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RESEARCH ARTICLE

# GLOBAL WARMING: CHANGES OF AGROCLIMATIC ZONES IN HUMID SUBTROPICAL, MOUNTAINOUS AND HIGH MOUNTAINOUS REGIONS OF GEORGIA

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ABSTRACT

According to humid subtropical, mountainous and high mountainous regions of Georgia there have been identified tendencies of changes of agro-climatic indicators caused by global warming (increase or decrease). Realized studies confirm that the impact of global warming is more reflected in the mountainous and high mountainous conditions, which has a significant impact on the increase in the sums of active temperatures, extension of the vegetation period, general reduction of atmospheric precipitation and frequent droughts. In humid subtropical, mountainous and high mountainous regions of Georgia by baseline and scenarios increase of the temperature by 1 and 2°C, there is an estimated duration of the vegetation period and are calculated values of the sum of active temperatures (>10°C). In particular, in the humid sub-tropical regions the sum of active temperatures makes 4170°C (baseline), according to the scenario in case of increase by 1°C it makes 4390°C, which is suitable for citrus, fruit, technical and other crops. In mountainous and high mountainous regions of Kakheti by the scenario in case of increase of temperature by 2°C, sum of active temperatures makes 4290-1890°C (respectively). In the mentioned regions according to the data of observations during 60 years (1949-2008) there were detected tendencies of increasing the sum of active temperatures and decreasing of atmospheric precipitation during the vegetation period. There are made regression equations to determine dates of average air temperature above 10°C and sums of active temperatures (>10°C) both for the humid subtropical and mountainous and high mountainous regions as well. By the equations there are defined sums of active temperatures according to baseline and scenarios of future temperature (2030-2050) in case of increase of temperature by 1 and 2°C and are separated zones for diffusion and development of agricultures, production of agricultural goods and their development and diffusion. In the humid subtropical region there are identified 4 micro-zones, which provide for the conditions for full growth of cultures and complete maturity of crops. There is also defined providing sums of active temperatures for full maturity of the crops of the mentioned citrus cultures (lemon, orange, grapefruit, tangerine) in every ten or more years. For hilly (500-1500 m) and mountainous (1500-2500 m) regions of Kakheti there are identified 4 agro-climatic zones according to baseline and scenario (increase by 2°C) stating possible diffusion and development of agricultures. According to future scenarios for the zones of distribution of agricultures will be moved up by 100-150 meters in humid subtropics, and in mountainous and high mountainous regions by- 200-300 m above compared to the current zones of diffusion.



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## INTRODUCTION

Global warming is caused by various factors, the most important among them is anthropogenic impact, which is revealed by a wasteful use of natural resources (coal, oil, deforestation, fire, emissions from large industrial plants and exhumed fumes from motor vehicles). It leads to accumulation of huge amounts of carbon dioxide ($CO_2$) in the atmosphere. The latter has a feature of conducting sun rays freely to the earth, while radiated heat from the warmed up earth is restrained and works analogical to a, greenhouse effect". According to the mentioned process there takes place ongoing warming (Bruce, 1990) in the atmosphere. At the end of the XX century carbon dioxide in the atmosphere has increased by 10% (Hefling, 1990), which continues and by 2030-2050 and could be doubled and the annual average air temperature will increase by 2-3°C (Budiko, 1980). Global warming is a very important phenomenon for modern humanity, because it causes floods, hurricanes, frequent storms, melting of eternal ice, droughts, regional macro- and micro-climate changes and other natural disasters on the earth which seriously damages the countries industries, including agriculture. Therefore, it is important to recognize the possible negative and positive challenges (Mavi and Tupper, 2004). The mentioned problems should be overcome by the joint efforts and actions of the world countries in accordance with each other. Otherwise, if global warming will be strengthened and preserved for a long

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time, it can have a strong negative impact on established ecological balance of the environment, the rhythm of human life and its relations with the earth. This would make impossible to providing protection of existence of life. Tendency of global warming was detected on the territory of Georgia too (The Second National Communication Climate Change of Georgia (2009); Tavartkiladze *et al*., 2012), intensity of which increases from the western humid subtropics to the east of Georgia including high mountainous region of Kakheti, where the average annual air temperature is increased by 0.2-0.5°C (respectively). The abovementioned temperatures for the future need to be considered, as the rise in temperature can continue and after four to five decades reach 1-2°C. So we need to know in advance the results of its impact on the country's economic fields, where in adapted conditions, from the point of economics, the most affected directions will be such vulnerable sectors of agricultural, as grain, vegetable and fruit cultivation, viticulture, tea, citrus, livestock, etc. It will be difficult to provide normal productivity of agricultural goods and sustainability of ecosystems and forest landscapes.

**Study area**

The area of Guria is 2033.2 km$^2$. According to official data of Geostat, by January 1, 2016, the population was 113.0 thousand inhabitants. 28.1% of the region population lives in cities, while 71.9% in the villages. The average population density is 56 people for 1 km$^2$. The whole area of the region makes 2.9% of the territory of Georgia. The area of Akhmeta Municipality, makes 2207.6 km$^2$. Population by January 1, 2016, was equal to 31.7 thousand. Most territory of the Municipality is mountainous. According to the census of 2014, in villages above 400 m population equals to 24.4 thousand residents. Share of urban and rural population is 22.6 and 77.4% respectively. Population density per 1 km$^2$ is 14 inhabitants. The area the Municipality is 3.2% of the whole country.

**Data and Methodology**

The aim of the study was to identify tendencies in the changes of agro climatic indicators caused by global warming (increase or decrease), (sums of active temperature and atmospheric precipitation, duration of vegetation period, frequency of droughts) during the vegetation period, which is the primary determinant of plant growth and productivity, by application of climatic trend method. The latter allows to determine their change in time and space. Also, our aim was to identify agro-climatic zones of normal growth, development and diffusion of agricultures according the baseline (current) and future scenarios. In order to solve the given issues in Georgia according to the western humid subtropical region of Guria and the eastern mountainous and high mountainous Akhmeta Municipality of Kakheti region of Georgia, we used and processed baseline (current) meteorological observation data for many years (1949-2008) by the Ministry of Environment and Natural Resources of Georgia - sums of daily average air temperatures and atmospheric precipitation (mm) during vegetation period. Similarly, were developed data for scenario of future climate (increase of temperature by 1 and 2°C for the period of 2020-2030), which was adopted by the regional climate model RegCM-4 and socio-economic scenario A1B1. Which has been used in the Third National Communication of Georgia on Climate Change (The Third National Communication Climate Change of Georgia (2015)).

## RESULTS AND DISCUSSION

According to the scenario in the humid sub-tropical zone of Guria region, Georgia (which extends from the Black Sea coast to the south-east to 500 m), in case of increase of temperature by 1°C and the baseline, there were determined sustainable transition dates in spring temperature above 10°C and in autumn under 10°C and according to data of the sums of active temperatures (>10°C) during the months between the dates. Determination of transition dates in spring and autumn with average monthly temperature above 10°C and under 10°C was realized by simple and reliable equations: $y = -2.4x + 79$ (Spring), $y = 3.2x - 33$ (Autumn). In the equations y - is the transition date in spring and autumn above 10°C and below 10°C, x - is the sum of average temperature of two months or so, each month in spring and autumn, (in spring in February-March, April-March or April-May; in autumn in September and October, October-November or November-December), for example, if determination of the date by the equation in spring starts in February-March, for any municipality and the number 60 is obtained, it will be counted from February 1, and the date will be 1.IV, by counting in March-April - it will be March 1 etc. If you start from the date in Autumn in September and October and the number 50 is obtained, the number will be counted from September 1, and the transition date of temperature below 10°C will be 20.X etc. In humid subtropical zone of Georgia, transition date in the spring (basic) temperature above 10°C will be 30.III, while in autumn transitions of the temperature below 10°C will be 27.XI. According to the scenario, transition date 23.III will be observed in spring during the increase of the temperature by 1°C above 10°C and 3.XII in autumn when temperature is below 10°C (Table 1).

According to the table, when there is an increase of temperature by 1°C, transition date above 10°C in spring is observed 7 days before on average compared to baseline, while in autumn transition date of temperature below 10°C is 6 days later. Therefore, in case of the temperature above 10°C duration of the vegetation period is increased by 13 days, or from 242 days (baseline) to 255 days. The prolongation of the mentioned vegetation period will allow agricultural workers and farmers to do soil development, introduction of organic and mineral fertilizers in the soil of citrus plantations, seed grain crops and vegetables, replant seedlings etc in spring 7 days earlier. In autumn vegetation period extending for 6 days, will be possible sowing of autumn crops in the soil at the optimum time, better ripening of citruses and oil (tung) crops and other fruits. In Table 1, given sums of active temperatures (>10°C), in the humid subtropical region make 4170°C (baseline), while the temperature by scenario in case of increase by 1°C make 4390°C. Sum of increased temperature will be favorable particularly for the development of citrus crops, for improvement of full maturity of fruit and its quality in the areas where there is a lack of the sum of temperature.

**Table 1. Transition dates of air temperature in the humid sub-tropical, mountainous and high mountainous regions of Georgia by baseline (current) and scenarios of temperature by increase of 1 and 2°C above 10C° and below 10°C, duration of the vegetation period (days) and the sum of active temperatures (>10°C)**

| Region, zone | Baseline (current) | | | | |
|---|---|---|---|---|---|
| | Meteorological station, altitude, masl | t>10°C Starting time | t<10°C Finishing time | duration of vegetation period (day) | ∑T>10°C |
| Guria, humid subtropical | Anaseuli, 158 | 30.III | 27.XI | 242 | 4170 |
| Kakheti, mountainous | Akhmeta, 567 | 5.IV | 2.XI | 211 | 3830 |
| Kakheti high mountainous | Omalo, 1880 | 31.V | 18.IX | 110 | 1440 |
| Guria, humid subtropical | Scenario, rise of temperature by 1°C | | | | |
| | Anaseuli, 158 | 23.III | 3.XII | 255 | 4390 |
| | Scenario, rise of temperature by 2°C | | | | |
| Kakheti, mountainous | Akhmeta, 567 | 25.III | 14.XI | 234 | 4290 |
| Kakheti high mountainous | Omalo, 1880 | 22.V | 28.IX | 129 | 1890 |

**Table 2. Active temperature and precipitation sums according to the change according the trend (1949-2008)**

| Region, zone | Meteorological station, altitude, masl | Sum of active temperatures (>10°C) | | | | Average speed in every 10 years | |
|---|---|---|---|---|---|---|---|
| | | Beginning of the period | End of the period | Increase | Decrease | Increase | Decrease |
| Guria, humid subtropical | Anaseuli (Ozurgeti) 158 | 4140 | 4160 | 20 | | 2.6 | |
| Kakheti, mountainous | Akhmeta 567 | 3670 | 4010 | 340 | | 56.7 | |
| Kakheti high mountainous | Omalo (Akhmeta) 1880 | 1340 | 1550 | 210 | | 35.8 | |
| | | Sum of atmospheric precipitation (mm) | | | | | |
| Guria, humid subtropical | Anaseuli (Ozurgeti) 158 | 1147 | 1008 | | 139 | | 23 |
| Kakheti, mountainous | Akhmeta 567 | 558 | 543 | | 15 | | 3 |
| Kakheti high mountainous | Omalo (Akhmeta) 1880 | 357 | 331 | | 26 | | 4 |

**Table 3. Regression equations for determination of dates of daily average air temperature of transition above 10°C, and the sum of active temperatures (> 10°C) in the humid subtropical, mountainous and high mountainous regions**

| t>10°C determination of starting date and ∑T | baseline, humid subtropical | scenario, increase by 1°C, humid subtropical | baseline, mountainous and high mountainous | scenario, increase by 2°C mountainous and high mountainous |
|---|---|---|---|---|
| determination of starting date | n=0.02h+59 | n=0.021h+54 | n=0.03h+55 | n=0.035h+38 |
| determination of ∑T | T=-38.53n-0.65h+6620 | T=-63.98n-0.011h+7920 | T=-30.92n-0.57h+6085 | T=-44.25n-0.15h+6742 |

In the equations n - is the number of days from February 1, with temperatures above 10°C to the date of occurrence, h - meters above the sea level (m), T - sum of active temperatures (>10°C).

**Table 4. Providing full maturation of citrus plants by the sum of active temperatures every ten years and more secure**

| Zone, altitude masl | Baseline, every 10 years ∑ t>10°C | | | | Scenario, increase by 1°C ∑ t>10°C every 10 years | | | |
|---|---|---|---|---|---|---|---|---|
| | ∑t>10°C | lemon | orange, grapefruit | tangerine | ∑t>10°C | lemon | orange, grapefruit | tangerine |
| I 20-100 | 4320-4200 | 10 | 6-7 | 10 | 4440-4330 | 10 | 10 | 10 |
| II 100-200 | 4200-4060 | _ ” _ | 2-3 | 9 | 4330-4200 | _ ” _ | 6-7 | 10 |
| III 200-300 | 4060-3920 | _ ” _ | | 3-4 | 4200-4060 | _ ” _ | 2-3 | 10 |
| IV 300-400 | 3920-3780 | _ ” _ | | | 4060-3920 | _ ” _ | 1 | 3-4 |

In addition, the sum of increased temperatures provides high quality of grain, tea, grapes, kiwi (Actinide), fruit, technical (tung, laurel, tobacco) and other high-yield crops, in the soil of corresponding humidity. In a mountainous region in spring date of transition of temperature above 10°C was observed on 5.IV (baseline), in autumn below 10°C - 2.XI. According to the future scenario, in case of increase of temperature by 2°C, in spring the transition date above 10°C will be observed on 25.III, in autumn transition date of temperature below 10°C on 14. XI. Therefore, by the scenario in spring transition date of the temperature above 10°C will start 11 days earlier, and in autumn 12 days later compared to the baseline. According to the abovementioned, vegetation period is expanded from 211 to 234 days or for 23 days. These days allow to conduct corresponding agro technical activities 11 days earlier in spring and 12-day prolongation in autumn for optimal time. Table 1 contains calculated sums of active temperatures (>10°C), which makes 3830°C (basic), for a mountainous region, and according to the scenario in case of increase by 2°C makes - 4290°C. It fully provides high quality productivity of grain, vegetables, vines, fruit and other crops in corresponding the soil humidity. In the high mountainous region, the date of temperature above 10°C will be observed on 31.V and transition date of temperature below 10°C will be - 18.IX (baseline). By the scenario in case of increase by 2°C, transition of temperature above 10°C in the spring will be marked on 22.V, in autumn transition of temperature below 10°C will be on 28. IX. (Table. 1). In the spring by the scenario in case of increase of temperature by 2°C, above 10°C will start 9 days before compared to the baseline and in autumn the vegetation period will be prolonged by 10 days. Therefore, the length of the vegetation period is extended from 110 days (baseline) to 129 days, or 19 days. In the terms of additional days, it will be possible to start the vegetation period 9 days earlier for pasture development and preparation of the animals prior to transportation to the pastures. And in autumn (in 10 days), preparation of more food for the coming winter and better preparation for the winter period. Due to global warming in the given high mountainous region by the scenario is envisaged (2030-2050), increase of temperature by 2°C where the calculated sum of active temperature makes 1890°C, which is significantly higher than the sum of the baseline temperature (Table 1). In conditions of mentioned temperature development of agricultures will be better guaranteed.

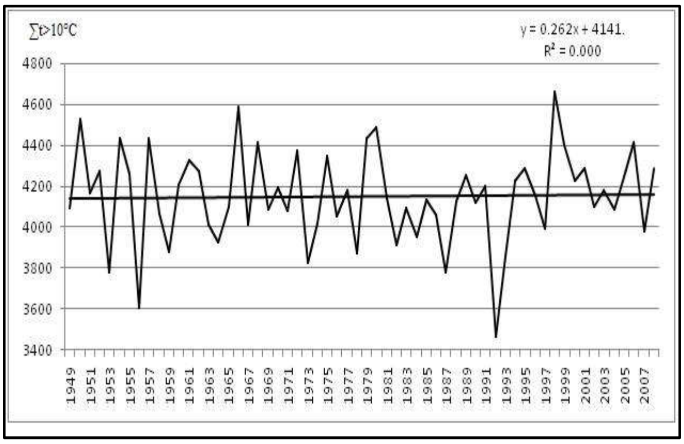


**Fig. 1. Dynamics of the sums of active temperature (>10°C) in humid subtropical region of Guria (Anaseuli-Ozurgeti, 1949-2008) in Georgia**

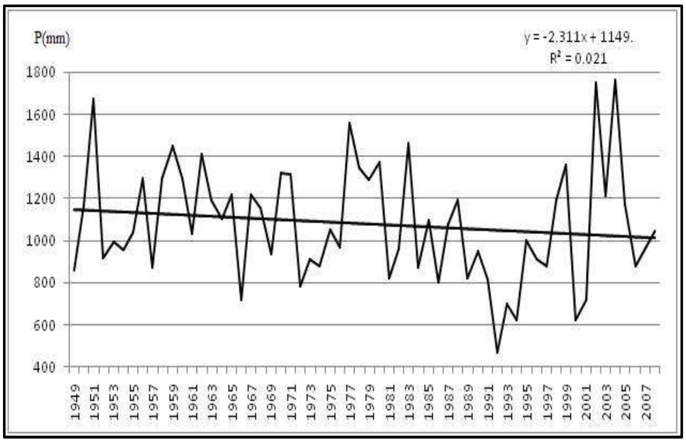


**Fig. 2. Dynamics of the atmospheric precipitation (mm) in humid subtropical region of Guria (Anaseuli-Ozurgeti, 1949-2008) in Georgia**

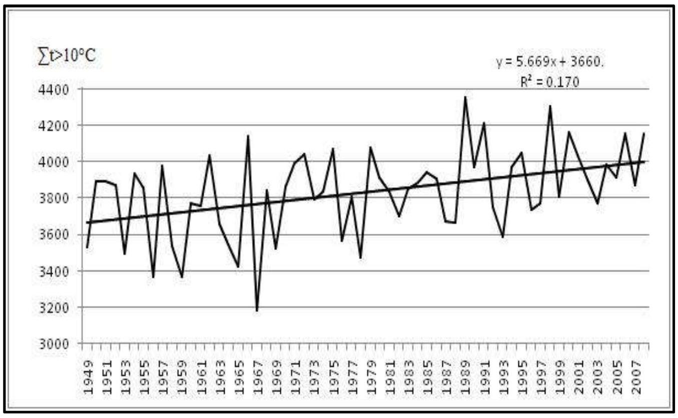


**Fig. 3. Dynamics of the sums of active temperatures (>10°C) the mountainous region of Kakheti, Georgia (Akhmeta, 1949-2008)**

According to the observation data during 60 years (1949-2008) in the region, global warming impact on the sums of active temperature and atmospheric precipitation was explained by the trends (Fig. 1, 2, 3, 4, 5, 6). In all regions during the vegetation period there were identified trends of increase of sums of active temperatures and decrease of atmospheric precipitation. For example, in the humid subtropical regions the sum of active temperature for the initial period (1949) made 4140°C, and by the end of 2008 reached 4160°C (Fig. 1, 2). There is detected the sum of the temperature increase before 20°C (Table 2).

It is clear, that the sum of the temperature increase is small, but the fact is that the tendency of increasing of sum of active temperatures is still observed. Materials of the above mentioned 60-year observation period include the initial period of global warming (70-80-ies of the XX century), when the process of its actions was revealed. In this period global warming had insignificant influence on the increase of the sum of active temperatures in the humid subtropical region. Because a big amount of heat was mainly spent for moisture evaporation spread from the Black Sea basin towards the land. As evidenced by the paper (Elizbarashvili *et al*., 2013), which stated that in the conditions of global warming due to the specific character of the west Georgian humid climate traits, a large amount of heat is spent on evaporation, and as a result the air is less heated despite of the above-mentioned tendency of small increase of the sum of active temperatures, in the humid subtropical region, according to the future scenario of temperature in case of increase of temperature by 1°C increase of the sum of temperatures (>10°C) the increase is expected to 200°C and a little more (by 2050). In connection to global warming of the climate, the picture is different in mountainous and high mountainous regions of East Georgia (Fig. 3, 4). According to the trend in the mountainous region (Figure 3,4) the surplus of the sum of temperature exceeds 300°C. In this period, it is quite a high increase, and every 10 years an average speed of increase is about 57°C (Table 2). Increased sum of active temperatures (4010°C) completely provides high productivity of agricultures and yields two harvests from the same land area (wheat, barley, oats, rye, corn, etc.). According to the trend in the high mountainous region at the beginning of 1949 the sum of active temperatures was 1340°C and for 2008 it amounted to 1550°C (Fig. 5, 6).

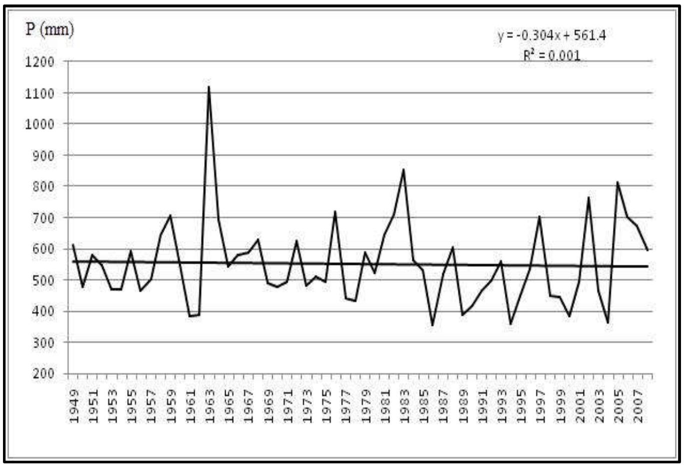


**Fig. 4. Dynamics of the atmospheric precipitation (mm) the mountainous region of Kakheti, Georgia (Akhmeta, 1949-2008)**

The sum of temperature increased by 210°C (Table 2). This is an impressive increase for the mentioned 60-year period, which will be useful for development of agricultures and forest landscapes in high mountainous conditions. Tendency of increase of the sum of active temperatures due to global warming if it continues this way (2040-2050), will increase by more 100-150°C. Which on the territories with less heat and with adequate soil humidity will improve the development of the plants.

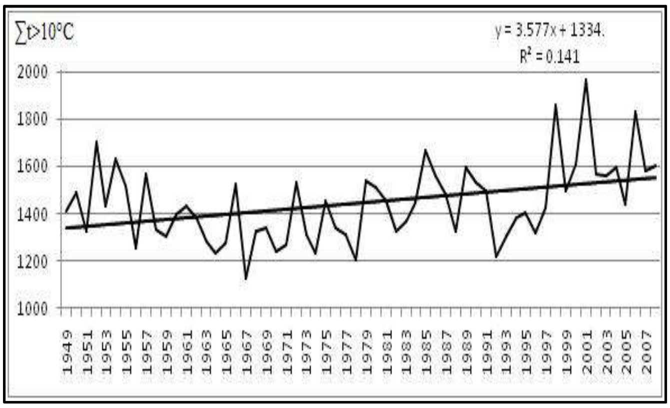


**Fig. 5. Dynamics of the sums of active temperatures (>10°C) the mountainous region of Kakheti, Georgia (Omali-Akhmeta, 1949-2008)**

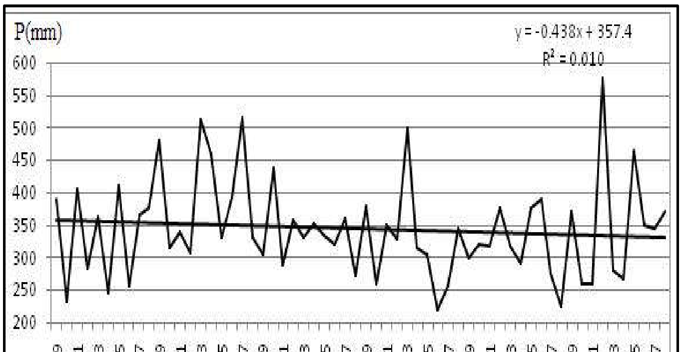


**Fig. 6. Dynamics of the atmospheric precipitation (mm) the mountainous region of Kakheti, Georgia (Omali-Akhmeta, 1949-2008)**

According to the trends in the mentioned regions, in the warm period (IV-X) there were also revealed tendencies of reduction of atmospheric precipitation (Fig. 1, 2, 3, 4, 5,6). So, for example, in humid subtropical regions precipitation is reduced by 139 mm, average speed of decline is 23 mm every 10 years, in Kakheti mountainous region it is reduced by 15 mm, and high mountainous regions by 26 mm (Table 2). The mentioned precipitation decreasing trend, if continued in the same way, for a given period (2040-2050) could be doubled by the end of the period in the mountainous and high mountainous regions with already small amount of precipitation. This will obviously create unfavorable conditions for production, growth and development of agricultures and other types of plants if the soil moisture deficits will be created. In this regard, we note that on the territories of several municipalities of eastern Georgia, as a result of the research was were confirms analogic tendencies of increase of the sum of active temperatures and decrease of the sum of atmospheric precipitation (Meladze and Meladze, 2013; Meladze and Meladze, 2015). In the conditions of global warming, while the increase of the sums of active temperatures (>10°C), for production of agricultures and the normal growth and development of productivity, atmospheric precipitation has the most important role in the vegetation period, especially during the active vegetation period (VI-VII-VIII), when the crop is being formed, buds are conceived in remontant cultures and more. Here we bring sums of multiannual average precipitation (1949-2008) for humid subtropical region during the vegetation period (IV-X). According to observation data of a meteorological station in Anaseuli (Ozurgeti Municipality) it makes 1079 mm. The mentioned precipitation during the whole vegetation period ensures normal development of the production of agricultures. However, in separate years in the active vegetation period (VI-VIII) precipitation is low (434 mm). In this case, there is the need to irrigation of the soil under the crops where it is possible.

In the mountainous region of Akhmeta Municipality according to the data of a meteorological station during the vegetation period atmospheric precipitation is 552 mm. Given amount of precipitation (552 mm), during the whole vegetation period and especially during the active vegetation period (237 mm) is not sufficient for plants. Moreover, the given the mountainous region is near the edge of the arid conditions, where the sum of active temperatures significantly increases and frequency of droughts is increased. Therefore, to improve the plant conditions and crop preservation, there will be necessary to increase irrigation 2 or 3 times, and preferably increase irrigation water norms by 15-20%, as well as loosening-cultivation of the soil surface under crops. In the high mountainous region of Omalo (Akhmeta Municipality) according to the data of a meteorological station during the vegetation period atmospheric precipitation is 344 mm. Vegetation period here is short (VI-IX), and during the active vegetation period (VI-VIII) it is 264 mm. Obviously, the amount of precipitation is small, but in the conditions of the area from corresponding cultures it is possible to obtain high-quality, satisfactory harvest - Autumn grain, vegetables, legume, potatoes, berries, roots for animal food (Kuuziku", „ ESCO") Also, it is recommended for the development of the Forest landscapes. In case of irrigation of crops, it is not excluded to obtain a high yield, because of the scenario in the region (increase by 2°C), the sum of active temperatures favorable for plants is markedly increased (Table 1).

Taking in view global warming for the humid subtropical, mountainous and high mountainous regions, by application of mathematical statistics method, accepted in Agrometeorology there were made regression equations (9, 10) (Table 3). For example, in the humid subtropical zone at 100 meters by scenario (increase by 1°C) was determined the sum of active temperatures (>10°C). In the corresponding equation (Table 3) n=0.021h +54, instead of h was inserted the number 100 and by mathematical action was adopted number 56 which starting from February 1, will give the number of days with temperature above 10°C to the date of occurrence. Inserting the obtained number (56) also in the equation of the corresponding humid subtropical zone instead of n (Table 3), by appropriate action will be obtained the sum of active temperatures of 4340°C (rounding). By the equations there are defined the sums of active temperatures according to baseline and future scenario (2030-2050), in case of temperature increase by 1 and 2°C and there are allocated the zones for distribution and development of agricultures. In the humid subtropical regions according to the altitude above the sea level, with every 100 m gradation there are separated 4 zones for distribution of major citrus crops, which provide conditions for the development and growth of high- quality fruits and full ripening conditions. In particular, generally tangerines need 4000-4200°C, oranges and grapefruit 4200-4300°C and more, lemon 4000-4100°C. But it is preferable to harvest fruits in case of 3800-4000°C, because the sums of mentioned temperature provide light green, partly yellowish coloring of fruits when content of vitamin „C'' is relatively high. Therefore, production of lemon is possible in all zones, if reliably protected from winter frosts (Table 4).

The table shows that by the scenario in case of increase by 1°C in the I - micro zone full maturation of citrus crops fruits is expected every ten and more years, while by the baseline in the same zone full maturation of lemon and tangerine is also expected every year, orange and grapefruit 6-7 times every ten or more years. Therefore, in the given zones it is possible to make evaluation of the full maturity of citrus fruits every ten and more years. Which points to the fact of possibility of diffusion of citrus fruits by the scenario in case of increase by 1°C, compared to baseline in I and II zones 100-150 m higher. By the future scenario (increase by 1°C) taking in view increase of the sum of temperature is expected improvement of the productivity and quality of the other types of agricultures (cereals, vegetables, tea, wine, technical-oils and oils), conditions of soil humidity ensured. In Kakheti mountainous (500-1500 m) and high mountainous (1500-2500 m) regions of eastern Georgia coming out from the above mentioned, there are separated agro-climatic zones, according to baseline and scenario in case of increase of the temperature by 2°C.

I - the zone includes the mountainous region and extends from 500 m to 1000 m altitude (masl). Sum of temperatures (>10°C) makes 3640-2890°C (baseline), and by the scenario in case of increase by 2°C, makes 4210-3360°C. The sum of increased temperature is sufficiently large, and can offer good opportunity for producing and distributing production of agricultures, especially in areas where there is the lack of heat. In mountainous regions it will also contribute to having the second harvest of the crops from the same area of land (barley, oats, spring wheat, early grain and silage corn), diffusion of late grape varieties providing their full maturity.

II - zone extends from 1000 m to 1500 m altitude, the sum of temperatures is 2890-2140°C, by the future scenario (increase by 2°C) 3360-2510°C. According to the increase of the sum of temperature, there will possible to grow early vines, fruit, grain, vegetables, potatoes and other crops.

III - belongs to a high mountainous region and extends to 1500 m to 2000 m altitude, within the boundaries of the zone the sum of baseline temperature is 2140-1390°C, and in case of increase by 2°C according to the scenario - 2510-1660°C. Among these altitudes it includes the lower border of subalpine zone (1800-2000 m). In the zone the sum of the baseline temperature is reduced, compared to future scenario (increase by 2°C) by 370-270°C. The sum of increased the temperature turns out to be useful for growth and development of autumn and spring grain, vegetables, potatoes, early fruit, berries (black and red currant), sea-buckthorn. Also for livestock juicy root food and grazing lands.

IV - zone extends from 2000 m to 2500 m altitude and includes upper subalpine border. In mountainous areas sum of the baseline temperature is smaller and according to the heights makes 1390-640°C. It is less cost-effective for development of vegetable crops and livestock pasture grasses, especially up to 2400-2500 m altitude. According to the future scenario (increase by 2°C) the sum of active temperatures is increased in accordance with the heights from 1660°C to 810°C, compared with the baseline, which will improve the development of the mentioned crops. In this area of 2000 m to 2300 m by scenario (increase by 2°C) it expected that the sum of the temperature will increase from 1660°C to 1180°C, which better compared to the baseline for spread and development of wheat (spring), vegetables, barley, oat, potato, berries, roots, livestock and grasslands. We note that as a result of the influence of global warming, analogical are changes of the zones of agricultures in the high mountainous areas, it is not excluded that there takes place changing of the forest landscape zones as well. To the North of the Central Caucasus range watershed in Kazbegi Municipality, Georgia, in the high mountainous zone there is recorded birch forest young natural plant seedling growth in the upper zone on the border of subalpine forests above 2560 m 125 meters. Which before, by the 2002 census was not observed at the altitude of 2685 meters. The researcher connects this fact to the impact of climate change (Togonidze, 2015).

## Conclusion

The given mountainous region with its natural landscape, orographic conditions and forest landscapes is also a very prospective region. With the spread of favorable production of agricultures in the new zones, during summer and autumn-winter seasons they have a significant condition for tourism and recreational development. Its great potential for tourism and recreation in the early years due to lack of infrastructure was virtually untapped. In the above mentioned region in allocated for agricultures agro- climatic zones, agricultural workers and farmers with the local population, will be able to grow and spread new varieties of cost-effective selected species. On the places where local population will be employed in their cultivation, demographic movement will stop (the process) and they will be settled. Products made by them will be mainly consumed by the local population, it will be possible to sell part of it, which will improve their socio-economic conditions. It should be noted that on July 16, 2015, the government of Georgia passed a law on the development of mountainous regions, with the aim to ensure the well-being of people living in mountainous regions, raising living standards, employment promotion, improvement of social and economic conditions. In accordance with this important law, this paper summarizes the results of survey directly for some of the mountainous regions. Our studies confirm global warming effect on humid subtropical, mountainous and high mountainous regions of Georgia, which is more intensive in the mountainous and high mountainous conditions. Global warming has a significant impact on the increase in the sums of active temperatures, prolongation of the vegetation period, general reduce of the precipitation and frequented droughts. Therefore, distribution zones of agricultures by future scenario are changing, in humid subtropical zones by - 100-150 m above and in the mountainous and high mountainous areas by 200-300 m above compared to the current spread of the zones. According to future scenarios (2030-2050) increase of temperature by 1 and 2°C shows that it will not have a significant effect on agricultures if increase of temperature in future by elaborated temperature scenarios will not exceed the temperature indicators. Though in case of increase of the sums of active temperatures, it is not excluded that there will be activated and widely spread pests and diseases of plants multiplies to 2-3-generations more than at present. It will create problems for entomologists and phytopathologists, thus it will be necessary to give more attention and efforts to fight against them for effective use of methods. Coming out from global warming impact it is recommended to use some of the softening means for expected negative events as adaptation measures: together with the main indigenous species, we need to promote selected agricultures, which will have a relatively high resistance to heat and drought. Developing of terraces (where available), on the slopes of mountains and high mountains (10 degrees or more) can reduce water runoff and intensive spending of soil moisture. According to the needs of agricultures, there should effectively be used various irrigation methods. It is important to build windbreaks, against the prevailing wind directions, which will protect agricultures and create conditions for development of favorable microclimate.

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