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Climate change: agroclimatic zoning of grape varieties in Eastern Georgia (on the example of Mtskheta-Mtianeti)

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Abstract. The spatial distribution of vine varieties on the territory of Georgia has certain peculiarities, taking into account the modern climate change. The tendency of changing of the sums of active temperatures (10°C) and precipitations (mm), as well as of hydrothermal coefficients (HTC) in Mtskheta-Mtianeti region of Eastern Georgia have been established, according to analysis and processing of multi-year (1948-2017) data of meteorological observations. On the background of climate change the possible future rise of temperature by 2°C (2030-2050) presumably causes the increase of the sum of active temperatures (>10°C) by 440° - 480°C in Mtskheta-Mtianeti region. According to above mentioned the agro-climatic zones of distribution varieties of grape, situated 200-300 m higher of the existing zones, have been selected. On the basis of results analysis it was concluded that the climate change cannot have any negative influence on the agro-climatic zones of viticulture, if the real temperature does not prevail the established temperature limit.

Key words: climate change, active temperature, vegetation period, sum of precipitations, agro-climatic zone

Introduction. The effect of climate change on the environment is wide and significantly influences the historically evolved ecological equilibrium and the Earths' atmosphere macroclimate totally. Climate change became evident in Georgia as well, especially - in the east Georgia, here the tendency of temperature increase (0.4°-0.5°C) compared to the west Georgia (0.2°C) is clear. The fact is based on the statistical analysis of multi-year meteorological observations. In case the process of global warming prolongs, the further increase of temperature is possible and in three-four decades it will reach 2°C and more [1]. That is why the preliminary forecasting of the influence of temperature change on the economy, especially on its agrarian section is important. The increase of temperature by 3-4°C and more may have a negative effect on plants, especially growing at lowlands, at 300-600m above sea level; because the heat accumulation here will be significantly high. The vulnerable fields of agriculture, among them the viticulture will be endangered [2, 3].

According on all above mentioned it is significant to select the vine varieties which will be cultivated under the changing climate conditions. It must be taken into account that each phenological phase of vine development needs a particular sum of active temperatures. According to this sum the number of days, necessary for each phase, may change. The climate change may affect the total number of the days as well as vine phenology, grape yield and its quality, wine style, varietal assortment, it may change the limits of vine migration, and cause activation of new diseases; i.e. the effect of climate change for different varieties of grape vine and regions will be diverse.

Materials and Methods. The meteorological and agro-meteorological data base of the institute of hydrometeorology of the Georgian Technical University were used for agro-climatic investigations, as well as the multiyear (1948-2017) basic and recent data of the Georgian Environmental Agency during the vegetation period (the sums of the means of the air daily temperatures and precipitations). The data of long-term (70-year) meteorological observations have been processed and analyzed by the method of mathematical statistics.

The changing of air temperature above and below 10°C in agro-climatic zones was calculated by means of corresponding equations:

$$y=-2.4x+79 \quad \text{(in spring)}$$
$$y=3.2x-33 \quad \text{(in autumn)}$$

y - is the date of air temperature change above and below 10°C in spring and autumn;
x - is the sum of mean temperatures of two months in spring and autumn (in spring period - February and March, or March and April; in autumn - September and October, or October and November); the mean temperature of the first month must be less than 10°C, and that of the second month - more than 10°C [4, 5].

The data of the future scenario (temperature increase by 2°C for the period of 2020-2050) which were received according to the regional climate model RegCM-4 and by the A1 scenario of social-economic development have been processed. This model was approved and used in the third Georgian national message of the climate change frame convention [6, 7].

The forecasting sums of active temperatures (>10°C, in case of increase by 2°C), for distinguishing the agro-climatic zones of grape vine distribution, were calculated by our equation:

$$n=0.036h+38 \text{ (for the calculation of date of the temperature above } 10^{o}C),$$
$$T=-44.254n-0.150h+6742 \text{ (for the calculation of sums of active temperatures (>10°C))}$$

n - is the date of the establishment of the mean daily temperature of air above 10°C; i.e. the number of days beginning from the 1st of February till the date of temperature establishment at 10°C;
h - height above sea level (m);
T - sum of active (≥10°C) temperatures.

Results and discussion. Experimental region of Mtskheta-Mtianeti is situated at 500-2000 m above sea level. Its landscape conditions are quite complex. The northern part of the region (Kazbegi region and part of Dusheti region) is situated on the south slope of the Central Caucasus. From the west it is surrounded with Shida Kartli region, from the north - by the North Caucasus, from the east - with the regions of Kakheti and Kvemo Kartli.

The agriculture of the given region is significant from the economical point of view. In spite of a complex mountain landscape and accordingly different type climatic conditions, development of high yield and quality viticulture is possible here [8, 9]. Further development of viticulture in the region is necessary from the economical point of view, as it ensures the rise of social and economical level of the population. This from its side demands the scientifically proved evaluation of agro-climatic conditions and their effective management, based on the principles of sustainable development.

The data of 70 years meteorological observations (1948-2017) of the National Agency of Environment have been processed and the agro-climatic indices for the worm period by districts and meteorological stations have been calculated, for the evaluation of agro-climatic resources of Mtskheta-Mtianeti region (Table 1).

Table 1 The agro-climatic characteristics of dry subtropical, mountain and high-mountain zones of Mtskheta-Mtianeti (1948-2017)

Region/ zone	Meteorological station, above sea level (m)	Change of the temperature >10°C	Change of the temperature <10°C	Duration of the vegetation (days)	The sum of active temperatures (>10°C)	The sum of precipitations (mm), IV-X	HTC (IV-X)	The sum of active temperatures (>10°C) VI-VIII	The sum of precipitations (mm), VI-VIII	HTC (VI-VIII)
Mtskheta-Mtianeti, dry subtropical	Mtskheta, 460	8.IV	26.X	201	3542	403	1.1	1980	178	0.9
Mountain	Dusheti, 922	18.IV	20.X	185	3095	509	1.6	1792	214	1.2
High-mountain	Kazbegi, 1744	21.V	22.IX	124	1628	476	3.0	1288	356	2.7

The sum of active temperatures (>10°C), precipitations (mm) and hydrothermal coefficient (HTC) during the vegetation period (IV-X) has been analyzed, processed and calculated according to the meteorological observations of Mtskheta-Mtianeti dry subtropical, mountain and high-mountain zones. Their dynamics was described by trends. The dry subtropical zone of Mtskheta municipality, which comprised our experimental territory, is presented as an example (Fig. 1).

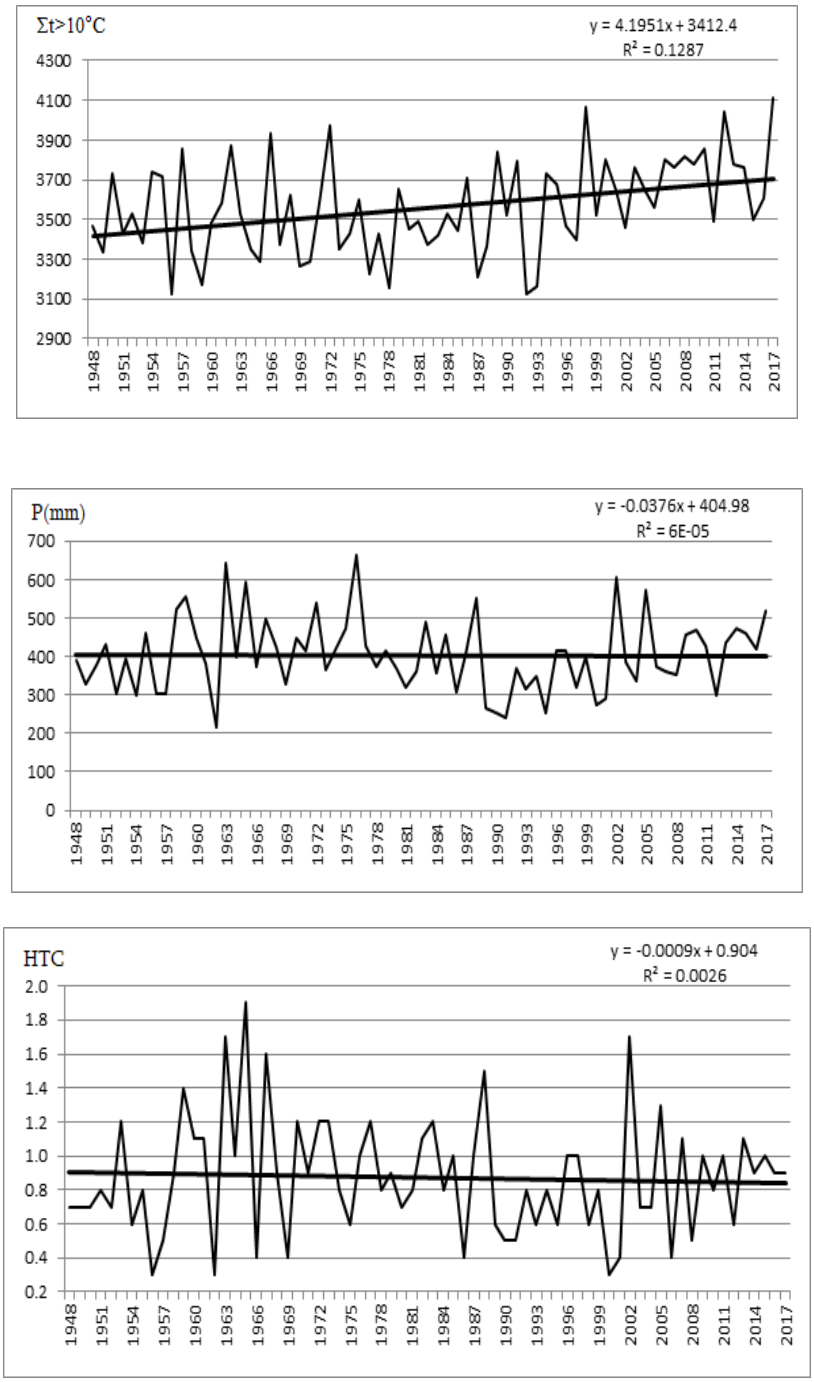

Fig. 1 The dynamics of sums of active temperatures (>10°C), precipitations (mm) and hydrothermal coefficient (Mtskheta)

The tendency of increase of the sum of active temperatures and decrease of atmospheric precipitations and hydrothermal coefficient was revealed according to trends. By the agro-climatic characteristics, calculated from trends equation, increase of the sum of active temperatures in dry subtropical zone in 1948-2017 was 289°C, in mountain and high-mountain zones - 216°C and 286°C respectively. The sum of atmospheric precipitations in dry subtropical zone decreased by 3mm, while in mountain and high-mountain zones - by 19 and 113mm respectively.

It must be mentioned that there is not any scientifically approved experience on the changing of agro-climatic indices of vine development and productivity on the given region under the climate changing conditions [10]. Accordingly the agro-climatic characteristics of Mtskheta-Mtianeti dry subtropical, mountain and high-mountain zones following the future scenario (2020-2049), in case of air temperature increase by 2°C, are presented (Table 2).

Table 2 The agro-climatic characteristics of Mtskheta-Mtianeti region on the background of global warming (increase of temperature by 2°C)

Zones of Mtskheta-Mtianeti region	Meteo-station, height a.s.l. (m)	Date of the change of air temperature >10°C	Date of the change of air temperature <10°C	Duration of the vegetation period (days)	The sum of active temperatures (>10°C)
Dry subtropical	Mtskheta, 460	31.III	7.XI	221	3986
Mountain	Dusheti, 922	9.IV	31.X	205	3581
High-mountain	Kazbegi, 1744	12.V	1.X	142	2088

From tables (1, 2) is clear that increase of the air active temperature above 10°C in dry subtropical zone of Mtskheta-Mtianeti happens in 8.IV (basic), and decrease of the temperature below 10°C - in 26.X (Table 1). Predictable by the scenario increase of temperature by2°C will change the date of 10°C limit prevailing and it will happen in 31.III; the fall of the temperature below the same limit comes in 7.XI (Table 2). Evidently, increase of the temperature by 2°C in spring will cause its rise above 10°C 8 days earlier, and in autumn decrease of the temperature below 10°C will happen 12 days later, compared to the basic date. Accordingly, the vegetation period in the given zone becomes longer by 20 days (from 201 days period to 221 days). In case of prolongation of the vegetation period (by 20 days) of the studied zone, according to the future scenario (2020-2049), the increase of the sum of active temperatures (>10°C) will make 444°C. This amount of temperatures sum will be favorable for normal growth and development and fruit ripening of experimental varieties of grape vine, under the normal humidity of soil.

In the mountain zone of Mtskheta-Mtianeti region the increase of air active temperature above 10°C in spring is observed on April 18 (basic date) (Table 1), while the rise of temperature by 2°C will change the date to 9.IV (Table 2). In autumn the decrease of temperature below 10°C stops on 20.X (basic), while temperature increase by 2°C will cause this event on 31.X. Thus, the mentioned events in spring will take place 9 days later (basic) and will finish 11 days earlier in autumn. Accordingly, in the mountain zone of the region the vegetation period will be prolonged by 20 days (from 185 to 205 days). Following the future scenario (rise by 2°C) the increase of sum of the active temperatures will make 486°C.

The global warming influences the agro-climatic characteristics of the high-mountain zone. The increase of air active temperature above 10°C in spring is observed on 21.IV, while in autumn the decrease of the temperature below 10°C happens on 22.IX (Table 1). Predictable by the scenario the increase of temperature by 2°C in spring will cause the rise of temperature above 10°C on 12.V, and in autumn - its decrease below 10°C on 1.X (Table 2). According to Tables (1, 2) following the scenario the temperature rise above 10°C in spring will began 9 days earlier, and its decrease below 10°C - 9 days later. Thus, the vegetation period in the high-mountain zone will change significantly and will be prolonged by 18 days (from 124 to 142 days). The sum of the active temperatures is also raised and reaches 460°C.

If the tendency of enhancement of the active temperatures sum continues in future, the sum of temperatures in dry subtropical zone 4-5 decades later may reach 3900-4000°C or more; in mountain zone - 3400-2500°C and more ; and in high-mountain zone – 1900-2000°C and more.

According to above mentioned the tendency of precipitations decrease in the given zones is observed. Therefore, additional water supply will be necessary in dry sub-tropical zone during the active vegetation period (VI-VIII). For the cultivation of corresponding varieties of grape vine by the altitudinal gradient in Mtskheta-Mtianeti region three agro-climatic zones has been distinguished [11, 12].

I - zone comprises the dry subtropical territory, at 600 m above sea level. The sum of active temperatures above 10°C makes 3651°C (basic) here, while according to the future scenario (2020-2049), in case of temperature rise by 2°C it will become 4211°C. Under this conditions cultivation of medium and early ripening varieties of grape is possible. The given zone is less provided for atmospheric precipitations during the active vegetation period (VI-VIII). That is why additional supplying with water is necessary for effective development of the mentioned varieties.

II - zone distributes till 1000 m above sea level. The sum of active temperatures (>10°C) makes 2917°C (basic), while in case of temperature rise by 2°C it will become 3362°C. Given temperatures are favorable for the distribution

and industry of varieties with middle (at 1300-1400 m) and late (at 1100-1200 m) ripening periods. The sum of the atmospheric precipitations in the period of active vegetation (VI-VIII) makes 180 mm, which is not enough for the normal development and productivity. Therefore, supply of the root system with water is necessary (soil watering and cultivation).

III - zone comprises mountain territories and expands from 1000 m till 1500m above sea level. The average sum of active temperatures (>10°C) is 2184°C, while in case of temperature rise by 2°C, according to the future scenario, it will become 2512°C. By these temperature characteristics cultivation of grape varieties is possible till 1300-1400 m. The sum of atmospheric precipitations in the period of active vegetation is 215 mm, winch is satisfactory for vine development and productivity.

Conclusion. The agro-climatic conditions characteristic for Mtskheta-Mtianeti region of east Georgia are responsible for the distribution of various vine varieties here. Maximally effective **a**pplication of the potential of micro-zones of vine distribution, for the purpose of their further widening, is of great importance; because the possibilities for cultivation of new vineyards is much higher, than it is really presented. The agro-climatic zones of grape vine distribution, distinguished by the agro-climatic characteristics make possible to produce different quality and purpose wines in future.

According to the future scenario (2020-2049), in case of temperature rise by 2°C in the agro-climatic zones of grape vine distribution the increase of sums of active temperatures (>10°C) and prolongation of the vegetation periods will not have any negative effect on the normal growth and development of the vine; as well as on the full maturity of fruits, under the suitable humidity of soil. The raised temperatures (if it does not prevail the level predicted by scenario), will be especially positive for those zones, where the temperature supply is limited. Corresponding translocation of the varieties is needed to avoid the negative influence of temperature increase on the development and productivity of grape vine under the conditions of climate change; otherwise long term changes in temperature regimen will be negatively reflected on the yield.

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კლიმატის ცვლილება: ვაზის ჯიშების აგროკლიმატური ზონირება აღმოსავლეთ საქართველოში (მცხეთა-მთიანეთის მაგალითზე /მელაძე გ., მელაძე მ./ სტუ-ის ჰმი-ის შრომათა კრებული-2024.-ტ.135.-გვ.ხხ-ხხ. -ქართ., რეზ. ქართ., ინგლ. საქართველოს ტერიტორიაზე ვაზის ჯიშების სივრცობრივ განაწილებას კლიმატის თანამედროვე ცვლილების გათვალისწინებით გარკვეული თავისებურება გააჩნია. მრავალწლიური (1948-2017) მეტეოროლოგიური დაკვირვებების მონაცემების ანალიზისა და დამუშავების საფუძველზე, აღმოსავლეთ საქართველოს მცხეთა-მთიანეთის რეგიონისათვის, გამოთვლილია და დადგენილია აქტიურ ტემპერატურათა (10°C) და ატმოსფერული ნალექების (მმ) ჯამების და ჰიდროთერმული კოეფიციენტების (ჰთკ) მატება/კლების ტენდენციები. კლიმატის ცვლილების გათვალისწინებით, მომავლის სცენარის მიხედვით (2030-2050 წწ), ტემპერატურის 2°C-ით მატებისას დადგენილია, რომ აქტიური ტემპერატურის ჯამები (>10°C) მცხეთა-მთიანეთის რეგიონში იზრდება 440-480°C-ით. აღნიშნულიდან გამომდინარე, გამოყოფილია ვაზის ჯიშების გავრცელების აგროკლიმატური ზონები, რომლებიც 200-300 მეტრით მაღლაა არსებულ ზონებთან შედარებით. ჩატარებული კვლევების ანალიზიდან ირკვევა, კლიმატის ცვლილება ნეგატიურ გავლენას ვერ მოახდენს მევენახეობის აგროკლიმატურ ზონებზე, თუ იგი აღნიშნულ სცენარში გათვალისწინებულ ტემპერატურას არ გადააჭარბებს.