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# LONG-TERM PREDICTION OF CLIMATE CHANGE IMPACT ON THE PRODUCTIVITY OF GRAIN CROPS IN UKRAINE USING SATELLITE DATA

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**Aim.** To analyze and predict the climate change impact on the crop structure, yield and gross collections of grain crops in short-term (2025), mid-term (2050) and long-term perspective. **Methods.** Analysis of long-term series of climatic parameters based on satellite data, climatic modeling, statistical analysis of crop yield and gross collection of grain crops. **Results.** The positive effect of historical and current climate change on grain crop yields in Ukraine is demonstrated. It is predicted that the preservation of this pattern and the implementation of an integrated system of measures for adapting agroecosystems to warming will promote further increase in the grain crop yield and thus its gross collection. **Conclusions.** According to the analysis of satellite data and climatic models, further climate warming is predicted and its positive impact on grain crop productivity is forecasted. In case of developing and implementing the measures to adapt agroecosystems to climate change, the grain yield in Ukraine may increase by 25 % in 2025 compared with the current period (2015) and by 29–30 % in 2050; the gross collection of grain crops will reach 75.0 million tons (in 2025) and 79.0–80.0 million tons (in 2050). On condition of efficient material and technical, scientific and informational support, further development of technical means, the reproduction of soil fertility and the improvement of irrigation technologies in the long-term perspective (by 2100), the gross grain collection may reach 92–95 million tons.

**Keywords:** Grain crops yield, satellite data, productivity, NDVI, temperature, precipitation, gross grain collection, long-term prediction, climate change impact.

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## INTRODUCTION

Paris Climate Change Summit (2015) highlighted the increasing risks of negative impact of global climate changes on the biosphere of Earth with the temperature increase by more than 2 ºC which is especially relevant for agriculture and food safety of many countries. Ukrainian agrosphere has a high potential of natural resources and, on condition of timely adaptation to climate change via the introduction of low carbon agro-production and proper material and technical provision, may implement both national and global mission of food safety to a considerable degree.

In Ukraine, the study of climate change, including temperature and moisture, is implemented under the auspices of the Ministry of Ecology and Natural Resources of Ukraine, and its results are generalized in the National Communications on climate change in accordance with the requirements of the UN Framework Convention on Climate Change (UN FCCC) [1]. This issue is also based on numerous scientific papers of the Ukrainian Scientific Research Hydrometeorology Institute (UkrSRHMI) where much attention is paid to the climate change impact on all the spheres of economic activity [2, 3]. However, the subject of climate change impact on the ecological condition of agrolandscapes, the system of land utilization, soil cover, agroecosystem productivity and agricultural industry in general is yet to be elucidated. In this respect, it is important to solve the problem of adapting the agricultural production to new climatic conditions and using efficiently the additional agroresource potential, including warmth and moisture.

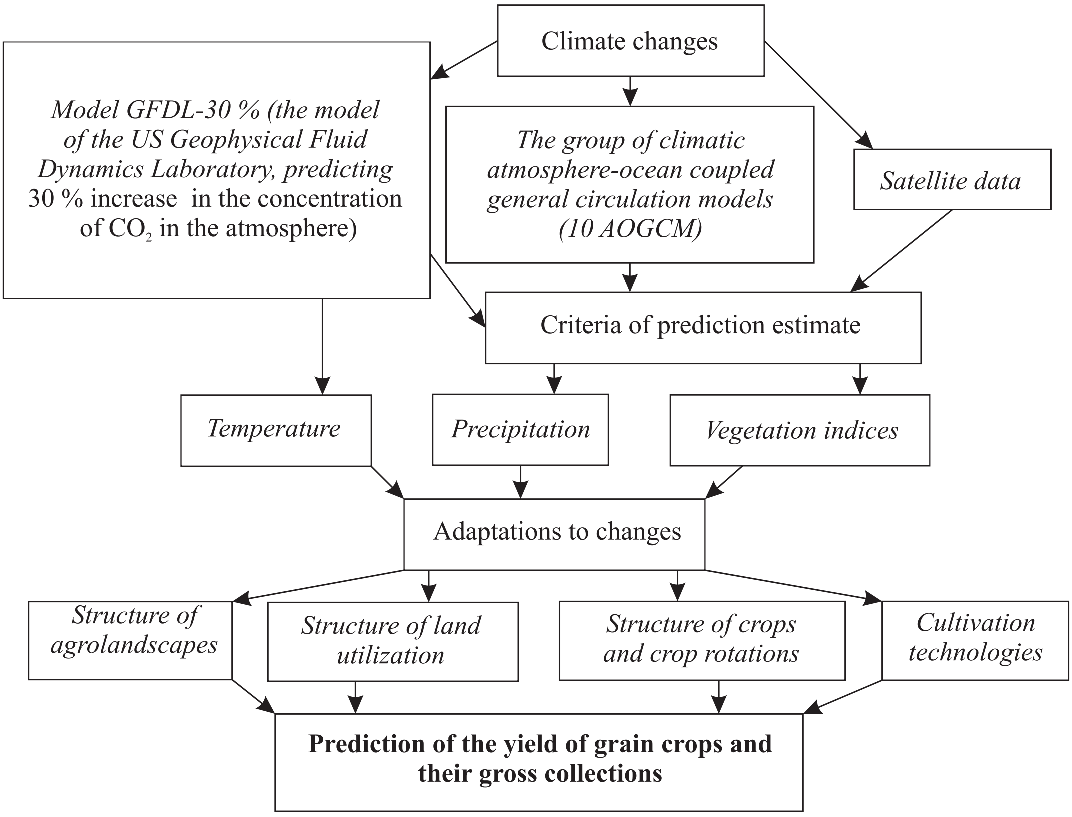



**Fig. 1.** The scheme of estimating and predicting the climate change impact on the yield of grain crops and their gross collections

The adaptation of agroecosystems to climate changes should be understood as the introduction of measures, aimed at preventing, mitigating, or using climate changes appropriately, for instance, warming-up in the northern regions, which may improve the productivity of agroecosystems [4]. The process of climatic adaptation is a multivector process, consisting of the correction of the structure of agrolandscapes, land utilization systems, crop structure, adherence to scientifically substantiated crop rotations, correction of seeding terms, introduction of moisture-preserving technologies of soil treatment, management of its fertility, improvement of irrigation technologies and systems of protecting the crops from pests and diseases. The UN Framework on Climate Change views the adaptation process as the adaptation to current or expected climatic impact or its consequences, which would mitigate the losses and open the possibilities for their prevention or reduction.

The climate of Ukraine is rather sensitive to global changes and the temperature increase in this territory occurs with higher tempo compared to the global rate [1]. For instance, it is established that there is a tendency to warming-up of the upper layer of the world ocean by 0.67 °C. The warming-up processes proceed faster in the Black sea, thus its upper layer warmed up by 0.96 °C from 1982 till 2005 [5]. This temperature increase may result in negative consequences for agroindustrial production, including the increasing risks of droughts and other extreme phenomena, which are especially common for the Steppe zone of Ukraine.

In this context, it is urgent and promising to implement the principles of “climate-smart” agriculture [6] which is first and foremost related to its adaptation to new natural climatic conditions, correcting the zone systems of land utilization and agrotechnology, including the reduction of greenhouse gas emission, preservation of the quality of absorbers, especially soils, as well as resources and energy. Thus, in these conditions it is necessary to perform objective analysis and prediction of climate change impact on yield in particular, as well as to estimate its both positive and negative impact on agricultural production, including the determination of possible risks for agrosphere and national food safety of the country.

## MATERIALS AND METHODS

The scientific research was conducted within the framework of a joint study involving the Marine Hydrophysical Institute (MHI), entitled “Spatial estimation of the degree of profitableness of future climatic conditions for the productivity of major grain crops and forests” [2]. Based on the analysis of results, obtained in modern climatic modelling [3, 7], satellite data [8–10], the results of long-term agrotechnical experiments of scientific institutions of the National Academy of Agrarian Sciences of Ukraine (NAAS) [11] and the statistical information on the yield of grain crops in different climatic zones of Ukraine, conducted according to the scheme, presented in Fig.1, the long-term prediction of climate change impact on the yield and gross collection of grain crops in Ukraine has been made.

Climatic modelling is one of the well-accepted methods of estimating and predicting climate changes, the theory of which is based on the regularities of the interaction of atmosphere and ocean circulation. The Coupled Model Intercomparison Project (CMIP3) selected ten global AOGCM models (atmosphere-ocean coupled general circulation model), elaborated by scientific institutions of EU states and the USA, which are the most suitable for the prediction of climatic situation in Ukraine, according to the analysis of UkrSRHMI and MHI. These models were also used in the preparation of the Fifth national communication on climate change in Ukraine [12–15].

There are extensive opportunities of observing and predicting climate changes using both the data of classic observations at the meteostations and the satellite data. In this respect, the climatic data of the series of NOAA satellites (National Oceanic and Atmospheric Administration), which are in free access starting from 1986, are especially valuable. The retrospective analysis of this information allows predicting the change in agroclimatic conditions, including temperature, in the territory of Ukraine as well, for short- and long-term periods.

The research used the satellite data of NOAA cosmic equipment, Terra and Aqua, for over 35 years (from 1980 till 2016). The analysis of temperature changes involved the use of weekly summarized data of SMT (Smoothed Brightness Temperature) of Advanced Very High Resolution Radiometer (AVHRR) [8]. The study of precipitation dynamics involved the study of monthly mean data of the Total Surface Precipitation product – MERRA-2/NASA [10], and the analysis of $CO_2$ dynamics in the atmosphere – the data of AIRS/Aqua [9]. The mean values for a year, a season, and a vegetation period (April-October) were analyzed and compared against the corresponding historic period (1986–2010). The information about the yield and agricultural crop planting was obtained from the statistics collections for the period of 1991–2016. The predictive estimation of climate change impact on the condition of plants was made using the analysis of logarithmic trends of temperature, precipitation, and NDVI index (Normalized Difference Vegetation Index), which usually changes for green vegetation in proportion to the phytomass increase [16].

## RESULTS AND DISCUSSION

*The analysis of changes in temperature regime.* According to climatic modelling, the prediction of temperature increase in both short- (2025) and mid-term perspective (2050) was established for all the soil-climatic zones of Ukraine. The group of 10 models for early XXI century forecasts the increase in air temperature by 1.0 °C compared to the current status (2001–2010). There is a predicted increase in the temperature by 2.0 °C in the third and fourth decades, as well as by 3.0 °C and, as per some models – by 4.6 °C, by the end of the century [17, 18].

Compared to 1986–2005, according to the most common model used in Ukraine, GFDL-30% (the model of US Geophysical Fluid Dynamics Laboratory, pre-

**Table 1**. Estimated temperature and mean daily precipitation in XXI century according to GFDL-30 % model compared against the historic period of 1986–2005 (According to MHI data) [13 5].

| Natural-climatic zones | Temperature increase, °C | | Mean daily precipitation, mm/day | |
|---|---|---|---|---|
| | 2046–2065 | 2081–2100 | 2046–2065 | 2081–2100 |
| Polissia | 3.5 | 4.4 | 7.5 | 7.9 |
| Forest-Steppe | 3.5 | 4.2 | 5.6 | 3.6 |
| Steppe | 4.0 | 4.1 | 3.1 | 2.9 |

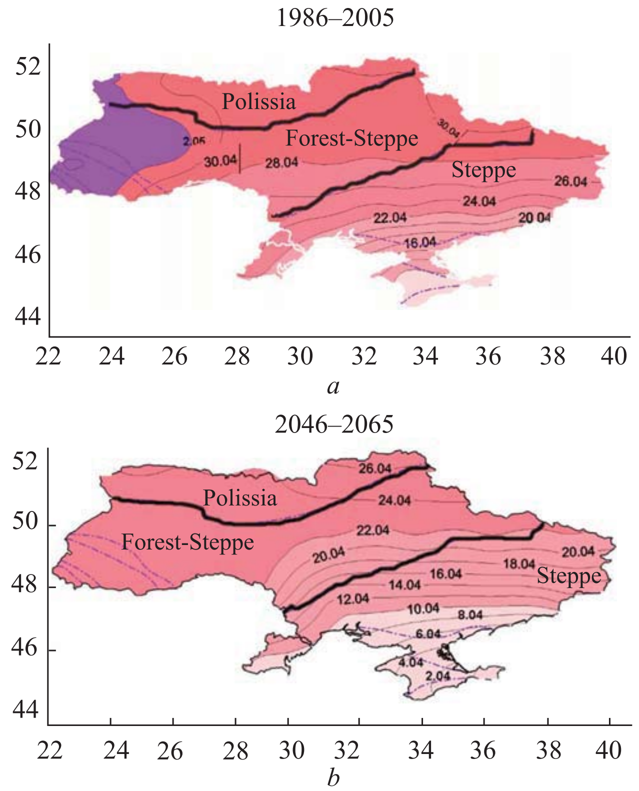



**Fig. 2.** The comparison of zone-wise transition of air temperature in the territory of Ukraine for 10 ºC for the period of 1986–2005 (*a*) and the forecast for 2046–2065 (*b*) according to GFDL-30 % (according to the data of MHI [13 5])

dicting 30 % increase in $CO_2$ concentration in the atmosphere), the mean annual temperature in 2046–2065 will also increase by over 3 ºC in all the natural climatic zones: for instance, in the Polissia zone – by 3.5 ºC, in the Forest-Steppe – by 3.33.5 ºC and the Steppe – by 3.3–4.0 ºC (Table 1). Thus, the analysis of predicting the temperature change using climatic models allows making a general conclusion on rather a fast rate of temperature increase for short-, mid-, and long-term (up to 2100) perspective (Table 1).

A relevant consequence of climate warming for Ukrainian agrosphere is the prolongation of the vegetation period. Compared to the historic period (1986-2005), by 2046–2065 the transition of temperature for 10 ºC will start 4 days sooner in Polissia zone, 6–8 days sooner in the Forest-Steppe, and 8–10 days – in the Steppe (Fig. 2).

One may assume that such considerable changes in the duration of the vegetation period in general should have a positive impact on the productivity of agroecosystems. At the same time, there is an increasing risk of droughts, sudden return of ground frost, as it was observed in spring of 2017, which will require elaborating the corresponding adaptation measures to mitigate their negative impact on agrophytocenoses.

Currently, the prediction of climate changes, including the ones on the regional level, widely involves satellite data, for instance, NOAA, in addition to climatic modelling [19, 20]. These open source data were used to build the flow charts of the sum of effective temperatures for the year for all the administrative regions of Ukraine and to determine their algebraic trends by 2025 and 2050. Figure 3 presents these data for typical administrative regions of the zones of Polissia, Forest-Steppe, and Steppe – Chernihiv, Poltava and Zaporizhzhia regions respectively.

If one assumes that in future the temperature increase, remarkable for the historic period of 1982–2016, will continue, by 2050 the estimated sum of effective temperatures, on average for the year, will increase by 65 °C in Polissia, by 60 °C – in the Forest-Steppe, and by 55 °C in the Steppe. As a result, by 2050 the sum of effective temperatures in the zone-wise breakdown will increase up to 600 °C, 650–660 °C and 800–820 °C (Fig. 3), and the mean annual temperature will increase by 2.3–3.0 °C in the Polissia zone, by 3.0–3.5 °C in the Forest-Steppe and by 3.0–4.4 °C in the Steppe by the end of the XXI century.

The comparison of the results of estimated temperature regime using GFDL-30 % model against the results, obtained with satellite data, yields a conclusion that in general, two different methods presented rather a close regularity of the increase in the air temperature for short- (2025) and mid-term (2050) perspective, which confirms rather a high probability of estimated warming-up in all the soil-climatic zones of Ukraine. In this context, there is a rising urgency and need for elaboration and step-wise implementation of both national and regional programs of adapting all the branches of agrarian production to new climatic conditions. First and foremost, this is related to the introduction of low-carbon agrotechnologies, energy- and moisture-preservation, creation of drought-resistant cultivars and hybrids of plants, protection from pests and diseases, management of soil fertility, their protection from degradation and devastation, as well as improvement of irrigation technologies.

*The analysis of changes in precipitation.* The prediction estimates of the change in the precipitation amount are different for different climatic models and have a wide range of gain in their mean annual amount: from 11.6 % to 23.0 % compared to current values. According to GFDL-30 % model, the amount of daily precipitation has positive prediction dynamics: in the Polissia zone up till 7.5–7.9 mm/day, in the Forest-Steppe – 3.6–5.6 mm/day, and the Steppe – 2.9–3.1 mm/day compared to the historic period (1986–2005). The group of climatic models also predicts the increase in the amount of daily precipitation by the middle of XXI century compared to the historic period: in the Forest-Steppe zone – up till 8 mm/day, and in the Steppe – up till 3.8 mm/day, which corresponds to satisfactory conditions of moisturization.

However, according to the satellite data, the monthly mean amount of precipitation for the vegetation period tends to decrease in the Polissia zone (Fig. 4, *a*). In particular, the linear trend in the Chernihiv region forecasts a reduction in precipitation down to 50 mm/month in the vegetation period in 2050. At the same time, the Forest-Steppe zone (Poltava region) demonstrates a tendency to some increase in the precipitation amount, and no considerable change in the precipitation amount is expected in the Steppe zone (Zaporizhzhia) in the vegetation period. Therefore, contrary to the temperature regime, the determination and prediction of moisture conditions coincides in neither climatic models nor satellite data. Still, there is a tendency for the perspective of increasing moisture deficit in all three zones, which is first and foremost connected to rather a considerable increase in the temperature and indefinite situation with the precipitation amount. It should also be noted that even with some increase in the precipitation amount for the vegetation period there is predicted downpour character, which, at the background of temperature increase will considerably reduce the coefficient of their usage due to losses on overland runoff and physical evaporation.

In spring, i.e. in the period of sowing grain crops in the Polissia zone, there was an observed tendency towards some increase in the amount of precipitation in 1980–2015. The precipitation amount will not increase on average in the zones of Forest-Steppe and Steppe for this period. Therefore, the trend for perspective may be used to forecast the moisture deficit for the period of sowing early grain crops (Fig. 4, *b*).

*Predictive estimate of the yield of grain crops.* The comparative analysis of the dynamics of aggregate NDVI values for the vegetation period (Fig. 5, *a*) and the sum of effective temperatures (Fig. 3) from 1982 till 2016 demonstrated that a gradual increase

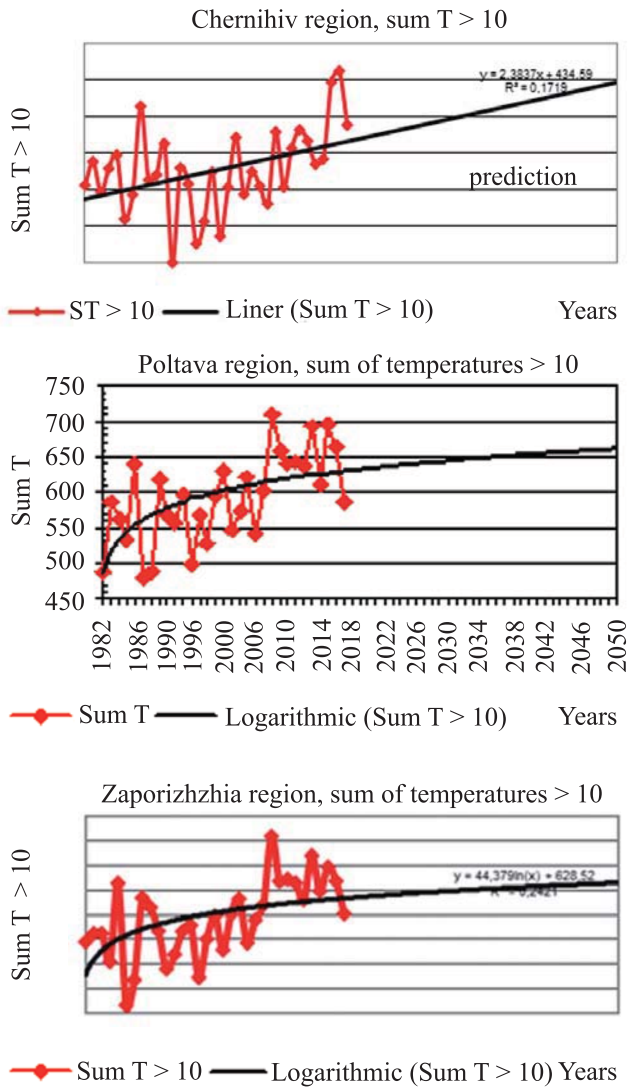



**Fig. 3.** The comparative dynamics of the sum of effective temperatures for 1985-2016 and the forecast of their change by 2025 and 2050 according to NOAA satellite data in the territory of Chernihiv, Poltava, and Zaporizhzhia regions of Ukraine

in the temperature has current positive impact on NDVI index.

The comparison of the aggregate NDVI for vegetation period and the yield of grain crops (Fig. 5) suggests a conclusion that the tendency of yield surplus for grain crops is in rather close correlation with NDVI index, according to the statistics data. This is especially true for the Forest-Steppe and Steppe climatic zones (in Poltava region – 0.48 and in Zaporizhzhia region – 0.5), where extended areas under tillage are the main reason why it is the plantings which form the value of spectral coefficients of the surface brightness of the Earth, used to determine the vegetation indices, while

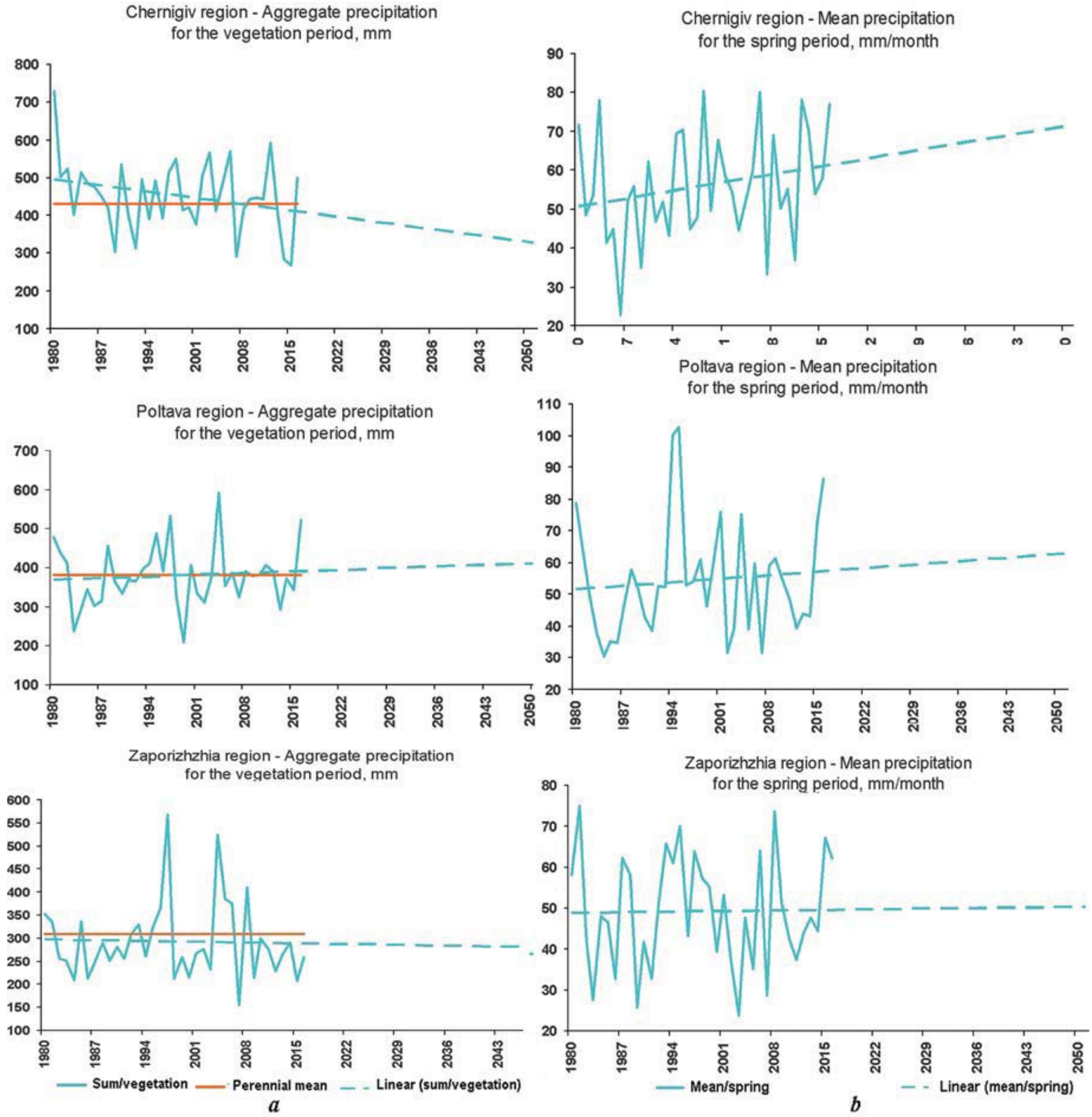



**Fig. 4.** The dynamics of the aggregate amount of precipitation for the vegetation period (*a*) and monthly mean values in spring (*b*) using the satellite data in the territory of Chernihiv, Poltava, and Zaporizhzhia regions

natural landscapes have insignificant impact on NDVI index.

According to the data of the State Statistics, the analysis of the zonal crop structure for the period of 1991–2016 established that the process of climatic adaptation of agricultural production in Ukrainian territory has already been observed throughout the last decade [22]. For instance, in the *Polissia zone* the crop structure demonstrates reduced areas of such cold-resistant crops as grains and grain legumes, flax, lupine, whereas the area of energy crops, including corn, soy and even sunflower has increased (Fig. 6).

In the Forest-Steppe zone, the soil-climatic conditions have been rather favorable for almost all the agricultural crops. However, recent years have witnessed recurrent droughts, especially during the period of sowing early grain and grain legume crops. Such changes aggravate the starting growth conditions and thus their yield, and vice versa – better vegetation conditions are formed for late crops, including corn, sunflower, and soy. As a result, for instance, in Poltava region, there has been an increase in the fields for corn in recent years, and vice versa, a reduction in the fields of spring grain crops, even winter wheat. As a result, the share

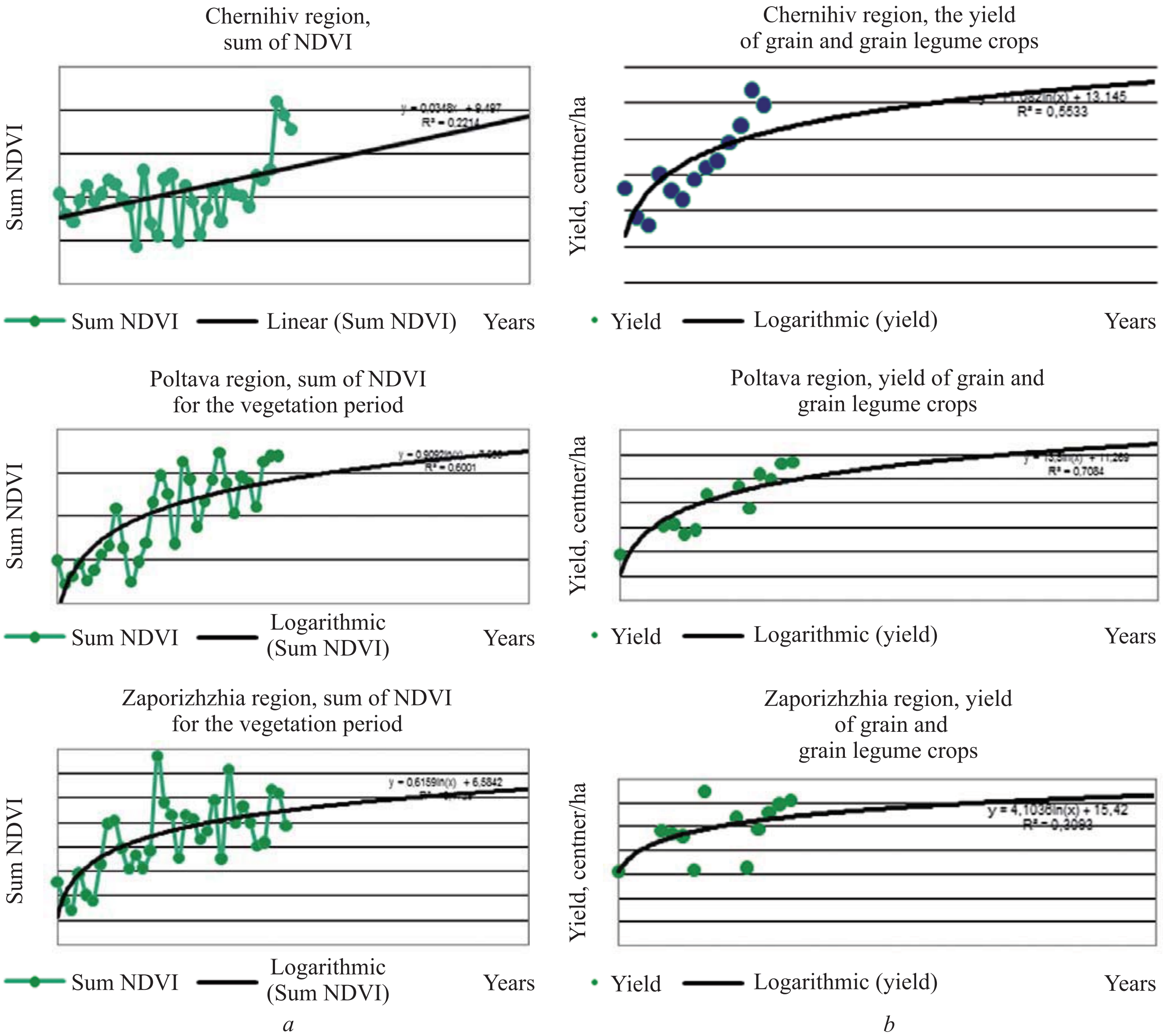
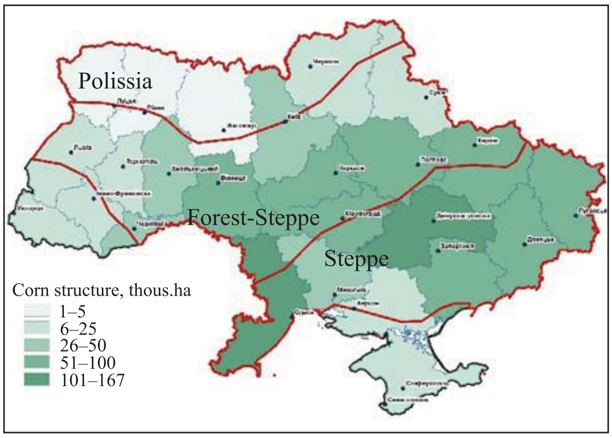



**Fig. 5.** The comparison of the formation of the dynamics of aggregate NDVI (*a*) and actual yield of grain and grain legume crops (*b*) for 1982–2016 and their trends by 2025 and 2050 in the territories of Chernihiv, Poltava, and Zaporizhzhia regions

of corn in the total area of grain crops has now reached almost 50 %. Similar changes in the crop structure have recently been observed in other regions of the Forest-Steppe zone as well, which creates conditions for the formation of powerful and highly productive corn-soy belt, in general.

*The Steppe zone* is remarkable for hot summer, short winter and moisture deficit during the vegetation period. In recent years, there is rather a considerable increase in the temperature, observed in comparison with early XX century, which is accompanied with insignificant improvement of moisturization conditions, especially in the northern Steppe. Such changes of hydrothermal regime also led to corrections in the crop structure, aimed at reducing the fields of spring grain crops and vice versa at increasing the fields of corn, sunflower and soy, which is first and foremost conditioned by the increase in precipitation amount in summer. Rather harsh conditions for dry-land farming were formed in the southern dry steppe, where the recent years have witnessed the increase in the temperature by 2 ºC compared to 1976–1980. Due to a considerable increase in temperature, the hydrothermal regime of dry Steppe continues its shifting towards aridization, which is enhanced with downpour character of precipitation, excessive saturation of crop rotations with sunflower, after which the deep-seated resources of moisture are restored only on the $4^{th}$–$5^{th}$ year.




*a*


*b*

**Fig. 6.** The comparison of corn fields for grain in 1995 (*a*) and 2016 (*b*)

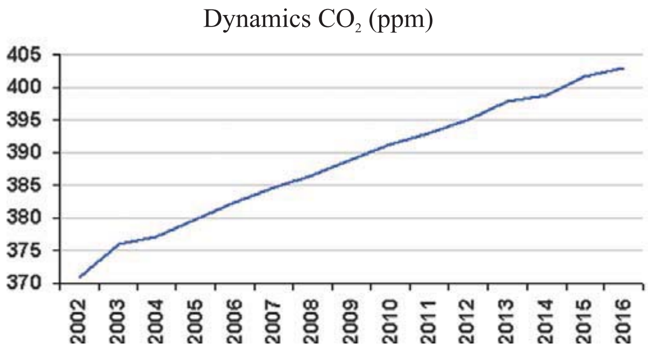



**Fig. 7.** The dynamics of $CO_2$ content in the atmosphere of Ukraine according to the satellite data of AIRS/Aqua

A positive impact of climate warming on the yield and thus on gross collections of grain crops is related both to the change in crop structure, including a considerable increase in fields of such a highly productive crop as corn (Fig. 7), capable of implementing the additional heat resources, and to the increase in the concentration of carbon dioxide in the atmosphere. According to the satellite data of AIRS/Aqua, it was established that the concentration of $CO_2$ in the atmosphere within the territory of Ukraine increases at rather a fast rate – by 35 ppm from 2002 till 2017 (Fig. 7) which coincides with global tendencies for the Earth.

It is known that in greenhouse conditions the increase in the content of $CO_2$ in air has a positive impact on the yield of vegetables. One of recently published NASA studies [23] presented the results, which prove that the increase in $CO_2$ concentration may lead both to the yield surplus and to its loss due to the increasing risk of droughts. Four crops (wheat, soy, corn, and rice) were used as an example to show that the increase in $CO_2$ concentration has positive impact on the productivity of these crops in two important ways: accelerating the photosynthesis speed, which stimulates growth, and reducing the amount of water, lost by plant due to transpiration. Such mechanisms may somewhat compensate for the yield loss due to unfavorable weather conditions, droughts in particular.

If one assumes the preserved favorable impact of climate changes, warming-up for instance, on the state of plants for the historic period of 1982–2016, according to the algebraic trend of NDVI and the sum of effective temperature by 2025 and 2050 there are grounds for predicting the surplus yield of grain crops. For instance, in the Polissia zone (Zhytomyr region) the NDVI index for the trend estimate will increase by 7–14 %, in the Forest-Steppe zone (Poltava region) – by 7–10 %, and in the Steppe zone (Kherson region) – by 8.5 %.

If the statistics data of the grain crop fields, their productivity, the volume of gross collections of grain for 2015 and 2016 are taken as initial data, the trend for both temperature and NDVI index by 2025 (Fig. 5) allows forecasting a relevant increase in the yield of grain crops from 4.1 (2015) to 5.0 t/ha, and by 2050 – to 5.3 t/ha. With such yield, even on condition of current level of material and technical provisions and solving problems, related to soil fertility, the gross collection of grain will amount to 75.0 million tons by 2025 and by 2050 – to 79.0 million tons (Table 2).

It should be stressed that if the current and estimated regularity of a positive impact of the temperature increase on NDVI index and thus the productivity of grain crops is preserved in conditions of optimal material, technical, and scientific provisions as well as solving problems of restoring soil fertility and improving the irrigation technology, there is a real perspective of increasing the gross collections of grain crops up to 92–95 million tons.

Regardless of current and predicted positive impact of climate changes on the yield of grain crops and our optimistic forecast for the period of up to 2025 and 2050, it is possible to make efficient use of the additional climatic resources and mitigate the risks of droughts, aridization, downpour character of summer precipitation and other critical phenomena, related to high temperatures only on condition of elaborating and introducing the results of the integrated system of scientific studies on adaptation measures.

The increase in the yield and gross collections of grain crops in Ukraine is related not only to the warming-up, the tendency of some increase in precipitation amount in some regions, or the prolongation of the vegetation period, but also to the increase in $CO_2$ in the air (Fig. 7). Corn plants are capable of more efficient use of both additional warmth resources compared to ear-forming grain crops and the factor of the increase in the $CO_2$ concentration in the atmosphere, which in general would ensure the gross collection of grain crops in Ukraine of over 60.0 million tons. It should be highlighted that the introduction of the zonal system of specialization for Ukrainian territory [24] with natural fertility of soils, with the consideration of the data of perennial agrotechnical experiments [25] ensures the basic perennial mean level of the gross collection of grain and grain legume crops at the level of 51.2 million tons, and in case of effective fertility, *i.e.* while using the intensification means at a modern level – 63.6 million tons. Here the presented parameters may change by 10–20 % on average due to fluctuations of weather and climatic conditions.

Thus, the adaptation of zonal agroecosystems to the climate changes should have systemic character and include a complex of measures, such as the optimization of the structure of agrolandscapes and systems of land utilization on the basis of reducing the tillage of agricultural fields and corresponding increase in their being covered with forests, reducing the erosion degradation of soils and restoration of their fertility via non-deficient balance of humus and biogenic elements in the agroecosystems, elaborating the systems of protecting plants from pests and diseases taking into consideration the change in the entomological situation, introducing the informational technologies of perfecting systems and technical means, irrigation, creating new drought-resistant cultivars and hybrids, which would ensure the formation of stable zonal agroecosystems, capable of functioning in more severe climatic conditions. All this will require a considerable increase in the volume of scientific research, concentration of intellectual potential and financial resources on priority directions of adapting agrosphere to more severe climatic conditions as well as close integration of scientific, management, and practical activity.

**Table 2.** The forecast for the yield of grain crops and their gross collections according to NDVI and its trend by 2025 and 2050

| Indices | Years | | |
|---|---|---|---|
| | 2015 | 2025 | 2050 |
| Field area, million ha | 14.6 | 15.0 | 15.0 |
| Yield, tons/ha | 4.1 | 5.0 | 5.3 |
| Gross collection, million tons | 60.0 | till 75.0 | till 79.0 |

## CONCLUSIONS

At present, one of the most important ecological, economic, scientific, and industrial problems of the agroindustrial complex of Ukraine is its timely adaptation to the climate change. It is necessary to both make predicted estimates of both negative and positive impact on the agricultural production, and predict future manifestations of crisis climatic phenomena, as well as to elaborate a corresponding system of effective adaptation measures on different levels of managing the agroindustrial production with the purpose of strengthening food safety, export potential of agricultural production and forming stable social and economic situation in the country.

In order to improve the information-consultation provisions of the agroindustrial complex, it is necessary to involve modern informational resources, including satellite data, into the process of monitoring agrosphere and agrarian production in general. In this respect, it has been both urgent and reasonable to launch a scientific-technical program “Agrocosmos” within the framework of scientific programs of NAAS, whose task is to provide central, regional authorities and industrial establishments with information-consultative and ecosystem services, prediction estimates and recommendations, including the ones in adapting to climate changes.

A relevant part of the system of agroecology monitoring and prediction is the preservation of the zonal system of perennial agrotechnical experiments under way in scientific institutions of NAAS and national agrarian universities. Long-term observations in these experiments ensure obtaining the basic information on establishing the regularities of the impact of climate changes on the productivity of agroecosystems depending on the interaction of different factors, the direction of soil-forming processes, including transformation of the living matter and energy, which allows performing predicted estimates regarding the development of agroecosystems for short-, mid-, and long-term perspective in the complex with satellite data.

Taking into consideration the dependence of agricultural production on climatic conditions, it is reasonable to have timely planning and elaboration of adaptation measures on different levels of management. It is important to have scientific substantiation of measures, directed at increasing the efficiency of using the additional agroresource potential, including warmth and moisture, as well as minimization or mitigation of possible risks in the form of different extreme phenomena, especially droughts, which may deteriorate considerably both the natural resource condition of agrolandscapes and rural area, and decrease the productivity of agroecosystems significantly. First of all, these risks include the increase in intensity, duration, and spatial distribution of droughts, manifestations of water and wind erosion, uncontrolled distribution of pests and diseases, as well as invasive species. In case of elaborating and introducing the scientifically-grounded system of measures to adapt the agroecosystems to climate changes, it is possible to predict that the yield of grain crops in Ukraine will increase up to 25.0 % by 2025, up to 29.0–30 % by 2050 compared to 2015, which will ensure reaching the gross collections of grain crops by 2025 – up to 75 million tons and by 2050 – up to 79–80 million tons. On condition of optimal material-technical and scientific informational provisions, solving problems, related to the restoration of soil fertility and perfecting irrigation technologies, it is possible to increase the level of gross collections of grain crops up to 92–95 million tons in perspective. As a result, Ukraine will become one of the main suppliers of food in the world.

**Довгострокове прогнозування впливу змін клімату в Україні на продуктивність зернових культур за супутниковими даними**

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**Мета.** Виконати аналіз та прогноз впливу кліматичних змін на структуру посівних площ, урожайність і валові збори зернових культур на ближню (2025 р.), середню (2050 р.) та дальню перспективу. **Методи.** Аналіз довгострокових рядів кліматичних параметрів за супутниковими даними**,** кліматичне моделювання, статистичний аналіз рядів урожайності та валових зборів зернових культур. **Результати.** Доведено, що історичні та сучасні зміни клімату на території України позитивно впливають на урожайність зернових культур. За збереження цієї закономірності та здійснення цілісної системи заходів з адаптації агроекосистем до потепління прогнозується подальше підвищення урожайності зернових культур і відповідно їх валових зборів. **Висновки.** За супутниковими даними та кліматичними моделями прогнозується, що потепління клімату позитивно впливає на продуктивність зернових культур на території України. За розробки та реалізації заходів з адаптації агроекосистем до змін клімату урожайність зернових в Україні до 2025 р. може підвищитись в порівнянні з сучасним періодом на 25 %, а до 2050 р. на 29–30 %; валовий збір зернових культур досягне 75.0 млн.т (2025 р.) та 79.0–80.0 млн.т (2050 р.). За умови оптимального матеріально-технічного та науково-інформаційного забезпечення, подальшого розвитку технічних засобів, відтворення родючості ґрунтів та удосконалення технологій іригації в дальній перспективі (2100 р.) валовий збір зерна може досягнути 92–95 млн.т.

**Ключові слова:** урожайність зернових культур, супутникові дані, продуктивність, NDVI, температура, опади, валові збори, довгострокове прогнозування, вплив змін клімату.

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