

E.H. Dehodyuk*

Doctor of Agricultural Sciences, Professor, Academician
National Scientific Center

"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

S.E. Dehodyuk

Doctor of Agricultural Sciences, Senior Researcher
National Scientific Center

"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

Yu.P. Borko

PhD in Agricultural Sciences
National Scientific Center

"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

O.A. Litvinova

PhD in Agricultural Sciences, Senior Researcher
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Yu.O. Ihnatenko

Postgraduate Student
National Scientific Center

"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

A.O. Mulyarchuk

Postgraduate Student
National Scientific Center

"Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine"
08163, 2B Mashinobudivnikiv Str., Chabany, Ukraine

Long-term monitoring of aridization in agriculture before and after climate change in Ukraine

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*Corresponding author



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Abstract. This paper presents the results of systematic monitoring in Ukraine for manifestations of aridity according to the method of summarizing spring, summer, and autumn droughts conducted by I. Ye. Buchynskiy for 1872-1969 and authors' meteorological generalizations according to weather types (1951-1984) and clearly expressed zonal climate changes (1985-2006) and statistical and local signs of climate aridization at the meteorological station in the northern part of the Forest Steppe ("Chabany") – 2006-2020, covering a total of 150 years of historical time. According to the spatial distribution of droughts, determined according to a unified methodology, starting from 1872 and ending in the late 1960s, the defining indicator is the gradual spatial distribution of seasonal local droughts with the recurrence of spring droughts after 2 years, summer droughts after 4 years, and autumn droughts, mainly in the south of Ukraine, after 2 years. The number of moderate and large droughts since the beginning of the 20th century (11-30% of the distribution area) are typical for the summer period, and they are repeated in the south after 4-5 years. Abnormal droughts (over 50%) are inherent in large areas for every tenth year, which, starting from the last quarter of the 19th century and until the 1950s, ended with famine for the population (especially the droughts of 1891, 1921, and 1947). Subsequent droughts of 1963 and 1968 were determined by abnormal weather conditions, but without the manifestation of a food crisis, which is associated with the beginning of chemicalization and an increase in agricultural culture. Meteorological indicators of six stations in diverse natural and climatic zones for 1951-1981 and 1985-2008 indicate a zonal systematic increase in positive air temperatures with a decrease in precipitation, the deficit of which is compensated by a farming system with a moderate saturation of organic and mineral fertilizers, which have a stabilizing effect in extreme years. Since the last quarter of the 20th century, climate changes have been identified that are associated not only with the greenhouse effect, but also with a periodicity that depends on the ecliptic of the globe. Climate changes in recent decades are particularly noticeable, which is accompanied by a systematic increase in air temperature and an increase in climate aridity and requires new technical and technological solutions from humanity

Keywords: seasonal droughts; air temperature; precipitation; agriculture; fertilizers; productivity; systematicity

RELEVANCE

The term "arid climate" (from Latin – dry) refers to the climate of semideserts and deserts with a small amount of precipitation (100-150 mm per year) with sharp fluctuations in day and night temperatures. Climate aridization is determined by human influence on nature, especially in the era of global warming with the transformation of large areas into steppes, semideserts, and deserts.

The process of climate change, which has become noticeable since the last quarter of the 20th century, is associated exclusively with the anthropogenic factor, mainly with the greenhouse effect, as a result of industrial emissions of carbon dioxide (CO₂), methane (CH₄), nitrogen oxide (N₂O), ozone (O₃) and water vapour. If the concentration of greenhouse gases in the atmosphere doubles, the average glob-

al temperature will likely increase from 1.5 to 4.5°C. Other causes of warming were as follows: changes in solar activity, increasing tropospheric ozone concentration, atmospheric electricity that depends on solar activity, etc. The results of instrumental observations and the materials of paleogeographical reconstructions indicate that the global climate is changing, and these changes are accompanied by adverse consequences for the economy and living conditions of humankind (M.I. Budyko, 1980; Lipinskii, 2003; V.F. Martizanova, O.K. Ivanova, 2010; O.O. Vrublevska, H.P. Katerusha, 2005; R.L. William *et al.*, 2010). This is attributed to an increase in air temperature of 1°C per century, whereas previously this happened in 1,000 years. This simplified approach to planetary changes is predictable but does not reveal the

underlying nature of these changes. The planet Earth is not a stationary system, but one that is in constant motion and changes its ecliptic relative to the sun, and solar activity also has its patterns. As a result of the influence of cosmic factors in the Cenozoic era, ice ages occur with systematic periodicity, lasting an average of 100 thousand years, and the warming time between them is on average 10 thousand years; at the same time, the onset, and disappearance of a glacier occurs rapidly – over hundreds of years. The last Valdai (Würm) glaciation began 110,000 years ago, preparing for the planet the Holocene period – an interglacial period with an optimum temperature regime of air and humidity, which ensured the flourishing of the green world, and with it the fauna and human civilization. Presently, the post-Holocene period has arrived, which marks the approach of a new ice age, which must come after the maximum warming, which will bring it closer due to the cooling of oceanic warm currents and the change of the Earth's ecliptic to the Sun. In nature, everything happens naturally, according to the established cosmic and planetary cycles.

The climate changes that occur are not uniform in time and space, and therefore it is necessary to investigate climate fluctuations in various regions, considering the characteristics of a particular region and the dependence of these fluctuations on atmospheric circulation.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Planetary climate change is the most pressing issue of modern times, attracting the attention of the scientific and public community. They pose threats to environmental security, require forecasting and feedback on the prevention of real threats, especially for agriculture as an open-air workshop. Famous works on climate change by US scientists, namely Fred Kempe, Berry Pavel (US Atlantic Council), Brent Scowcroft, David Mitchell, English scientists of the Royal Institute of International Relations – Bernes Lee, Jonathan Parris and many others (Shevchenko, 2017).

Considerable attention in foreign literature is paid to the dynamics of human development

in conditions of climate change (Bondarenko *et al.*, 2018; Parri, 2019; Snakin, 2019;), adaptation of farming to climate change (Brouder & Volenec, 2008; Sanderson *et al.*, 2018), problems of microbiology in these conditions (Hutchins *et al.*, 2019) and preservation of soil fertility (Haasnoot *et al.*, 2018; Pikovska, 2020); threats to natural biodiversity and natural ecosystems (Pugnaire *et al.*, 2019; Turner *et al.*, 2020).

A considerable contribution to the theory and practice of climate change has been made by Ukrainian scientists, the results of which are presented in publications of professional journals and materials of numerous conferences covering this topical issue (Baliuk *et al.*, 2018; Vozhegova & Kokovikhin, 2018; Zatula & Zatula, 2020; Dehodiuk and Dehodiuk, 2008; Petrychenko *et al.*, 2018; Pysarenko *et al.*, 2019; Polovyi *et al.*, 2017; Kholiavchuk & Shkaieva, 2021; Loboda *et al.*, 2010).

The purpose of this study was to generalize a 150-year period of the distribution patterns of seasonal and zonal droughts on the territory of Ukraine, to systematize their recurrence, the causes of catastrophic droughts and climate changes since the last quarter of the 20th century, to determine the decisive role of agriculture and fertilization systems in stabilizing crop yields under extreme weather conditions.

MATERIALS AND METHODS

During systematization of spatial, zonal, and local climatic conditions over the past 150 years in Ukraine, the methods adopted in meteorology and agrochemistry were applied – monographic and systematic analysis, statistical, statistical-logical, graphic methods regarding the patterns of distribution of extreme weather conditions and climate changes in Ukraine based on monographic generalizations and own research.

RESULTS AND DISCUSSION

Monitoring of spatial droughts in Ukraine in 1872-1969 It is known that the Holocene had an amplitude of oscillation from warming to small ice ages (13th-19th centuries). According to the information of I. Ye. Buchynskyi (1970), according to

literary sources, in the 10th-11th centuries, 14 dry years were registered on the territory of modern Ukraine, in the 14th century – 10 droughts, in the 15th-17th centuries – 17 anomalous phenomena, of which a third with an onrush of locusts, during the 18th century there were 28 dry years, of which 9 were marked by an onrush of locusts.

According to I.Ye. Buchynskyi (1970), the year 1872, when the meteorological service was introduced on the territory of Ukraine, should be considered the starting point of the modern meteorological era. Almost 100 years of monitoring (1872-1969) determined, using a single method, the spatial distribution of spring, summer, and autumn droughts according to the characteristics of local (1-10% of the covered territory), moderate (10-20%), large (21-30%), massive (31-50%) and catastrophic (> 50% of the territory of Ukraine).

The authors of this study conducted a quantitative analysis of the drought phenomena identified by I.Ye. Buchynskyi, indicating that during almost a century of observation, absolutely favourable weather conditions throughout the territory of Ukraine during spring droughts amounted to 16 years, summer droughts – 11 years, and autumn droughts – 17 years. Or, on average, it can be assumed that approximately 85% of growing seasons were extreme for agriculture in a certain way. In the spring and autumn periods, local droughts were most common (61% and 57%) of the total number, and in the summer – half as many. The proportion of moderate droughts is almost evenly distributed between seasons – 17% each in spring and autumn, and 23% in summer. Large and massive droughts accounted for 19% in spring, 43% in summer, and 26% in autumn, indicating that the threat of summer droughts is twice as high as that of other growing seasons. The largest spring droughts in the 19th century occurred in 1872 (40% of the territory), in the 20th century – 1934 (80%), 1946 (60%), 1957 (33%), 1968 (52%). The most noticeable are the summer droughts, which covered 50-55% of the territory for 8 years (1876, 1895, 1900, 1903, 1904, 1923, 1952, 1953) and over 60% of the affected territory for 3 years

(1874, 1890, 1909). Therefore, over a period of almost a hundred years, 10% falls on an unfavourable type of weather, of which the coincidence of spring and summer droughts is particularly dangerous, which caused the complete death of crops and hunger among the population. Abnormal drought was recorded in 1891, which covered 40% of the territory of the east and south of Ukraine, then the amount of precipitation at the weather station in Kherson city was 21 mm, or 4 times less than normal, and at the Odesa station – 18 mm. Severe droughts in 1921 engulfed the South, Centre, and part of territory in the east of Ukraine. Then in the southern regions for 6 months (X-XII, I-III) less than 10% of precipitation fell compared to the norm, and the air temperature in May and June was 31.5°C and 34.5°C, respectively, at the norm up to 20°C. Spring droughts in 1932 and 1933 were not recorded, the summer drought in 1932 was at the level of moderate distribution (16.2% of the territory), and in 1933 – local (4.5%). The drought of 1947 covered 46% of the territory of Ukraine, except for parts of the centre and northwest, when the air temperature in the south exceeded the norm in May and June by 3.3°C and 5.1°C, respectively, and the amount of precipitation was 6 mm above the norm of 72 mm.

Subsequent droughts of 1950 (21%), 1952 (53%), 1953 (52.3%), 1962 (43.1%), 1963 (36.1%), 1967 (55%) were severe but not as damaging as previous ones. The explanation for this lies in the weakening of spring droughts and the fact that with the growth of technical equipment with the use of fertilizers, the stability of agriculture against adverse conditions of the growing seasons increased.

The spread of autumn droughts was mostly local in nature, intensifying the effects of subsequent or previous droughts in certain periods. The largest of them were defined in 1883 – 46.9% of the territory of Ukraine, 1942 – 27.9%, 1949 – 42.5%, 1963 – 38.8%, 1967 – 38.1%. Local autumn droughts for almost a hundred years covered 57% of the territory of Ukraine, moderate and severe – 17% each, and very severe – 10% (Fig. 1).

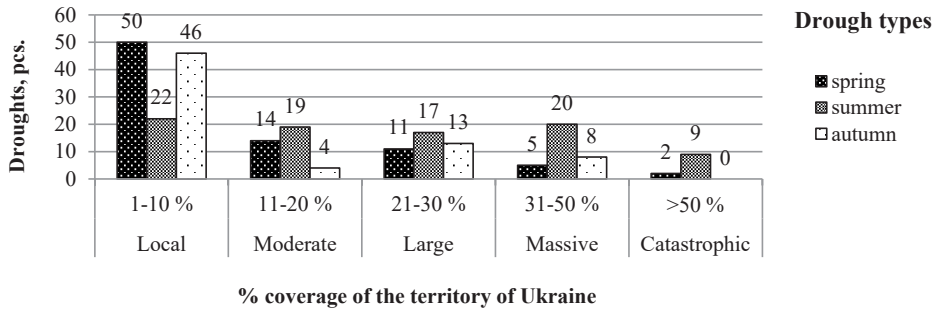


Figure 1. Summary data of age-related changes in seasonal aridity of climate on the territory of Ukraine for 1872-1969 (according to I.Ye. Buchinskyi, 1970)

The age-old amplitude of dry phenomena in Ukraine is associated with the invasion of Ukrainian territory by cold air from the north, northwest, and west, and the formation of a powerful anticyclone behind the cold front, in which high pressure, weak wind, and sunny weather with high dryness and heat are formed in summer. Anticyclones move slowly, sometimes almost without movement, sometimes replacing each other. They move clockwise, while the northern ones move along the southern periphery to the eastern and south-eastern ones, creating an impression of the desert origin of droughts (I.Ye. Buchinskyi, 1970).

Zonal features of weather conditions formation in 1951-1984 The authors of this study monitored the amount of precipitation and air temperature during the specified period according to the data of weather stations located in characteristic points of the soil and climate zones of Ukraine – Polissia (Chernobyl, Teteriv, Makariv

weather stations); Prykarpattia (Ternopil); Western Forest-Steppe (Khmelnitskyi) and Central Forest-Steppe (Bila Tserkva); Eastern (Kirovohrad (currently Kropyvnytskyi)); Steppe (Bashtanka, Mykolaiv region).

The systematization of meteorological indicators determined during this time three types of weather – favourable, dry, overmoistened, and cold (E. H. Dehodiuk, 1993). According to the amount of precipitation in favourable years up to 585 mm, the difference between the northern and southern meteorological stations was 85 mm and 52 mm, respectively, in dry years – 416 mm and 61-95 mm, respectively. In wet and cold growing seasons, the average amount of precipitation at 6 weather stations was 462 mm with a deviation of 30 mm at the Ternopil weather station and 101 mm at the Bashtanka weather station, which indicates a high differentiation of moisture depending on the type of weather (Figs. 2, 3).

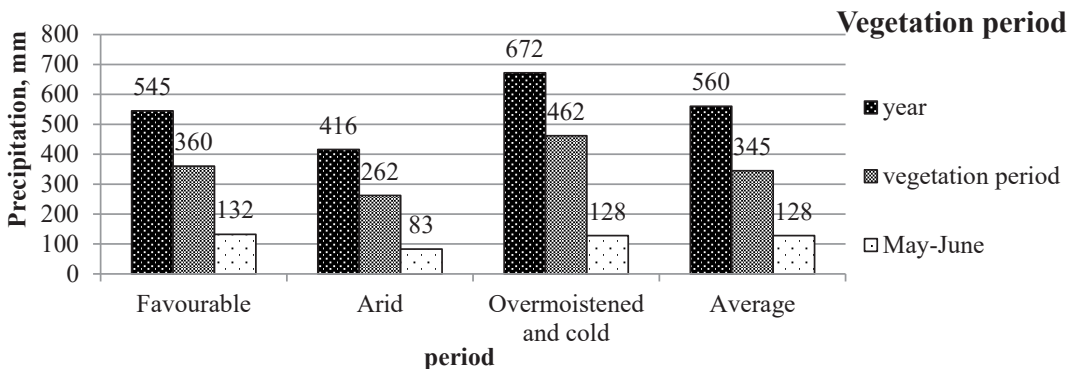


Figure 2. Precipitation on average according to 6 observation stations in the main soil and climatic zones of Ukraine for 1951-1984 (according to E.H. Dehodiuk, 1993)

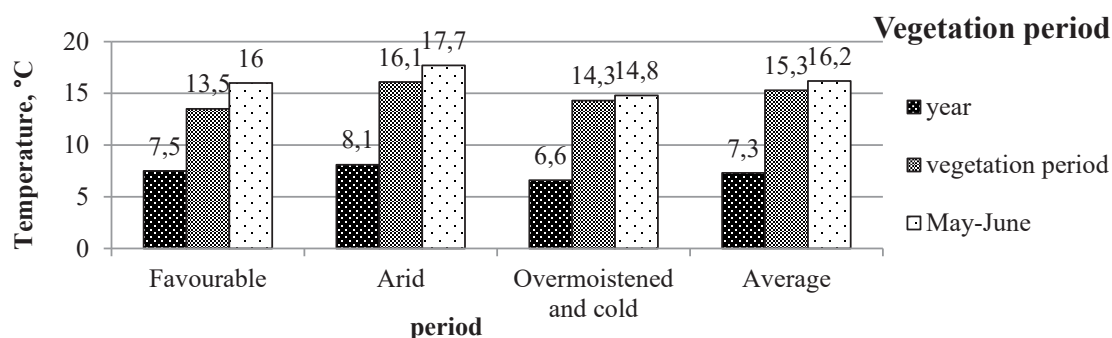


Figure 3. Average air temperature according to data from 6 observation stations in the main soil and climate zones of Ukraine for 1951-1984 (according to E.H. Dehodiuk, 1993)

The average air temperature for the year came close to the average statistical values – 7.3°C, but in dry years its temperature increased by 11%, and in wet and cold years it also decreased by 11%. On a zonal level, the annual temperature difference between the south and the north reached 23% in favourable years, 34% in dry years, and 21% in wet and cold years.

During the monitoring period, the number of favourable years in the Polissia zone was 52%,

60% – in the Forest-Steppe and 46% – in the Steppe, 24% and 25% of dry and overmoistened years in the Polissia and Forest-Steppe, respectively, and 44% – in the Steppe zone.

During monitoring, the authors of this study summarized over 40 field experiments with fertilizers conducted in the research network of Ukraine on crops – winter wheat, maize, barley in variants without fertilizers and with their application in optimal doses and for each crop (Table 1).

Table 1. Yield of agricultural crops and their increments under dry weather in the main zones of Ukraine, average for 1965-1984, t/ha

Crop	Average fertilizer doses	Polissia			Forest-Steppe			Steppe		
		Harvest without fertilizers	Increment from fertilizers	%	Harvest without fertilizers	Increment from fertilizers	%	Harvest without fertilizers	Increment from fertilizers	%
Winter wheat (grain)	Manure aftereffect (25 t/ha) + $N_{70}P_{70}K_{70}$	2.13	1.58	74	2.25	1.2	53	2.16	0.61	28
Spring barley (grain)	Manure aftereffect (30 t/ha) + $N_{60}P_{80}K_{70}$	1.04	1.5	144	3.09	1.29	48	1.28	0.12	9
Grain maize	Manure 30 t/ha + $N_{60}P_{50}K_{55}$	2.71	1.93	71	3.29	1.79	54	2.92	0.36	12
Maize for silage, green mass	Manure 20 t/ha + $N_{140}P_{90}K_{100}$	18.0	17.8	98	27.6	12.2	44	16.5	14.5	87
Mean				97			50			34

In dry summers during 1965-1984, with the application of fertilizers, the stabilization effect on these crops, compared to the control without fertilizers, in Polissia ranged from 71% to 144% (an average of 97%), in the Forest-Steppe zone – 26-53% (an average of 50%), and in the Steppe by grain group – 34%, which indicates the importance of irrigation in this zone. The average amount of precipitation for May-June for 1951-1984 here was 83 mm, or 65% of the average annual norm, which noticeably stabilized the harvest in those years.

Monitoring of weather conditions for climate change in the post-Chernobyl period. The next

zonal monitoring was conducted within the previous 6 weather stations for 1985-2006, conventionally named as “post-Chernobyl”, which covers 21 years (1985-2006) and is defined as the period of the beginning of climate changes (S.E. Dehodiuk, E.H. Dehodiuk, 2008). This is evidenced by a comparison of the temperature regime and precipitation with the previous period (1951-1984). During this period, decisive is the onset of a new type of weather that did not exist before – mixed, when overmoisturization and cooling occur in one growing season, changing to aridity – heat and rainlessness. And all this against the background of increasing air temperatures (Fig. 4, 5).

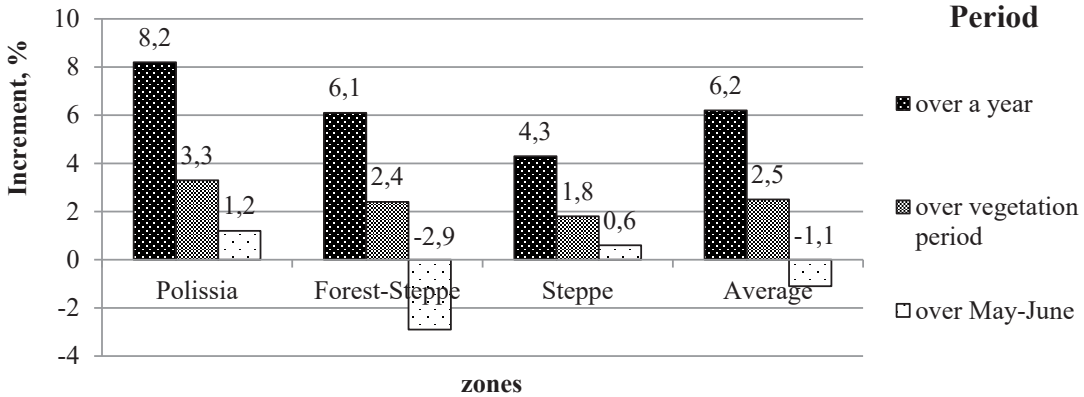


Figure 4. Temperature increment for the second round of observations (1985-2006) compared to the previous period (1954-1984), % (Dehodiuk & Dehodiuk, 2008)

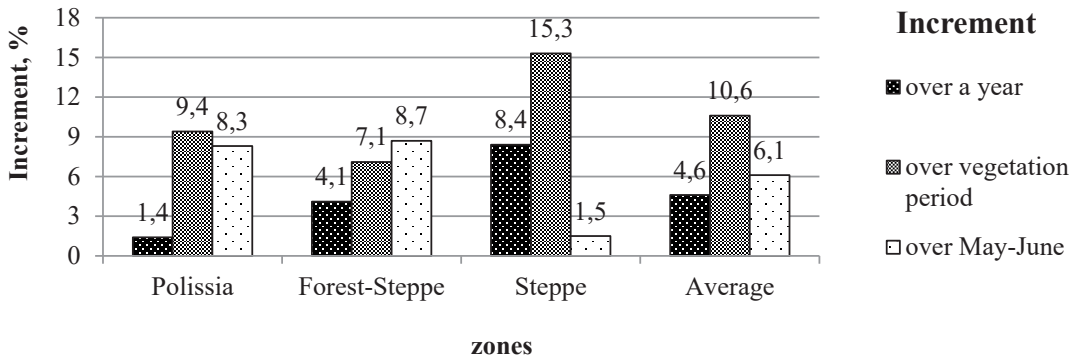


Figure 5. Precipitation increment for the second round of observations (1985-2006) compared to the previous period (1954-1984), mm (Dehodiuk & Dehodiuk, 2008)

On average for the year during the second stage of observations, the greatest warming was determined in the Polissia zone – +8.2% compared to the previous period, in the Forest-Steppe – +6.1%, and in the Steppe – +4.3%. In May, the average temperature in the Forest-Steppe was 2.6% lower compared to the previous study period. A tendency to increase the average annual temperature regime up to 9.5%, during the growing season – up to +2.5%, upon signs of cooling in May (-1.1%), upon an increase in the average annual amount of precipitation – by +5%, during the growing season – +10% and in May-June – up to +6%. This shows that in a historically short period of time within the 54-year cycle from the second part of it, trends emerged that are not explained by changes in the distribution of weather between cyclones and anticyclones (Figs. 4, 5). After all, a considerable part of Polissia has acquired the characteristics of a forest-steppe in terms of temperature, and the hu-

midification of the northern part of the Steppe has approached the Forest-Steppe in terms of precipitation, while the regions of the southern Steppe experienced aridization.

Local monitoring of climate changes on the model of the Chabany weather station (NSC “Institute of Agriculture of the National Academy of Agrarian Sciences”) for 2006-2020. The progressive increase in air temperature over the past decades has increased the evaporation of water from the world's oceans and the disturbance of air masses, which expand arid zones in some places, while in others an excess of atmospheric moisture leads to weather anomalies.

The monitoring carried out at the Chabany weather station indicates that over the past 15 years, with each five-year period, there has been a progressive increase in temperature locally with a one-time decrease in the amount of precipitation, in contrast to the 1985-2006 period (Table 2).

Table 2. Dynamics of changes in air temperature and precipitation at the Chabany weather station for 2006-2020

Period, years	Air temperature, °C				Precipitation, mm			
	Per year		During vegetation		Per year		During vegetation	
	°C	% to normal	°C	% to normal	mm	% to normal	mm	% to normal
2006-2010	9.4	21	17.3	10.1	629	95	60	95
2011-2015	9.7	24	17.8	13.3	657	99	50	79
2016-2020	11.2	32	18.3	16.5	153	70	35	56

Note: the long-term average annual air temperature is 7.8°C, during vegetation – 15.7°C, the average annual precipitation is 659 mm, during the growing season – 63 mm per month

The progressive increase in annual air temperature from 21% to 32% per year and from 10% to 16.5% during vegetation, with the average annual temperature for 2016-2020 – 11.1°C, indicates that the thermal regime of Kyiv is approaching that of Odesa in the middle of the 20th century with the sign of the steppe zone with the amount of precipitation for 2019, 2020, 399 and 389 mm, respectively. In 2006-2010, the amount

of precipitation was 95%, the next period – 79%, and the last five years – 56% of normal. It is characteristic that during local monitoring in May-June, an average of 68 mm of precipitation fell, compared to the norm of 88 mm, or 72% of it. Such a situation necessitates the adaptation of agricultural technologies to climate variability, where not only fertilization systems play a stabilizing role in agriculture, but also there is a

need for purposeful selection work, agricultural techniques for soil cultivation, adaptation of crop rotations to stressful conditions, and optimization of fertilization systems. Therefore, to obtain planned yields and scientifically sound placement of agricultural crops, along with a detailed assessment of agroclimatic resources, it is necessary to investigate the temporal variability of yields in different agroclimatic zones (Adamenko, 2004; Polovyi, 2005, 2007).

Another feature of this period is the absence of such a type of weather as “cold and overmoistened”. After all, for 15 years, the air temperature during the growing season exceeded the norm by an average of 13%, and the amount of precipitation in 2008 and 2013 alone was higher than 700 mm compared to the average annual norm of 659 mm, and in 11 years out of 15 it was less than the norm (from 3% to 40%). This gives reason to define these years as dry-mixed, which ensured the formation of non-critical crop levels even during the dry growing seasons of 2015,

2019, and 2020, when the amount of precipitation was below 400 mm.

In 2016-2020, there was an increase in air temperature by 18.3% and a decrease in precipitation to 56%, compared to the norm of the growing season, which created unfavourable conditions for the growth and development of agricultural crops. The results of field studies in a short-term 5-field crop rotation (winter wheat, maize over grain, spring barley, buckwheat, peas) planted on Alfisols found that, compared with extensive crop rotation (without fertilizers), the greatest stabilization effect was obtained with organic-mineral fertilizer system – 70%, with an organic system, due to limited resources – 37%, with the introduction of straw with a biodestructor – 11%. It is promising to use a new generation of organic-mineral bioactive fertilizers (OMBF), which provided an increase in yield compared to the control without fertilizers when applying 1 t/ha of 4-4-4 OMBF at 57%, and 2 t/ha of 0-0-0 (organic farming) – at 44% (Table 3).

Table 3. Productivity of crops of 5-field crop rotation in a long-term experiment on Alfisols of the NSC “Institute of Agriculture of the National Academy of Agrarian Sciences” under different fertilization systems in the conditions of an arid-mixed climate for 2016-2020

Fertilizer systems	Fertilizers					Productivity	Increment	%
	Manure	Straw	Mineral resources, kg/ha					
	t/ha		N	P	K	t/ha		
Without fertilizers (control 1)	-	-	-	-	-	3.05	-	-
Straw (control 2)	-	3	-	-	-	3.23	0.18	6
Organic	12	3	-	-	-	4.42	1.19	37
	-	3 + biodestructor	-	-	-	3.6	0.37	11
Mineral	-	-	40	60	60	4.80	1.78	53
	-	-	60	90	90	4.93	1.91	63
Organic-mineral	12	-	40	60	60	5.13	2.11	70
	6	-	40	60	60	3.97	0.95	31
OMBF 4-4-4	0.5	-	40	-	-	4.75	1.73	57
OMBF 0-0-0	2.0	3	-	-	-	4.66	1.43	44

Therefore, in the context of climate change, it is necessary to abandon the unsystematic management of agriculture and bring it closer to a scientifically sound direction with clear observance of crop rotation, water-saving systems of soil cultivation, fertilization and plant protection, which will be accompanied by nature-restoring measures in the basins of small rivers with cultural and technical works, agro-, chemo-, bio-, and phytomeliorations.

CONCLUSIONS

Data of meteorological observations for 150 years (1872-2020) with manifestations of seasonal dry phenomena were systematized and the beginning of climate changes from the last quarter of the 20th century, which continue to this day, were recorded. During the 100-year period (1872-1969), it was found that only 16 years of spring droughts had favourable growing season conditions in all territories of Ukraine, 11 years of summer droughts, and 17 years of autumn droughts.

Local droughts are most inherent in spring and summer droughts – 72% and 61%. Large and massive droughts (21-30% and 31-50%) prevailed in the summer and covered 43% of the territory of Ukraine. Abnormal droughts (50% of the territory) occurred due to the coincidence of autumn, spring, and summer droughts with an average frequency of 10 years.

The droughts of 1891, 1922, and 1947 ended in crop failure without recurrence in the future due to the disappearance of spring droughts and the improvement of agriculture.

The zonal monitoring of weather conditions for 1954-1984 was determined by 4 types of weather – favourable, dry, overmoistened, and cold with a noticeable increase in temperature in summer by 0.6°C, in winter – up to 2°C, and an increase in the amount of precipitation – per year up to 4.6 mm, during the growing season – up to 11 mm. Repeated monitoring of zonal weather conditions for 1986-2006 determined an added mixed type of weather, with a further noticeable increase in the temperature regime and a slight increase in the amount of precipitation.

Local weather monitoring at the weather station of the National Scientific Centre “Institute of Agriculture of the National Academy of Agrarian Sciences” established a constant increase in the annual air temperature to 20-21% per year and 10-17% during the growing season with a decrease in the amount of precipitation from 95% to 50% during vegetation, which indicates an increase in climate aridity.

The study established the stabilization effect in the formation of the productivity of agricultural crops due to the improvement of the technical equipment of agriculture and the use of fertilizers.

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Є.Г. Дегодюк

Доктор сільськогосподарських наук, професор, академік
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

С.Е. Дегодюк

Доктор сільськогосподарських наук, старший науковий співробітник
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

Ю.П. Борко

Кандидат сільськогосподарських наук
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

О.А. Літвінова

Кандидат сільськогосподарських наук, старший науковий співробітник
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Ю.О. Ігнатенко

Аспірант
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

А.О. Мулярчук

Аспірант
Національний науковий центр
«Інститут землеробства Національної академії аграрних наук України»
08163, вул. Машинобудівників, 2Б, м. Чабани, Україна

Тривалий моніторинг аридизації в землеробстві до змін і за змін клімату в Україні

Анотація. Наведено результати систематичного моніторингу в Україні за проявами посушливості методом узагальнення весняних, літніх і осінніх посух, проведених І.Є. Бучинським за 1872-1969 рр. та наших метеорологічних узагальнень за типами погоди (1951-1984 рр.) і чітко виражених зональних змін клімату (1985-2006 рр.) та статистично-локальних ознак аридизації клімату по метеорологічній станції в північній частині Лісостепу («Чабани») – 2006-2020 рр., охоплюючи загалом історичний проміжок часу в 150 років. За просторовим поширенням посух, визначених за єдиною методикою, починаючи із 1982 р. і до кінця 60-х рр. XX ст., визначальним показником є поступове просторове поширення сезонних локальних посух із повторенням весняних через 2 роки, літніх – через 4 і осінніх, переважно на півдні України, через 2 роки. Кількість помірних і великих посух із початку XX ст. (11-30 % площі поширення), характерні для літнього періоду і вони повторюються на півдні через 4-5 років. Аномальні посухи (понад 50 %) характерні для великих територій для кожного десятого року, які, починаючи з останньої чверті XIX ст. і до 50-х рр. XX ст. закінчувалися голодом для населення (особливо посухи 1891, 1921, 1947 рр.). Наступні посухи 1963, 1968 рр. визначались аномальними погодними умовами, але без прояву продовольчої кризи, що пов'язано з початком хімізації й підвищення культури землеробства. Метеопоказники шести станцій у різних природно-кліматичних зонах за 1951-1981 і 1985-2008 рр. вказують на зональне систематичне наростання позитивних температур повітря зі зменшенням кількості опадів, дефіцит яких компенсується системою землеробства з помірним насиченням органічними й мінеральними добривами, які мають стабілізуючий ефект в екстремальні роки. З останньої чверті XX ст. визначено зміни клімату, які пов'язані не тільки з парниковим ефектом, а й із періодичністю, що залежить від екліптики земної кулі. Особливо помітні кліматичні зміни останніх десятиліть, що супроводжується систематичним підвищенням температури повітря й наростанням аридності клімату і вимагає від людства нових технічних і технологічних рішень

Ключові слова: сезонні посухи; температура повітря; опади; землеробство; добрива; продуктивність; систематичність