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PECULIARITIES OF CHANGES IN MOISTURE CONDITIONS ON THE TERRITORY OF UKRAINE

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Ukraine is one of the richest countries in fertile soils, and the combination of a fairly favourable temperate climate makes it an agricultural region of Eastern Europe. Large-scale circulating processes often move to its territory, which leads to the formation of periods with low rainfall and high air temperature, which causes the arid phenomena such as droughts, dry winds and ect.

Much attention is paid to the study of the occurrence and forecasting of the arid phenomena, as, according to the UNO estimation, the damage caused by these phenomena is 20% of the total damage caused by the natural disasters.

Considering the fact that drought is a complex phenomenon that occurs due to the changes in temperature rate, lack of moisture in the atmosphere and soil, lack of precipitation, and significant evaporation from the surface, it is difficult to express it through any meteorological parameter. In addition to simple estimates, such as determining the rate of precipitation and their anomalies, complex numerical and drought indicators and indices, which can detect the presence of the arid phenomena and estimate their intensity, are used.

The aim of the study is to analyze the moisture conditions on the territory of Ukraine, to determine the peculiarities of its spatial distribution under the influence of modern regional climate changes.

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***Keywords*:** temperature rate, moistening of the territory, atmospheric precipitations, climatic norm, regional climate changes, drought, hydrothermal coefficient, drought index, anticyclone.

Introduction. Significant natural hazards such as floods, droughts etc. occur worldwide [1, 2]. The drought has its own peculiarity, because it usually develops slowly, without obvious manifestations and can have great economic and socio-environmental consequences. Arid conditions have a significant impact on agro-industrial production, water resources, and water supply. Worldwide the drought, when spreading to 7.5% of the world's land area of the Earth, is the geographically

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greatest threat after the flood (11%). It has been found out that the share of the area suffered from the severe drought has doubled from the 1970s to the early 2000s.

A number of works are devoted to the conditions of the arid phenomena formation [2–6]. The formation of the arid phenomena on the territory of Europe is due to the movement of air masses and cyclonic activity [7–11]. The forecasting estimations indicate that the droughts are now becoming a climatic peculiarity in a large part of Europe, the Mediterranean, Western, Central and Eastern Europe [5]. The conducted studies indicate an increase in the frequency and duration of this atmospheric phenomenon over a sixty-year period. The peculiarities of regional climatic conditions of drought and dry winds formation on the territory of the steppe zone of Ukraine are highlighted in [3]; it is noted that on the territory of Ukraine the seasonal droughts of varying intensity and duration occur almost annually.

The studies by Spinoni J., Naumann G. and Vogt J. [5] indicate the complex character of this phenomenon; they note its various hydrometeorological aspects and the variety of possible definitions and effects. The main attention is paid to the meteorological drought, where the moistening and temperature rates are determined with the help of various indicators (PET, SPI, SPEI). The study was mainly conducted on the seasonal droughts for the period of 1950–2015. The tendencies of frequency and extreme droughts for the periods of 1981–2015 were identified.

There are different approaches to determining the arid conditions, so the standardized precipitation index (SPEI) is used in various climatological and hydrological studies [12], where the real-time drought monitoring is possible.

Depending on the conditions of the drought formation, it can be distinguished as atmospheric, soil and atmospheric and soil ones. The atmospheric drought most often occurs against the background of a long period of dry weather with low humidity and high air temperatures. Under a significant duration the atmospheric drought can lead to the soil drought, where there is a loss of moisture in the surface layer of the soil. The occurrence of soil drought can often be due to the fact that the water reserves in the upper meter layer of the soil are insufficient, as during the warm period of the year there are significant evaporation and transpiration from the soil surface. The combination of manifestations of atmospheric and soil droughts in some cases is distinguished as general (atmospheric and soil), which is quite dangerous, because it covers the large areas and lasts for a long time.

The droughts can be considered as a manifestation of climate variability, where they are distinguished as the meteorological, hydrological, agricultural, and socio-economic droughts, when the intensity and scale of the precipitation shortage have a detrimental effect on economic growth of the country, and leads to the significant social consequences [2, 13, 14].

The impact of climate changes on various sectors of agriculture is given in the works [15–18], which focus on the adaptation of agricultural crops and the profitability of their cultivation. Most often the arid conditions are considered as an agrometeorological phenomenon that causes a sharp discrepancy between the normal need of plants for moisture and its obtaining from the soil. The consequence of this discrepancy is a shortage in the crop yield capacity.

Thus, the drought is a complex atmospheric phenomenon caused by a prolonged and significant lack of precipitation with high air temperature.

Modern changes in climatic conditions form new requirements for the world and domestic economy.

Materials and Methods. The initial data are a number of climatological observations within the State Framework of the Ukrainian Hydrometeorological Center and its regional department – Kharkiv Regional Center for Hydrometeorology, namely: the data of air temperature, and precipitation for the period of 1961–1990, and 2005–2020. The basis of the study is the spatial and temporal analysis of climatic indicators on the territory of Ukraine when using the statistical and mathematical as well as the cartographic methods.

Results and Discussion. To characterize the arid conditions of any area, various developed indicators are used: the coefficients and indices considering the temperature rate and moistening conditions for the studied period of time. Some meteorological quantities such as the evaporation, amount of precipitation, air temperature, and radiation balance cannot explain the complex character of this phenomenon. Among the dry weather indices considering more than one parameter of the environment, first of all, it should be noted the indicators that represent a combination of air temperature and amount of precipitation for a certain period of time. These indices can be effectively compared for relatively homogeneous regions, characterized by a high consistency of the ratio between the air temperature and precipitation during the summer season.

Along with the statistical indicators of dry weather, the indices, which can be called physical and geographical, have been widely used, because they are based on the known physical laws. The use of such indicators and the ways of their relationship are associated with the processing of empirical data that have a certain spatial and temporal regular character. As a result, different indices cannot be considered universal, as they have their own advantages and disadvantages.

The most common aridity index based on the precipitation data was the Standardized Precipitation Index (SPI), developed by McKee T.B., Doesken N.J. and Kleist J. [18]. The precipitation data for a continuous period of at least 30 years are collected. The set of periods to make the average is calculated for the time scales; they are usually 1, 3, 6, 12, 24 or 48 months and are selected depending on the task. These are randomly selected periods, but they are typical for the formation of the precipitation shortage and its impact on moisture content in the soil. Once such a relationship is established, the calculation of the probability of any precipitation recorded at the point begins. It is used together with the estimation of the inverse normal distribution, calculated as the deviation of precipitation from the density of the normal distribution with a mean zero value of the standard mean-square deviation by formula:

$$\mathrm{SPI} = F^{-1}G(R), \qquad (1)$$

where G is an integral gamma distribution function; R is a precipitation rate; F^{-1} is an inverse rate fixed Gaussian distribution.

If the SPI value is positive, then it indicates more than the average amount of precipitation; if it is negative, then vice versa, the amount of precipitation is less than the average. If a time pace of one month is used, i.e. the SPI1, then the precipitation data for only one month are taken for the calculation. This is useful for detecting the atmospheric droughts due to their similarity with the distribution of the monthly

precipitation amounts. Respectively, the SPI3 uses the precipitation data for the three-month period (the current and two previous ones). It shows the seasonal precipitation estimate and short- and medium-term moistening conditions, which is useful for detecting the agro-climatic droughts. Such time scale as the SPI12 (or more) is used to determine the moistening conditions and total amount of precipitation during the year. It is useful for detecting the long arid and wet periods, which is typical for the hydrological drought.

Variation in the scale of average making makes it possible to use this index to observe both the agricultural and hydrological effects of droughts associated with the objects having different perceptibility to the shortage of precipitation.

The Palmer Drought Severity Index (PDSI) [19], is the most widely used in world practice for the analysis of the arid conditions at prolonged intervals of short duration, which determined the meteorological conditions corresponding to abnormally arid or abnormally wet periods during the long-time intervals. When calculating the PDSI index, the equation of water balance is used, which includes the data on air temperature, the precipitation amount and constant parameters that characterize the moisture content in the soil. This indicator was in good coordination with the hydrological and hydrometeorological indicators all around the globe.

To estimate the atmospheric droughts for the period of many-years on large territories there exists a hydrothermal coefficient (HTC), which was developed by H.T. Selyaninov [20] and became the most widely used in domestic agrometeorology. It characterizes the evaporation and is calculated by the formula:

$$\mathrm{HTC} = \frac{\sum R}{0.1 \sum T}, \qquad (2)$$

where $\sum R$ is the amount of precipitation per month, *mm*; $\sum T$ is the sum of air temperature for the period with the average daily temperatures above +10°C.

The HTC can characterize not only the conditions of moistening, but also the productive consumption of moisture, which is associated with evaporation from the soil surface. The main disadvantages of the HTC index include disregarding the spring soil moisture reserves, which can differ significantly having the same value of the HTC during the growing season and is a good indicator of moistening in the regions where there is a uniform amount of precipitation. According to the HTC values, the following types of the atmospheric droughts intensity are distinguished in the agro-climatic zones of Ukraine: 1) 0.7–1.0 – moderate drought; 2) 0.5–0.7 – severe drought; 3) 0.3–0.5 – very severe drought.

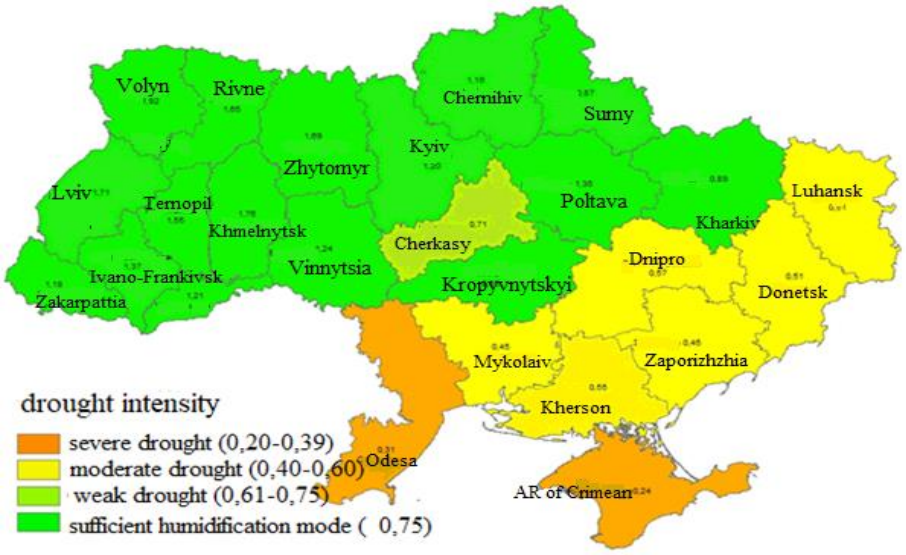
The HTC was calculated according to the data about the air temperature and amount of precipitation during the growing season with the average daily temperatures above 10°C for the period of 2005–2017 (Tab. 1). The spatial analysis of the peculiarities of the arid phenomena spreading on the territory of Ukraine was carried out using the cartographic method (Fig. 1).

It was found out that the arid conditions on the territory were present in the South, and South-East of the country. The severe drought in 2005 was observed in the Autonomous Republic of Crimea, the moderate drought was recorded within Odesa, Kherson and Zaporizhzhia Regions, and the light one was present in the Eastern regions of the country (Kharkiv, Donetsk, Sumy, and Dnipropetrovsk). The rest of the country had the sufficient moistening conditions.

Table 1

Hydrothermal coefficient (HTC), 2005

Region of Ukraine	Temperature ($\sum T$), °C	Precipitation ($\sum R$), *mm*	HTC
AR of Crimea	3312.3	67	0.20
Vinnytsia	2537.8	238	0.94
Volyn	2505.9	281	1.12
Dnipropetrovsk	2971.9	191	0.64
Donetsk	2909.2	186	0.64
Zhytomyr	2605.2	258	0.99
Zakarpattia	2762.1	477	1.73
Zaporizhzhia	3059.9	130	0.42
Ivano-Frankivsk	2481.8	339	1.37
Kropyvnytskyi	2784.1	282	1.01
Luhansk	2933.2	239	0.81
Lviv	2411.45	371	1.54
Mykolaiv	3042.4	243	0.80
Odesa	3052,0	173	0.57
Poltava	2804.6	214	0.76
Rivne	2470.2	340	1.38
Sumy	2687.8	185	0.69
Ternopil	2429.6	259	1.07
Kharkiv	2745.4	195	0.71
Khmelnytsk	2481.7	730	2.94
Cherkasy	2720.8	238	0.87
Chernivtsi	2601.1	263	1.01
Chernihiv	2625.1	505	1.92
Kherson	3028.6	172	0.57
Kyiv	2758.6	297	1.08



Moistening rate, 2007 (scale 1 : 5 000 000).

According to the results of studies in 2006, 2008, 2010, on the territory of the country the arid phenomena were lightly expressed: the drought of average intensity was observed in Kherson Region, and the light ones were in Donetsk and Luhansk Regions. In general, the moistening conditions were favourable throughout the territory of Ukraine.

In 2007 and 2009 the arid conditions were observed on the territory; they covered the entire southern and South-Eastern part of the country. The severe drought was recorded in Odesa Region and in the AR of Crimea, and the moderate drought was observed in the South-Eastern part away from Mykolaiv, Donetsk and Luhansk Regions. There was also a light drought in Cherkasy Region.

The severe drought was observed in the AR of Crimea in 2011 and 2012, the drought of moderate intensity was typical for the South-Western Region of the country, and the light one was recorded in Kharkiv, Vinnytsia and Odesa Regions.

In the South and South-East of the country the arid phenomena of moderate intensity were observed during the growing season of 2013 and 2014.

The calculations of the HTC on the territory of Ukraine during the growing season of 2015 and 2017 indicate the existence of the severe arid conditions of varying intensity on the territory of the country from the southern regions to the central ones.

Table 2

Hydrothermal coefficient (HTC)

Region of Ukraine	HTC, 1961–1990	HTC, 2005–2020
AR of Crimea	0.78	0.45
Vinnytsia	1.44	1.06
Volyn	1.32	1.63
Dnipropetrovsk	0.82	0.74
Donetsk	0.88	0.69
Zhytomyr	1.47	1.15
Zakarpattia	1.36	1.24
Zaporizhzhia	0.77	0.72
Ivano-Frankivsk	1.75	1.56
Kropyvnytskyi	1.00	0.86
Luhansk	0.80	0.67
Lviv	1.76	1.64
Mykolaiv	0.79	0.66
Odesa	0.69	0.67
Poltava	1.01	0.95
Rivne	1.38	1.34
Sumy	1.20	1.07
Ternopil	1.52	1.31
Kharkiv	0.95	0.83
Khmelnytsk	1.63	1.73
Cherkasy	1.00	0.97
Chernivtsi	1.57	1.18
Chernihiv	1.47	1.47
Kherson	0.73	0.59
Kyiv	0.78	0.45

It is established that the arid conditions of different intensity, which covered large areas, became frequent on the territory of Ukraine. The most severe droughts were observed in 2007, 2009, 2015, 2017, 2019 and 2020 against the background of the precipitation shortage during the summer and autumn period and under the high air temperatures.

Comparing the moistening conditions of the modern period with the standard climatic rate (1961–1990) makes it possible to establish the changes in the climatic conditions of the territory with further development of measures to adapt agriculture to the new production conditions.

The hydrothermal conditions for two periods: I – 1961–1990; II – 2005–2020 were analyzed (Tab. 2). In most areas the HTC indicator has decreased, which indicates a tendency to increase the intensity of the droughts and their duration.

It is established that the climatic conditions on the territory of Ukraine are characterized by the growth of arid phenomena of various types, which strongly affect both agricultural activity and the natural state of the territory as a whole.

Conclusion. The results of the study indicate the relevance of the identified factors that affect the changes in the agrometeorological resources of the territory. It is established that the arid conditions mainly occur due to the peculiarities of the regional circulation of the atmosphere. The severe droughts on the territory of Ukraine occur during the development of the anticyclonic process. During the period of 2005–2020, the droughts occurred in most parts of the country. According to the spreading of the arid conditions, three areas can be identified: the first one covers the Northern regions, where the drought almost does not occur; the second region is the Central one, which is characterized by the droughts of light and moderate intensity; and the third region is the South, where the severe droughts are observed. In 2007, 2009, 2015, 2017, 2019, and 2020, according to the weather conditions in the South and South–East, the severe droughts were widespread and they covered a larger area of the country.

The comprehensive studies of the moistening conditions will further optimize the agro-technical measures to reduce the effect of droughts on the crop yield capacity and develop the measures to adapt to modern climate changes.

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ՈՒԿՐԱԻՆԱՅԻ ՏԱՐԱԾՔՈՒՄ ԽՈՆԱՎԱՑՄԱՆ ՊԱՅՄԱՆՆԵՐԻ ՓՈՓՈԽՈՒԹՅՈՒՆՆԵՐԻ ԱՌԱՆՁՆԱՀԱՏԿՈՒԹՅՈՒՆՆԵՐԸ

Ամփոփում

Ուկրաինան բերրի հողերով ամենահարուստ երկրներից մեկն է, իսկ բավական բարենպաստ բարեխառն կլիմայի համադրումը այն դարձնում է Արևելյան Եվրոպայի կարևոր գյուղատնտեսական շրջան: Մթնոլորտային շրջանառության լայնամասշտաբ պրոցեսները հաճախ տեղափոխվում են նրա տարածք, ինչը հանգեցնում է տեղումների ցածր քանակով և օդի բարձր ջերմաստիճանով ժամանակաշրջանների ձևավորմանը: Վերջինս առաջացնում է չորային երևույթներ, ինչպիսիք են երաշտը, չոր եղանակը և խորշակը (չոր քամիները):

Մեծ ուշադրություն է դարձվում չորային երևույթների առաջացման և կանխատեսման ուսումնասիրությանը, քանի որ, ՄԱԿ-ի գնահատմամբ, այդ երևույթների հասցրած վնասը կազմում է բնական աղետների ընդհանուր վնասի 20%-ը:

Հաշվի առնելով այն հանգամանքը, որ երաշտը բարդ երևույթ է, որն առաջանում է ջերմաստիճանի արժեքների փոփոխության, մթնոլորտի և հողի խոնավության բացակայության, տեղումների բացակայության և մակերևույթից զգալի գոլորշիացման պատճառով, դժվար է այն արտահայտել օդերևութաբանական որևէ պարամետրով: Բացի պարզ գնահատականներից, ինչպիսիք են տեղումների արագության և դրանց անոմալիաների որոշումը, օգտագործվում են բարդ թվային և երաշտի ցուցիչներ ու գործակիցներ, որոնք կարող են հայտնաբերել չորային երևույթների առկայությունը և գնահատել դրանց ինտենսիվությունը:

Ուսումնասիրության նպատակն է վերլուծել Ուկրաինայի տարածքում խոնավության պայմանները, որոշել դրանց տարածական տեղաբաշխման առանձնահատկությունները՝ ժամանակակից տարածաշրջանային կլիմայական փոփոխությունների ազդեցության տակ:

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ОСОБЕННОСТИ ИЗМЕНЕНИЯ УСЛОВИЙ ВЛАЖНОСТИ НА ТЕРРИТОРИИ УКРАИНЫ

Резюме

Украина – одна из самых богатых плодородными почвами стран, а сочетание довольно благоприятного умеренного климата делает ее сельскохозяйственным районом Восточной Европы. На ее территорию часто перемещаются масштабные циркуляционные процессы, что приводит к формированию периодов с малым количеством осадков и высокой температурой воздуха, что вызывает такие явления, как засухи, суховеи и др.

Большое внимание уделяется изучению возникновения и прогнозированию засушливых явлений, так как, по оценке ООН, ущерб, причиняемый этими явлениями, составляет 20% от общего ущерба от стихийных бедствий.

Так как засуха представляет собой сложное явление, возникающее из-за изменения температурного режима, недостатка влаги в атмосфере и почве, недостатка осадков и значительного испарения с поверхности, ее трудно выразить через какой-либо метеорологический показатель. Помимо простых оценок, таких как определение нормы осадков и их аномалий, используются комплексные числовые индикаторы и индексы засухи, позволяющие выявить наличие засушливых явлений и оценить их интенсивность.

Цель исследования – проанализировать условия влажности на территории Украины, определить особенности ее пространственного распределения под влиянием современных региональных климатических изменений.