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IMPACT OF CLIMATE CHANGE ON AGRO-CLIMATIC CHARACTERISTICS AND ZONES OF MTSKHETA-MTIANETI REGION

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Summary: *The temporal change tendency of agro-climatic characteristics for the vegetation period in the Mtskheta-Mtianeti region has been revealed taking into account climate change; In particular, the vegetation period prolongation in the arid subtropical, mountainous and highland zones of the region and the increase of the active temperature sum (>10°C), and the decrease dynamics of atmospheric precipitation (mm) and hydrothermal coefficient (HTC). According to the current (basic) and future scenarios (2020-2049), agro-climatic zones are allocated taking into account the temperature increase by 2°C, with recommendations for the spread of appropriate perspective crops by the height above the sea level. The forecast equation for the potato crop is drawn according to the temperature of the latter scenario. It is established that according to the future scenario (2020-2049), the increase of the projected temperature by 2°C will not have a negative impact on agricultural crops.*

Key Words: *climate change, active temperature, agroclimatic zone*

Introduction. The impact of climate change on the environment is far-reaching and is reflected on the ecological equilibrium established during centuries and on the macro-climate of the Earth's air wholly. Its action can lead to the melting of eternal glaciers, floods, storms, hurricanes, droughts and other natural disasters (catastrophes). Many sectors of the Worlds economics, including agriculture, damage significantly. Modern climate change has also affected the territory of Georgia, especially the eastern part of Georgia, where there is a tendency of higher temperatures compared to the western part of Georgia. This is indicated by the statistical analysis of multi-year meteorological observation data. Temperature increase was observed from the western humid subtropics of Georgia to the highland area of the Kakheti region in the east of Georgia (0.2-0.5°C), respectively [1, 2]. The given temperatures have to be taken into account, because if the process of global warming is prolonged, the temperature may rise further and reach 2°C and above in three to four decades. Therefore, it is necessary to know in advance what impact it will have on the sectors of the country's economy, especially the agrarian sector. The temperature increases by 3-4°C and above can have a negative impact on existing, adapted plants, especially in lowland areas up to 300-600m above the sea level, because, even more heat will be accumulated in such places. Therefore, the normal productivity of vulnerable crops such as cereals, fruits, vegetables and other crops will be in danger.

Methods. Our aim was to identify agroclimatic zones for distribution of crops according the baseline (current) and future scenario (2ºC temperature increase) in Mtskheta-Mtianeti region. In order to solve the given issues we used and processed baseline (current) meteorological observation. The data of the many-year (1948-2017) meteorological observations of the National Environment Agency of Georgia - average air temperatures and atmospheric precipitation sums (mm) are used and processed. The data of agrometeorological observations were treated by using the method of mathematical statistics. Also, the data of the future scenario are processed, temperature increase by 2°C (2020-2049), which were obtained by regional climatic model RegCM-4 and social-economic development scenario A1. This was used for the Framework Convention on Climate Change in the scope of the Third National Frame Communication of Georgia [1]. In the above-mentioned region, the date of transition of air temperature above >10°C to below <10°C was determined by the following equations: y=-2.4x+79 (in spring), y=3.2x-33 (in autumn). In the equations - y is the dates of the spring and autumn temperatures above >10°C and below <10°C; x - the sum

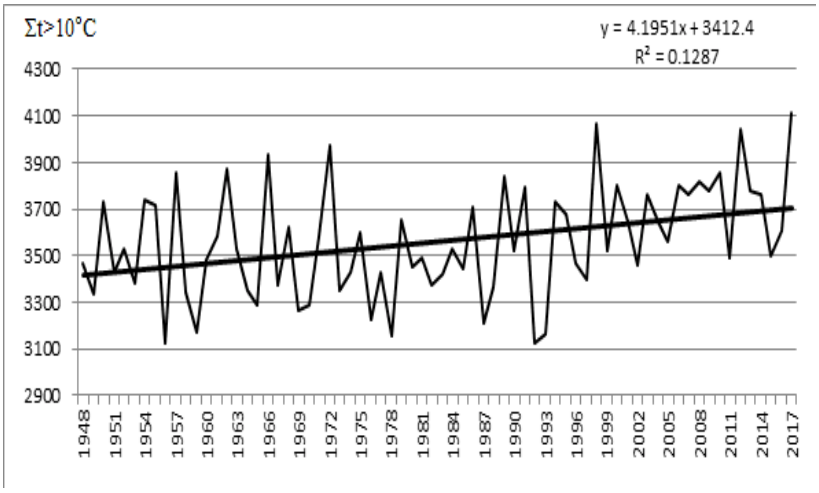
of the average temperatures of two months or each month in spring and autumn. Also, the method of harvesting agrometeorological forecasting is used.

Results and discussion. The agriculture of Mtskheta-Mtianeti region is economically important, which is reflected in ensuring the social and economic level of the population. Despite the rather difficult mountainous terrain and, consequently, the different types of climatic conditions created here, it is possible to develop cereals, fruits, vines, vegetables, beekeeping, livestock and other fields of agriculture and get high quality crop [3]. In the context of recognized global climate change, there is no relevant scientifically sound experience as to whether the agro-climatic characteristics of normal development and productivity of these crops in the territory of a given region will change. Therefore, it is advisable to identify their changes in order to develop appropriate mitigation measures and recommendations for the negative impact on the agro-climatic characteristics.
In this regard, the agro-climatic characteristics of the arid subtropical, mountainous and highland zones of the Mtskheta-Mtianeti region with the future scenario (2020-2049), taking into account global warming when the air temperature rises by 2°C (Tab. 1).

Tab. 1 Agroclimatic characteristics according to the scenario, with the temperature rises by 2°C

Region/ Zone	Meteo-station, Altitude (mm) a.s.l.	Data of transition air temperature t>10°C	Data of transition air temperature t<10°C	Duration of the vegetation period	Sums of active temp. >10°C (IV-X)
Mtskheta-Mtianeti, arid subtropical	Mtskheta, 460	31.III	7.XI	221	3986
Mtskheta-Mtianeti, Mountainous	Dusheti, 922	9.IV	31.X	205	3581
Mtskheta-Mtianeti, Highland	Kazbegi, 1744	12.V	1.X	142	2088

According to the future scenario (2020-2049) the temperature increase by 2°C in the given zones, the increase of active temperature sums (> 10°C) and the prolongation of vegetation periods will not negatively affect the normal growth and development of crops and full fruit ripening if soil moisture remains in adequate conditions. The growth temperature will be especially positive for the normal development-productivity of crops that have limited heat supply. Based on the meteorological observations, the active temperature sums (>10°C) and atmospheric precipitation (mm) in the warm period (IV-X and V-IX) are also analyzed, processed and calculated for dry subtropical, mountainous and highland areas of Mtskheta-Mtianeti, also the hydrothermal coefficients during the period of active vegetation (VI-VIII). The dynamics of their course were depicted by trends, for example in the arid subtropical zone Mtskheta is presented (Fig. 1).



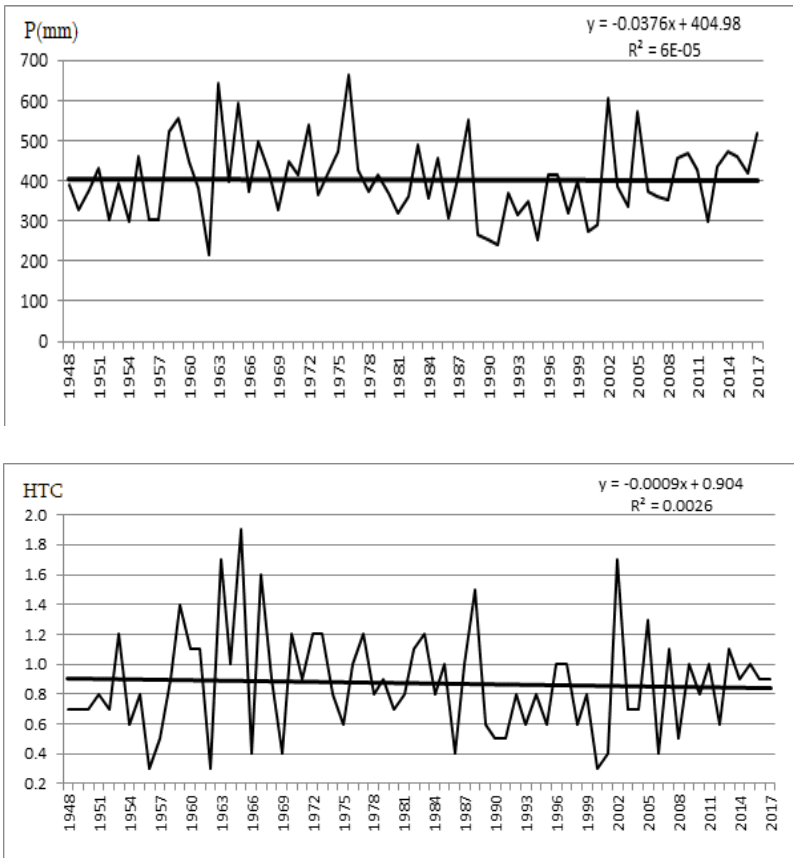


Fig. 1. Dynamics of sums active temperatures (> 10°C) and atmospheric precipitation (mm) and HTC (arid subtropical zone, Mtskheta)

According to the zones trends, the tendencies of increasing the active temperature sums and decreasing tendencies of atmospheric precipitation and hydrothermal coefficients are revealed. According to the agro-climatic characteristics calculated from the trend equations, the active temperature sums in the arid subtropical zone in 1948-2017 is 289°C, in the mountains and in the highlands - 216°C, 286°C, respectively. The atmospheric precipitation sum is reduced by 3 mm in the arid subtropical zone, and by 19 and 113 mm in the mountainous and highland areas, respectively. If the active temperature sums trend increasing continues in the future, after 4-5 decades the temperature sums in the arid subtropical zone may reach 3900-4000°C and slightly higher, in the mountainous zone - 3400-3500°C and slightly higher, and in the highlands - 1900-2000°C and slightly more. However, it will not be a nuisance for mountainous and highland areas, as for normal development and more productivity the agricultural crops are less heat-supplied. Conversely, it may even be beneficial in conditions of adequate soil moisture. Based on the above, the atmospheric precipitation decrease tendency will be observed in the given zones. Therefore, during the active vegetation period (VI-VIII) in the arid subtropical zone it will be necessary to carry out watering measures 2-3 times for annual crops and 1-2 times for perennials.

The 5 agro-climatic zones were allocated in the territory of Mtskheta-Mtianeti region with vertical zoning in order to spread the relevant agricultural crops.

Zone I includes the arid subtropical area of the region, located at the 600 m above the sea level. The active temperature sum above 10°C is 3651°C (basic), and by the future scenario (2020-2049) when the temperature rises by 2°C - 4211°C. In the conditions of the mentioned zone it is possible to expand the distribution area and produce of dry subtropical fruit crops, cereals, early and late grape varieties. The given zone is less provided with atmospheric precipitation during the active vegetation period (VI-VIII). Therefore, for the unimpeded development of the specified crops, it is necessary to provide the soil with adequate moisture.

The II - Zone extends up to 1000 m above the sea level. The active temperature sums (> 10°C) is 2917°C (base) and when the temperature rises by 2°C - 3362°C. The given temperatures are favorable for the propagation-production of early (1300-1400 m elevation) and late (1100-1200 m altitude) vine varieties, widespread propagation-production of wheat, corn, vegetables, fruits and other crops. The atmospheric

precipitation sum during the active vegetation period (VI-VIII) is 180 mm, which is not enough for the normal development and productivity of plants. Therefore, water should be provided to the plants root system (soil irrigation-cultivation).

The III - Zone includes mountainous areas and extends from 1000 m to 1500 m above the sea level. The sum of active temperature sum (> 10°C) averages 2184°C, and by the scenario, when the temperature rises by 2°C - 2512°C. Due to the thermal characteristics of this zone, it is possible to propagate autumn and spring wheat, barley, potato, corn and vegetable crops up to 1200-1300 m, and early vine varieties up to 1300-1400 m. During the active vegetation period (VI-VIII) the atmospheric precipitation sum is 215 mm, which is sufficient for the development-productivity of the indicated crops.

The IV - Zone extends from 1500 to 2000 m above the sea level and includes highland areas. The sum of active temperature sum (> 10°C) is slightly reduced and amounts to 1451°C (basic), by the scenario, when the temperature rises by 2°C - 1663°C. The atmospheric precipitation sums during the period of active vegetation (VI-VIII) averages to 355 mm. It is possible to grow autumn and spring wheat up to 1600-1800 m and more, to grow the early fruit, berries and livestock feed in the zone.

The V - Zone extends from 2000 to 2500m above the sea level. It almost covers the upper border of the subalpine zone. The sum of active temperature sum (> 10°C) at 2500 m altitude in this zone is significantly reduced (717°C, basic). According to the scenario, it reaches 814°C. Under such temperature, the development and productivity of barley, oats, potatoes, vegetables, berries, and livestock root crops are limited and unprofitable. According to the future scenario, the active temperature sum (> 10°C) at the altitude of 2300 m if temperature increases by 2°C is 1153°C, which creates relatively favorable conditions for the development of these crops. The atmospheric precipitation amount in the zone is sufficient, it is almost identical to zone IV.

Given the above, whilst promising crops propagation indicated in agro-climatic zones, it is important to take into account their forecasted yield [4]. Crop formation during the development of different phenological phases depends on the need for environmental factors. For example, the period from the emergence of flower cockles to the flowering phase is of great importance for the potato crop, between which the tubers are formed in June-July. It is this period that is remarkable for how it will be provided with precipitation and more than >10 mm rainfall days. The height (cm) of the potato crop should also be considered, as the height is closely related to the crop with atmospheric precipitation. In the absence of plant height biometric observation data, the following equation is used: $U = 0.3565*x + 5.918$. In the equation x - is the atmospheric precipitation sum (mm) in June-July; Here is the prediction equation of potato crop yield:

$$U = 1.5866*x + 2.7075*y-4.5406*z + 16.60$$

In the equation: U - is the forecasted crop, t/ ha; x - atmospheric precipitation sum (mm) in June-July; y - ≥10 mm number of rainy days in the same period; z - average height (cm) of potato plant at the end of July from $1m^2$. The total multiple correlation coefficient is R=0.92, the equation allowable error is Su ± 1.5 t/ha. The forecast is made in the first pentad of August; the expectancy is up to 2.5 months.

Conclusion. Climate change in the Mtskheta-Mtianeti region leads to the changes of agro-climatic characteristics, in particular, increase of active temperatures, prolongation of the vegetation period, reduction of atmospheric precipitation and hydrothermal coefficients during the vegetation period. As a result of the influence of these characteristics, the agro-climatic zones of plant distribution is changed. Nevertheless, according to the future scenario (2020-2049), the projected temperature increase by 2°C will not have the negative impact on the development of agricultural crops if it does not exceed this temperature increase.

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