steppe. As a result, production is gradually moving from the Steppe zone (the share of the area decreased from 46.6 to 35.1%) to the Forest-Steppe and Polyssia zones (the share of the area increased, respectively, from 40.6 to 48.2% and from 9.6 to 11.7%).

The agricultural sector of Ukraine in the current century is expected to undergo significant changes due to the impact of climate change. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change demonstrates the urgent need for substantial and sustainable decarbonization and climate change adaptation measures in the area of food security (IPCC, 2014). Forecast estimates given in the Report demonstrate the negative impact of climate change on the yield of agricultural crops. In particular, in regions with a tropical and temperate climate, an increase in temperature by 2°C without adaptation to it will negatively affect the yield of wheat, corn, soybeans, and rice, although in some regions it will have positive consequences. An increase in the global temperature by 4°C, which will be accompanied by a reduction in the volume of water resources and an increase in competition for them, will become a risk factor for food security on a global scale. In Ukraine, according to the Representative Concentration Pathways (RCP) scenarios, the following is expected:

according to the RCP 4.5 scenario, temperature increase throughout Ukraine: about 1.65°C (Steppe) and 1.74°C (Forest-Steppe); the change in the amount of precipitation will not be significant and will vary from 13 mm in the Steppe zone to 55 mm in the Forest Steppe;

under the RCP 8.5 scenario, a temperature increases from 2.68°C (mixed forest zone) to 2.98°C (Steppe); changes in the level of precipitation will be noticeable - more than 80 mm in the zone of mixed forests and less than 13 mm in the Steppe zone.

The result of these changes may be a reduction in production by 2070 due to climate change. The greatest reduction is possible in the Steppe zone: a probable reduction of wheat production by 11% for the RCP 4.5 scenario and 18% for the RCP 8.5 scenario.

Research carried out at the Ukrainian Hydrometeorological Center on the cultivation of the main grain crops (winter wheat and corn) using climatic scenarios transformed into the growing season of these crops and the use of a dynamic model of crop formation made it possible to quantitatively assess the reaction of plants to changes in agroclimatic growing conditions (Adamenko, 2012).

The obtained results indicate that the expected weather conditions during the next 10-20 years will be quite favorable for grain production in Ukraine. For winter wheat, it is possible to shift the sowing dates by 20–40 days and more effectively use the conditions of the autumn vegetation, which can lead to an increase in the total productivity of crops by 20–40%.

A positive impact of warming on corn productivity is also expected due to earlier sowing times and an increase in the area of cultivation to the northern and western regions due to the increase in heat supply of these areas, where it will be possible to grow mid-late and late-ripening hybrids of corn, the potential yield of which is higher than early and mid-early by 30 -50%.

Due to increased aridity, conditions may worsen for early spring grain crops (spring barley, spring wheat, oats). Under unchanged moisture conditions, this can cause a drop in the yield of spring cereals due to a shorter growing season and earlier ripening.

As a result of climate change, the border of the steppe will move significantly to the north, ending up in the current forest-steppe zone, which will shift the northern border of commercial cultivation of eggplants, sweet peppers and tomatoes. At the same time, the territory of agroclimatic regions favorable for the cultivation of potatoes, cabbage and cucumbers will decrease. The area of insufficient irrigation will increase significantly, where it will be necessary to revive and develop irrigation.

The consequences of the destruction of the Kakhovskaya HPP will also significantly affect the agroclimatic conditions. In the long term, large areas of Southern Ukraine are expected to experience unpredictable climate changes exacerbated by this ecological disaster, including: a decrease in precipitation, dust storms, and an increase in temperature in the region due to the opening of a large area of the sandy bottom of the reservoir. The destruction of the Kakhovskaya HPP will lead to the fact that the fields in the south of Ukraine may turn into deserts as early as next year, in 2024. Ecologists predict that the topographic features of steppe Ukraine cause dust storms to occur, which contribute to the growth of this desert and ultimately harm crops even in the most remote fields of southern and central Ukraine.

That is, in addition to the loss of irrigated fields in Kherson, Zaporizhzhya and Dnipropetrovsk, the surrounding territories may suffer in the following years due to the general deterioration of the climate.

In order to preserve the efficiency of the production of plant products in the conditions of climate change, it is necessary to adapt the components of the agrotechnology of growing crops. In particular, changes in temperature regimes in spring lead to a shift in the beginning of the sowing campaign, and accordingly, all other stages, in recent years. Yes, the sowing campaign begins on average 2 weeks earlier. To preserve moisture in the soil, it is necessary to use the properties of soil ecosystems, which are formed under the condition of reducing the depth and intensity of soil cultivation and covering the soil surface with plant mulch. So, surface soil loosening technologies (mini-till) are used, and in the southern regions, in the absence of soil compaction, the use of technology (no-till) is justified. The same technologies make it possible to reduce soil erosion and restore its fertility. The transition to the use of seeds resistant to climatic factors (drought and high temperatures) or hybrids is important. Also, due to unfavorable weather conditions caused by strong winds and high temperatures, farms postpone work to night time.

It should also be noted that almost all cultivated areas of agricultural crops in Ukraine are located in the zone of risky agriculture (territories with a natural deficit of precipitation), where there is a constant risk of loss of harvest volume in an excessively dry year or loss of harvest quality in an excessively rainy year.

Expected changes require the implementation of measures to prevent their negative impact on the functioning of the agricultural sector. The main areas of adaptation of crop production to climate change are:

– selection of drought-resistant and high-yielding varieties and hybrids of agricultural crops;

– expansion of sown areas for types and varieties of agricultural crops with a short vegetation period, which will make it possible to obtain more harvests of individual crops;

– implementation and restoration of effective irrigation systems (in particular, drip irrigation);

– restoration and creation of new field protection forest strips (agroforestry);

– shifting the sowing dates of spring crops to earlier and winter crops to later dates, which will ensure effective use of soil moisture reserves by crops;

– improvement of the monitoring system for diseases and pests;

– improvement of an effective insurance system in crop production.

Discussion and conclusions. Currently, the agricultural sector of Ukraine is not extremely vulnerable to climate change. However, changes in weather conditions (increased air temperature, uneven distribution of precipitation, which has a torrential nature in the warm season, inefficient accumulation of moisture in the soil) lead to an increase in the number and intensity of drought events. Together with other negative factors of anthropogenic influence, this can lead to the expansion of the zone of risky agriculture and to desertification in the southern regions of Ukraine.

In addition to the significant territorial redistribution of the structure of agricultural crops, uneven dynamics and growth rates of their productivity are noted. In general, the general increase in the yield of grain and leguminous crops in Ukraine occurred due to the more moisture-provided regions of the state of the Forest-Steppe and especially Polyssia.

Actual issues that require scientifically based solutions for their solution are the implementation of national programs for observing and studying climate change, combating land degradation and desertification, increasing forest cover, restoring and sustainable use of peatlands, increasing the territories and objects of the nature reserve fund, using the best domestic practices of land use and agricultural technologies aimed at adapting to climate change and mitigating its negative consequences.

REFERENCES

Abrol, Y. P., & Ingram, K. T. (1996). Effects of higher day and night temperatures on growth and yields of some crop plants. In: *Global climate change and agricultural production. Direct and indirect effects of changing hydrological and plant physiological processes* (pp. 304-310). Rome, Italy.

Adamenko, T. (2012). Bez paniky: klimatychni zminy mozhut vyiavytysia korysnymy dlia silskoho hospodarstva. [Don't Panic: Climate Change May Be Good for Agriculture]. *Tyzhden.* https://tyzhden.ua/

Adamenko, T. (2019). *Zmina klimatu ta silske hospodarstvo v Ukraini: shcho varto znaty fermeram* [Climate change and agriculture in Ukraine: what farmers need to know?]. APD-Ukraine.

Dem'yanenko, S. (2012). Stratehiya adaptatsiyi ahrarnykh pidpryyemstv Ukrayiny do hlobal′nykh zmin klimatu. *Ekonomika Ukrayiny*, 6, 66-72 [In Ukrainian].

EL-Mansoury, M., & Saleh, S. (2017). Influence of Climatic Changes on Faba Bean (Vicia faba L.) Yield in North Nile Delta. *Journal of Soil Sciences and Agricultural Engineering*, *8*(1), 29-34. https://doi.org/10.21608/jssae.2017.37065

Field, C. B., Barros,V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L. Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., & White, L. L. (Eds.). (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Gritsyuk, P. M., & Bachishina, L. D. (2016). Vliyanie izmeneniya klimaticheskih usloviy na dinamiku urozhaynosti zernovyih v Ukraine. *Ekonomika Ukrayiny*, 6, 68-75.

Hatfield, J. L., & Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and climate extremes*. 10, 4-10.

How climate change affects the area of major agricultural crops in Ukraine. *NAS of Ukraine*. https://www.nas.gov.ua/UA/Messages/Pages/View.aspx?MessageID=7830

Kryvoshein, V., Odnolietok, L., & Dziuba L. (2016). Otsinka vplyvu pohodnykh umov ta orhanizatsiino-tekhnolohichnykh zakhodiv na urozhainist ozymoi pshenytsi za yii klimatychnym potentsialom. *Naukovi pratsi UkrNDHMI*, 269, 151-158.

Munich Security Report. (2020). www.securityconference.org/en/publications/munich-security-report

Schönhart, M., Schauppenlehner, T., Kuttner, M., Kirchner, M., & Schmid, E. (2016). Climate change impacts on farm production, landscape appearance, and the environment: Policy scenario results from an integrated field-farm-landscape model in Austria. *Agricultural Systems*, 145, 39-50. https://doi.org/10.1016/j.agsy.2016.02.008

Stepanenko, S. M., & Pol'ovyj, A. M. (2018). Klimatichni riziki funkcionuvannya galuzej ekonomiki Ukrayini v umovah zmini: monograph. Odesa: TES.

The Global Climate in 2015-2019. (2019). *World Meteorological Organization.* https://wmo.int/