ТЕРМИЧНИ РЕСУРСИ НА УКРАЙНА В УСЛОВИЯТА НА КЛИМАТИЧНИ ПРОМЕНИ
ТЕРМИЧЕСКИЕ РЕСУРСЫ УКРАИНЫ В УСЛОВИЯХ ИЗМЕНЕНИЯ КЛИМАТА
THERMAL RESOURCES OF UKRAINE IN THE CONDITIONS OF CLIMATE CHANGE

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Резюме

Рассматриваются в сравнении показатели термического режима за период 1986–2005 гг. и ожидаемые их изменения, рассчитанные по трем сценариям изменения климата GFDL-30 %, A1B, A2 на период 2011–2050 гг. по территории Украины. Отмечаются ожидаемые более ранние даты перехода температуры воздуха через различные пределы весной и более позднее их наступление осенью, общее повышение средней температуры, сумм температур и изменение амплитуды температур.

Ключевые слова: изменение климата, глобальное потепление, термические ресурсы, сумма температур, амплитуда температуры.

Abstract

This article offers comparative analysis of the thermal regime figures from 1986 to 2005, and outlines expectations for their change, calculated for the territory of Ukraine, 2011-2050, in accordance with three scenarios of climate change: GFDL-30%, A1B, and A2. Among these expectations are earlier dates for air temperatures transitioning between ranges in the spring, as well as later dates in the fall, general increase in mean air temperatures, growth in temperature sums, and changes in temperature amplitudes.

Key words*:* climate change, global warming, thermal resources, sum of air temperature, temperature amplitude.

INTRODUCTION

The climate change as a result of global warming is one of the problems of the twenty-first century. It is characterized by a variety of features, most prominent of which are the changes in frequency and intensity of climate anomalies and extreme (dangerous) weather phenomena. According to the prognoses of prominent scientists and specialists, in the next decade climate changes will, in their scale and intensity, go far beyond the warnings of the previous decade.

Increasing surface air temperature in the Northern Hemisphere has caused acute periodical changes in agriculturalproductivity, specifically affecting the production of foodstuffs. As a result, the world is now faceding the problem of providing food to the population of our planet. Solving the problem of food supply is the most important strategic task of the new century; it is not only the main condition for the continuing existence of our planet's population, but also the decisive factor of social stability both for individual countries and for the global community as a whole.

In the conditions of climate change, and specifically of rising temperatures, increasing the effectiveness of agriculture in Ukraine depends on the using of scientific evidence to select precise locations of sowingof agricultural crops and adapt these crops to the changes. These measures will allow for a more effective use of natural resources in the new climate conditions, a steady increase of quantity and quality of crops, and an improvement of yield of agricultural crops, energy, and labour resources.

MATERIALS AND METHODS

In order to evaluate possible climate changes, we used three alternative scenarios. First, GFDL-30% is the "soft" scenario, which assesses the anticipated increase in CO2 emissions into the atmosphere at 30% (Israhel and Antokhin, 2001; Krakovs'ka et al., 2008; Christensen et al., 2007; Jacob et al., 2001).

Second, A1B is the "moderate" scenario, which anticipates a balance between all energy sources. Finally, A2 is the "harsh" scenario, which anticipates an ambiguity in the indirectly determining factors and is based on using a variety of modelling concepts, which use comparable assumptions about the indirectly determining factors.

One of the simplest methods of mapping possible changes in climate regimes of any meteorological value is through comparing it with the past data – in particular, with the long-term means collected over a base period. In this study, the base period is defined as the period from 1986 to 2005, in accordance with the agro climatic reference guide for the territory of Ukraine (Adamenko et al., 2011, an agroclimatic reference book is for territories of Ukraine 2011).

In examining climate changes, global temperature and precipitation trends are usually used as criteria for these changes (Polevoy, 1983; Stepanenko and Polevoy, 2011; Tarko, 2005 et al.).

We have analyzed the potential effects of climate change on the thermal resources of Ukraine by comparing the values calculated in accordance with the climate scenarios *GFDL*-30%, *A1B,* and *A2,* to the long-term means for three periods: 1986-2005 – base period, 2011-2030 – first period, and 2031-2050 – second period.

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To assess thermal resources, we have calculated:

– the dates with air temperatures over the mark of 0, 5, or 10°C in the spring and autumn;

– the duration of the period with air temperatures above 0, 5, and 10°C;

– the sums of positive air temperatures during the period with temperatures staying above 0°C, 5°C, and 10°C;

– mean air temperatures for January and July;

– Temperature amplitudes.

RESULTS AND DISCUSSION

Thermal resources of Ukraine's climate zones, calculated under different scenarios of climate change are presented on Calculations were made for individual climate zones of Ukraine Table 1.

The analysis showed that if any of the climate changes scenarios take place, an increase in thermal resources on the territory of Ukraine should be expected. This increase will not be homogenous, both due to the differences in scenarios and do to the variation in climate zones.

The increase of thermal resources from 2011-2030 is expected to be relatively fast. While the increase of thermal resources will continue during the subsequent period, the pace of this increase will be slower. In addition, the increase of thermal resources will be different in different climate zones of Ukraine and under different scenarios.

The greatest deviation of all values of thermal regime will be observed in all climate zones of Ukraine under the conditions of the scenario GFDL-30%. Under this scenario, the dates of air temperatures passing the mark of 0, 5, or 10°C in the spring and autumn will shift, for both periods under calculation, to a month earlier in the spring and two months later in the fall, in comparison to the long-term means. During the second period under calculation (i.e. 2031-2050), temperatures are not expected to fall below zero throughout the year in Polesye and the Forest Steppe zone. In the Steppe zone, temperatures are not expected to fall below zero during the year throughout both periods under investigation.

The duration of periods with temperatures above 0, 5, and 10°C for all climate zones under scenario GFDL-30% will increase, in comparison to the long-term means, by 50 to 60 days and will, accordingly, amount to 260 and 220 days out of 365 (Table 1).

The change in duration of periods with different temperature levels will result in a difference of sums of temperatures.

So, under the scenario GFDL-30 %, the sum of temperatures above 0°C in Polesye and the Forest Steppe zone will constitute 4500–4770°C, in Northern Steppe – 5100°C, and in Southern Steppe – 5700°C.

Under the scenarios A1B and A2, thermal resources throughout the territory of Ukraine will also increase, although the pace of this increase will be significantly slower.

Table 1. Thermal resources of Ukraine's climate zones, calculated under different scenarios of climate change

Period, in years	Dates of air temperatures passing the mark of 0,5°C				Duration of the period (in days) with temperatures higher than		Sums of temperatures (°C) higher than	
	Spring		Autumn		0°C	5°C	0°C	5°C
	0°C	5°C	5°C	0°C				
Polesye								
1986–2005	26.02.	06.04.	26.11.	29.10.	272	206	3077	2861
Scenario *GFDL – 30 %*								
2011–2030	25.02.	04.03.	03.11.	03.02.	343	254	4453	4170
2031–2050	-	02.03.	20.11.	-	365	263	4611	4238
Scenario *A1B*								
2011–2030	12.02.	28.03.	11.11.	04.12.	296	229	3356	3235
2031–2050	26.02.	24.03.	08.11.	07.12.	284	218	3555	3415
Scenario *A2*								
2011–2030	21.02.	23.03.	04.12.	01.11.	282	218	3230	3057
2031–2050	23.01.	20.03.	10.11.	04.12.	310	236	3356	3172
Forest Steppe								
1986–2005	03.03.	31.03.	27.10.	21.11.	265	212	3227	3136
Scenario *GFDL* - 30 %								
2011–2030	23.02.	03.03.	16.11.	04.02.	346	257	4655	4379
2031–2050	-	01.02.	25.11.	-	365	270	4772	4456
Scenario *A1B*								
2011–2030	06.03.	08.04.	19.11.	06.12.	284	225	3450	3351
2031–2050	06.03.	28.03.	06.11.	08.12.	286	243	3528	3393
Scenario *A2*								
2011–2030	28.02.	25.03.	04.11.	27.11.	272	225	3223	3151
2031–2050	14.02.	26.03.	26.10.	08.12.	297	215	3227	3016
Northern Steppe								
1986–2005	06.03.	01.04.	30.10.	21.11.	262	213	3409	3356
Scenario *GFDL* - 30 %								
2011–2030	-	27.02.	-	25.11.	365	272	5116	4720
2031–2050	-	10.02.	-	08.12.	365	242	4831	4476
Scenario *A1B*								
2011–2030	27.02.	23.03.	13.11.	01.12.	278	235	3450	3354
2031–2050	17.02.	18.03.	18.11.	01.01.	317	245	4048	3895
Scenario *A2*								
2011–2030	21.02.	20.03.	02.11.	01.12.	284	226	3541	3366
2031–2050	23.01.	14.03.	07.11.	01.01.	343	240	3642	3479
Southern Steppe								
1986–2005	19.02.	21.03.	11.11.	03.12.	287	236	3819	3690
Scenario *GFDL* - 30 %								
2011–2030	-	15.02.	15.12.	-	365	304	5788	5619
2031–2050	-	10.02.	13.12.	-	365	308	5602	5304
Scenario *A1B*								
2011–2030	08.02.	20.02.	06.12.	11.12.	307	258	4971	4812
2031–2050	-	12.02.	15.12.	-	365	280	5344	5123
Scenario *A2*								
2011–2030	14.02.	20.03.	02.11.	09.12.	300	223	4401	3366
2031–2050	-	04.03.	07.11.	-	365	259	4693	3870

So, in Polesye and in the Forest Steppe zone, in comparison with mean long-term values thermal resources will increase by 200°C during the first period of calculation, and by 300°C during the second period. In the Northern Steppe, during the period from 2011 to 2030, the sum of temperatures above 0°C will be close to the long-term values, while during the period from 2031 to 2050, it will increase more than by 600°C under the scenario A1B and by 200°C under the scenario A2. A critical increase in thermal regime is expected for the Southern Steppe, where the sums of temperatures under both scenarios will increase, during the first period under investigation, almost by 1000°C, and during the second period by 1500°C under the scenario A1B and almost by 800°C under the scenario A2.

Where agricultural production is concerned, it is important to note the thermal values after the air temperature passes the marks of 5 and 10°C. As table 1 show, under the scenario GFDL-30%, the increase in sums of temperatures above 5°C will be most intensive in the period before 2030. In Polesye and the Forest Steppe zone, the sums of temperatures above 5°C will increase by 1200–1300°C, in the Northern Steppe – by 1400–1500°C, and in the Southern Steppe by 1900°C, becoming, respectively, 4100, 4300, 4700, and 5600°C. In the period between 2031 and 2050, the pace at which sums of temperatures are expected to increase will grow significantly slower and become, in Polesye, the Forest Steppe zone, and the Northern Steppe, only 100°C higher than during the first period under calculation. In the zone of Southern Steppe, during the second period under calculation, the sum of temperatures will decrease, in comparison with the first period under calculation, by 300°C and will constitute approximately 5600°C.

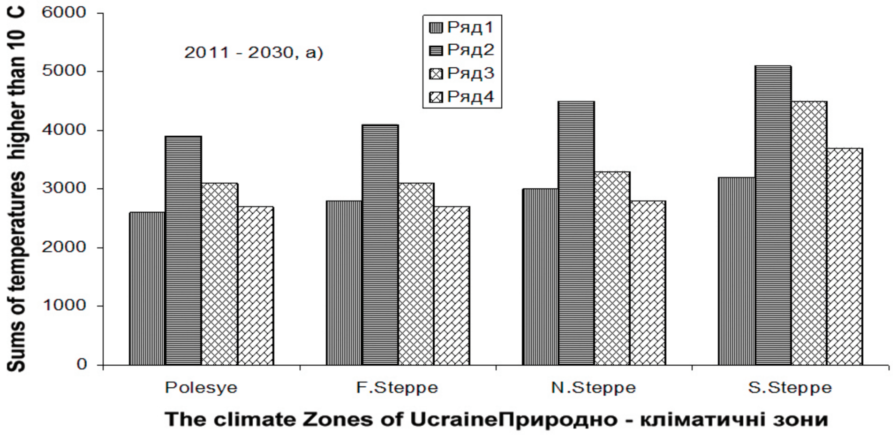
Under the scenarios A1B and A2 the sums of temperatures above 5°C will increase by 400–500°C during both periods under calculation, in comparison with the mean long-term values in Polesye and the Forest Steppe zone. It is necessary to note that especially abrupt changes in temperature regime are expected in the Southern Steppe. During the period between 2011 and 2030, the sums of temperatures above 5°C in this area will increase by 1100°C under the scenario A1B, and almost by 1500°C under the scenario A2. In the Northern Steppe under both scenarios, and in the Southern Steppe under the scenario A2, the sums of temperatures will be close to the mean long-term values.

The patterns of sums of temperatures above 10°C will differ both during different periods under calculation and in different climate zones (figure 1).

During the period from 2011 to 2030, a significant increase of sums of temperatures is expected under the scenario GFDL-30% in all climate zones, except for the Forest Steppe zone (table 1, figure 1). In Polesye, the expected sums of temperatures above 10°C will increase to 3770°C, which is higher than the mean long-term sum of the base period by almost 1200°C; in the Northern Steppe these sums will reach 4300°C, which is higher than the mean long-term values by 1300°C. In the Southern Steppe, the sum increases to 4900°C, meaning that it exceeds the long-term mean by 1600°C. In the Forest Steppe zone, the expected sums of temperatures will be almost equal to the mean long-term values, as demonstrated by the calculations under all three scenarios.

Significantly lower sums of temperatures above 10°C will be observed during both periods under calculation, under the scenarios A1B and A2. So, calculations under the scenario A1B show that in Polesye the sums of temperatures will be higher than the long-term means by 300°C in the first period under calculation, and by 500°C during the second. Under the scenario A2 throughout the period from 2011 to 2030, the sum of temperatures above 10°C will be almost identical to the mean sum of the base period, and will reach 3150°C. During the period from 2031 to 2050, this sum will fall somewhat below the mean long-term values. In the Northern Steppe, under the scenarios A1B and A2, the sums of temperatures above 10°C during both periods under calculation will be approximately identical to the mean long-term sums of temperatures.

In the Southern Steppe, under the scenario A1B, during the first and second periods, the sums of temperatures above 10°C will reach 4300–4400°C, which is more than 1000°C higher than the sum during the standard period. Under the scenario A2, the increase of the sums of temperatures will be more gradual and, during the period before 2030, will be higher than the mean long-term sum by almost more than 300°C, and during the period between 2031 and 2050 by 500°C.



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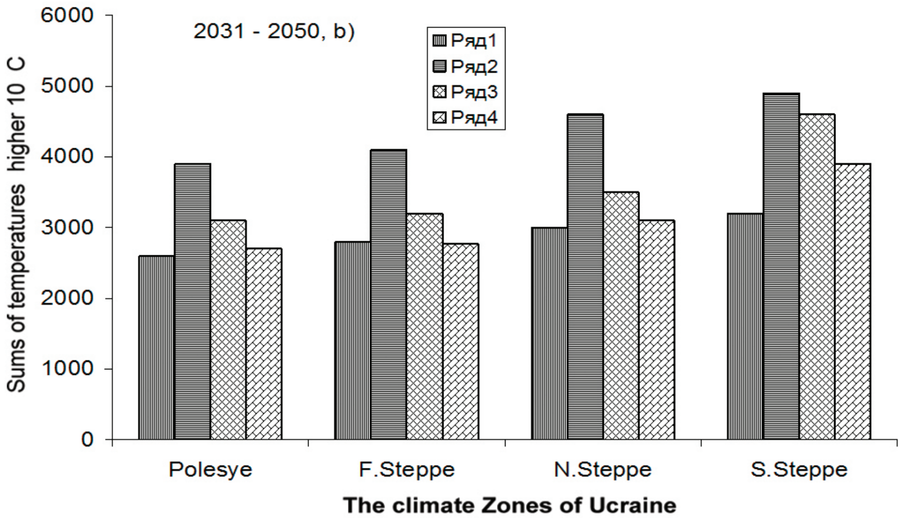

B

Fig. 1. *Comparative description of the sums of temperatures during the period with temperatures above 10°C throughout the climate zones of Ukraine:*
A) period from 2011 to 2030; B) period from 2031 to 2050
1 (column 1) – long-term mean from 1986 to 2005; 2 (column 2) – scenario GFDL-30%;
3 (column 3) – scenario A1B; 4 (column 4) – scenario A2.

As demonstrated by table 2 and figure 1, the greatest divergences in the sums of temperatures under the influence of climate changes are seen in the Southern Steppe zone during the period with temperatures above 10°C, under the calculations according to all scenarios.

Figure 2 shows the distribution of sums of temperatures during the period with air temperatures above 10°C under the scenario A1B. The vertical axis represents the divergences of sums of temperatures, under the scenario A1B from the mean long-term sums of the standard period.

Table 2. Distribution of sums of temperatures above 10°C on the territory of Ukraine, calculated under the scenario *A1B* for the period before 2050 year

Period, in years	Dates of air temperatures passing the mark of 0, 5°C				Duration of the period (in days) with temperatures higher than		Sums of temperatures (°C) higher than	
	Spring		Autumn		10°C	15°C	10°C	15°C
	10°C	15°C	15°C	10°C				
Polesye								
1986–2005	22.04.	21.05.	06.09.	01.10	162	107	2582	1902
Scenario *GFDL* - 30%								
2011–2030	25.03.	25.04.	05.10.	26.10	217	163	3766	3174
2031–2050	22.03.	24.04.	08.10.	23.10	215	167	3880	3190
Scenario *A1B*								
2011–2030	18.04.	18.05.	17.09.	13.10.	181	119	2820	2389
2031–2050	13.04.	22.05.	20.09.	20.10.	190	121	3126	2250
Scenario *A2*								
2011–2030	18.04.	24.05.	05.09.	10.10.	172	119	2715	2045
2031–2050	19.04.	26.05.	08.09.	09.10.	174	102	2715	1781
Forest Steppe								
1986–2005	19.04.	07.05.	09.09.	03.10.	168	115	2817	2113
Scenario *GFDL* - 30%								
2011–2030	23.03.	25.04.	07.10.	25.10.	215	164	3936	3102
2031–2050	21.03.	23.04.	09.10.	27.10.	220	170	4073	3432
Scenario *A1B*								
2011–2030	28.04.	25.05.	28.09.	20.10.	175	126	2987	2389
2031–2050	14.04.	21.05.	20.09.	18.10.	7	11	3183	2317
Scenario *A2*								
2011–2030	18.04.	25.05.	05.09.	20.10.	185	103	2843	1843
2031–2050	19.04.	24.05.	08.09.	07.10.	171	106	2701	1951
Northern Steppe								
1986–2005	01.04.	15.05.	15.09.	07.10.	173	123	3010	2372
Scenario *GFDL* - 30%								
2011–2030	17.03.	24.04.	24.10.	11.11.	226	174	4372	3714
2031–2050	09.03.	23.04.	20.10.	07.11.	242	180	4476	3784
Scenario *A1B*								
2011–2030	11.04.	11.05.	24.09.	23.10.	194	135	2987	2389
2031–2050	09.04.	15.05.	29.09.	16.10.	189	142	350	2695
Scenario *A2*								
2011–2030	13.04.	18.05.	13.09.	09.10.	177	119	2976	2182
2031–2050	15.04.	17.05.	19.09.	08.10.	176	126	3036	2275
Southern Steppe								
1986–2005	15.04.	12.05.	25.09.	19.10.	186	136	3322	2707
Scenario *GFDL* - 30%								
2011–2030	09.03.	24.04.	13.09.	28.10.	233	183	4924	4113
2031–2050	05.03.	23.04.	19.09.	24.10.	237	181	4930	4069
Scenario *A1B*								
2011–2030	20.04.	03.05.	17.10.	12.11.	225	163	4340	3540
2031–2050	27.03.	20.04.	18.10.	06.11.	198	180	4449	3804
Scenario *A2*								
2011–2030	08.04.	13.05.	06.10.	26.10.	200	145	3620	2905
2031–2050	06.04.	11.05.	30.09.	18.10.	195	142	3870	3117

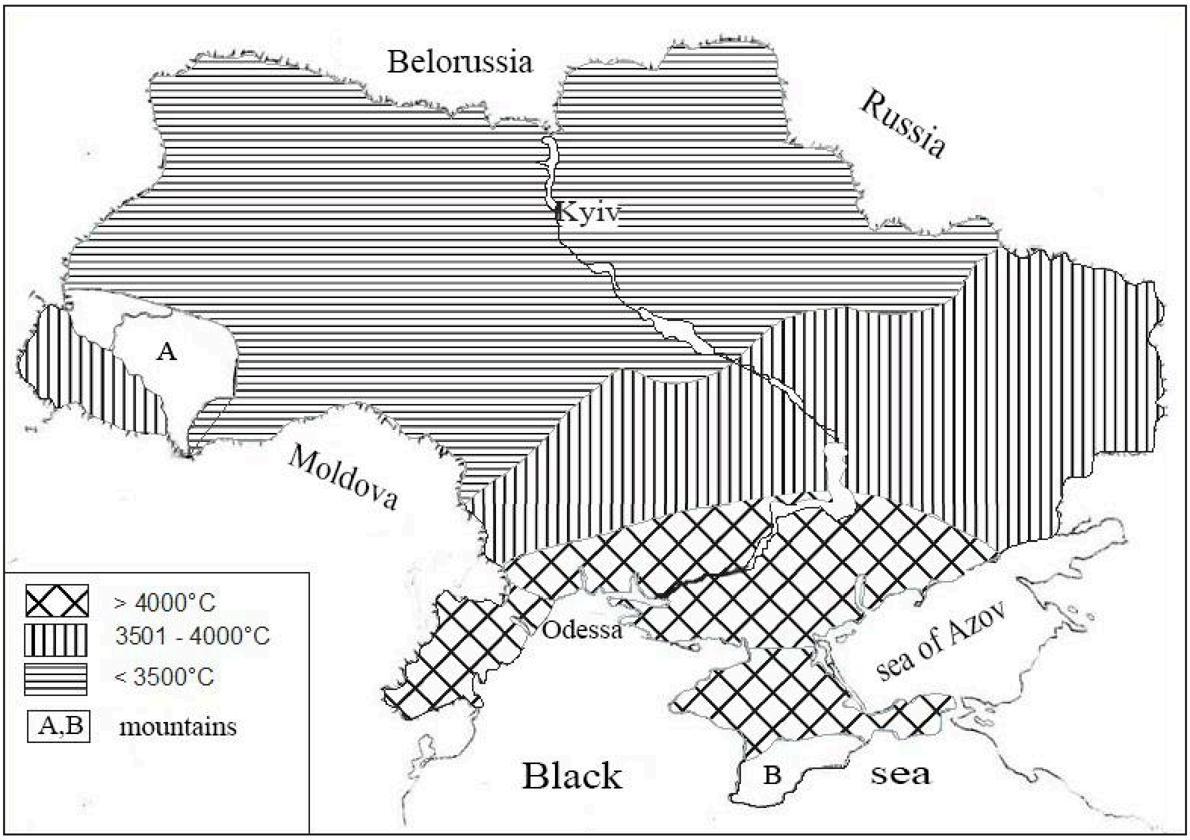

Fig. 2. *The distribution of sums of temperatures above 10°C on the Territory of Ukraine, calculated under the scenario A1B for the period before 2050 year*

The analysis of the mean temperatures for January and July, as well as of the temperature amplitude, demonstrated that more significant changes will be observed in mean temperature values for January. The changes in the January temperatures will differ depending on the scenario used in calculations. Under the conditions of scenario GFDL - 30%, we have noted significant increases of the mean temperature, rising above zero in January for all climate zones. Both Polesye and the Forest Steppe zone, during both periods under calculation, are expected to have mean temperatures of 2,6…3,7°C in January, which is more than 6°C higher than the mean long-term temperature. In the Northern and Southern Steppes, these values will be higher than the mean temperature for January of the base period by, respectively, 5,2 and 7,0°C. The same divergences in the mean temperature for January are observed in the Northern Steppe under the scenario A1B.

Calculations under the scenarios A1B and A2 demonstrate that throughout the climate zones of Ukraine, the patterns of change in January temperatures will differ drastically. This is especially noticeable in the case of the Forest Steppe zone, where, during the period before 2030, under the scenario A1B, the mean temperature for January is expected to be lower than the mean long-term temperature by 2°C, and, in the period from 2031 to 2050, is expected to be close to the mean long-term temperature. Under the scenario A2, the patterns of temperature change in January are similar, but the values differ. In the period before 2030, the temperature will be below the mean long-term temperature, and reach – 4,2°C.

In the period between 2031 and 2050, we are expecting an increase in the mean temperature for January, in comparison with the mean base temperature, by almost 4°C for the Forest Steppe zone, by 3°C for the Northern Steppe, and by 4…5°C for the Southern Steppe (table 1).

The mean long-term temperature for July throughout the territory of Ukraine fluctuates from 19,4°C in Polesye to 23,7°C in the Southern Steppe. Calculations under the scenarios GFDL - 30% and A1B showed that temperatures in July, during the period before 2030, will be close to the mean long-term values only in Polesye and in the Forest Steppe zone. In the Northern and Southern Steppe, they will increase, respectively, by 0,9 and 0,4°C.

Under the scenario A2, in the first period under calculation, mean temperatures for July are lower than the mean long-term temperatures, and fluctuate from 18,2°C in Polesye to 22,5°C in the Southern Steppe. During the period between 2031 and 2050 under this scenario, the mean air temperatures for July are also lower than the mean long-term temperatures, and the fluctuations constitute 0,8°C in Polesye, 1,5°C in the Forest Steppe zone, and 2°C in the Northern Steppe. In the Southern Steppe the temperature will be close to the mean temperature of the base period.

The temperature amplitude in the climate zones will change in correlation to the changes in the mean temperatures for January and July. In all zones except for the Forest Steppe zone, as a result of the significant increase in the mean temperature for January and fractional increase in the mean air temperature for July, the temperature amplitude will decrease in comparison with the mean long-term under all scenarios. Only under the scenario A1B in the first period under calculation, the temperature amplitude will increase to 25,9°C in Forest Steppe zone, which is 2°C higher than the mean long-term temperature amplitude.

CONCLUSIONS

1. Global warming is impacting in the territory of Ukraine. A comparison between the projected thermal resources in climate zones of Ukraine, calcula-ted under different scenarios, enables us to conclude that, under any of the discussed scenarios, thermal resources will increase.

2. At realization any scenario sum of air temperature above 0, 5 and 10°C will increase over 1000°C in whole territory of Ukraine. Especially perceptibly will increase the sums of temperatures at the realization of scenario of GFDL - 30%, Less intensive increase in sums of air temperatures above 0, 5 and 10°C is expected at realization of scenario of A2.

3. This might lead to the shifting of the northern boundaries of the climatic zone in Ukraine, which will permit re-thinking the allocation of sowing areas for thermopile crops.

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