Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(3), 256-261, doi: 10.15421/2021_169

ORIGINAL ARTICLE

Development of agroecosystems under climate change in Western Polissya, Ukraine

Z. Z. Sobko[1], N. M. Vozniuk[2], O. A. Likho[2], A. M. Pryshchepa[2], Z. M. Budnik[2*], O. I. Hakalo[3], V. P. Skyba[4]

[1]Rivne regional center for hydrometeorology, 4 Hoholia street, Rivne, Ukraine, 33028
[2]National University of Water Management and Nature Resources Use, 53 a N. Karnaukhova street, Rivne, Ukraine, 33018
[3]Technical college of the National University of Water Management and Nature Resources Use, 35 Orlova street, Rivne, Ukraine, 33028
[4] Dmytro Motornyi Tavria State Agrotechnological University, 18 B. Khmelnitsky street, Melitolopol, Zaporizka obl., Ukraine, 72312
**Corresponding author Email: z.m.budnik@nuwm.edu.ua*
Received: 10.04.2021. Accepted 27.05.2021

New agricultural operations using intensive technologies more and more intensify processes of soil cover degradation, which are substantially accelerated due to climate changes. Climate is the primary factor that determines agricultural productivity. Due to the significant increase of air temperature in winter months, the temporal shift of development of natural processes, prolongation of frost-free period and duration of vegetation period for crops, there happens a change of agroclimatic conditions of growth, development, and productivity of crops. The purpose of this article is to present the results of a study of peculiarities of agroecosystems state formation in the Western Polissya region of Ukraine under effects of climate change and to determine agroecological consequences of such changes. The study was performed in conditions of the Rivne region (oblast) located within the Western Polissya region of Ukraine. Climate changes have enabled growing non-typical Western Polissya warm-weather crops, including early- and late-ripening sunflower varieties. During the last five years, sunflower yields in the Rivne region are 19% greater than average yields in Ukraine and 39% greater than average yields in southern regions of Ukraine, for which this agricultural crop is typical. Thanks to sufficient water availability, plantings do not require irrigation, which substantially decreases costs. At the same time, much greater washing out of organic compounds and nutrients from the soil. An increase of sunflower cultivation area displaces traditional cereal cultures will aggravate the disbalance of agroecosystems of Ukrainian Western Polissya, promote further development of degradation processes, and impede agrosystems self-recovery and self-regulation. According to prognosis results, we estimated that it is necessary to maintain a balanced approach to growing crops (first of all, the new warm-season ones, which have appeared in the structure of planted areas due to climate change). We also suggest changing their growing techniques, as it is impossible to obtain high productivity with no environmental damage just thanks to climate changes, without maintaining an ecological balance in the agroecosystems.
Keywords: climate change, agroecosystems, sustained development, sunflower, crop yield, agroecological soil state, soil degradation, prognosis.

Introduction

Climate change is one of the most pressing problems facing humankind. NASA (USA) climate researchers have determined that during the last ten years temperature of the troposphere has increased by 0.12 °C, during 1965-1995 period the planet had grown warmer for 0.4 °C at average, and during the whole century, it had become 0.8 °C warmer (Romaschenko et al., 2003). It has been calculated that Earth's last 25 years average surface temperature has increased approximately by 0.74 °C (Orlenko et al., 2010). Change of climate conditions is occurring on the territory of Ukraine as well. Thus, the yearly average air temperature in Ukraine during last 100 years has grown by 0.8-1.0 °C in Polissya and Forest Steppe zones and by approximately 0.5 °C in Steppe zone (Kulbida et al., 2013).

Climate is the primary factor that determines agricultural productivity. Concerns about the potential consequences of long-term climate change for agriculture have prompted many scientific studies during the last decades. Of particular interest in the context of climate change are studies of the potential regional impact on agricultural systems and potential changes of food production profiles (Adams et al., 1998). One of the first attempts to monitor and identify the consequences of drought in agriculture using remote sensing data was made by an American scientist (Kogan, 1990, 1997, 2001). Data from advanced, very-

high-resolution radiometer (AVHRR, 17) in visible, infrared, and near-infrared spectrum channels are used to identify and classify vegetation stress caused by drought. Vegetation Health Index (VHI) is used to detect and control droughts. Climate change due to global warming, both observed today and expected in the future, may have significant consequences for nature, the economy, and society. Therefore, a need arises to determine the impact of expected global climate changes and develop corresponding adaptation solutions for these changes to mitigate their consequences (Romaschenko et al., 2003; Klymenko et al., 2007; Homyakov et al., 2001). Results of scientific studies based on analysis of years-long climatic data series obtained from space monitoring, climatic modeling, statistical analysis of crop yields, and gross cropping of crops permit us to estimate further climate warning (Tarariko et al., 2017).

Due to significant increase of air temperature in winter months, growth of several long thaws, the temporal shift of development of natural processes, change of year's seasons' length, prolongation of frost-free period and duration of vegetation period for crops there happens a change of agroclimatic conditions of growth, development, and formation of crops, as well as of their productivity (Sobko and Vozniuk, 2017). Taking all these aspects into account, we now observe a shift of agroclimatological zones to the north. According to data from the National Academy of Agrarian Sciences of Ukraine, natural-climatic zones have moved by 100-150 km to the north (Pysarenko et al., 2019). As a consequence, the areal of growing warm-season crops is expanded.

Over recent years at the territory of Ukrainian Western Polissya, plantings of a heat-loving crop that is non-typical for this zone, sunflower, are on the rise. Thanks to high-profit margins, agricultural businesses are constantly increasing the production of this commercial crop by increasing its planted areas in the structure of agriculture. Studies of Yeremenko et al., 2018 are devoted to the estimation of ecological plasticity and resilience of sunflower hybrids (Helianthus annuus L.) in conditions of the Ukrainian Steppe. Contemporary sunflower hybrids show intensive response to changes of agrometeorological conditions of growing. Best results have been demonstrated by those hybrids characterized with greater sensitivity to different environments and stability. It has been established that growing hybrids of different intensity levels that are genetically and biologically diverse allows exploiting the agroecological potential of different zones efficiently. Expansion of sunflower growing areas is accompanied by deterioration of the agroecological state of soil cover and its degradation. It is believed that the main reason for that is disruption of crop rotations and quicker return of sunflower to the plots where it had been grown previously. It is known that the more significant is part of sunflower plantings in the crop rotation areas, the more often, with shorter intervals, one is forced to replant this crop at the previously used location (Kohan et al., 2015). Researchers have also determined that 1 ton of primary sunflower production takes 43 kg of nitrogen, 17 kg of phosphorus, and 10 kg of potassium out of the soil (Chumak et al., 2012). Most scientists believe that sunflower should be planted again at previous locations, not more often than once in 8-10 years (Boyko, 2010; Dolgova, 1986; Inshin, 1985). An increase in sunflower planting areas became possible due to climate changes caused by global warming.

Considering the facts above, we may conclude that agriculture requires adaptation first of all to climatic changes, as this branch of the economy is most sensitive to any changes. Moreover, it is the re-orientation of agricultural businesses to increase production of business crops that are non-typical for the territory (including warm-weather crops) that will promote deterioration of the ecological state of the agroecosystems.

The purpose of this article is to study the peculiarities of agroecosystems state formation in the Western Polissya region of Ukraine under the effects of climate change and to determine the agroecological consequences of such changes.

Materials and methods

The study was performed for the territory of the Western Polissya region of Ukraine in conditions of the Rivne region, which is located within Western Polissya borders. The study uses materials obtained from the State Statistics Service of Ukraine, from the Main Department of statistics in the Rivne region, and the Rivne regional center of hydrometeorology. Primary indicators that were studied are average crop yield of sunflower in Rivne region, application of organic and mineral fertilizers, average air temperature, maximum and minimum temperatures at the soil surface, the temperature of plowing layer, precipitation amount, the sum of active and effective temperatures of 10 ºC and greater, deposits of productive water in topsoil, hydrothermal coefficient during the growing season. The study spanned the period from 2000 to 2019.

As the primary method for studying the impact of sunflower growing on the agroecological state of soils, an approach to the calculation of humus and nutrients balance from NSC "O.N. Sokolovsky Institute for Soil Science and Agrochemistry Research" was used. (Balyuk et al., 2011). The article states the results of sunflower crop yield estimation performed using specialized Matlab software. In this estimation, we have used crop yield data and climatic factors parameters for the yrs. 2000-2019 period.

Results

Western Polissya zone of Ukraine, including the Rivne region, is characterized by agrarian orientation and favorable natural conditions for agriculture. Plains relief is typical for this territory; tectonic and geological features have translated into substantial multiformity of kinds of soils, which, for their part, have shaped soil conditions.

The territory of Western Polissya and the whole Ukrainian territory is affected by global warming processes. Among other things, we determined that during 1986-2018, the average atmospheric temperature had grown by 1 °C, precipitation amount and the sum of effective air temperatures have been slightly reduced, while conditions of atmospheric moistening of territory had mildly worsened (Vozniuk et al., 2017). The growth of air temperature causes an increase in heat provision for the plantings of crops. We have studied the dynamics of active temperatures of 10 ºC and higher and their sufficiency for ripening heat-loving crops using the example of the Rivne region. We performed our study for sunflower varieties with different maturation (season duration) (see Fig. 1).

We argue that sums of active temperatures (of 10 ºC and higher) are sufficient for early-ripening and late-ripening sunflower varieties. Overall in 2000-2019, the sum of active temperatures (10 ºC and above) varies within the limits of 2560-3460 ºC, while similar multi-year sums in the Steppe zone of Ukraine lie within 2865-3350 ºC.

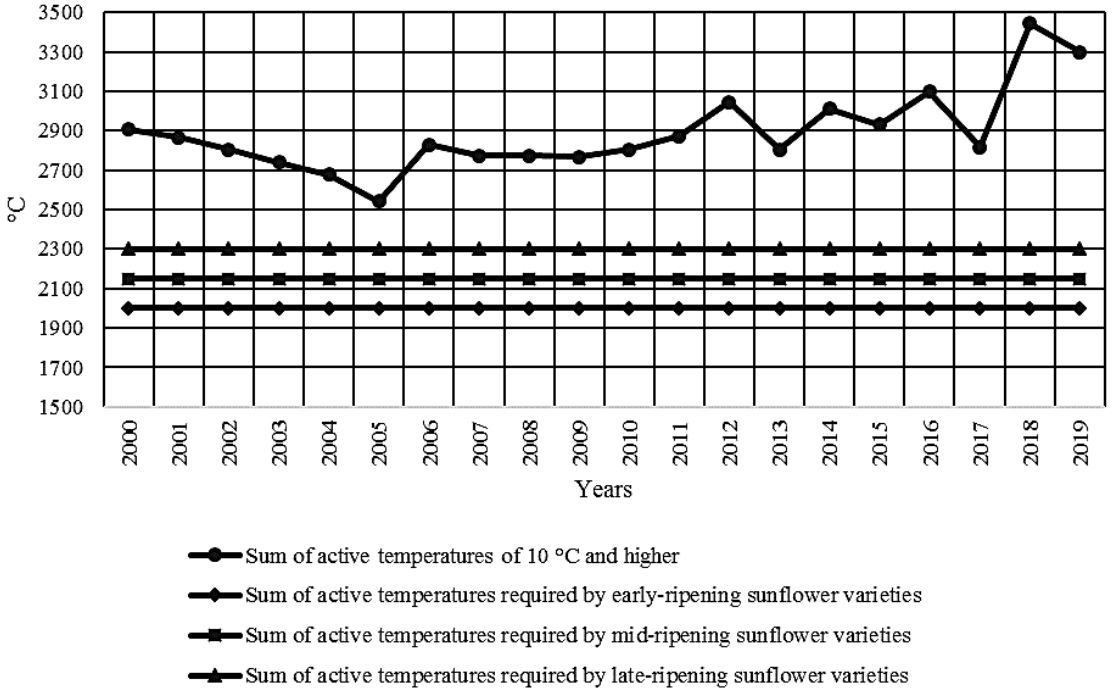

Fig. 1. Dynamics of sums of active air temperatures (10 °C and higher) on the territory of Rivne region

We also suggested that there happens a shift of agroclimatic zones on the territory of Ukraine from south to north. Ukraine grows 32% of the world's crop of sunflower seeds – 13,3 million tons. Ukraine has a complete set of beneficial factors for growth. In Western Europe, cultivated areas are constantly shrinking for the last 15 years, and the most deficient soils are dedicated to sunflower cultivation, while in Ukraine, opposite things are happening (Ilkiv, 2017). In 2019, sunflower cultivation areas in Ukraine amounted to 5.9 million hectares, with a crop yield of 2.6 tons/ha. Primary sunflower production zones in the country are southern Forest-Steppe and Steppe. Nevertheless, in recent years sunflower plantings occur increasingly frequently on the territory of Western Polissya in Ukraine. We studied the dynamics of sunflower cultivation areas and crop yields during the years 2000-2019 in Rivne region conditions (Fig. 2).

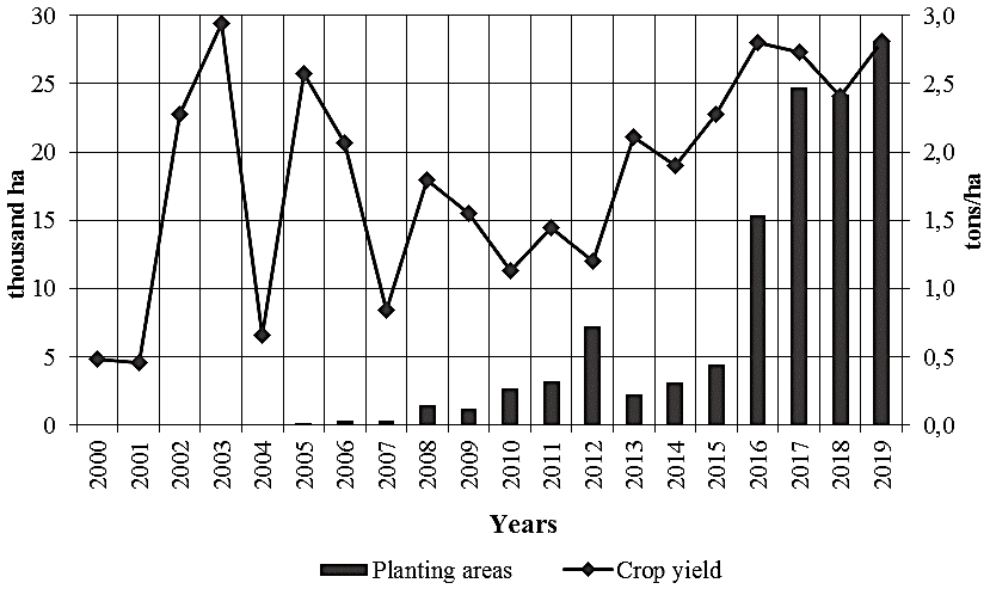

Fig. 2. Dynamics of sunflower cultivation areas and crop yields on Rivne region territory during years 2000-2019

Before 2008, the sunflower cultivation areas did not exceed 0.5 thousand ha. We observed the rapid growth of cultivation area in 2012, when it doubled (to 7.2 thousand ha), in 2016, when it went up three and a half times (to 15.4 thousand ha), and in 2017, when it doubled again (to 24.6 thousand ha). Since 2013 sunflower crop yield tended to stabilize. Overall crop yield varied within 0.5-2.9 tons/ha. Sunflower cultivation areas in the Rivne region as of 2019 comprise less than 1% of total sunflower planting areas in Ukraine, yet in the Rivne region, we see crop yield numbers greater than average crop yield in Ukraine and in its southern region regions, for which this agricultural crop is typical. Thus, during the last five years (years 2015-2019) average sunflower crop yield in Ukraine was 2.3 tons/ha, in the southern part of Ukraine (Odessa, Mykolaiv, Kherson and Zaporizhzhya regions) – 1.8 tons/ha, and in Rivne region – 2.6 tons/ha, that is 13% and 44% greater than former values, correspondingly. The growth of temperature and sufficient water availability has allowed the growth of sunflower in Western Polissya.

Due to the increase of sunflower planting areas in the Rivne region territory, for which this commercial crop is newly introduced, we have studied the impact of its growth on the agroecological state of soils by calculating balances of humus and nutrients (nitrogen, phosphorus, and potassium). We proved that increased production of sunflower that is happening now with the application of intensive techniques causes not only deterioration of the agroecological state of soils. During the period studied, under sunflower crops, the humus balance is estimated as negative and was equal in average to -0.0113 tons/ha, while varying from -0.0002 tons/ha (2002, 2004 years) to -0.0465 tons/ha (2018). Balance of nutrients is also negative, as follows: nitrogen: -0.2686 kg/ha, phosphorus: -0.4091 kg/ha, potassium: -4.0545 kg/ha; the indicators had varied: nitrogen: from +0.2174 kg/ha (2012) to -1.7739 kg/ha (2017); phosphorus: from +0.0065 kg/ha (years 2000, 2001) to -2.1506 kg/ha (2019); potassium: from -0.0172 kg/ha (2004) to -19.8340 kg/ha (2017). The only positive change was water balance with an average value during the period studied of +21.02 m³/ha, with values varying throughout from +0.4 m³/ha (2002) to +104.8 m³/ha (2017). A positive balance of moisture confirms a sufficient level of water availability for sunflower at the Western Polissya as a whole and on the territory of the Rivne region specifically. In general, we see a trend to deterioration of the situation, except as for water availability. However, the further temperature increase will intensify evaporation, thus reducing moisture reserves.

Table 1. Calculated balances of humus, nutrients, and humidity under sunflower plantings during the 2000-2019 years period on the territory of Rivne region

Year	Calculated balance				
	humus, tons/ha	nitrogen, kg/ha	phosphorus, kg/ha	potassium, kg/ha	moisture, m^3/ha
2000	-0.0012	0.0391	0.0065	-0.0589	3.4
2001	-0.0013	0.0420	0.0065	-0.0539	4.1
2002	-0.0002	-0.0088	-0.0066	-0.0662	0.4
2003	-0.0004	-0.0040	-0.0030	-0.2500	2.1
2004	-0.0002	0.0066	0.0008	-0.0172	0.6
2005	-0.0004	-0.0291	-0.0188	-0.1717	1.1
2006	-0.0006	-0.0264	-0.0208	-0.2108	2.3
2007	-0.0008	0.0379	0.0041	-0.2247	2.1
2008	-0.0035	-0.0507	-0.0672	-0.8530	13.6
2009	-0.0030	-0.0240	-0.0530	-0.6120	6.6
2010	-0.0077	0.0358	-0.0889	-0.9661	20.0
2011	-0.0085	0.0592	-0.1168	-1.6175	8.5
2012	-0.0203	0.2174	-0.1185	-2.4977	46.9
2013	-0.0048	-0.1108	-0.1326	-1.2772	10.9
2014	-0.0066	-0.0626	-0.1435	-1.5862	12.4
2015	-0.0083	-0.2361	-0.2696	-2.7518	5.0
2016	-0.0252	-1.0132	-1.2065	-11.5900	40.5
2017	-0.0429	-1.7739	-2.0653	-19.8340	104.8
2018	-0.0465	-0.8307	-1.7378	-16.7092	68.4
2019	-0.0428	-1.6394	-2.1506	-19.7421	66.7
Average for the whole period	-0.0113	-0.2686	-0.4091	-4.0545	21.02

Having analyzed the obtained results of the study, we can argue that increasing sunflower planting areas that displace traditional cereal crops will increase the imbalance in the agroecosystems of Ukrainian Western Polissya. This, in its turn, in combination with contemporary intensive agriculture techniques, will promote further development of degradation processes, breakdown of agroecosystem self-recovery, and self-regulation processes. Therefore, considering that climate changes per se have conditioned the possibility of growing sunflower and having high yields on the territory of Ukrainian Western Polissya, we have performed an estimation of crop yields using specialized Matlab software. In it, we calculated only climate changes, presuming that the existing intense growing system remains used. Climate changes included a change of following climatic factors: average air temperature, the maximum and minimum temperature at the ground surface, an average temperature of the plowed soil layer, amount of precipitation, the sum of active and effective temperatures of 10 °C and higher, deposits of productive moisture in the plowed soil layer, the hydrothermal coefficient for vegetation period, all for the interval of years 2000-2019. While analyzing obtained results of estimation of sunflower crop yield (Fig. 3) in conditions of Rivne region, we have concluded that it is necessary to change methods of growing crops, as only thanks to climate change, without supporting the dynamic balance in agroecosystems, it is impossible to achieve high crop yields without environmental damage. As Figure 3 shows, by 2025, one should expect the sunflower crop yield to drop to about 1.7 tons/ha, which is about 40% of crop yield numbers for 2019. The percentage error of estimation was 8.6%. However, it is worth remarking that such agroecosystem productivity results can be expected because there are no adverse agrometeorological events.

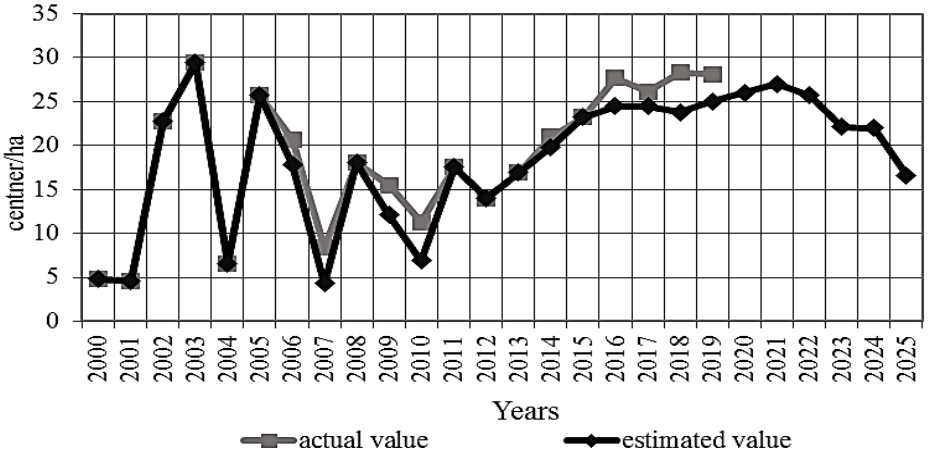

Fig. 3. Results of estimation of sunflower crop yield in Rivne region conditions

Discussion

During 1991-2017, significant social and economic reforms occurred in Ukraine, including reforms of land matters initiated by the dissolution of the Soviet Union (Zhukov and Ponomarenko, 2017). The process of land relations reform in Ukraine is happening for about 20 years already, but it still has not achieved success as to its primary goal – increasing agricultural production efficiency while simultaneously lowering the anthropogenic burden on the environment (Pankov, 2011).

The absence of rational, sustainable land use in Ukraine has led to excessive land utilization. So, 72% of land resources developed, while the acceptable norm is 60-65% of total land area; plowed areas make up 58%, while the acceptable norm is 40%. For comparison, in developed European countries plowed area index does not exceed 32% (Lupenko and Messel-Veselyaka, 2012). Intensification of agricultural production, which is not accompanied by environmental protection measures, causes disturbance of the natural environment (Smolenyuk, 2013).

As most of the world countries, including Ukraine, support initiatives of environmental conservation and have chosen as a basis for their growth the sustained development concept that promotes harmonization of economic, social, and ecological constituents of human activity; therefore, in agriculture, too, it is reasonable to implement and abide by these principles. As far back as in 1992 on the Rio de Janeiro Earth summit, the Food and Agriculture Organization of the United Nations had given the following definition to "sustainable agriculture and agricultural development": "Sustainable development calls for rational use and conservation of natural resources, for such redirection of technological and organizational changes as to ensure continuous satisfaction of human needs for current and future generations. Such sustained development in agriculture enables land conservation, does not cause deterioration of the natural environment, is technically achievable, economically feasible and socially acceptable" (Yusupova, 2013). The idea of sustained development has assumed first-priority importance in conditions of growing anthropogenic impact on the environment, as there is now a choice: either society embraces ecologically balanced, safe husbandry or ecological problems will become acute and cause irreparable changes in natural landscapes, agroecosystems, and soils (Borschuk and Zagorsky, 2005).

Agriculture does also requires adaptation to climate changes which have both positive and negative consequences. Positive consequences include increased duration of vegetation period, expansion of warm-climate crops growth zone to the north, optimization of the physiological state of field horticultural crops in winter period; negative consequences include degradation of soil fertility, more intense propagation of agricultural crop pests and diseases, more frequent extreme events related to water resources (Stephanovska and Pidlisnyuk, 2010). Using the Rivne region located in the Western Polissya zone of Ukraine, we can observe the absence of rational land utilization, growing non-typical warm-loving crops on unreasonably large areas with violations of rational growing technique that causes deterioration agroecological state of soils, their exhaustion, and degradation.

Conclusions

Climate changes caused by global warming and experienced on the Ukrainian Western Polissya and economic feasibility have allowed to change planted areas and expand the assortment of grown crops. On the territory of the Rivne region, specifically, planting areas of warm-loving crops in general and sunflower, in particular, have substantially increased. Sums of active air temperatures over 10 ºC have grown to numbers that allow ripening even of late-ripening sunflower varieties.

We determined that in conditions of the Rivne region during the last five years, sunflower yields were 19% greater than average yields in Ukraine and 39% greater than average yields in southern regions of Ukraine, for which this agricultural crop is typical. Due to sufficient water availability on Western Polissya, in contrast to the south of Ukraine, sunflower plantings do not require irrigation, thus providing economic benefits.

However, high crops and the absence of irrigation expenses do not compensate for ecological damages, as growing sunflower without abiding by rational land utilization principles leads to deterioration of the agroecological soil conditions. According to calculated balances of organic material and nutrients, we determined that in intense growing, the soils lose on average 0.0113 tons/ha of humus, 0.2686 kg/ha of nitrogen, 0.4091 kg/ha of phosphorus, and 4.0545 kg/ha of potassium.

Having performed estimation of sunflower yields until 2025, taking only climatic changes into account, we have determined that it is necessary to change methods of growing this warm-loving crop, as only thanks to climate change, and without the support of dynamic balance in agroecosystems, one should not expect high crop yields.

References

Adams, R.M., Hurd, B.H., Lenhart, S., Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. Climate Research, 11(1), 19-30.

AVHRR Level 1b Product Guide Ref.: EUM/OPS-EPS/MAN/04/0029. Available from: http://oiswww.eumetsat.org/WEBOPS/eps-pg/AVHRR/AVHRRPG-6ProdFormDis.htm/.

Balyuk, S.A., Grekov, V.O., Lisovy, M.V., Komarysta, A.V. (2011). Calculation of balance of humus and nutrients in agriculture of Ukraine at different management levels. Kharkiv. Institute for soil science and agrochemistry named after O.N. Sokolovsky.

Borschuk, Ye.M., Zagorsky, V.S. (2005). Concept of sustained development and problems of optimization of ecological-economical systems. Regional Economics, 3, 113-119.

Boyko, P. (2000). Growing sunflower in crop sequences. Propozitsia, 4, 36-38.

Chumak, V.S., Desyatnyk, L.M., Kohan, A.V. (2012). Nutrition regimen of cereal and oil-bearing crops on Ukrainian black soils. Bulletin of Institute of steppe zone agriculture of NAAS of Ukraine, 3, 131-134.

Dolgova, E.M. (1986). How to protect plantings from rots. Oil-yielding crops, 2, 28-30.

Homyakov, P.M., Kuznetsov, V.I., Alferov, A.M. (2011). Impact of global climate change on the performance of primary economy branches and the health of Russia's population. Moscow, Editorial URSS.

Ilkiv, L.A. (2017). The efficiency of production of high-oleic sunflower in Ukraine. Young Scientist, 11 (51), 1171-1174.

Inshin, N.A. (1985). Strict adherence to crop sequences. Oil-yielding crops, 2, 24.

Klymenko, M.O., Rokochynsky, A.M., Klymenko, Z.S., Kotyay, L.M. (2007). Estimation of weather and climate conditions on human ecology during global warming (for Western Polissya zone of Ukraine). Bulletin of the National university of water and environmental engineering, 4(40), 3-25.

Kogan, F.N. (1997) Global drought watch from space. Bulletin of the American Meteorological Society, 78, 621-636.

Kogan, F.N. (2001). Operational Space Technology for Global Vegetation Assessment. Bulletin of the American Meteorological Society, 82 (9), 1949-1964.

Kogan, F.N. (1990) Remote sensing of weather impacts on vegetation in non-homogeneous areas. International Journal of Remote Sensing, 11, 1405-1419.

Kohan, A.V., Gangur, V.V., Koretsky, O.Ye., Len', O.I., Man'ko, L.A. (2015). The sunflower in crop rotations of left-bank Forest Steppe of Ukraine. Bulletin of the Center Science Provision of Agribusiness in the Kharkiv region, 18, 62-68.

Kulbida, M.I., Elystratova, L.O., Barabash, M.B. (2013). The contemporary state of the climate of Ukraine. The problems of environmental protection and ecological safety, 35, 118-130.

Lupenko, Yu.O., Messel'-Veselyaka, V.Ya. (2012). Strategic directions of Ukrainian agriculture development for the period up to 2020. Kyiv, NSC "Institute of the Agrarian Economy".

Orlenko, S.L., Zhalilo, Ya.A., Trofimova, I.V. (2010). Counteracting global climate change in the context of Kyoto protocol: Ukrainian dimension. Kyiv, NISS.

Pysarenko, V.M., Pysarenko, P.V., Pysarenko, V.V., Gorb, O.O., Chayka, T.O. (2019). Drought in context of a change of Ukrainian climate. Bulletin of Poltava State Agrarian Academy, 1, 134-146, doi: 10.31210/visnyk2019.01.15

Romaschenko, M.I, Sobko, O.O., Savchuk, D.P, Kulbida, M.I. (2003). On certain objectives of agrarian science related to climate change. Scientific-informative report. Kyiv, Institute of hydrotechnics and melioration of NAAS.

Smolenyuk, R.P. (2013). Development of agriculture based on principles of the green economy. Sustained development of economy, 4, 37-44.

Sobko, Z.Z., Voznyuk, N.M. (2017). Impact of agrometeorological factors on yield of warm-weather crops (as exemplified by Rivne oblast). Young Scientist, 8, 5-9.

Stefanovska, T.P., Pidlisnyuk, V.V. (2010). Assessment of the vulnerability of Ukrainian agriculture to climate changes. Ecological safety, 1, 62-66.

Tarariko, O. H., Ilienko, T. V., Kuchma, T. L., Velychko, V. A. (2017). Long-term prediction of climate change impact on the productivity of grain crops in Ukraine using satellite data. Agricultural science and practice, 2, 3-13.

Voznyuk, N., Prischepa, A., Sobko, Z. (2017). Strategic directions of agricultural sustained development on the territory of the Rivne region. Formation of modern social, economic and organizational mechanisms development of entities agrarian business. ISMA University. Riga: "Landmark" SIA, 69-77.

Yeremenko, O. A., Kalytka, V. V., Kalenska, S. M., Malkina, V. M. (2018). Assessment of ecological plasticity and stability of sunflower hybrids (*Helianthus* annuus L.) under conditions of the Ukrainian Steppe. Ukrainian Journal of Ecology, 8(1), 289-296

Yusupova, O.O. (2013). Sustainable agriculture is an important component of ecological safety. Theoretical and practical aspects of economics and intellectual property, 1 (1), 292-296.

Zhukov, O.V., Ponomarenko, S.V. (2017). Spatial-temporal dynamics of sunflower yield – the ecological and agricultural approach. Ukrainian Journal of Ecology, 7(3), 186-207.

Citation:

Sobko, Z.Z., Vozniuk, N.M., Likho, O.A., Pryshchepa, A.M., Budnik, Z.M., Hakalo, O.I., Skyba, V.P. (2021). Development of agroecosystems under climate change in Western Polissya, Ukraine. *Ukrainian Journal of Ecology, 11* (3), 256-261.

This work is licensed under a Creative Commons Attribution 4.0. License