საერთაშორისო სამეცნიერო კონფერენცია „დედამიწასა და მის გარსებში მიმდინარე გეოფიზიკური პროცესები“
შრომები, თბილისი, საქართველო, 16-17 ნოემბერი, 2023 წ.
International Scientific Conference "Geophysical Processes in the Earth and its Envelopes"
Proceedings,Tbilisi, Georgia, November 16-17, 2023

AGROCLIMATIC CHANGES IN THE MOUNTAINOUS REGIONS OF GEORGIA

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Abstract*. Based on the meteorological observations carried out in the areas of the mountainous and high-mountainous areas of Mtskheta-Mtianeti in east Georgia and Samegrelo-Zemo Svaneti in west Georgia, the trend of changing agro-climatic characteristics under the global warming has been revealed. According to the equations drafted by future (2020-2050) scenarios (1ºC and 2ºC temperature increase), the sums of active temperatures (>10ºC) were determined and agroclimatic zones were identified. As per the scenarios developed for global warming, a temperature increase will not have any significant negative impact on the agricultural crops provided it is not higher than the increase forecasted by the scenario. On the contrary, it may be beneficial to grow the crops at different altitudes from the sea level, by considering vertical zoning, where a 1ºC temperature increase will make it possible to grow the crops 100-200 m higher and 200-300 m higher with a 2ºC temperature increase as compared to the present zones.*

Keywords*: global warming, future scenarios, active temperatures, agroclimatic zones*

In terms of contemporary global climate warming, the problem of slowing down the ongoing climate change and vulnerability and adaptation to it has become a world-wide issue, which was recognized as the major challenge of the UNO at the beginning of the present century. The global warming may lead to the melting of eternal glaciers, floods, storms, hurricanes, droughts and other natural calamities. As the researchers conclude, the present-day frequent natural calamities are caused by both, natural and unforeseen anthropogenic actions. By the end of the XX century, the content of CO_2 in the atmosphere reached 10%. Unless the exhaust fumes are limited, by 2030-2050, the content of carbon gas may double and the temperature may rise by another 2-3ºC. This will lead to the establishment of an absolutely different system of industry and transport and particularly agricultural sector and other branches of economy [1]. Therefore, most world countries must agree to take preventive measures to reduce the emissions of such natural resources as oil, coal, as well as CO_2 and other greenhouses gases from big factories and vehicles into the air. The said emissions create so called “greenhouse effect” in the atmosphere, with an increased near-earth surface temperature as its major outcome. Following the above-mentioned, global warming is a problem to solve by the joint action of the word countries [2, 3, 4].

In terms of global warming, interesting data of meteorological observations are fixed in relation to the glacier melting on the Caucasian [5] in the high-mountainous zone of Mestia, where a many-year average air temperature increase of 0.1ºC is observed what supports the melting of glaciers. Another reason for the reduction of glaciers is an increase in temperature by 0.3 and 0.2ºC in the high-mountain zone of east Caucasian (Jvari Pass, Kazbegi). The given studies, alongside with the increasing trend of sum of active temperatures identified by us, evidence the trend of another kind of (many-year average) temperature increase in terms of global warming, what activates the glacier melting process.

As regards the global warming, the upper limit of the plantation of young birch forest fixed in the high-mountainous zone of Mtskheta-Mtianeti region of east Georgia (on the territory of Kazbegi Municipality) at 2685 m above sea level is noteworthy, while as suggested by the census of 2002, the upper forest limit ended at 2560 m asl. As a result of global warming, the upper limit of the forest is subject to vertical migration [6].

The impact of global warming on the natural environment is immense. For instance, a rise in the near-land air temperature of the crop plantations may be negative in respect of propagation of twice or thrice more new generations of the organisms causing plant diseases. They may appear in the areas where they were not seen before. This will cause problems for agrarian specialists (entomologists, phytopathologists). Therefore, it will be necessary to take relevant efficient measures against them to avoid expected plant diseases reducing the productivity (harvest) by 40-50%. In this connection, we would like to note that in 2017, in Samegrelo-Zemo Svaneti and Imereti regions in west Georgia was seen a massive raid of invasive plant pest brown marmorated stink bug, which was not seen in the region before. The pest badly damaged annual and perennial crops. The agricultural specialists assume that their mass propagation is expected in east Georgia as well and relevant measures were planned against them. Global climate warming is named as the major reason for the propagation of this pest during the vegetation period.

Consequently, the study of the impact of irregular climate change on the productivity and vulnerability of the agricultural crops and expected transformation of the existing agroclimatic zones is necessary and topical.

The goal of the study was, by using the relevant trends, to identify the trend of change of agroclimatic properties (increase/decrease (of the sums of active temperatures (>10°C) and atmospheric precipitations (mm)) under the influence of global warming on the territories of the mountainous and high-mountainous zones of eastern and western regions of Georgia during the vegetation period, which is the major determinant of the plant growth and development and harvest formation and productivity. By using these trends, the dynamics of their change in time could be specified. Another goal of the study was to identify the agroclimatic zones suitable for the satisfactory yield and spread of agricultural crops according to the current (baseline) and future scenarios - in terms of a 1-2ºC temperature increase. A mathematical statistical method was used to process and analyze the data of many-year (70-year-long) meteorological observation for Khaishi and Mestia Municipalities of mountainous and high-mountainous Samegrelo-Zemo Svaneti region in west Georgia and Dusheti and Kazbegi Municipalities of mountainous and high-mountainous Mtskheta-Mtianeti region in east Georgia.

The dynamics of the course of the said indices was presented with trends, according to which, the trends of increasing sums of active temperatures (>10°C) and decreasing sums of the atmospheric precipitations (mm) were identified in the mountainous and high-mountainous regions of west Georgia and mountainous and high-mountainous regions of east Georgia. The equations of the trends were used to calculate increasing and decreasing trends of the sums of active temperatures (>10°C) and atmospheric precipitations (mm) (Table 1).

Table 1. The sums of active temperatures (>10°C) and atmospheric precipitations (mm) according to trends.

Region/ zone	Meteo-station	Sum of active temperatures (>10°C)					
		Beginning of the period	End of the period	Increase	Decrease	Average speed in every 10 years	
						Increase	Decrease
Samegrelo-Zemo Svaneti/ Mountainous	Khaishi	3178	3470	292		41.7	
High-mountainous	Mestia	1877	2134	257		36.7	
Mckheta-Mtianeti/ Mountainous	Dusheti	2987	3203	216		30.7	
High-mountainous	Kazbegi	1511	1797	286		40.8	
Samegrelo-Zemo Svaneti/ Mountainous	Khaishi	Sum of atmospheric precipitations (mm)					
		690	655		35		5.0
High-mountainous	Mestia	449	430		19		2.7
Mckheta-Mtianeti/ Mountainous	Dusheti	514	495		19		2.7
High-mountainous	Kazbegi	507	388		119		17.0

As the given Table shows, there is a trend of decreasing atmospheric precipitations (119 mm) in the high-mountainous zone of east Georgia. The average velocity of the given reduction is 17 mm in every 10 years. The increasing and decreasing trends of agroclimatic values in other zones are relatively less.

In order to identify the agroclimatic zones in the above-said regions, the scenarios consider a 1ºC temperature increase in the regions of west Georgia and a 2ºC temperature increase in the regions of east Georgia. The dates of average daily air temperature above 10ºC, sums of active temperatures and altitude above sea level (m) were used for this purpose. The latter is in direct correlation with the regular change in air temperature depending on the altitude [7]. The given data were processed by using the mathematical statistics method adopted in agrometeorology with close correlations established. Following the obtained reliable associations, relevant regression equations were drafted (Tab. 2). At different times, the equations of the given type were used to identify the sums of active temperatures to identify the relevant zones of crops [8].

Table 2. Regression equations to determine the dates of average daily air temperature transition above 10ºC and sums of active temperatures in the mountainous and high-mountainous regions of Georgia.

Determination of starting date t>10°C and ∑T	Current (baseline), mountainous and high mountainous (West Georgia)	Scenario, increase by 1°C, mountainous and high mountainous	Current baseline, mountainous and high mountainous (East Georgia)	Scenario, increase by 2°C mountainous and high mountainous
determination of starting date (t>10°C)	n=0.025h+57	n=0.028h+51	n=0.029h+55	n=0.035h+38
determination of ∑T	T=-36.53n-0.75h+6537	T=-16.711n-1.127h+5496	T=-30.923n-0.57h+6085	T=-44.25n-0.15h+6742

In the equations: n - is the number of days from the 1st of February to the date of the temperature above >10ºC; h - is the altitude above sea level (m); T - is the sum of active temperatures (>10°C).

By using the given equations, the sums of active temperatures by considering the current (baseline) values and future (2020-2050) scenarios (a temperature increase by 1 and 2ºC) were identified and the agroclimatic zones of the distribution of crops in the regions were defined [9, 10].

The mountainous area of the region spreads from 500 to 1500 m above sea level of the humid subtropical zone of Samegrelo-Zemo Svaneti region of west Georgia, where two agroclimatic zones (I and II) were identified:

The I agroclimatic zone extends from 500 m to 1000 m altitude above sea level. The sum of baseline active temperatures is 3620-2790°C and is 3800-3110°C under the scenario with a 1°C temperature increase.

The II agroclimatic zone extends from 1000 m to 1500 m altitude above sea level. The sum of current (baseline) active temperatures is 2790-1960°C and is 3110-2430°C under the scenario.

Higher mountainous area of the given region, from 1500 to 2500 m altitude, there extends the high-mountainous area of the region, where two agroclimatic zones are identified (III and IV)

The III agroclimatic zone extends from 1500 to 2000 m altitude. The sum of baseline active temperatures in the given zone is somewhat reduced and makes 1960-1130°C on average and 2430-1760°C in case of the scenario.

The IV zone agroclimatic zone extends from 2000 m to 2500 m altitude above sea level. The sum of baseline active temperatures in the given zone is 1130-300°C. The sum of temperatures is obviously reduced, and it is 630°C (baseline) at the altitude of 2300 m.

In respect of global warming, the air temperature in Mtskheta-Mtianeti region in east Georgia is increasing more. As it was noted, the temperature is risen by 0.5°C here unlike Samegrelo-Zemo Svaneti region in west Georgia. Therefore, a 2ºC temperature increase is considered by the scenario, where 3 agroclimatic zones were identified:

The I agroclimatic zone spreads from 1000 m to 1500 m altitude above sea level in the west and south-east of the region. This zone covers the mountainous areas of Dusheti and Tianeti Municipalities. The sum of current (baseline) active temperatures is 2920-2180°C and is 3360-2500°C under the scenario (a 2ºC temperature increase).

The II agroclimatic zone belongs to the high-mountainous region, which is located up to 2000 m in the east. The sum of current (baseline) active temperatures is 2180-1450°C and 2500-1660°C under the scenario. Under the

future scenario (a 2ºC temperature increase), the sum of temperatures, as compared to the sum of baseline temperatures, is almost 300°C more.

The III high-mountainous agroclimatic zone spreads from 2000 m to 2500 m altitude above sea level. It covers the upper border of the subalpine zone. In this high-mountainous region, the sum of baseline active temperatures is obviously reduced (to 700ºC).

In the considered region, in the zones designated, where high-mountainous villages of Mestia Municipality (e.g. Ushguli (2200 m asl)), villages of Dusheti Municipality (Khone (2150 m a.s.l.), Roshka (2050 m a.s.l.)), villages of Kazbegi Municipality (Juta (2200 m asl)) and other villages (Akhieli, Shatili, at relatively lower altitudes) are located, the agricultural specialists and agricultural farmers, together with the local residents, with the future perspective, will be able to grow the crops profitable for them and to produce high-quality products with them to be used by the residents of the above-listed villages. If necessary, they will even realize some of the products. This will promote the employment and establishment of the local residents what will support the reduction of depopulation in the mountainous and high-mountainous zones of the country. As a result, the social-economic conditions will improve. These activities are supported by the Law of Georgia, On the Development of High Mountainous Regions" adopted by the Government of Georgia on July 16, 2016 as well. In particular, the goal of the Law is to ensure the wellbeing of the residents in the high-mountainous regions of Georgia, support employment and improve the quality of life and social-economic conditions. In line with this major Law, the results of the study conducted by us for high-mountainous regions given in the present work are worthwhile. It should be noted that the given regions with their natural location (relief and orographic conditions, diversified forest landscape, etc.) are interesting and attractive. They have good prospects to develop tourism and recreation activities in summer, autumn and winter seasons. On the territory of Mestia (located at 1500 m above sea level and higher), ski mountaineering is very popular sports in autumn and winter seasons, while sporting activities organized in Gudauri Ski Resort (at 2200 m above sea level and higher) are also very important.

Following the global warming, certain mitigation and adaptation measures against some negative events are recommended to use in the agrarian sector at present and in the future. Growing selective crops, which are resistant to higher temperatures and droughts, is a good choice. Besides, it is important to make terraces over the mountain and high-mountain slopes (with >10° gradient) to reduce intense evaporation of water runoff and water from soil; soil surface cultivation and loosening to reduce water evaporation from the soil is another efficient measure. Besides, efficient use of modern irrigation and drip irrigation and other methods will be beneficial.

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