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Justification of irrigation restoration in the central forest-steppe taking into account the climate change trend

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The purpose. To carry out an analysis of climatic changes in the central part of the Forest-Steppe, to justify the feasibility of restoring irrigated drainage systems. **Methods.** Assessment of changes in the agrometeorological resources of the territory was carried out by the method of mathematical-statistical analysis of complex indicators of heat and moisture conditions: climate water balance and hydrothermal coefficient. The stationary experiment data were processed by the methods of system generalization, correlation, economic, calculation, and comparative analyses. **Results.** The climate of the region is determined by a sufficient level of heat resources and unsustainable moisture. Due to a steady increase in the temperature regime, the supply of active air temperatures increased from 2880 °C to 3300-3500 °C, the total annual deficit of the water balance increased to 150 mm. As a result, in 32% of cases, that is, 3 years out of 10, in the region strong and moderate arid conditions of the growing season are observed. Fluctuations in meteorological conditions over the years directly influence the yield of field crops, in particular, winter wheat and sugar beet. Years with high crop yields are characterized by close to optimal levels of natural moisture supply. It has been established that the coefficient of variation of winter wheat yield over the years depending

on the predecessor and the background of fertilizer can reach 39, sugar beet — 41%. **Conclusions.** In the forest-steppe zone, the maximum realization of the potential of the existing agrometeorological (heat, light) and chemical-technogenic resources is possible only if the water regime is regulated with the obligatory consideration of other factors determining a high level of effective soil fertility. So, the natural background of the typical deep low-humus chernozem in the Right-Bank Forest-Steppe provides the yield of winter wheat at the level of 4 t/ha. With the improvement of nutrition and moisture conditions, the maximum crop yield increases 1.7 times, and with the optimization of all factors, it can be increased 2.5 times.

Key words: *agrometeorological resources, winter wheat, productivity, optimization, moisture supply.*

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In recent decades, research has been carried out at the NMC “Water Resources and Reclamation”, namely at the Institute of Water Problems and Reclamation of the NAAS, it is proved that the reclaimed territories of the irrigation and drainage zones of Ukraine are characterized by a rather high potential of agricultural resources [1 – 6]. According to long-term average data, productivity of zonal rotations on natural background of fertility of organic and mineral soils of Polissya for the main and by-products, respectively, 40 and 45 feed units of centers/hectare, in the Steppe on the black earth — 30 centers of feed units/hectare. With the improvement of the nutritional regime of these soils, the productivity of typical crop rotations is increases and equals respectively 65, 75 і 40 centers of feed units/hectare, optimization of rotation and nutritional regime provides 90, 100 і 50 centers of feed units/hectare. On the reclaimed lands additional regulation of the water-air regime of the organogenic soil makes it possible to obtain 140 centers of feed units/hectare, mineral — 150, black earth in the Steppe — 130 centers of feed units/hectare [7–10].

At the same time, studies were conducted on climate change trends in different soil and climate zones of Ukraine [11, 12]. In the Steppe, such changes lead to a decrease in favorable conditions for cultivation of all field crops, and in the humid zone there are positive trends in the productivity of agricultural land.

In the forest-steppe zone with a high probability of favorable and unfavorable hydrothermal conditions these trends give reason to expect an increase in variability or the instability of crop productivity and the profitability of agricultural production [13].

As of 1994, the area of irrigated land in Ukraine was 2604.9 thousand hectares. Of these, in the forest-steppe zone within the Vinnytsia, Kyiv, Poltava, Sumy, Ternopil, Kharkiv, Khmelnytsky, Cherkasy and Chernivtsi regions The irrigation network covered 791.8 thousand hectares. In the Poltava region, the total area of land reclaimed was 88 thousand hectaresincluding 69 irrigation systems on an area of 50.8 thousand hectares, on the territory of Kharkiv region the accounting area of land reclaimed was 94.2 thousand hectares, of them irrigated lands —82,4 thousand hectares, there were in Vinnytsia region 81,1 thousand hectares of reclaimed land, of which 23.8 thousand hectares — irrigated lands, in Cherkasy region – 118.9 thousand hectares of land reclaimed, including 63.2 thousand hectares of irrigated land, in the Kiev region the area of reclaimed land was 232.7 thousand hectares, of which irrigated – 43.9 thousand hectares [14, 15]. Unfortunately, the possibility of regulating the water-air regime of the soil these lands are poorly used, that in the event of rapid deterioration of moisture conditions, appropriate measures should be taken.

Purpose of research — to analyze climate change in the central part of the forest-steppe, to prove the feasibility of restoration and expansion of the area of irrigated lands.

Research methodology. Climate change was assessed on the basis of Climate Water Balance (CWB) and Hydrothermal Coefficient (GTC) values. Long-term hydrothermal indicators of the Bila Tserkva meteorological station were used to solve these tasks (attitude 49.78°; longitude 30.12 WMO index 33464) and information base of stationary field agrotechnical experiment of the Institute of bioenergy crops and sugar beet of NAAS "Finding ways to increase the effective soil fertility and crop yields based on a combination of different crop rotations and fertilizer systems [16]. The experiment was founded in 1973 at the Bilotserkivskii Research and Breeding Station. Crop rotation: 1 – clover, 2 – winter wheat, 3 – sugar beets, 4 – peas, 5 – winter wheat, 6 – sugar beets, 7 – corn for green feed, 8 – winter wheat, 9 – sugar beets, 10 – barley. The cultivation of the soil is multi-depth combined: deep plowing 28-30 cm under sugar beets, 20-25 cm – under fodder, small tillage (12-15 cm). Fertilizer systems were compared: 1 – control, 2 – $N_{50}P_{66}K_{66}$ + 8 tons/hectare of manure. Soil – chernozem typical deep low humus large-medium-loamy with humus content of 3.6-4.1%, mobile phosphorus and potassium (according to Chirikov) respectively 13-15 and 5-7 mg/100 grams of soil, alkaline hydrolyzed nitrogen (12 Corn – hydrolyzed) – 14 milligrams / 100 grams of soil.

The coefficient of variation was used to estimate crop yield fluctuations and crop rotation productivity by year [17]. The estimated coefficient of variation (Kv) of the studied indicator can be grouped according to the accepted scale of qualitative assessment: less than 15% – low; 15-30 – average; over 30% is high.

The natural background of fertility is determined in the variants without fertilizers by the indicators of the average annual crop yields. The maximum level of productivity of crops against this background in the most favorable year in the history of the experience of the year shows the role of optimization of the water-air regime of the soil. The average yield over the years of research over the long-term use of organo-mineral fertilizer systems indicates the role of improving the nutrient regime of the soil cover. The maximum productivity of crops against the background of long-term use of fertilizers simulates the simultaneous improvement of conditions of water supply and plant nutrition.

Research results. The climate of the region is determined by a sufficient level of heat supply and unstable humidity. The average annual temperature for the years 1991-2018 was 9.0°C and was constantly increasing. In the last 10 years, its value has been below 9.5°C only in 2 cases (Fig. 1).

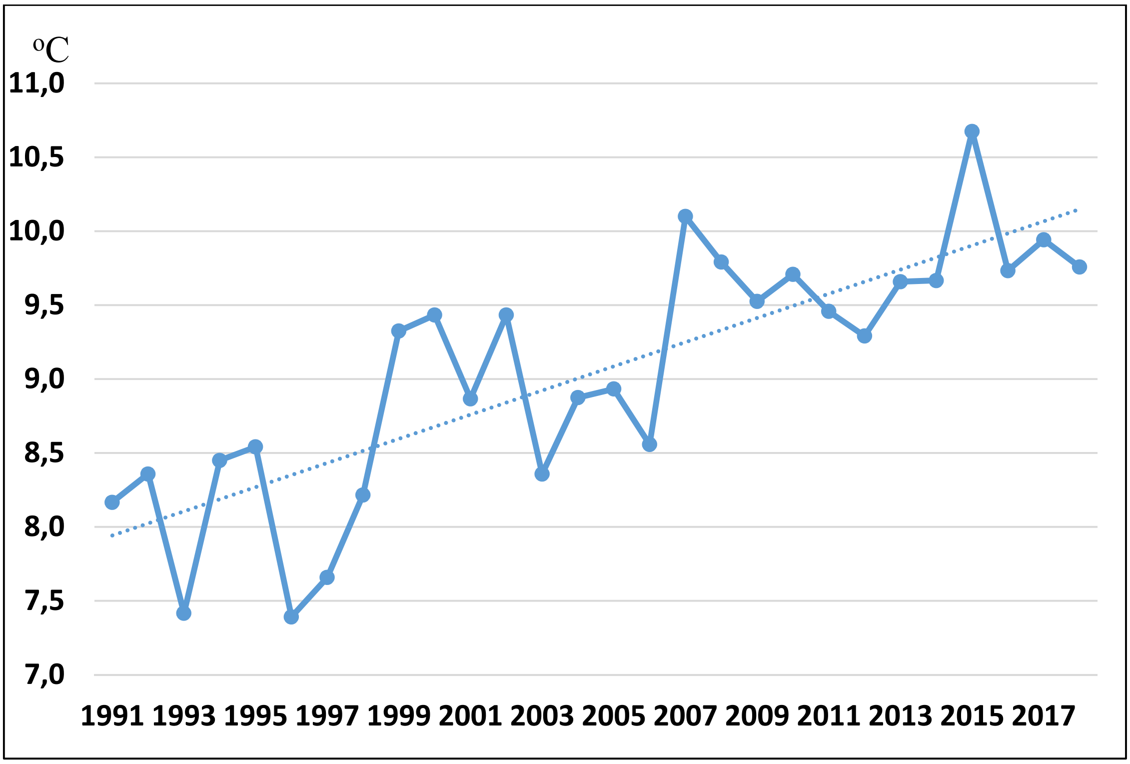

Fig. 1. Dynamics of average annual air temperature, °C

Due to the steady increase in temperature, the region is characterized by an increase in the level of active air temperatures (above 10°C). Thus, if by the mid-1990s the sum of active air temperatures averaged 2880°C, now it ranges between 3300-3500°C. Efficient use of thermal resources in the region is limited by the unstable humidity conditions. The average annual rainfall for the years 1991-2018 is 615 mm, and their overall dynamics since 1991 is aimed at a slight decrease. The regime of water supply of the territory and crops is determined not only by the amount of rainfall, but also by their cost part. For example, in the region, between January and April, the average monthly rainfall is 35-40 mm, which amounts to nearly 150 mm. During this period, the potential total evaporation averages 140 mm (Fig. 2).

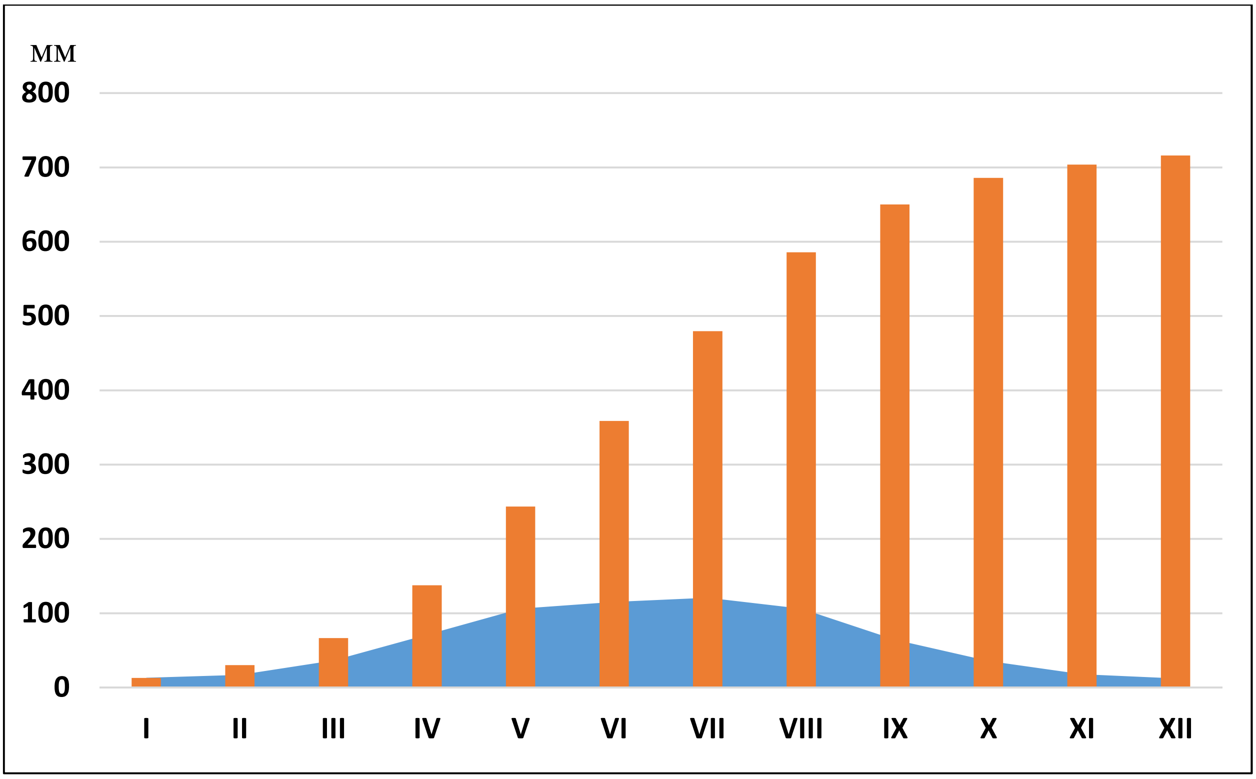

Fig. 2. Potential total evaporation by months in 1991–2018, mm: per month; an increasing result (for Fig. 2, 3)

Evaporation (on an increasing basis) on average outweighs the amount of moisture coming in with rainfall by 33 mm from the beginning of the year, and by the end of June the moisture deficit will be 70 mm, and in July it will be 127 mm (Fig. 3).

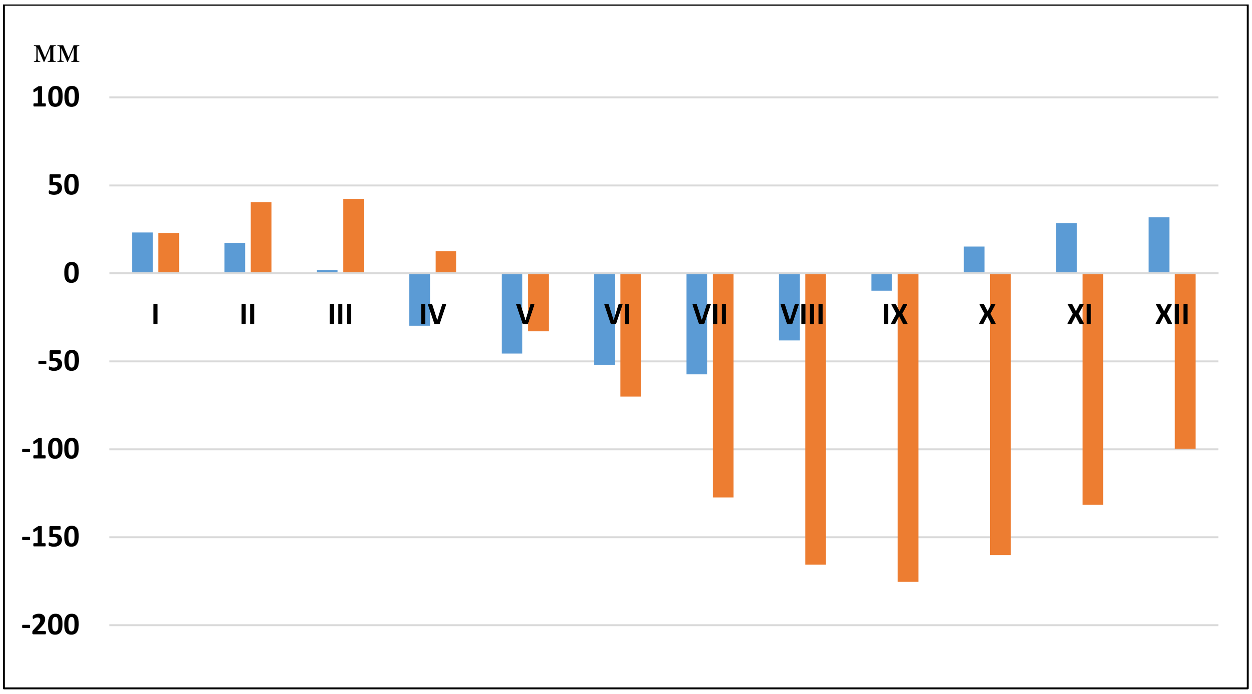

Fig. 3. Climate water balance values by months of the year (average for 1991–2018), mm

This indicates that in order to form an optimal level of productivity of early crops, additional moisture supply should be provided within the range of 1100-1300 thousand m^3/ha.

By the end of the late vegetation period (August-September), due to the high level of evaporation (evapotranspiration), the moisture deficit is still increasing and reaches 165-175 mm. That is, the irrigation rate for providing soybean yields in the range of 4-4.5 t/ha, corn for grain – 12-14 t/ha will grow to 1600-1800 m^3/ha. The calculations shown in Fig. 3, 4, is the basis for determining irrigation and irrigation rates depending on the type of crops. In general, in the region, the trend towards increasing the temperature of the CWB speaker is directed towards the deterioration of the humidity conditions (Fig. 4).

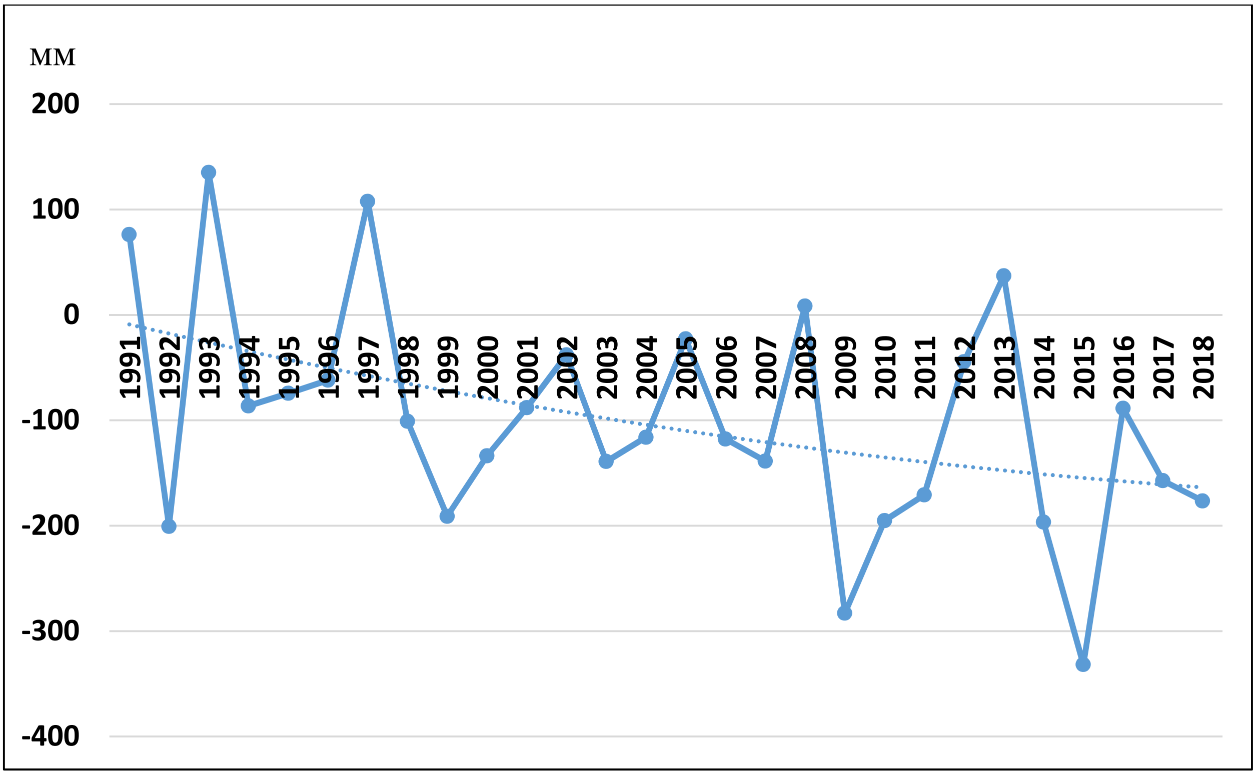

Fig. 4. Dynamics of the annual CWB for 1991–2018, mm

1. Frequency of repetition of different levels of moisture during the growing season (April – September) for 1991–2018

GTC	The degree of aridity	Frequency, %
Less 0,7	Very dry	7
0,71–1,00	Medium arid	25
1,01–1,20	Weak moisture	25
1,21–1,80	Adequate moisture	43

GTC (rainfall to active air temperature) can also be used to assess the conditions of moistening of the growing season in the region and to decide on the expediency of irrigation. If the GTC of the vegetation period averaged 1.4 in the early 1990s and met the conditions of sufficient moisture, in the last 4 years it did not exceed 1, which corresponds to arid conditions.

In addition, in 1991-2018 in the region in 32% of cases, i.e. 3 years out of 10, there are severe and average drought conditions of the growing season (Table 1). In 43% of cases there is a sufficient level of moisture during the growing season. However, this does not indicate that there is no need for water regulation in separate periods of plant development, because GTC gives an idea of the conditions of moistening of the growing season as a whole and does not characterize its separate periods.

Therefore, changes in meteorological conditions over the years directly affect the level of crop yields, as evidenced by the results of the regional field stationary experiment, where other factors of production remain constant over a long period.

For example, in the 9th year of research (Fig. 5), there was a relatively high yield of winter wheat, which ranged from 35.2 c/ha against the background of natural soil fertility (without fertilizers) to 75.4 c/ha in the organ-mineral system. fertilizers (table 2).

2. ***Influence of agrometeorological conditions on crop productivity and its variability***

Year	***Average annual air temperature***, °C	***Annual precipitation, mm***	GTC ***of the growing season***	***Annual CWB, mm***	Yield, kg/ha	
					no fertilizer	with fertilizers
Winter wheat, Kv=16–39%						
1993	7,4	756	1,6	135	35,2	75,4
1994	8,5	592	1,2	-86	8,2	16,0
Sugar beet, Kv=16–41%						
2002	9,4	699	1,54	-38	342	412
2003	8,4	547	0,91	-139	135	165

In 1994, there was a significant decrease in its yield: against the background of natural soil fertility – up to 8.2 c/ha, in fertilized areas – up to 16 c/ha. Analysis of the agrometeorological conditions of these years showed that the annual rainfall in high-yielding 1993 was 756 mm, the GTC of the vegetation period corresponded to wet conditions – 1.6, and the annual climatic water balance was positive and amounted to 135 mm. In the 1994 low-yield year, agrometeorological conditions varied significantly: annual precipitation was 592 mm (22% less than in 1993), GTC – 1.2 (25% lower), and CWB year deficit was 86 mm. The situation is similar with respect to sugar beet yields. For example, in moderately humid 2002, its level was 2.5 times higher than in 2003, which was characterized by a significant deficit of moisture.

Conclusions

As a result of climate change, the CVB deficit in the Central Forest Steppe zone increased by 150 mm over the period 1991-2018, and the hydrothermal coefficient of the growing season decreased from 1.5 (sufficient humidity) to 1 (average arid conditions). It is established that in the soil-climatic conditions of the Right-bank Forest Steppe the productivity of crops of all crops is determined by the peculiarities of weather conditions of a particular year and is characterized by high instability. The interannual coefficient of variation in winter wheat yield by year, depending on the precursor and background of the fertilizer, ranges from 16 to

39, sugar beet – 16 – 41%. The maximum realization of the potential of existing agrometeorological (heat, light) and chemical-technogenic resources in the study area is possible only if the water regime is regulated, with due consideration of other factors that determine the high level of effective soil fertility.

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