ФІЗИЧНА ГЕОГРАФІЯ

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REGIONAL CLIMATE CHANGES OF THE INTERZONAL GEOECOTON OF UKRAINE «FOREST-STEPPE-STEPPE»

The influence of anthropogenic factor on the formation of negative natural processes and phenomena that lead to changes in the temperature regime of the interzonal geoecoton «forest-steppe-steppe» of Ukraine has been studied. The analysis of temperature over a 59-year period allows us to draw conclusions about the positive empirical linear trend of average annual temperatures in the geoecoton and predict the dynamics of temperature rise in the transition zone of forest-steppe and steppe to the end of the XXI century. The influence of the temperature regime on other climatic characteristics, in particular on the amount of precipitation, the reduction of which contributes to the development of aridization of the climate of the interzonal geoecoton «forest-steppe-steppe» of Ukraine.

Keywords: *interzonal geoecoton, forest-steppe, steppe, climate changes, aridization, Haivoron district of Kirovohrad region.*

Formulation of the problem. One of the most curent scientific problems of the modern world is the global changes in the long-term weather regime, initiated by human economic activity. It is especially important to address the regional environmental and socio-economic consequences of climate change, which are manifested in Ukraine [2, 4, 5, 6, 7, 11]. In 2007, the United Nations Intergovernmental Panel on Climate Change (IPCC) published the Fourth Report, which reaffirmed the anthropogenic nature of global warming. These examples show that with the beginning of the XXI century the rise in air temperature remains quite intense. Study of the age course of air temperature anomalies on the territory of Ukraine during the XX-beginning – XXI century found similarity with the age course of global temperature [2].

If the intensity of global warming in the twentieth century was about 0.5 ºC and was expected to increase, then over the past decade, the growth rate of annual temperature on average in Ukraine is 1.5 times faster than globally [1]. This factor has given special importance to the problem of climate change in Ukraine over the past 10 years and requires detailed study.

Against the background of global and regional warming, not only air temperature changes, but also other climatic characteristics: atmospheric circulation, humidification regime, length of seasons, aridity, etc. [2, 16]. Much less attention is paid to local changes in various climatic elements, especially in natural regions, where the anthropogenization of natural landscapes is extremely high: transitional ecotones of zonal and regional levels, in particular the interzonal geoecotone «forest-steppe-steppe» of Ukraine, or its parts.

The climatic conditions of Haivoron district differ within a certain feature (within the administrative division before the adoption of the Resolution of the Verkhovna Rada of Ukraine № 3650 of 17.07.2020 «On the formation and liquidation of districts»), as one of the natural regions of Kirovograd region, territory, ancient development, which has undergone a corresponding long-term anthropogenic impact. Therefore, the study of regional climate change of the interzonal geoecoton «forest-steppe – steppe» of Ukraine is an actual scientific problem.

Analysis of recent research. Problems of climate change and its individual characteristics on the territory of Ukraine are devoted to the works of such scientists: V.F. Martazinova, O.K. Ivanova [10], M.B. Barabash, O.G. Tatarchuk [3], V.M. Babichenko [2], S. Boychenko [4], V.M. Voloshchuk [7], O.O. Kosovets, O.E. Pakholyuk [9], V. Yeremeev, V. Yefimov [8] and others. Climatic conditions of Kirovohrad region and their features are presented in works on the climate of Ukraine, the issue of climate of Haivoron district is partially revealed in the materials of scientific conferences, creative works of local historians, in encyclopedias, etc. [12].

Examining current climate change and its manifestations, the authors note that climate change is an indisputable fact in the context of global warming and these changes have a negative impact on the overall ecological condition of the environment at the global and regional levels. In particular, M.B. Barabash, O.G. Tatarchuk [3], studying the spatio-temporal dynamics, revealed the main patterns of temperature in Ukraine in the context of global warming and note a significant increase in temperature throughout the country. Analysis of changes in the amount of active

temperature for the first decades of the XXI century proves the specified tendency to warming within the vegetative period in the future in the conditions of the forecasted warming of the global climate.

V.M. Babichenko, N.V. Nikolaeva, L.M. Gushchyna [2], considering the course of air temperature in Ukraine in the late twentieth and early twenty-first century, note that due to global climate change, which affects the transformation of the regional climate and certain meteorological values, the average monthly air temperature for the past 15 years has undergone significant changes compared to the climatic standard (1961-1990). The air temperature rose in most months and in general for the year, only in September, November and December it became slightly lower.

V.F. Martazinova, O.K. Ivanova [10] point out that in accordance with global warming, changes in annual temperature are observed almost throughout Ukraine except the southern regions and this increase is 1.5-2.3 °C in the winter months. According to generalized theoretical research, the authors considered the current manifestations of climate change, their possible consequences both at the global level and on the example of Ukraine and noted that climate change is an indisputable fact in global warming, these changes negatively affect the overall environment and population. All this determines the need for further development of adaptive measures through appropriate comprehensive research on relevant sectoral, governmental and interstate programs.

The purpose of the study is to study the climatic changes of the interzonal geoecotone «forest-steppe – steppe» of Ukraine and its separate territory – Haivoron district of Kirovohrad region.

Presenting main material. To determine the dynamics and trends of temperature regime of the interzonal geoecotone of the forest-steppe-steppe of Ukraine had been analysed the temperature for the 59-year period – from 1961 to 2019. Average annual temperatures and average temperatures for certain periods of time had been calculated (January-February, March-May, June-August, September-November). Linear trends for the corresponding periods were determined.

The analysis of the obtained results showed that within the ecotone territory a positive empirical linear trend of average annual temperatures is observed. The temperature rise is about 1 ºC and more, depending on the selected periods.

Statistical analysis of the results of hydrometeorological observations performed within the interzonal geoecoton shows that this area is characterized by processes and phenomena similar to the processes and phenomena observed throughout Ukraine.

In general, the fact of global temperature rise is beyond doubt. During the study period, the value of the coefficient of the linear trend of average air temperature anomalies is from 0.1 ºC and more than 10 years. The most pronounced positive trend is observed for the past 2000-2019. The increase in average annual air temperature values was mainly due to warming in winter, which cannot be compensated by lower temperatures in autumn.

Comparing the trend of temperature increase over time, we can assume that by 2025 the temperature will rise by 1.5 ºC, by 2050 – by 2.0 ºC, by 2100 – by 2.5 ºC. This will lead to the destruction of the dynamic relationship that develops in the transition zone of the forest-steppe and steppe.

Against the background of global and regional global warming, not only air temperature changes, but also other characteristics change: atmospheric circulation, humidification regime, length of seasons, aridity, etc. [2].

The distribution of changes in annual precipitation on the territory of Ukraine is not consistent with the seasonal. The regional climate is influenced by large-scale processes, including anthropogenic factors. Considering the age dynamics of precipitation in Ukraine during the XX-XXI centuries it should be noted that there is no clear trend in the range of precipitation. The change in their annual number is not the same and is in the range of 85-115% of the norm [18].

Given that agriculture is one of the leading sectors of the interzonal geoecotone «forest-steppe-steppe» of Ukraine, the question arises of determining ways to further its development. Over the past few decades, its development has taken place in an arid climate, which is primarily manifested in the progressive increase in moisture deficit. Its characteristic features are an increase in air temperature, a decrease in precipitation, a decrease in humidity, as well as an increase in the frequency of droughts and dry winds [18]. It is known that arid conditions develop with the establishment of a stable atmosphere in large areas of the Earth. In some regions, droughts are exacerbated by areas of high pressure, cold ocean currents and dry winds, most often occurring in situations of blocking anticyclones, which long disrupt the west-east transfer in the middle latitudes. Quite often the cause of dry winds in Ukraine is large-scale invasions of cold Arctic air

with its subsequent warming and removal from the state of saturation.

Thus, aridity is a characteristic feature of the climate and is manifested within the interzonal geoecotone «forest-steppe-steppe» of Ukraine. The rapid development of climate aridization in recent decades is characterized by frequent manifestations of severe and moderately arid conditions of the growing season. If in the early 90's of XX century the territory of the geoecoton was characterized by a sufficient level of moisture, in recent years there have been pronounced arid conditions (SCC did not exceed 1). In the conditions of modern climate changes in Ukraine (aridization and warming) there is an actual shift of the boundaries of natural-climatic zones by 100-150 km to the north [18]. The crop industry is sensitive to the new climatic realities within the interzonal geoecotone «forest-steppe-steppe» of Ukraine. In addition to traditional crops, farmers are beginning to grow so-called niche crops (chickpeas, lentils, safflower, sorghum, millet, etc.) with small production volumes, which, however, are characterized by high drought resistance and export capacity [19].

In addition, the probable consequences of rising temperatures and redistribution of rainfall may also be: 1) changes in the species composition of vegetation; 2) change in the landscape structure of the territory; 3) deformation of the configuration of the boundaries of the territory of the interzonal geoecotone «forest-steppe – steppe» of Ukraine.

Kirovohrad region, occupying a central place within the interzonal geoecotone «forest-steppe – steppe» of Ukraine, belongs to the Atlantic-continental climatic region of the temperate zone with slight temperature fluctuations and increasing continentality from west to east (Table 1). Despite its relatively small area (24.6 thousand km^2), the climatic features of Haivoron district differ from the average values. This is due to the considerable length of the Kirovohrad region from west to east and the extreme western position of the Haivoron district.

The general features of the climate of Haivoron district, as well as Kirovohrad region, are determined by the dominance of temperate continental air masses and the influence of transformed marine. The formation of the baric field is significantly influenced by the baric axis of Voeikov, which crosses the territory of the region. The circulation of the atmosphere over the territory of the Kirovohrad region is due to air currents coming mainly from the Atlantic, Eurasia and the Arctic. The western component of the circulation is 40% of the days of the year. Wet Atlantic air masses in winter bring thaws, snowfalls, ice, and in summer and autumn – cloudy weather with prolonged rains and fogs, ie the bulk of precipitation. Invasion of continental air in winter leads to significant cooling, and in summer is accompanied by hot and dry weather. The frequency of the eastern component of the circulation is 30-35%, it is most often observed in winter under the conditions of the Siberian anticyclone. The circulation of Arctic masses accounts for 25-30% of days.

Table 1

Influence of climate-forming factors on climate Kirovograd region

Climate-forming factors	Features of climate
1. Location in temperate latitudes, significant length of territory from west to east.	1.Moderate air masses are formed, continentality increases from west to east.
2. Location of the region in the center of Ukraine.	2. Like the main part of Ukraine Kirovograd region is in the temperate zone.
3. The dominance of temperate continental air masses and the influence of transformed marine.	3. The climate of the region is moderately continental.
4. The flatness of the territory.	4. Invasion of Arctic (from the north) and tropical (from the south) air masses
5. Frequent passage of cyclones and anticyclones.	5. Frequent and abrupt changes in weather.

Under the influence of inhomogeneity of the state of the underlying surface there is a local circulation, which is manifested in the surface layer of the atmosphere and is part of the microclimate. Local circulation is clearly visible near the shores of ponds and reservoirs, and also occurs between settlements and the surrounding area, between forest areas and agricultural land. The earth's surface affects weather processes through the absorption and conversion of solar radiation, as a result of the transformation of air masses. The presence of hills, lowlands, forests, agricultural lands, swamps, water surface leads to the formation of local climatic features. The absence of high mountain systems promotes the free movement of air masses of various origins, which causes significant variability of weather processes in certain seasons.

Thus, the formation of the climate of Haivoron district, as well as other areas is

influenced by relevant factors: solar radiation, atmospheric circulation, the underlying surface. In general, in the territory of Gaivoronshchina all seasons are expressed, which are characterized by various features: unstable weather, temperature and precipitation.

For the climatic norm it is accepted to use average monthly indicators of temperature and precipitations for 1961-1990 (Table 2).

Table 2

Average monthly indicators of temperature, precipitation and relative humidity at the Gaivoron meteorological station for 1961-1990

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
t ºC	-5.1	-3.6	1.2	9.1	15.2	18.2	19.5	18.9	14.4	8.3	2.8	-1.6	8.1
Precipitation, mm	38.0	39.0.0	34.0	41.0	55.0	85.0	85.0	55.0	42.0	28.0	39.0	41.0	582.0
Relative humidity, %	82.0	82.0	78.0	68.0	64.0	70.0	71.0	71.0	72.0	78.0	85.0	86.0	75.0

For Haivoron district, the normal atmospheric pressure is 990-997 hPa. During the year, the amplitude of its oscillations is 40-50 hPa, due to the frequent change of air masses due to the movement of cyclones and anticyclones and associated atmospheric fronts.

An important characteristic of the radiation regime is the duration of sunshine, which is 1920-1925 hours / year, and during the growing season – 1620-1625 hours. During the warm period of the year (April-October), the greatest duration of sunshine is observed in July – more than 300 hours, the lowest value of this indicator is recorded in October – about 140 hours.

Processes that occur in the geographical environment are determined by thermal conditions. Air temperature, which determines the nature and mode of weather, affects human life and is characterized by such indicators as the average annual air temperature, absolute maximum and minimum temperatures, January and July temperatures, and so on.

A significant decrease in air temperature is due to the movement of cold Arctic air masses, which due to low humidity and high transparency undergo further radiation cooling. The air temperature during their invasion may decrease during the day. The absolute minimum air temperature is much lower than the average monthly air temperature and depends on local conditions and terrain. Analyzing the thermal regime of the air of Gaivoron district, it is necessary to note a wide range of temperature changes. The average temperature in summer (July) in the shade is +19.5 °C, and in some years varies from +17.4 °C to +22.0 °C, and even up to +24.4 °C.

The weather is changeable, especially in winter. Waves of heat and cold lasting 3-5 (sometimes 15-22) days change 2-5 times a month, and the temperature can deviate significantly from the average perennial for this time of year. The average temperature in winter (January) is -5.1 °C, and in some years varies from -8.0 °C to +2.8 °C.

According to the observations of the Gaivoron meteorological station, the average annual temperature in the Gaivoron district is +8.1 °C, and during 1950-1959 its indicators were +8.1 °C, in 1960-1969 +8.1 °C, in 1970-1979 +8.0 °C, 1980-1989 + 7.8 °C, 2000-2009 + 9.6 °C, and for 2010-2019 +10.0 °C. Thus, over the past 20 years there has been a significant increase in average annual temperatures.

The average temperatures of the 5 coldest months (November, December, January, February, March) were: in 1950-1959 -1.7 °C, 1960-1969 -1.5 °C, 1970-1979 -1.4 °C, 1980-1989 -1.5 °C, 1990-1999 -0.4 °C, 2000-2009 +0.4 °C, 2010-2019 -1.3 °C. However, we can give an example of winters when air temperatures were lower than the long-term average.

The average temperatures of the 5 warmest months (May, June, July, August, September) were: in 1950-1959 +17.8 °C, 1960-1969 +17.5 °C, 1970-1979 +16.5 °C, 1980-1989 + 16.9 °C, 1990-1999 +17.4 °C, 2000-2009 +18.4 °C, 2010-2019 +19.1 °C.

A characteristic feature of the climate of Haivoron district, as well as Kirovohrad region and a large area of Ukraine, is the instability of weather in winter. Even in abnormally cold January there are at least 3 days with a sharp warming. At the end of January warming is observed more often and in some years at this time there is a steady transition of temperature through 0 ºC in the direction of increase, ie meteorological spring comes. The average temperature in February is rarely close to normal. The frost-free period is 275-285 days, the number of days with a temperature above +5 °C – 220-225 days, and with a temperature above +10 °C – 175-

185 days.

Wind is one of the main and changing characteristics of the state of the atmosphere, which significantly affects the living conditions and economic activities of man.

The wind regime of Haivoron district is determined by macrocirculatory processes in the atmosphere and the position of the pressure centers over Eurasia and the Atlantic. The movement of air masses is determined by the circulation of the atmosphere and is determined by the presence of stationary pressure centers, as well as the nature of the terrain and the underlying surface. Of particular importance in the wind distribution are the height, protection of the terrain and the roughness of the underlying surface. In some places, the distribution of wind direction and speed depends on the orientation of the valleys, the presence of reservoirs, and so on. During the year there is a change in the prevailing direction and wind speed. Seasonal displacement and intensity of individual centers of the atmosphere determine the annual course of wind characteristics.

In general, the north-western winds are prevalent in the Haivoron district, which is explained by the location of its territory north of the baric axis of Voeikov, which is why the western, northern and north-western winds predominate. Given that the Voeikov axis passes approximately through Kremenchuk, Znamyanka, Pomichna, Lyubashivka and Chisinau, it can be assumed that its current border has shifted slightly to the north.

An important characteristic of the wind regime is the wind speed, which is determined by the pressure gradient and atmospheric circulation conditions. In Haivoron district, the average wind speed varies from 2.6 m/s to 3.9 m/s. The highest average wind speed is observed in January-February, in some cases – in March or April (from 3 to 4.5 m/s), which is due to the active manifestation in the winter-spring season of cyclonic circulation, which leads to increased speed winds of different directions at this time. The lowest wind speed is observed in summer, when the area is under the influence of the Azores anticyclone, and cyclonic activity is weakened, in July-August the wind speed decreases to a minimum (from 2 to 3.2 m/s). In the summer months, the wind speed has a clear daily course. Its maximum value is observed in the afternoon and occurs at 15 o'clock. The minimum speed is fixed at night.

Precipitation is an important characteristic of moisture. They are the main source of replenishment of water reserves and moisture in the soil and their loss is closely related to moisture. An important characteristic of intracontinental moisture is the ratio of external and internal (local) precipitation or the ratio of all precipitation to external, ie the coefficient of moisture. This coefficient shows how many times the moisture brought from outside in the process of moisture circulation falls in the form of precipitation until the atmospheric circulation and river runoff take it outside the territory. It is obvious that with a small amount of internal precipitation, the coefficient of moisture is close to 1, and with increasing their number – exceeds 1. For Haivoron district, it is 1… 0.1, ie advective precipitation prevails and only 3… 4% of it is formed from water vapor of local origin.

The formation and precipitation within the Gaivoron district is a consequence of complex macrocirculatory processes that determine heat and moisture exchange in the atmosphere, the essence of which is to transfer heat and moisture from the Atlantic and Mediterranean Seas, as well as the development of powerful convective movements.

The main amount of precipitation falls from the front clouds. In winter, they fall due to Mediterranean cyclones moving from the Black Sea in a northerly and northeasterly direction. In summer, only a small part of the precipitation falls in the rear of the cyclones directly from the sea air masses in the form of convective instability precipitation. The formation of the humidification regime of the territory is influenced by tropical air, which moves from the southeast through the southern and southwestern periphery of the anticyclone, moistens and, meeting with the polar air, gives a large amount of rainfall.

On average, 582 mm of precipitation falls on the territory of Haivoron district, but the figures for some years may differ significantly. For example, 742.9 mm fell in 1948 alone, 1,013 mm in 1966, 788.6 mm in 1970, 734.7 mm in 1971, 707 mm in 1982, and 826.6 mm in 1991. However, during some years (1950, 1952, 1954, 1957, 1959, 1960, 1968, 1974, 1986, 1992, 1995, 2015) the amount of precipitation was lower than the long-term average. More precipitation falls in the warm period of the year (from April to October) 391 mm, and in November-March – 191 mm. The highest monthly precipitation amounts on average long-term observations are 85 mm in June and July, the lowest amount of precipitation falls in October – 28 mm in accordance. The intensity of precipitation has increased especially in recent decades. Meteorological stations Gaivoron recorded in 2008 – 150 days with precipitation, in 2009 – 158, in 2010 – 148, in

2013 – 146. The amount of precipitation that exceeded 20 mm per day is no longer surprising against the background of recorded indicators – 53.6 mm (June 3, 2007), 57.9 mm (August 30, 2007), 68.6 mm (May 2, 2008), 40.2 mm (June 15, 2010), 47.7 (October 9, 2011), 65.0 mm (24.07.2014), 108.2 mm (09.07.2015), 47.5 mm (18.01.2018), 59.8 mm (04.06.2019), 104 mm (05.06. 2019). Particularly impressive in terms of consequences were the high-intensity torrential rains on June 4-05, 2019, when 59.8 and 104 mm fell in 2 days, respectively, and 212.5 mm in June.

Comparing the average monthly temperature and precipitation for 1961-1990 and 1990-2019 (Table 2,3), we can identify: 1) a steady tendency to increase the temperature during the year and the average annual temperature exceeds the accepted climatic norm by 1.2 ºC; 2) precipitation indicators do not differ significantly, only their intensity and distribution over time changes; 3) increase in the temperature background with a constant amount of precipitation and their uneven precipitation causes a decrease in the coefficient of humidity of the territory.

Table 3

Average monthly indicators of temperature, precipitation and relative humidity at the Gaivoron meteorological station for 1990-2019

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
t, ºC	-3.0	-1.6	3.2	10.0	16.0	19.4	20.9	20.7	15.0	8.5	3.3	-1.4	9.3
Precipitation, mm	30.0	28.6	31.7	37.9	51.0	83.3	76.4	49.4	53.6	37.5	37.8	36.5	554.0
Relative humidity, %	82.0	81.0	71.0	66.0	66.0	67.0	70.0	66.0	73.0	79.0	84.0	85.0	74.0

Some concern is the temperature and humidity conditions over the past decade (2010-2019), which can be compared with the generalized results of meteorological observations published by the Copernicus Climate Change Service, which confirm the warming trend in Europe (Table 4).

Table 4

Average monthly indicators of temperature, precipitation and relative humidity at the Gaivoron meteorological station for 2010-2019

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
t, ºC	-3.8	-1.8	3.6	11.1	17.1	20.7	22.0	21.6	16.0	8.7	4.6	-0.3	10.0
Precipitation, mm	45.7	31.3	30.7	35.3	57.8	102.0	71.9	29.3	42.2	40.5	35.2	41.3	563.0
Relative humidity, %	81.0	82.0	66.0	63.0	67.0	62.0	69.0	66.0	70.0	77.0	83.0	85.0	73.0

There is a tendency to reduce soil moisture. The simplest reason is that the amount of precipitation remains approximately the same, but the temperature rises, which leads to an increase in evaporation.

Taking into account the average annual temperature indicators, accordingly, the coefficients of humidification of the territory of Haivoron district are determined. Analysis of the results of meteorological observations for 1961-1990, 1990-2019, 2010-2019, taking into account the average temperature, precipitation, relative humidity and evaporation, showed that the territory of Gaivoronshchyna is located within the subhumid zone of degradation and desertification and is characterized respectively, the coefficients of humidity: 1.2, 1.0, 0.9. According to the classification of N.M. Ivanov, Kzv indicates natural areas: semi-deserts – 0.5; dry steppe – 0.5-0.8; steppe – 0.8-1; forest-steppe – 1-1.2; forest area – more than 1.3. Thus, there is a steady downward trend in the values of the moisture content. Despite the abstractness of this indicator and the presence of many factors that affect the actual humidity of the climate, rainfall and average temperature and humidity are the main indicators, and in general the location of natural areas is really consistent with them. Interestingly, the ratio of precipitation and evaporation, which reflects the coefficient of moisture (aridity), affects natural ecosystems more than the absolute amount of precipitation itself.

During the naturalistic observations of local ethnographers during the 80-90s of the twentieth century plants typical of the Ukrainian Steppe were rare in the district. Among them: meadow clover (Trifolium pratense), common bruise (Echium vulgare L.), common beard

(Bothriochloa ischaemum), goose onion (Gagea minima), snake onion (Muscari botryoides), sand cumin (Helichrysum arenarium), common mullein, purple mullein (Verbascum l.) – representatives of these species were found in low-moisture, dry areas, in old abandoned sand quarries, on granite slopes covered with loess-like loams.Today, these plants are distributed throughout Gaivoronsky district.

Among the representatives of the animal world should be noted the spread throughout the spider tarantula (Lycosa) (in the 90s of last century was absent in the area). The green lizard (Lacerta viridis) and the common lizard (Coronella austriaca) were uncommon, occurring only in the valley of the Southern Bug on the granite slopes. Today, both species are found throughout the territory.

On the example of Haivoron district it is possible to assert about shift of borders of natural zones and, considering tendencies of temperature changes, it is expedient to assume transformation of the investigated territory in due course on dry steppe.

The territory of Haivoron district is characterized by manifestations of atmospheric phenomena, ie physical processes that occur in the atmosphere during certain weather conditions and are accompanied by a qualitative change in its state. The cold period is characterized by atmospheric phenomena associated with the development of winter weather processes, including anomalous ones. These include blizzards of various intensities, snowfalls, frosts, fogs, etc. In the warm period of the year, strong heat, dry winds, extreme fire danger, intense rains, thunderstorms, squalls, etc. are recorded.

According to the observations of the local meteorological station, thunderstorms, hail, fog, ice, no rain, the number of days with temperatures above 30 °C, etc. are observed among the adverse atmospheric phenomena in Haivoron district (Table 5).

Table 5

Extreme temperatures and recurrence of adverse weather events at the Gaivoron meteorological station

№	Year	$t^0 \geq 30$ ^{0}C	max. t °C	min. t °C	Thunderstorm, days	Hail, days	Fog, days	Drain. rain, days	Drain. snow / wet snow, days	Rainless days
1	2006	18	33.1	-27.6	28	1	33	47	10/2	8
2	2007	54	39.9	-18.0	30	1		58	5	40
3	2008	26	37.9	-18.7	27		31	68	6/4	11
4	2009	35	35.4	-20.0	32		33	62	7/1	20
5	2010	42	36.3	-27.0	46	1	39	66	/1	11
6	2011	28	33.5	-16.2	29	3	23	68	9/2	20
7	2012	58	33.5	-28.4	38	2	24	90	8/1	35
8	2013	24	33.4	-17.2	38	2	47	75	12	23
9	2014	23	35.2	-23.4	28	4	38	75	4	15
10	2015	47	37.0	-19.8	23	2	22	87	8/3	34
11	2016	39	35.2	-21.8	31	2	19	82	19/4	9
12	2017	40	37.4	-20.3	29	3	21	59	6/1	20
13	2018	31	33.5	-22.4	27	1	34	58	10/3	25
14	2019	47	35.4	-19.2	42	3	29	61	1/2	26

The warming and cooling of the earth's surface of Haivoron district, in addition to weather, is influenced by many other factors: the heterogeneity of the underlying surface, geological structure, physical properties of surface and deep soil layers, the presence and depth of groundwater and more.

Due to the formation of weather processes and climatic conditions, there is a natural change of seasons.

The duration of spring in Gaivoronshchina is 55-60 days. The beginning of the spring period is considered to be the transition of the average daily temperature through 0 °C. This period falls at the end of the 2nd decade and the beginning of the 3rd decade of March. The snow cover falls at the end of the 1st decade of March and at the end of the 3rd decade of the month and the beginning of the 1st decade of April the soil thaws completely and begins to warm up well at the end of the 1st decade of April. The transition of the average daily air temperature through +5 °C begins on April 3-5, and through +10 °C – in the 3rd decade of April (20-22 days). The average

date of the last frost in the air falls on the 2nd decade of April, with the transition of temperature through +10 °C begins intensive plant growth and sowing of heat-loving crops.

The beginning of the summer season is considered to be the transition of the average daily temperature through +15 °C. Summer begins on May 15-17 and ends in the 1st decade of September (8-10). In early summer, warm, and then hot weather (July, August). The average daily air temperature in May-June is +15 °C… + 19 °C, in July-August +19 °C… + 22 °C, the maximum indicators exceed +35 °C (+ 39.9 °C – 21.07.2007; +37.9 °C – 16.08.2008; +38.5 °C – 07.08.2012; +37.4 °C – 05.08.2017).

Precipitation falls mainly in June-July, in June 85 mm, in July – 85 mm, August – 55 mm. Most precipitation fell in June 2019 – 212.5 mm, but it happens that in these months there is little precipitation. In 1968, 17 mm fell in June, and in mid-1975 – 8 mm. In June-July there are days with showers and thunderstorms, which leads to lodging of bread.

The transition from summer to autumn begins when the air temperature is above +10 °C, but below +15 °C. This period begins on September 8-10 and lasts until October 3-5.

a) b)

Fig.1 (a, b). Element in the Gaivoron region (June 2019)

The summer of 2019 turned out to be interesting, marked by extreme temperature contrasts – from the heat, the longest in June, to cool days and almost cold nights, which were observed monthly, but most of them were in July, a significant deficit of precipitation in July-August, long periods rainlessness and at the same time a large number of local, sometimes destructive showers, squalls and hail in June, which led to significant damage (washed roads, felled trees, washed away and damaged crops, etc.) (Fig. 1).

Despite the lack of rain in summer, due to periodic cold spells and active dew, the effects of droughts did not become irreversible – there was no significant deterioration in the condition of crops on production crops. However, there were extremely favorable conditions for the emergence and spread of pests and fungal diseases on crops. And their future harvest largely depended on timely processing. The summer heat had a positive effect on the sugar content of fruits and vegetables. Due to the deficit of precipitation in July-August, the conditions for the formation of moisture for the harvest of winter crops in 2020 were unfavorable.

The transition period is characterized by warm weather with little rainfall. The average decadal air temperature during this period is +9 °C… +14 °C, precipitation is 70 mm. In September-October weather conditions promote sowing and the further vegetation of winter, maturing of thermophilic cultures, for. At the end of October, cloudy, rainy weather is observed with the transition of the 25-27 number of the average daily temperature through +5 °C downwards. Already at the end of October the winter vegetation stops. In November, at the end of the 3rd decade (28-30), there is a transition of the average daily temperature through 0 °C.

The autumn of 2019 was marked by very warm weather, which alternated with short periods of intense cooling. So, along with the heat in early September, at the end of the month there were the first frosts. Rains were requested and in most areas there was not only a significant shortage, but also the longest periods of rainlessness since the beginning of the growing season – up to 70 days. Given the deficit of precipitation in September-October. The actual

severe drought of the last 50 years, which has lasted since the beginning of summer, has affected the rate of sowing of winter crops and the condition of crops before the onset of winter. At the level of the lowest values there was also moistening of a meter layer of soil, which at the end of October was 20-60 mm, with average long-term values of 110-130 mm.

Winter begins in late November and lasts until mid-March. Unstable temperature and unstable snow cover are typical for winter. In winter, there are sharp changes in temperature. Average monthly temperatures are within -6 ºC, but there are years when the average monthly temperature is positive. In 1960, 1964, 1965, 1971, 1976 it was in the range of +1 ºC ... + 3 ºC. The absolute minimum temperature is observed in January (-31.7 °C in 1972). Thaws are often observed after frosts, when the air temperature rises from +3 °C to +12 °C. This temperature leads to the formation of ice crust, which adversely affects the overwintering of winter crops and fruit crops. Snow cover during the winter is unstable, formed in late 1-2 decades of December and can reach a height of 5-10 cm in February – 8 cm. In early March, snow begins to melt and snow cover decreases to 2-3 cm. The depth of soil freezing is 60-90 cm.

The winter of 2019/2020 turned out to be peculiar due to weather conditions, which in the complex led to a decrease in crop yields in 2020 (Fig. 2).

a) b)

Fig. 2 (a, b) Suppressed by lack of moisture crops

Conclusions. Global climate change and the replacement of forest, forest-steppe and mainly steppe landscapes by field ones have led to significant regional changes in climatic conditions within the interzonal geoecotones of Ukraine. Thus, within the interzonal geoecotone «forest-steppe-steppe» of Ukraine, for almost 60 years the annual precipitation trend is mostly negative, and the relative humidity is declining. There is a general tendency to increase the temperature, which can not be offset by an increase in precipitation over time. Accordingly, the moisture content decreases. The territory of the geoecoton is covered by aridization processes. All this leads to the destruction of the unstable dynamic balance of landscapes in the transition zone of forest-steppe and steppe, as evidenced by field landscape research.

Statistical analysis of the results of hydrometeorological observations shows that the territory of Haivoron district is characterized by processes and phenomena similar to the processes and phenomena observed throughout Ukraine: constant uneven precipitation, which is associated with abnormally wet periods with extremely severe droughts, especially in last 15-20 years; the spread of arid phenomena that were not considered the norm for the study area. Thus, the fact of redistribution of average annual rainfall is not in doubt. The steady decrease in precipitation in the winter-spring period cannot be fully compensated by the increase in their amount in the summer-autumn period, which leads to the destruction of the dynamic ratio that once developed in the transition zone of forest-steppe and steppe, which includes Haivoron district. The probable consequences of the increase in temperature and redistribution of precipitation may be the processes characteristic of the entire territory of the geoecoton: shifting the boundaries of the steppe zone to the north and aridization of the territory; further change in the species composition of vegetation; change of landscape structure of the territory, etc. The location of Haivoron district within the interzonal geoecotone «forest-steppe – steppe» of Ukraine and relative to the barometric axis of Voeikov, local landscape features contribute to the formation of climatic conditions characteristic only of this area. Their further research is necessary for a more detailed knowledge of the nature of Haivoron district, rational use of local resources, solving environmental problems and nature protection.

It is advisable to perform a detailed comparative analysis of regional changes in climatic conditions of individual territories, using

the results of observations of meteorological stations located in the Middle Dnieper and in the eastern part of the interzonal geoecotone «forest-steppe-steppe» of Ukraine.

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Анотація

Григорій Денисик, Олексій Ситник, Ірина Кравцова, Леонід Стефанков. РЕГІОНАЛЬНІ ЗМІНИ КЛІМАТУ МІЖЗОНАЛЬНОГО ГЕОЕКОТОНУ УКРАЇНИ «ЛІСОСТЕП-СТЕП»

Важливим у науковому і практичному аспектах є дослідження змін клімату в широкому діапазоні метеорологічних величин, серед яких вивчення сучасного стану і прогнозування тенденцій змін теплового режиму та режиму зволоження приземного шару повітря на майбутнє є досить актуальною проблемою. У зв'язку з цим, звертається увага на просторово-часові особливості змін температури повітря та кількості опадів на території Украйни наприкінці XX-поч. XXI ст. для виявлення тенденції теплозабезпечення території. В дослідженнях переважають загальні питання формування кліматичних умов значних за розмірами територій (України, окремих її регіонів), впливу господарської діяльності людей на клімат та його окремі елементи, зокрема підвищення температури тощо. Значно менше приділено уваги локальним змінам різноманітних кліматичних елементів, особливо своєрідних у природному відношенні регіонів, де антропогенізація натуральних ландшафтів є надзвичайно високою – перехідним екотонам зонального й регіонального рівнів, зокрема міжзональному геоекотону «лісостеп-степ» України, або окремих його частин. Глобальні зміни клімату й заміна лісових, лісостепових і переважно степових ландшафтів польовими, призвели до суттєвих регіональних змін кліматичних умов у межах міжзональних геоекотонів України. Досліджено вплив антропогенного чинника на формування негативних природних процесів і явищ, що призводять до змін температурного режиму території міжзонального геоекотону «лісостеп-степ» України. Проведений аналіз температури за 59-річний період дозволяє зробити висновки про позитивний емпіричний лінійний тренд середньорічних температур на території геоекотону та спрогнозувати динаміку підвищення температур в перехідній смузі лісостепу і степу до кінця XXI ст. Виявлено вплив температурного режиму на інші кліматичні характеристики, зокрема на опади, зменшення кількості яких сприяє розвитку аридизації клімату території міжзонального геоекотону «лісостеп-степ» України. Аналіз був виконаний на основі метеорологічних показників метеорологічних станцій, які розміщені в межах геоекотону і репрезентують вказаний регіон, а також на прилеглій території. Обраховані середньорічні температури і середні температури за окремі проміжки часу (січень-лютий, березень-травень, червень-серпень, вересень-листопад). Визначені лінійні тренди за відповідні періоди. Аналіз отриманих результатів показав, що в межах геоекотонної території прослідковується позитивний емпіричний лінійний тренд середньорічних температур. Підвищення температури складає близько 1 ºС і більше, залежно від виділених періодів. Усе разом призводить до руйнування нестійкої динамічної рівноваги ландшафтів у перехідній смузі лісостепу і степу. Польові ландшафтознавчі дослідження підтверджують, що ці процеси уже розпочались.

Певною особливістю вирізняються кліматичні умови Гайворонського району, як одного із своєрідних у природному відношенні регіонів Кіровоградської області, складової міжзонального геоекотону «лісостеп-степ» України, території давнього освоєння, що зазнала відповідного тривалого антропогенного впливу. Простежується загальна чітка тенденція підвищення температури, що не може компенсуватись збільшенням кількості опадів за окремі періоди і, відповідно, зростанням показників коефіцієнта зволоження, Територія Гайворонщини, згідно кліматичних даних, охоплена процесами аридизації та спустелювання. Можна стверджувати про зміщення меж природних зон і, враховуючи тенденції температурних змін, доцільно припустити перетворення досліджуваної території з часом на сухий степ.

Статистичний аналіз результатів гідрометеорологічних спостережень показує, що для території Гайворонського району характерні процеси і явища, подібні до процесів і явищ, що спостерігаються на всій території України.

Ключові слова: міжзональний геоекотон, лісостеп, степ, кліматичні зміни, аридизація, Гайворонський район Кіровоградської області.

Аннотация:

Г.И. Денисик, А.И. Ситник, И.В. Кравцова, Л.Л. Стефанков. РЕГИОНАЛЬНЫЕ КЛИМАТИЧЕСКИЕ ИЗМЕНЕНИЯ В УСЛОВИЯХ МЕЖЗОНАЛЬНОГО ГЕОЭКОТОНА УКРАИНЫ «ЛЕСОСТЕПЬ-СТЕПЬ»

В статье исследовано влияние антропогенного фактора на формирование негативных физико-географических процесов, которые приводят к изменениям температурного режима территории межзонального геоэкотона «лесостепь-степь» Украины. Анализ температуры за 59-летний период показал положительный эмпирический тред среднегодовых температур на территории геоэкотона и дал возможность сделать прогноз динамики повышения температуры в переходной полосе лесостепи и степи к концу XXI века. Показано

влияние температурного режима на другие климатические характеристики, а именно: количество осадков, умельшение количества каких благоприятствует аридизации климата территории межзонального геоэкотона Украины «лесостепь-степь». Анализ был сделан на основе метеорологических показателей метеорологических станций, которые находятся на территории геоэкотона и представляют данный регион, а также примыкающих территорий. Были рассчитаны среднегодовые температуры и средние температуры за определённые промежутки времени (январь-февраль, март-май, июнь-август, сентябрь-ноябрь). Определены линейные тренды за соответствующие периоды. Анализ полученных результатов показал, что в пределах геоэкотонной территории наблюдается положительный эмпирический линейный тренд среднегодовых температур. Повышение температуры составляет около 1 ºС и выше, в зависимости от определённых периодов.

Ключевые слова: межзональный геоэкотон, лесостепь, степь, климатические изменения, аридизация, Гайворонский район Кировоградской области.

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ОСОБЛИВОСТІ МОРФОЛОГІЇ ҐРУНТІВ БЕЛІГЕРАТИВНИХ СПОРУД КАМ'ЯНЕЦЬ-ПОДІЛЬСЬКОГО ДЕРЖАВНОГО ІСТОРИЧНОГО МУЗЕЮ-ЗАПОВІДНИКА

Проаналізовано ступінь вивченості питання морфології сучасних і похованих ґрунтів белігеративних комплексів. Подано детальні описи морфологічної будови профілів сучасних і похованих ґрунтів белігеративних споруд Старого і Нового замків Кам'янець-Подільського державного історичного музею-заповідника. Висвітлено особливості морфологічних властивостей досліджуваних ґрунтів. Значна увага приділена встановленню діагностичних морфологічних ознак ґрунтів белігеративних комплексів.

Ключові слова: *Морфологічні ознаки, ґрунт, белігеративний комплекс, Старий замок.*

Постановка науково-практичної проблеми. Морфогенетичні властивості ґрунтового профілю є стійкою зовнішньою характеристикою, яка відображає його властивості, походження і розвиток. Власне, вивчення морфологічних ознак ґрунту є найпершим і одним із найдоступніших та найпоширеніших методів дослідження. Зовнішній вигляд ґрунту є відображенням ґрунтотворного процесу [8]. Відтак вивчення зовнішніх ознак ґрунтового профілю безпосередньо в польових умовах дозволяє робити висновки про: речовинний склад, переважання тих чи інших ґрунтотворних процесів та відслідкувати їхній перебіг впродовж історичного розвитку ґрунту.

Результати вивчення морфологічних ознак ґрунтів, похованих під різновіковими ґрунтово-земляними антропогенними насипами – курганами, оборонними валами, городищами, все частіше використовують для встановлення еволюції сучасних ґрунтів і ґрунтового покриву загалом. Як зазначають С.П. Позняк та І.Я. Папіш, поховані ґрунти археологічних пам'яток, на відміну від реліктових ознак у профілі сучасних ґрунтів, надійно ізольовані від діагенетичного впливу сучасних ґрунтотворних процесів. До того ж, вони краще збережені, ніж фосилізовані викопні ґрунти плейстоцену, оскільки не зазнали активної дії педометаморфічних процесів у перигляціальних умовах плейстоцен-голоцену [7]. *Метою дослідження* є вивчення особливостей морфологічної будови ґрунтів белігеративних споруд Старого і Нового замків Кам'янець-Подільського державного історичного музею-заповідника. Для досягнення поставленої мети необхідно вирішити основні *завдання дослідження*: визначити ступінь вивченості морфологічних властивостей сучасних і похованих ґрунтів; провести морфологічні описи ґрунтових розрізів і ґрунтових розчисток ключових ділянок; встановити основні діагностичні морфологічні ознаки ґрунтів белігеративних споруд. *Об'єктом дослідження* є природно-антропогенні й антропогенні ґрунти різних за функціональним призначенням белігеративних споруд Старого і Нового замків Кам'янець-Подільського державного історичного музею-заповідника. *Предметом дослідження* є морфологічні властивості та діагностичні ознаки ґрунтів досліджуваної території.

У процесі досліджень морфологічних особливостей ґрунтів белігеративних споруд на території Старого і Нового замків Кам'янця-Подільського державного історичного музею-заповідника нами використано такі наукові методи: морфологічний, картографічний, джерелознавчий, проблемно-хронологічний, порівняльно-географічний, археологічний.

Актуальність і новизна дослідження. Морфологічні властивості ґрунтів беліге-