

TRANSFORMATION OF AGROCLIMATE RESOURCES OF SOUTHERN UKRAINE IN CONNECTION WITH GLOBAL WARMING

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Abstract: Climate change due to global warming is one of the challenges of the 21st century. It is characterized by various manifestations, including changes in the frequency and intensity of climate anomalies and extreme (dangerous) weather events. As climate change occurs, natural resources also change. Current warming immediately requires a change in the agroclimatic approach to the growth, development, and formation of agricultural productivity. Global warming is accompanied by significant changes in air temperature during the winter months, increased precipitation, disruption of natural processes, changes in seasonal consumers, the duration of the frost-free period, and drought during the growing season of agricultural crops. An increase in the frequency of extreme weather events, a decrease in soil moisture and changes in soil fertility, depletion of freshwater reserves in flooded areas of the country, and soil degradation are possible. At the same time, the main feature of global warming has become uneven precipitation during the period, which has led to increased arid conditions. Due to significant temperature fluctuations during the summer season, Ukraine's food security will largely depend on how effectively agriculture adapts to upcoming climate change. Maintaining climate-resilient natural resources has always been of great importance, especially in agriculture, as climate change alters climate resources. Due to its geographical location, economic structure, and environmental conditions, Ukraine is one of the countries for which the socioeconomic consequences of climate change may be irreversible. Therefore, climate change requires further research.

Keywords: solar radiation, climatic models, winter barley, temperature regime, crops

1. Introduction

The climatic regime of each region is formed as a synthesis of the features of temperature, humidity, precipitation, wind, which are based on the laws of distribution of radiation, heat and water balances and the influence of atmospheric circulation. The diversity and huge number of climate-forming factors determine the state of the climate with a very complicated spectrum of fluctuations. The increase in surface air temperature in the Northern Hemisphere has caused a sharp interannual variability of agricultural productivity due to a significant change in agroclimatic conditions for the formation of crop productivity. The main climatic characteristics are average monthly air temperature and precipitation. Changes in air temperature and precipitation are a universal characteristic of the observed climate changes.

2. Literature analysis

A wide range of studies have been carried out to investigate the peculiarities of various processes in the atmosphere, which cause changes in the moisture-temperature regime of the underlying surface [1, 2]. It has been established that a particularly large role in climate change during warming is played by the change in large-scale atmospheric circulation through those that circulate all the warehouses of weather minds. The world's scholars have recognized the fact that climate change has been intensifying recently [3,4,5]. This caused the hourly disruption of the development of natural processes, a constant increase in air temperature, an increase in the frequency of extreme natural phenomena, etc. In the event of climate change, as the criteria for such changes, global climate models are most often used, which are the main tools that are used to design waste and intensity. climate change in the future. In this case, climatic models of different levels of foldability are developed, from simple climatic models to models of transitional foldability, advanced climatic models, and models of the entire Earth's climate system. These models will resolve future climate regimes based on low scenarios of changes in anthropogenic factors. The models allow us to look not only at changes in the global climate, but also to evaluate its regional aspects [2].

3. Research objective

Changing Earth's radiation balance is reshaping key agroclimatic parameters that determine which crops can be grown where. Due to the increasing radiation balance, thermal zones are shifting toward the poles (northward in the Northern Hemisphere). Belts of stable agriculture are shifting by 100–300 km for every 1°C of warming. This opens up opportunities for agriculture in more northern latitudes, but is limited by the fertility of local soils.

Increased thermal (longwave) radiation leads to temperature sums exceeding +10⁰ C. This leads to the following:

- enables the cultivation of more heat-loving and late-ripening crops (corn, sunflower, soybeans, grapes) in regions where this was previously impossible;
- accelerates the ripening of grain crops, but due to the too rapid development phases, the grain does not have time to fill out, which can reduce yields;
- increases the length of the growing season; the period between the temperature crossing +5⁰ C in spring and fall increases by 10–20 days. This allows for two harvests of some early-ripening crops (greens, radishes, early potatoes) in a single season.

The purpose of this study is to determine the characteristics of temperature changes in the territory of the southern steppe of Ukraine during the period from 1890 to 2025.

4. Research methods and materials

The analysis of meteorological indicators was conducted across the main agro-climatic zones of Ukraine; these zones were further subdivided into sub-zones to provide a more detailed territorial characterization. Climate change trends were analyzed by comparing long-term average meteorological and agrometeorological indicators across three periods: the first - prior to 1960; the second - from 1961 to 1990; and the third - from 1991 to 2025. Long-term average values served as the baseline for comparing meteorological indicators. The key characteristics of the temperature regime included: dates when air temperature crossed the 0, 5, 10, and 15°C thresholds in spring and autumn; the duration of periods with air temperatures exceeding 0, 5, 10, and 15°C; the sums of positive air temperatures for periods with temperatures above 0°C, 5°C, 10°C, and 15°C, as well as for the 5–15°C range in spring and the 15–5°C range in autumn; the duration of periods with temperatures between 5 and 15°C in spring and between 15 and 5°C in autumn; average air temperatures for January and July; and temperature amplitude.

If increased radiation is not compensated by precipitation, the Selyaninov hydrothermal coefficient (HTC) decreases. This leads to droughts, soil degradation, and reduced crop yields in traditional "breadbaskets" (southern steppe zones). Thus, all changes in thermal resources can be presented in Table 1.

Table 1. Changes in agroclimatic indicators of thermal resources during climate warming

Agroclimatic indicators	Trend in a warming environment	Impact on agriculture
Influx of PAR	Uneven (growth of diffuse radiation)	Potential increase in biomass productivity
Sum of active temperatures	Significant growth	The expansion of subtropical and heat-loving crops to the north
Duration of the growing season	Increase by 1.5–3 weeks	Delayed sowing dates, risk of late spring frosts
Soil evaporation	A sharp increase	Increasing moisture deficit, need for artificial irrigation

For the southern steppe of Ukraine (Odesa, Mykolaiv, Kherson, and Zaporizhzhia), changes in radiation conditions and global warming pose critical challenges. Winter wheat and winter barley are C₃-dependent crops. This means they directly benefit from rising CO₂ concentrations, but are extremely sensitive to radiation and heat stress during key developmental stages. The southern steppe of Ukraine is experiencing the most severe consequences of changing radiation and thermal conditions in Ukraine.

Positive factors:

- Mitigation of wintering: Rising winter temperatures reduce the risk of winter barley (which is less winter-hardy than wheat) freezing. Winter crops continue their sluggish growth even during the January "windows," accumulating biomass.
- Effect of CO₂ fertilization: In early spring (March-April), when soil moisture is still sufficient and temperatures are moderate, elevated CO₂ levels allow stomata to remain semi-closed. Plants conserve water but photosynthesize intensively.

Negative factors (Critical challenges):

- Radiation and heat shock during the grain filling phase (grain trapping): A shift in the radiation balance leads to temperatures consistently exceeding 30°C under cloudless skies as early as May (intense direct radiation). According to Farquhar's model, this causes the destruction of photosystem II (photoinhibition). Leaves turn yellow prematurely, grain filling ceases, and grains become "shrinking."
- Shortening of interphase periods: Due to the high sum of active temperatures, the plant goes through the tillering, booting, and heading stages at an accelerated pace. The plant simply does not have time to form a large ear and develop a strong root system.
- Shift in sowing dates: Due to severe late summer and autumn droughts (high radiation → extreme evaporation), optimal sowing dates have shifted from September to October and sometimes November to catch the autumn rains.

Thus, our agroclimatic modeling of thermal resource transformation in the Odessa, Mykolaiv, and Kherson regions reveals the following long-term trends:

1. A catastrophic decline in the hydrothermal coefficient (HTC): Radiative heat amounts are increasing, while annual precipitation remains virtually unchanged, but its nature has become torrential. The HTC in May and June often drops below 0.5 (severe drought). The southern steppe is gradually acquiring characteristics of a semi-desert.
2. Shift in agroclimatic zones: The climate zone of Ukraine's southern coast is de facto shifting toward a Mediterranean or semi-arid type. This requires a revision of all cultivation technologies.

3. Increased evaporation: Even if the spring was rainy, excess solar radiation dries out the top layer of soil (0–20 cm) in a matter of days, depriving winter barley (which has a more superficial root system than wheat) of nutrition during the critical tillering phase.

Therefore, to compensate for radiation stress in southern Ukraine due to global warming, it is necessary to implement agronomic adaptations:

- Ultra-early varieties: Selection is aimed at allowing wheat and barley to finish flowering and develop grain before peak radiation and temperature loads (before mid-June).
- No-Till/Strip-Till technologies: Retaining crop residues on the field surface. This increases soil albedo (light straw reflects radiation better than dark bare soil) and reduces soil temperature by 3–5°C, conserving moisture.
- Liquid nitrogen fertilizers (LNF): Switch to liquid fertilization in early spring, as there is simply no moisture to dissolve dry granules under conditions of rapid radiation-induced soil desiccation.

5. Conclusions

Providing food for people has always been a critical issue for the planet's ever-growing population. Despite the steady increase in global food production, this problem remains acute in many countries. On the one hand, a growing global population requires a significant increase in food production, while on the other, it increases anthropogenic pressure on natural ecosystems. Therefore, the rational use of agroclimatic resources is of paramount importance.

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