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Global Climate Crisis and its Impact on the Development of The Agricultural Sector of the Ukrainian Economy

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▸ **Abstract.** Currently, climate change is manifested throughout the territory of Ukraine. Rural areas are the most sensitive to these changes, as the manifestations of climate change, such as rising temperatures, changing precipitation patterns, and natural weather events significantly affect agriculture and the quality of life in rural areas. The purpose of the research – explore the impact of the global climate crisis on the development and efficiency of the agricultural sector of the Ukrainian economy at the zonal level and scientifically substantiate the conceptual vision of the strategic principles of adaptation of agricultural production to its consequences. In performing the study, a set of general scientific methods and techniques was used: monographic – in the study of domestic and foreign publications on the studied issues; mathematical statistics – to assess the absolute and relative deviation of agricultural production of strategic agricultural products from the average long-term volume at the regional level of the economy in terms of ensuring food security in the context of achieving sustainable development purposes; system approach based on the principles of system analysis and synthesis – to substantiate the relationship between sustainable development and food security, and the efficiency of agricultural production; abstract-logical – for theoretical generalisation of research results; economic analysis – to study the efficiency of agricultural production. The climate data of Ukraine are analysed. Based on a systematic analysis, the impact of the global climate crisis on the development of the agricultural sector of the economy in terms of assessing the level of food security in the context of achieving sustainable development purposes is explored. Established that during the period of data analysis from 2015 to 2020, due to a combination of adverse weather and climatic factors, fluctuations in annual precipitation and an increase in average air temperature, the level of sustainability of agricultural production in the Steppe regions decreased. A high level of variability in grain production was observed in some regions of all-natural and climatic zones. Based on the combination of theories of socio-economic and sustainable development, the theoretical and methodological approaches to assessing the impact of the global climate crisis on the development and efficiency of the agricultural sector of the Ukrainian economy at the zonal level were further explored. The results of the study are acceptable for practical use in the development and substantiation of regional and national strategies for the development of agro-industrial production and its adaptation to the challenges associated with the global climate crisis, and in further scientific research

▸ **Keywords:** efficiency, development, agricultural production, variation, climate, food security, economy

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▸ Problem statement

Rapid changes in the climate system caused by anthropogenic activities are resulting in rising air temperatures and sea level rise, which has significant implications for socio-economic activities around the world. There is an urgent requirement for appropriate adaptation and mitigation strategies to address climate threats in various sectors, including agriculture (Wang, Vanga, Saxena, Orsat, & Raghavan, 2018; Attri, 2020).

The world community is beginning to acknowledge the significance of food systems for peace and security. The Norwegian Nobel Committee has awarded the 2020 Nobel Peace Prize to the UN World Food Programme. In the context of the increasingly complex climate crisis, scientific, political and geostrategic security imperatives must come together to properly assess the overall situation while there is still time and resources to address it, rather than face the consequences in the distant future. These collaborative efforts require closer cooperation within the framework of interaction between humanitarian action, sustainable development and the global community to develop and implement systemic approaches aimed at transforming food systems and thus improving living conditions in rural areas (Läderach, Pacillo, Thornton, Osorio, & Smith, 2021).

For Ukraine, as for the rest of the world, the issue of climate change research and the prediction of its consequences is considered an urgent task for science. In domestic conditions, the achievement of sustainable development purposes at the regional level requires a comprehensive study of the basic theoretical and methodological foundations for the development of new forecasting and modelling systems that will address the most efficient use of available resource potential in the context of adaptation to global climate change and assess the adaptive capacity of food ecosystems.

Food systems research plays an important role in deepening the understanding of how climate change exacerbates existing risks, conflicts and crises in the world (Läderach, Pacillo, Thornton, Osorio, & Smith, 2021). Climate crisis is the term that currently best describes anthropogenic global warming and its consequences and conveys a sense of irreversibility associated with the inability of humanity to perform sufficient actions to decelerate, stop and reverse global warming (Shanabhoga, Krishnamurthy, Suresha, & Shivani, 2020). In Ukraine and abroad, the study of this problem has become one of the current fields of research. Modern theoretical and methodological aspects of the study of the impact of the climate crisis on the development of the agricultural sector are considered in many scientific works of domestic scientists, among which should be separately highlighted publications by T.I. Adamenko (Adamenko, 2019), V.R. Vozhehova, (Vozhehova, 2019), Yu.O. Lupenko (Lupenko, 2012), V.Ya. Mesel-Veseliak (Mesel-Veseliak, Pekhota, & Hryshchenko, 2011), O.M. Nechyporenko (Nechyporenko, 2020), B.Ya. Panasiuk (Panasiuk, 2015), K.O. Prokopenko (Prokopenko, & Udova, 2017), M.I. Puhachov (Puhachov, 2017), O.G. Tarariko (Tarariko, Ilienko, & Kuchma, 2016), O.V. Khodakivska (Khodakivska, 2015), O.V. Shubravska (Shubravska, 2017). Among foreign scientists, notably, the latest research of S.D. Attri (Attri, 2020), M.P. Baldwin, M.B. Shanabhoga (Shanabhoga, Krishnamurthy, Suresha, & Shivani, 2020) etc. The above scientific studies, to some extent, cover most of the issues that address the global climate crisis. However, the results of processing their scientific achievements demonstrate that today theoretical, methodological and practical issues related to some aspects of the study of the impact of climate change on the development of the agricultural sector of the economy of Ukraine at the zonal level are still insufficiently explored. These aspects determine the relevance of their implementation.

The purpose of the research – explore the impact of the global climate crisis on the development and efficiency of the agricultural sector of the Ukrainian economy at the zonal level and scientifically substantiate the conceptual vision of the strategic principles of adaptation of agricultural production to its consequences.

▸ Outline of the main material

Agricultural production is extremely vulnerable to climate change, and this problem could complicate food support for the growing world population by 2050. Thus, understanding how and to what extent climate change will affect agricultural productivity is crucial for food security in many countries (Kim, & Kwak, 2020).

Ukraine historically has a temperate continental climate, characterised by hot summers and cold winters. However, according to new meteorological observations in recent decades, annual precipitation has been gradually decreasing, and air temperature is rapidly rising from midnight to mid-day.

Exploring the dynamics of annual precipitation in different natural and climatic zones according to the analysis of the Ukrainian Hydrometeorological Center, it can be observed how extreme these changes have become. There is a steady downward trend in precipitation in the Steppe regions. In the Forest-Steppe and Polissya zones, this trend is less pronounced. Although in some years in these agroclimatic zones a significant decrease is recorded (Table 1).

Table 1. Annual precipitation in different climatic zones according to the Ukrainian Hydrometeorological Center, mm

Year	Steppe	Forest-steppe	Polissya
2005	529.0	644.0	713.0
2010	630.0	690.0	842.0
2015	485.0	478.0	543.0
2020	387.0	539.0	720.0
2020 to 2005, +-	-142	-105	7
2020 to 2005, +-	-98	61	177

Source: compiled based on generalisation of data (Verner, 2021)

For example, in 2020, compared to 2005, the average annual precipitation in the zone

In the Steppe zone, it was 142 mm, and in the Forest-Steppe zone – by 105 mm lower. It is respectively 73.2% and 83.7% of the 2005 level.

Recently, according to domestic scientists, every year, compared to the climatic standard, the average annual air temperature is 1-2 degrees above the norm. (Adamenko, 2019; Dankevych, 2020; Ivaniuta, 2020). According to the National Academy of Agrarian Sciences of Ukraine, in recent decades, the boundaries of natural and climatic zones have shifted 100-150 km to the north. If the current trends of climate change continue in the next 20 years, the danger of actual loss for intensive agro-industrial production of both the Steppe zone and more than half of the arable land of Ukraine will become quite probable and real (Tarariko, Ilienko, & Kuchma, 2016; Khodakivska, 2015; How climate change affects…, 2021).

According to the analysis of information from the Ukrainian Hydrometeorological Center over the past 20 years, in all-natural and climatic zones, there is an increase in the average annual air temperature (Table 2).

Table 2. Average annual air temperature in different climatic zones based on the Ukrainian Hydrometeorological Center, 0°C

Year	Steppe	Forest-steppe	Polissya
2005	10.3	8.4	7.9
2010	11.0	8.9	8.4
2015	10.9	9.9	9.9
2020	11.6	10.4	10.4
2020 to 2005, +-	1.3	2.0	2.5
2020 to 2005, +-	0.7	0.5	0.5

Source: compiled based on generalisation of data (Verner, 2021)

Quite a significant increase in average annual air temperature was recorded in the zone of Polissya and Forest Steppe, respectively by 2.5 and 2°C. In the Steppe regions, the average annual air temperature increased by 1.3°C. In the Steppe zone, due to the lack of moisture and significant fluctuations in maximum temperatures during the growing season, there is a specific demand for using irrigation technologies even for those crops that did not require it before (in particular, wheat and barley). With a high probability, given the above, it can be argued that in the short term, this will result in a significant increase in financial costs in agricultural production. Therewith, the issue of assessing the economic consequences of shifting climate zones for the agricultural sector requires additional research.

Changes in the temperature regime in the warm period of the year affected the thermal resources of Ukraine, for the assessment of which the indicator of the sum of active (positive) air temperatures above +10°C accumulated during the warm period is used. Comparison of these amounts for different periods demonstrates their increase by an average of 200-400°C (Adamenko, 2019, p. 16).

Therewith, the sum of active air temperatures above +10°C is constantly increasing for a long period in all-natural and climatic zones (Table 3).

Table 3. Sums of active air temperatures above +10°C in agroclimatic zones of Ukraine for different periods

Agroclimatic zone	1961-1990	1991-2019	2010-2019
Steppe	3145	3400	3550
Forest-steppe	2705	2950	3150
Polissya	2500	2770	2950

Source: (Adamenko, 2019, p. 16)

According to K.O. Prokopenko and L.O. Udova, climate warming will cause both positive results and adverse consequences for agriculture. The positive effects include improvement of growing conditions and reduction of harvesting time; possibility of efficient introduction of late-ripening varieties (hybrids), which require more thermal resources; improvement of wintering conditions for crops and perennial grasses; increase in the efficiency of fertilizer application. Among the adverse effects: increased concentration of CO_2 in the air with a positive impact on crop yields, this will result in deterioration of grain quality; more frequent and severe droughts during the growing season; deterioration of soil moisture in the southern regions; failure to ensure full vernalisation of grain; increase in the number of pests, the spread of plant pathogens and weeds due to favourable conditions for their overwintering; increase in wind and water erosion of soil caused by an increase in the number of droughts and extreme precipitation; increase in the risk of freezing of winter crops due to the lack of stable snow cover with a significant decrease in temperature. Weather conditions of recent years have demonstrated the urgency of adapting crops to the conditions of global warming since the profitability of their cultivation largely depends on it (Khodakivska, 2015).

However, other researchers are much more pessimistic about the possible consequences of the climate crisis. In their opinion, the expected climate change and, especially, the increase in ambient temperature will result in a decrease in the yield of major crops (Wang, Vanga, Saxena, Orsat, & Raghavan, 2018).

Agricultural production is a complex dynamic system of social and economic relations based on forward and backward linkages, which are associated with the factors of resource, biological, technological, innovative, demographic, environmental, climatic deterministic, and stochastic nature of influence in a market environment. One of the urgent problems of the development of the domestic agricultural sector is to ensure the sustainable economic growth of agricultural production. The complexity and unpredictable nature of the conditions of the interaction of exogenous and endogenous factors affecting agriculture cause some problems in analysing the dynamics of its economic growth indicators and determining the magnitude of their impact on the total gross output, and forecasting the prospects of the industry.

Conducted within the framework of the implementation of the IPA NAAS 36 and task 36.00.00.24. P "To develop a scientifically based system for forecasting and modelling the development of agro-industrial production of the Steppe zone regions in the context of global climate change", the study of the impact of climate change on the sustainability and dynamics of the agricultural sector of the economy demonstrated that in recent years the most unstable agricultural production has been observed in some regions of the Steppe, Forest Steppe and Polissya (Table 4).

Three statistical indicators were used to analyse and assess the impact of the climate crisis on the sustainability of agricultural production of grains, vegetables, potatoes, and sunflowers. Notation: Av – the average long-term value of the indicator of production of main crops, thousand tons; STDev – standard deviation of production of main crops, thousand tons, and Cv – coefficient of variation (variability, deviation from the mean value), %.

Table 4. Analysis of the dynamics of grain production in different climatic zones, thousand tons

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Dnipropetrovsk	3866.2	3480.8	3578.4	3487.5	4285.4	3539.5	3706.3	317.4	8.6
Donetsk	1536.1	1793.4	1908.0	1344.4	1968.7	1988.0	1756.4	261.3	14.9
Zaporizhzhia	2728.1	2624.4	2907.1	2233.3	3339.1	2964.4	2799.4	370.5	13.2
Kirovohrad	3313.9	3725.8	2858.0	3763.2	4346.6	2689.1	3449.4	620.6	18.0
Luhansk	992.8	1274.2	1276.2	1159.4	1446.5	1375.9	1254.2	161.2	12.9
Mikolaivska	2896.4	2725.5	2674.6	2673.4	3137.9	2362.1	2745.0	258.6	9.4
Odesa	3489.0	4403.3	4264.9	4319.9	3747.9	1955.0	3696.7	926.3	25.1
Kherson	2621.9	2262.4	2545.4	2267.7	2739.7	2719.9	2526.2	214.0	8.5
Together in the Steppe zone	**21444.4**	**22289.8**	**22012.6**	**21248.8**	**25011.8**	**19593.9**	**21933.6**	**1777.1**	**8.1**
Vinnytsia	3768.3	5563.5	4888.9	5911.1	5936.2	4015.3	5013.9	951.0	19.0
Kyiv	2820.0	3327.5	2646.9	4081.5	4215.7	2987.2	3346.5	662.1	19.8
Poltava	5363.2	5783.1	4241.4	6341.8	6118.8	5050.3	5483.1	771.4	14.1
Sumy	3734.5	3816.2	3686.2	4470.1	4432.6	4819.7	4159.9	475.3	11.4
Ternopil	2199.0	2448.6	2622.3	2631.9	2699.9	2837.4	2573.2	222.4	8.6
Kharkiv	4209.7	4316.7	3859.2	3829.2	4416.1	4852.6	4247.3	381.2	9.0
Khmelnytsky	2792.9	3085.5	3421.4	3861.0	3798.2	3985.3	3490.7	475.9	13.6
Cherkasy	3745.5	4091.7	2926.5	4644.0	4559.8	2692.3	3776.6	820.3	21.7
Chernivtsi	523.5	507.4	603.9	586.4	642.0	578.2	573.6	50.3	8.8
Together in the Forest-Steppe zone	**29156.6**	**32940.2**	**28896.7**	**36357.0**	**36819.3**	**31818.3**	**32664.7**	**3411.5**	**10.4**
Volyn	1062.3	1109.7	1165.2	1237.2	1292.6	1401.2	1211.4	124.9	10.3
Zhytomyr	1459.6	2093.9	1993.7	2424.1	2738.3	2526.1	2206.0	457.8	20.8
Zakarpattia	332.4	412.4	390.1	375.9	391.7	327.0	371.6	34.5	9.3
Ivano-Frankivsk	688.5	772.8	753.7	804.5	743.6	826.5	764.9	48.7	6.4
Lviv	1366.3	1428.8	1417.0	1440.0	1643.7	1607.4	1483.9	113.2	7.6
Rivne	1101.5	1300.5	1208.7	1259.5	1493.0	1443.7	1301.2	146.5	11.3
Chernihiv	3514.2	3739.9	4079.0	4909.5	5009.2	5389.3	4440.2	764.6	17.2
Together in the Polissya region	**9524.8**	**10858.0**	**11007.4**	**12450.7**	**13312.1**	**13521.2**	**11779.0**	**1572.4**	**13.3**
Ukraine	60125.8	66088.0	61916.7	70056.5	75143.2	64933.4	66377.3	5505.0	8.3

Source: compiled based on generalisation of data (Verner, 2021)

It is established that a high level of variability of grain production is present in some regions of all-natural and climatic zones. In the Steppe – Odesa (coefficient of variation 25.1%) and Kirovohrad (18%) regions, in the Forest-Steppe – Cherkasy (coefficient of variation 21.7%), Kyiv (19.8%) and Vinnytsia (19%) regions, in Polissya – Zhytomyr (coefficient of variation 20.8%) and Chernihiv (17.2%) regions. The production of potatoes, the second most strategically significant crop for the food security of the state, was the least stable primarily in the Steppe regions – Odesa, Mykolaiv, Luhansk, Zaporizhzhya and, partially, in the Forest-Steppe and Polissya regions – Kharkiv and Zhytomyr (Table 5).

Table 5. Analysis of potato production dynamics in different climatic zones, thousand tons

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Dnipropetrovsk	560.3	602.1	567.9	523.9	434.1	466.1	525.7	64.4	12.3
Donetsk	397.7	409.1	446.8	343.8	358.0	417.5	395.5	38.4	9.7
Zaporizhzhia	258.5	263.7	226.2	189.7	218.8	177.7	222.4	34.9	15.7
Kirovohrad	525.5	603.4	559.9	575.8	503.1	515.5	547.2	38.9	7.1
Luhansk	208.0	252.8	298.7	232.0	208.6	213.8	235.7	35.4	15.0
Mikolaivska	196.1	268.4	183.0	171.4	176.8	207.0	200.5	35.7	17.8
Odesa	494.6	541.1	393.0	304.8	381.0	361.5	412.7	88.1	21.4
Kherson	287.2	279.6	271.0	296.4	258.8	279.7	278.8	13.0	4.7
Together in the Steppe zone	**2927.9**	**3220.2**	**2946.5**	**2637.8**	**2539.2**	**2638.8**	**2818.4**	**257.9**	**9.2**
Vinnytsia	1836.6	1848.5	1884.9	1907.6	1826.7	1907.8	1868.7	36.1	1.9
Kyiv	1433.6	1703.1	1700.5	1830.7	1506.4	1549.3	1620.6	148.6	9.2
Poltava	1137.9	1065.4	996.6	1096.0	996.3	1003.9	1049.4	59.9	5.7
Sumy	1068.4	1065.6	1107.4	1000.7	950.9	901.6	1015.8	78.9	7.8
Ternopil	927.8	987.0	991.3	1035.8	960.6	914.1	969.4	44.9	4.6
Kharkiv	1029.0	1077.7	1077.8	1078.8	843.0	712.8	969.9	155.4	16.0
Khmelnytsky	1064.9	1320.5	1385.3	1386.8	1096.6	1279.8	1255.7	141.8	11.3
Cherkasy	778.2	839.2	731.6	915.8	632.1	729.2	771.0	98.2	12.7
Chernivtsi	586.3	594.7	615.3	613.8	579.5	597.0	597.8	14.4	2.4
Together in the Forest-Steppe zone	**9862.7**	**10501.7**	**10490.7**	**10866.0**	**9392.1**	**9595.5**	**10118.1**	**584.9**	**5.8**
Volyn	1098.8	1132.4	1139.4	1164.5	1174.2	1201.5	1151.8	36.0	3.1
Zhytomyr	1176.8	1316.6	1648.4	1879.1	1598.9	1773.8	1565.6	269.4	17.2
Zakarpattia	545.8	534.3	531.0	529.8	494.7	477.6	518.9	26.5	5.1
Ivano-Frankivsk	942.5	975.0	1000.2	1009.8	1007.8	999.2	989.1	26.0	2.6
Lviv	1622.5	1618.9	1693.8	1698.2	1572.9	1601.1	1634.6	50.7	3.1
Rivne	1227.6	1249.4	1310.9	1310.8	1284.7	1286.0	1278.2	33.5	2.6
Chernihiv	1434.7	1201.8	1447.3	1408.0	1204.7	1264.5	1326.8	115.9	8.7
Together in the Polissya region	**8048.7**	**8028.4**	**8771.0**	**9000.2**	**8337.9**	**8603.7**	**8465.0**	**394.8**	**4.7**
Ukraine	20839.3	21750.3	22208.2	22504.0	20269.2	20838.0	21401.5	883.6	4.1

Source: compiled based on generalisation of data (Verner, 2021)

The vegetable sector proved to be somewhat more resilient to climate change than others, as evidenced by the analysis of the coefficient of variation of the average annual production of vegetable crops. Thus, vegetable production is the least stable in Odesa and Zaporizhzhya regions (Table 6).

Table 6. Analysis of the dynamics of vegetable production in different climatic zones, thousand tons

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Dnipropetrovsk	728.3	732.7	702.6	749.0	727.5	684.6	720.8	23.2	3.2
Donetsk	208.0	213.8	233.1	235.8	270.2	241.4	233.7	22.1	9.5
Zaporizhzhia	435.7	391.4	352.3	273.9	273.9	254.0	330.2	74.2	22.5
Kirovohrad	234.8	233.9	243.2	257.6	260.8	254.0	247.4	11.7	4.7
Luhansk	163.3	168.0	186.8	164.2	177.8	148.5	168.1	13.2	7.8
Mikolaivska	483.0	500.9	554.5	515.6	478.5	575.3	518.0	39.2	7.6
Odesa	436.5	348.8	287.7	270.7	289.4	246.6	313.3	69.2	22.1
Kherson	1251.5	1278.2	1268.9	1317.0	1320.0	1315.7	1291.9	29.4	2.3

Table 6. Continued

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Together in the Steppe zone	**3941.1**	**3867.7**	**3829.1**	**3783.8**	**3798.1**	**3720.1**	**3823.3**	**75.8**	**2.0**
Vinnytsia	460.4	477.8	483.3	461.4	455.7	429.7	461.4	18.9	4.1
Kyiv	511.2	631.1	581.1	604.2	565.8	566.5	576.7	40.6	7.0
Poltava	517.3	522.2	402.4	524.5	545.6	563.1	512.5	56.6	11.1
Sumy	189.2	200.4	183.9	201.2	203.2	205.2	197.2	8.6	4.3
Ternopil	255.4	259.3	274.3	265.3	282.9	272.7	268.3	10.2	3.8
Kharkiv	689.8	692.5	687.7	694.4	675.9	578.6	669.8	45.2	6.7
Khmelnytsky	187.4	227.5	268.7	262.8	249.4	224.6	236.7	30.1	12.7
Cherkasy	365.3	354.2	313.3	354.7	358.8	387.9	355.7	24.2	6.8
Chernivtsi	222.3	227.7	234.3	238.3	247.5	253.7	237.3	11.8	5.0
Together in the Forest-Steppe zone	**3398.3**	**3592.7**	**3429.0**	**3606.8**	**3584.8**	**3482.0**	**3515.6**	**91.0**	**2.6**
Volyn	276.4	288.7	302.6	280.2	281.9	279.9	285.0	9.6	3.4
Zhytomyr	271.9	297.0	327.2	340.1	393.7	403.3	338.9	52.0	15.4
Zakarpattia	267.2	267.2	271.3	283.6	271.0	280.9	273.5	7.0	2.6
Ivano-Frankivsk	169.8	172.2	174.2	177.6	181.5	185.2	176.8	5.8	3.3
Lviv	483.5	505.7	511.1	512.8	709.1	806.7	588.2	135.5	23.0
Rivne	213.6	236.2	268.1	265.1	268.9	274.7	254.4	24.2	9.5
Chernihiv	192.2	187.1	173.7	190.2	198.6	220.0	193.6	15.3	7.9
Together in the Polissya region	**1874.6**	**1954.1**	**2028.2**	**2049.6**	**2304.7**	**2450.7**	**2110.3**	**220.9**	**10.5**
Ukraine	9214.0	9414.5	9286.3	9440.2	9687.6	9652.8	9449.2	190.5	2.0

Source: compiled based on generalisation of data (Verner, 2021)

The analysis of the range of variation in sunflower production is of some scientific and practical interest. According to the analysis of available data, the share of the coefficient of variation of sunflower production increases from the Steppe zone to the Polissya zone (Table 7). In the Steppe, this figure is the lowest, at 11.5%. In the Forest-Steppe it is 15.1% and in Polissya – 25.7%. The high variation of sunflower cultivation in Polissya is explained by the almost absence of this crop among the crops typical for this zone in previous years. Warming has established conditions favourable for growing sunflowers in it. However, for the less fertile soils of Polissya, its cultivation can potentially become rather risky soon compared to other zones.

The research of the reasons for the high variation of intrazonal production of major crops in all categories of farms of the main natural and climatic zones over the years of observation allowed the establishment of some regularities and trends. First of all, for grains, sunflowers, and vegetables, the coefficient of variation increases from the Steppe to Polissya, while for potatoes, on the contrary, it decreases.

Table 7. Analysis of sunflower production dynamics in different climatic zones, thousand tons

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Dnipropetrovsk	1198.6	1264.1	1202.8	1283.2	1448.6	1013.5	1235.1	141.6	11.5
Donetsk	528.3	620.0	555.5	531.0	685.7	571.8	582.1	60.8	10.4
Zaporizhzhia	961.8	985.2	866.4	720.5	1020.5	827.3	897.0	113.3	12.6
Kirovohrad	1170.1	1293.8	1091.9	1458.7	1540.3	1033.1	1264.7	203.4	16.1
Luhansk	484.8	670.1	566.1	720.9	860.6	678.3	663.5	129.5	19.5
Mikolaivska	938.7	1162.3	875.8	1087.2	1063.4	691.9	969.9	171.2	17.7
Odesa	755.3	1004.2	903.9	886.3	693.4	452.9	782.7	195.9	25.0
Kherson	486.5	613.1	499.2	552.8	641.1	531.6	554.1	61.9	11.2

Table 7. Continued

Natural and climatic zone, region	2015	2016	2017	2018	2019	2020	Av	STDev	Cv, %
Together in the Steppe zone	**6524.1**	**7612.8**	**6561.6**	**7240.6**	**7953.6**	**5800.4**	**6948.9**	**798.1**	**11.5**
Vinnytsia	503.6	819.8	725.8	808.1	846.0	773.4	746.1	125.9	16.9
Kyiv	292.1	452.6	397.5	570.1	508.0	454.8	445.9	95.3	21.4
Poltava	848.4	824.4	730.9	943.9	979.3	974.1	883.5	99.0	11.2
Sumy	471.2	488.4	516.3	621.0	777.1	880.1	625.7	168.7	27.0
Ternopil	74.7	149.1	234.2	190.6	215.6	285.4	191.6	73.0	38.1
Kharkiv	1172.2	1352.2	1103.0	1468.2	1480.6	1355.8	1322.0	154.3	11.7
Khmelnytsky	105.9	346.7	438.7	484.1	513.4	568.8	409.6	166.6	40.7
Cherkasy	541.6	576.0	504.7	640.9	673.7	568.8	584.3	62.7	10.7
Chernivtsi	20.8	55.5	43.6	52.4	34.3	52.6	43.2	13.5	31.1
Together in the Forest-Steppe zone	**4030.5**	**5064.7**	**4694.7**	**5779.3**	**6028.0**	**5913.8**	**5251.8**	**794.5**	**15.1**
Volyn	5.2	15.6	39.5	69.5	94.5	100.9	54.2	40.4	74.5
Zhytomyr	141.5	231.7	247.6	298.6	324.6	346.0	265.0	74.7	28.2
Zakarpattia	4.7	6.9	6.8	5.4	8.0	6.4	6.4	1.2	18.4
Ivano-Frankivsk	27.3	53.1	76.9	57.6	61.1	64.3	56.7	16.5	29.1
Lviv	27.8	67.6	73.7	79.8	72.7	84.8	67.7	20.5	30.2
Rivne	9.6	37.0	67.0	58.4	77.9	101.7	58.6	32.2	54.9
Chernihiv	410.4	537.5	467.7	576.0	633.7	692.1	552.9	104.2	18.8
Together in the Polissya region	**626.5**	**949.4**	**979.2**	**1145.3**	**1272.5**	**1396.2**	**1061.5**	**272.8**	**25.7**
Ukraine	11181.1	13626.9	12235.5	14165.2	15254.1	13110.4	13262.2	1437.0	10.8

Source: Compiled based on generalisation of data (Verner, 2021)

To a large extent, under specific conditions, the adverse impact of climate change can be reduced if specific standards of environmentally safe agricultural production are observed. However, in practice, in a significant number of farms, these requirements have not been observed for many years and are deliberately violated.

In particular, according to Y.M. Gadzalo and Yu. Luzan, only 15% of agricultural producers use scientifically based crop rotations, while in most farms other agrotechnical and environmental requirements are actually not observed, there is no balanced application of organic and mineral fertilizers, uncontrolled use of plant protection products, the decline of land reclamation continues, and the natural fertility of soils is generally lost (Läderach, Pacillo, Thornton, Osorio, & Smith, 2021). As noted by Sh.I. Ibatullin, O.V. Shanin and other researchers, in the field of crop production there is a transformation of the structure of agricultural land use and a change in the regional specialisation.

The process has a spontaneous, opportunistic nature, which violates the technological and environmental foundations of farming and requires state regulation. Export-oriented crops dominate, which increases the environmental load on land resources (Ibatullin, Shanin, & Stepenko, 2014). In general, throughout the Steppe zone, according to the results of research and analysis of long-term statistical data and the calculation of the coefficient of variation, it was established that the shortfall in grain production on average due to the impact of climate change can range from 1 to 5 million tons per year. This aspect has a significant impact on the economy of agricultural production, which is confirmed by the results of the analysis of gross agricultural production per 100 hectares. In the steppe zone, which suffered from climate problems in 2020, agricultural production per 100 ha is much lower (Table 8).

Table 8. Analysis of agricultural production efficiency per 100 ha of agricultural land by region (in constant prices of 2016)

Natural and climatic zone, region	Average for 2015-2020			For 2020		
	Total of 100 hectares, thousand UAH	Including, %, to the indicator		Total of 100 hectares, thousand UAH	Including, %, to the indicator	
		thousand UAH	Ukraine		Steppe zone	Ukraine
Dnipropetrovsk	1525.0	127.1	94.9	1448.8	137.5	93.5
Donetsk	892.0	74.4	55.5	949.1	90.1	61.2
Zaporizhzhia	1098.1	91.5	68.3	1072.4	101.8	69.2
Kirovohrad	1510.5	125.9	94.0	1249.5	118.6	80.6
Luhansk	647.4	54.0	40.3	671.5	63.7	43.3
Mikolaivska	1176.2	98.1	73.2	991.5	94.1	64.0
Odesa	1090.5	90.9	67.9	666.2	63.2	43.0
Kherson	1386.3	115.6	86.3	1375.4	130.6	88.7
Together in the Steppe zone	**1199.5**	**100.0**	**74.7**	**1053.4**	**100.0**	**68.0**
Vinnytsia	2586.3	215.6	161.0	2419.9	229.7	156.1
Kyiv	2320.3	193.4	144.4	2129.4	202.1	137.4
Poltava	1931.6	161.0	120.2	1776.0	168.6	114.6
Sumy	1690.3	140.9	105.2	1846.5	175.3	119.1
Ternopil	2229.7	185.9	138.8	2341.8	222.3	151.1
Kharkiv	1566.1	130.6	97.5	1582.8	150.3	102.1
Khmelnytsky	2194.9	183.0	136.6	2241.1	212.7	144.6
Cherkasy	2547.5	212.4	158.5	2187.0	207.6	141.1
Chernivtsi	2165.5	180.5	134.8	2238.6	212.5	144.4
Together in the Forest-Steppe zone	**2110.9**	**176.0**	**131.4**	**2029.4**	**192.7**	**130.9**
Volyn	1518.0	126.5	94.5	1603.5	152.2	103.5
Zhytomyr	1629.8	135.9	101.4	1733.5	164.6	111.8
Zakarpattia	1879.8	156.7	117.0	1897.7	180.2	122.4
Ivano-Frankivsk	2132.8	177.8	132.7	2216.6	210.4	143.0
Lviv	1770.8	147.6	110.2	1933.7	183.6	124.8
Rivne	1767.4	147.3	110.0	1871.6	177.7	120.7
Chernihiv	1432.2	119.4	89.1	1558.3	147.9	100.5
Together in the Polissya region	**1947.0**	**162.3**	**121.2**	**1942.5**	**184.4**	**125.3**
Ukraine	1606.8	134.0	100.0	1550.0	147.1	100.0

Source: Compiled based on generalisation of data (Prokopenko, 2021)

In modern conditions, the determining factors of adaptation to climate change in all-natural and climatic zones are the choice of zoned varieties, using the optimal fertilizer system and integrated plant protection. The factor of timeliness and quality of implementation of all these measures is important. The problem of developing and implementing new strategies for the organisation of climate-optimised agro-industrial production, which will solve the socio-economic problems of the industry and consider weather and climate changes and their impact on the development of the agricultural sector, is currently relevant Hadzalo, & Luzan, 2017; Baldwin, & Lenton, 2020).

Conclusions

In the Steppe regions, the impact of climate change on the sustainability and dynamics of agricultural production is quite significant, which requires the development of a scientifically based forecasting and modelling system to prevent potential economic losses and assess risks. This situation is primarily conditioned upon the frequent combination of two adverse environmental and climatic factors in some years – the increase in the average annual temperature and a sharp decrease in precipitation.

Achievement of strategic areas of agrarian development by the Concept of implementation of the national policy in the field of climate change for the period up to 2030 requires a systematic analysis of the problems of efficient management of economic and agro-climatic potential at the regional level to ensure balanced use of labour, financial and natural resources, and the development of a qualitatively new institutional environment while maintaining sustainable growth dynamics, environmentally safe and competitive functioning of industries.

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Глобальна кліматична криза та її вплив на розвиток аграрного сектору економіки України

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▸ **Анотація.** Сьогодні зміна клімату проявляється по всій території України. Найбільш чутливими до цих змін є сільські території, адже прояви зміни клімату, як то підвищення температури, зміна режиму опадів та стихійні погодні явища безпосередньо впливають на сільське господарство та якість життя у селі. Мета статті – дослідити фактор впливу глобальної кліматичної кризи на розвиток і ефективність аграрного сектору економіки України на зональному рівні та науково обґрунтувати концептуальне бачення стратегічних засад адаптації агропромислового виробництва до її наслідків. При виконанні дослідження застосовано сукупність загальнонаукових методів і прийомів: монографічний – при вивченні вітчизняних і зарубіжних публікацій досліджуваної проблематики; математичної статистики – для оцінки абсолютного й відносного відхилення аграрного виробництва стратегічних видів сільськогосподарської продукції від середнього багаторічного обсягу на регіональному рівні економіки з точки зору забезпечення продовольчої безпеки в контексті досягнення цілей сталого розвитку; системного підходу на основі принципів системного аналізу і синтезу – для обґрунтування взаємозв'язку сталого розвитку й продовольчої безпеки, а також ефективності аграрного виробництва; абстрактно-логічний – для теоретичного узагальнення результатів досліджень; економічного аналізу – для вивчення ефективності аграрного виробництва. Проаналізовано кліматичні дані України. На основі системного аналізу досліджено вплив глобальної кліматичної кризи на розвиток аграрного сектору економіки із точки зору оцінки забезпечення рівня продовольчої безпеки в контексті досягнення цілей сталого розвитку. Встановлено, що за період аналізу даних із 2015-го по 2020 р. через поєднання комплексу несприятливих погодно-кліматичних факторів коливання річних опадів і підвищення середньої температури повітря знизився рівень стійкості аграрного виробництва регіонів Степу. Високий рівень мінливості виробництва зернових культур спостерігався в окремих регіонах усіх природно-кліматичних зон. На основі поєднання теорій соціально-економічного та сталого розвитку набули подальшого вивчення теоретико-методичні підходи до оцінки впливу глобальної кліматичної кризи на розвиток і ефективність аграрного сектору економіки України на зональному рівні. Результати дослідження прийнятні для практичного використання при розробці й обґрунтуванні регіональних і загальнодержавних стратегій розвитку агропромислового виробництва та адаптації його до викликів, пов'язаних із глобальною кліматичною кризою, а також у подальших наукових дослідженнях

▸ **Ключові слова:** ефективність, розвиток, аграрне виробництво, варіація, клімат, продовольча безпека, економіка