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THE IMPACT OF CLIMATE CHANGE ON THE EFFICIENCY OF AGRICULTURAL CROP CULTIVATION IN THE RIVNE REGION

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The article examines the impact of climate change on the efficiency of crop cultivation in the Rivne region, which serves as a representative area for studying adaptation processes in the context of changing climatic conditions in north-western Ukraine. It has been established that an increase in average annual temperatures, a decrease in uniform precipitation, and more frequent droughts significantly affect the yield of major crops and cause their spatial differentiation. The study includes a spatial analysis of agricultural production, an assessment of climate-related risks in the administrative districts of the region, and the identification of regional differences in the impact of climatic factors. The effectiveness of growing various crops in the new climatic conditions was assessed. The results indicate the need to adjust the crop structure in favour of more adaptive and profitable crops, such as potatoes, corn, open-field vegetables, and fruit and berry crops. An optimised crop structure adapted to the current agroclimatic conditions of the region is proposed. The study uses an interdisciplinary approach that combines agroclimatic analysis, economic assessment and spatial modelling.

The results obtained can be used to develop strategies for adapting the agricultural sector to climate change, ensuring food security and increasing the

economic sustainability of agricultural production in the Rivne region and similar regions of Ukraine.

Keywords: climate change, agriculture, economic efficiency, crop yields, agroclimatic risks, crop rotation, food security.

Problem statement. Climate change has become a global issue in recent decades, significantly affecting various areas of economic activity, particularly agriculture. Ukraine, as one of Europe's leading agricultural countries, is particularly vulnerable to climate change, which manifests itself in changes in temperature, moisture deficiency, an increase in the frequency of extreme weather events and soil degradation. These factors directly affect the productivity of agricultural land and, accordingly, the economic efficiency of its use.

At present, Ukraine's agricultural sector is not highly vulnerable to the effects of climate change. At the same time, changing weather conditions, combined with other negative effects of human activity, may lead to an expansion of areas of risky farming and increased desertification in the southern regions of Ukraine.

Over the past decades, intense climate change has led to significant transformations in the structure of agricultural production, particularly in the distribution of areas planted with cereals and legumes. It should be noted that the dynamics of yields of major crops in recent decades have been uneven: while in the Forest-Steppe and Polissya regions the average yield of cereals and legumes has increased by 46–61% compared to 1990, in the Steppe, on the contrary, a 10% decrease has been recorded. Similar changes have been observed in the productivity of other major crops. Overall, the general increase in the yield of cereals and legumes in Ukraine has occurred mainly in regions with better moisture conditions — Polissya and the Forest-Steppe. [2,4,7,8]

Analysis of statistical data shows that in the Steppe zone, where 46% of grain crops are concentrated, only 35% of total grain production is currently

generated, which is a significant decrease compared to 45% in 1990. The average grain yield in this zone during 2013–2017 was 32.2 centners per hectare, while in 1990 this figure was 35.8 centners per hectare, despite an overall increase in grain crop yields in Ukraine of 21%. [4,6,7,8]

Accordingly, it can be stated that ensuring stable economic efficiency in the agricultural sector under conditions of climate change requires the introduction of new approaches to land use, the use of adaptive technologies, changes in crop structure and strategic planning based on forecast scenarios. Assessing efficiency under new conditions is becoming an important tool for justifying decisions aimed at increasing the sustainability of agricultural production and maintaining food security.

Despite numerous scientific studies in the field of agricultural production and climate change, Ukraine still needs regionally oriented assessments that would take into account the specifics of different natural and climatic zones, especially those such as Polissya and Lisostep, where changes are manifested unevenly. In this regard, the Rivne region was selected as a representative region for the study.

Analysis of recent studies and publications. Recent studies and analytical materials unanimously indicate that climate change is already significantly affecting the efficiency of crop cultivation in various regions of the world. Rising average temperatures, changing precipitation patterns, frequent droughts and extreme weather events are reducing the yields of major crops such as corn, wheat, soybeans and rice. It has been established that a one-degree Celsius increase in temperature reduces crop yields by an average of 5–8%, posing a serious threat to global food security. [1]

The article by Rosenzweig et al. (2013) presents the concept and initial results of the international AgMIP (Agricultural Model Intercomparison and Improvement Project) project, which aims to improve the prediction of the impact of climate change on agriculture. The authors developed uniform protocols for

comparing crop yield models for different climate scenarios and emphasised the importance of an interdisciplinary approach, which will allow for more accurate assessment of food risks and the development of adaptation strategies for different regions of the world. [5]

A study by Moore, Baldos, Hertel and Diaz (2017) analysed scientific data on the impact of climate change on agriculture and argued that traditional estimates underestimate the scale of economic losses. The results of the study point to the need to review climate policy, taking into account more realistic economic consequences for the agricultural sector. [3]

Publications by Ukrainian scientists also indicate growing attention to the problem of the impact of climate change on agricultural production efficiency. The ‘Methodology for forecasting the impact of climate change on the productivity of agroecosystems’ developed by the Institute of Agroecology and Nature Management of the National Academy of Agrarian Sciences of Ukraine presents a practical approach to assessing changes in crop productivity using remote sensing and agroclimatic indicators. In particular, emphasis is placed on the use of the NDVI index and effective temperature sums to forecast crop yields under climate change conditions, which allows for a timely response to potential risks. [8]

A comprehensive analysis of the economic consequences of climate change for Ukraine's agricultural sector is presented in the ‘Report on Climate and Development in Ukraine: Agriculture,’ published by the Kyiv School of Economics. [7]

The document provides an assessment of the risks associated with changing climatic conditions and offers recommendations for adaptation, including the development of irrigated agriculture, the introduction of climate-resistant crop varieties, and support for farms in conditions of increased climatic instability. Particular attention is paid to the economic assessment of losses and the need for investment in improving the sustainability of agricultural production. [7]

Research objective. The objective of the research is to identify potential climate threats to agriculture in the Rivne region and to justify ways of adapting agricultural production to new climatic conditions.

Materials and methods of scientific research. The methodological basis of the study is based on an interdisciplinary approach that combines agroclimatic analysis, economic assessment, spatial modelling, and statistical interpretation of data. This set of methods allows us to assess both the direct and indirect impact of climate change on the efficiency of crop cultivation in the Rivne region. Agroclimatic analysis was used to study long-term series of air temperature, precipitation, frequency of droughts and extreme weather events. Modelling methods were used to identify spatial differentiation of climate risks, analyse areas of increased aridity and waterlogging, and assess the suitability of crop structures to natural and climatic conditions. Analytical and comparative methods were used to summarise data from official statistics, international studies and scientific reports.

Research results and discussion. Climate change is becoming one of the main factors affecting agriculture in Eastern Europe, particularly in Ukraine. In the Rivne region, which is traditionally characterised by a temperate continental humid climate, the last few decades have seen significant climatic changes. Rising temperatures, irregular rainfall and longer periods of drought are changing the agricultural landscape of the region. Awareness of these impacts is important for the development of adaptation strategies aimed at maintaining the productivity of the agricultural sector and ensuring food security.

The territory of Rivne Region covers 2,005,100 hectares, of which 46.2% is agricultural land (926,200 hectares), including 658,000 hectares of arable land, which accounts for 70.8% of the total agricultural area. Forests and wooded areas cover 805.8 thousand hectares, which is 40.2% of the total area, water bodies cover 43.2 thousand hectares (2.2%), open wetlands cover 106.6 thousand

hectares (5.3%), built-up areas — 59.6 thousand hectares (3.0%), other categories of land — 31.8 thousand hectares (1.6%). [6]

The region's agricultural sector specialises mainly in the cultivation of cereals and legumes, industrial crops (in particular sugar beet, rapeseed, sunflower), potatoes and vegetables, as well as in the production of livestock products, in particular meat, milk and eggs.

In the structure of gross agricultural production of all categories of farms, crop production prevails, accounting for 68.5%, while livestock production accounts for 31.5%. (Table 1).

Table 1

Structure of agricultural production by administrative districts of Rivne Region (2023) [6]

Administrative District	Grain area (thousands of hectares)	Grain yield (centimeters per hectare)	Industrial crop area (thousands of hectares)	Industrial crop yield (centimeters per hectare)	Potato area (thousands of hectares)	Potato yield (centimeters per hectare)	Vegetable area (thousands of hectares)	Vegetable yield (centimeters per hectare)
Dubno	85.0	42.5	22.0	30.5	8.0	140.0	2.0	170.0
Rivne	80.0	41.0	18.5	29.0	12.0	135.0	3.5	175.0
Sarny	45.0	36.5	7.5	25.0	18.0	130.0	2.0	165.0
Varash	25.0	32.0	4.8	22.0	15.0	120.0	1.5	160.0

An analysis of the structure of agricultural production indicates the existence of regional specialisation in agricultural production in the Rivne region. Accordingly, the Dubno and Rivne districts are distinguished by the largest areas of grain and industrial crop cultivation, which is due to favourable agroclimatic

conditions and soil fertility. In the Sarny and Varash districts, there is a predominance of potato and vegetable cultivation due to the characteristics of the soil and climate.

Over the past three decades, there has been a gradual increase in the average annual air temperature in the Rivne region. This trend is consistent with the general climate changes observed in the northern and north-western regions of Ukraine. [6,10] Climate change, in particular the rise in air temperature and the increase in the duration of dry periods, has a significant impact on agriculture. This impact manifests itself in reduced crop yields, shifts in agroclimatic zones, and an increased risk of simultaneous crop failures in the region. This necessitates the adaptation of agricultural technologies and the implementation of soil moisture conservation measures, especially in the central and southern parts of the region. There has also been a decrease in evenly distributed precipitation during the growing season and an increase in the frequency of droughts. Periods of prolonged drought have become more frequent, especially in the spring and summer months, which is critical for crops such as corn, soybeans and winter wheat. Between 1990 and 2023, the average annual temperature in the region increased by approximately 1.2°C. The amount of summer precipitation decreased by 6–8%, while the amount of extreme precipitation in the spring and autumn increased. Droughts are now recorded once every 3–4 years. [6,10] Thus, the identified climate trends indicate the need to adapt the agricultural sector of the Rivne region to new temperature and hydrothermal conditions in order to maintain the productivity of agroecosystems and the economic sustainability of farms.

Accordingly, a spatial analysis of agricultural production and climatic influences in the Rivne region was carried out by administrative districts, each of which has different climatic, soil and socio-economic characteristics that determine the specifics of agricultural production. In particular, it was established that the Rivne district is the most economically promising for the development of

crop production (especially corn, potatoes, and vegetables). The problem is the risk of summer droughts and the need to introduce moisture conservation technologies. Sarny district: there are areas with high levels of natural moisture, and the priority is the development of crops that are resistant to waterlogging (rye, perennial grasses). The prospect is agroforestry and the development of livestock farming. Dubno district: an area of intensive agriculture, but with a growing threat of summer droughts. Prospects — development of drought-resistant crops (corn, soybeans) and the use of minimum tillage technologies. Varash district: mainly forested areas, agriculture is of limited importance. It is recommended to preserve natural ecosystems, develop ecological production and organic farming on small areas. (Table 2.)

Table 2.

Spatial characteristics of agricultural production and climate risks in administrative districts of Rivne Region

Administrative District	Main areas of economic activity	Climatic features	Main risks due to climate change
Dubno	Growing of cereals, corn, livestock	The climate is favorable, with less precipitation compared to the north of the region	Moisture deficiency in the second half of summer, heat
Rivne	Crop production (cereals, potatoes, vegetables), dairy farming	Temperate continental climate, sufficient rainfall, risk of dry summers	Summer droughts, local showers, risk of soil erosion
Sarny	Forestry, partly agriculture (rye, potatoes).	Increased humidity, high level of waterlogging	Overwatering of soils, risk of crop loss in rainy years.

Varash	Forestry, little agricultural land	The greatest waterlogging, low density of agricultural production	Increased risk of flooding, instability of agricultural production

Climate change is already affecting agriculture in the Rivne region, particularly the yield and economic efficiency of growing major crops. According to World Bank data, in the northern and north-western regions of Ukraine, which include Rivne, winter wheat yields are expected to increase by 20–40% by 2050 compared to 2010, due to higher temperatures and increased precipitation. [9] However, these positive changes may be accompanied by increased risks, such as more frequent droughts, extreme weather events and changes in typical vegetation, which in turn may negatively affect other crops, particularly maize and soybeans, which are sensitive to water shortages. With this in mind, the effectiveness of crop cultivation in the Rivne region under conditions of climate change was assessed.

Table 3

Effectiveness of crop cultivation in the Rivne region under conditions of climate change

Crop	Current profitability	Climate change resilience	Area recommendation	Comment
Fruit and berry crops	Very high	High	Expand areas	High profitability, adaptability
Open-field vegetables	Very high	High	Expand areas	Maintains yield under new conditions
Potatoes	High	High	Save / slightly expand	Requires moisture control

Corn	High	High	Maintain / expand	Resistance to temperature increases
Rapeseed	Average	Medium	Optimize technologies	Requires better water management
Soybeans	Average	Medium	Optimize technologies	Requires drought-resistant varieties
Wheat	Below average	Medium	Save with technological optimization	Possible losses without technology adaptation
Barley	Low	Low	Reduce areas	High risks of economic losses
Sunflower	Low	Low	Reduce areas	Sensitivity to summer droughts

Based on the analysis of the effectiveness of crop cultivation in the Rivne region under conditions of climate change, an optimised crop structure has been proposed (Table 4).

Table 4

Optimal crop structure in the Rivne region under conditions of climate change

Agricultural crops	Share in the structure of crops (%)
Fruit and berry crops	15–20%
Outdoor vegetables	10–15%
Potatoes	20–25%
Corn	20–25%
Winter wheat, soybeans, rapeseed	15–20%
Barley and sunflower	≤5%

Conclusions. Ensuring the stability of agricultural production in the context of climate change requires a systematic approach that combines agroclimatic monitoring, regional specifics, the use of climate-resistant varieties, rational water resource management, and the development of adaptive technologies. Climate change is having an increasingly significant impact on agricultural production in the Rivne region, causing both direct and indirect consequences for

agriculture. Rivne region, which has a predominantly temperate continental climate, has become characterised by unstable weather conditions, frequent spring and autumn frosts, increased summer droughts and periods of abnormal heat. Excessive precipitation in the northern districts of the region (Varash, Sarny) causes flooding of lowlands, swamping, erosion of slopes and ravines, and, as a result of heavy rains, soil erosion. In the southern part of the region (Rivne and Dubno districts), droughts are becoming more frequent, leading to a decline in the yield of grain and fodder crops. It is also worth noting that climate change affects the water balance and availability of water resources, which is particularly noticeable in small river basins (Goryn, Styr, Sluch, Ubor). The water supply of farms, especially those operating on reclaimed land in Polissya, depends on the intensity of precipitation and the level of surface runoff.

Therefore, potential climate threats to agriculture in the region include: an increase in the average annual air temperature and an increase in the number of days with temperatures above +30°C; an increase in the frequency of droughts, especially in the eastern and southern parts of the region; an increase in the number of extreme precipitation events, leading to flooding and erosion of arable land; an increased risk of forest and peatland fires in northern Polissya; favourable conditions for the spread of pests and diseases affecting agricultural crops. Climate change is already leading to changes in land use patterns. The region is seeing a trend towards a reduction in the area under traditional fodder crops and an increase in the cultivation of industrial crops (rapeseed, soybeans) and cereal crops that are more resistant to drought. In contrast, in the northern areas, where there is still excess moisture, the role of land reclamation systems and drainage infrastructure is increasing. Higher temperatures may cause a shift in agroclimatic zones: part of the region may move from the Polissya to the Forest-Steppe zone, opening up opportunities for growing more heat-loving crops (maize, soybeans, winter wheat). However, this requires the adaptation of cultivation technologies, the renewal of varieties and the strengthening of

agricultural reclamation measures. Along with the risks, climate change also creates new opportunities for the agricultural sector in Rivne region.

Extending the growing season will help increase crop yields and enable the introduction of new varieties and crops. In northern regions, there are growing prospects for the development of berry farming (blueberries, blackberries, cranberries), organic farming, and the production of environmentally friendly products. At the same time, it is important to develop innovative irrigation and water conservation systems, digital soil moisture monitoring, and the use of adapted minimum tillage technologies. Such measures will contribute to food security, economic efficiency, and the environmental sustainability of agroecosystems in the Rivne region.

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І.П.Купріянчик.

Вплив зміни клімату на ефективність вирощування сільськогосподарських культур у Рівненській області

У статті досліджено вплив зміни клімату на ефективність вирощування сільськогосподарських культур у Рівненській області, територія якої слугує репрезентативним напрямом для вивчення адаптаційних процесів в умовах зміни кліматичних умов на північному заході України. Встановлено, що підвищення середньорічних температур, зменшення рівномірної кількості опадів, почастішання посух суттєво впливають на врожайність основних сільськогосподарських культур і обумовлюють їх просторову диференціацію. Дослідження включає просторовий аналіз сільськогосподарського виробництва, оцінку ризиків, пов'язаних з

кліматом, в адміністративних районах регіону, а також виявлення регіональних відмінностей у впливі кліматичних факторів. Була проведена оцінка ефективності вирощування різних сільськогосподарських культур в нових кліматичних умовах. Результати свідчать про необхідність коригування структури посівів на користь більш адаптивних та рентабельних культур, таких як картопля, кукурудза, овочі відкритого ґрунту та плодово-ягідні культури. Запропоновано оптимізовану структуру посівних площ, адаптовану до сучасних агрокліматичних умов регіону. У дослідженні використовується міждисциплінарний підхід, який поєднує агрокліматичний аналіз, економічну оцінку та просторове моделювання. Отримані результати можуть бути використані для розробки стратегій адаптації аграрного сектору до зміни клімату, забезпечення продовольчої безпеки та підвищення економічної стійкості сільськогосподарського виробництва в Рівненській області та аналогічних регіонах України.

Ключові слова: зміна клімату, сільське господарство, економічна ефективність, врожайність сільськогосподарських культур, агрокліматичні ризики, сівозміна, продовольча безпека.