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Ecology

Agroclimatic Zone Scenarios of the Distribution of Crops with Account of Global Warming

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ABSTRACT. Main aspects of global warming as a result of man-induced (anthropogenic) impact and partially the unstable ecological state of the biosphere are considered. A trend towards a rise in air temperature in Eastern Georgia against Western Georgia is revealed. In this connection a rise in temperature by 2 and 1°C, respectively, for agroclimatic zones is taken into consideration. According to the completed regression equations, the active temperature sums at a 1000°-gradation of air temperature (above 10°) are determined. Five agroclimatic zones for distribution of respective crops are marked out for the territory of Georgia in the case of a rise by 2 and 1 degrees under the developed scenarios, according to which in the case of a rise in temperature by 1 and 2 degrees, the active temperature sum exceeds on the average the active temperature sum in the currently existing zones by 200-300 degrees and 400-500 degrees, respectively. *© 2009 Bull. Georg. Natl. Acad. Sci.*

Key words*: global warming, ecological state of biosphere, agroclimatic zone, active temperature sum, regression equation.*

At the end of the 20th century, analysis of abnormal ecological events on the Earth enabled scientists to conclude a disruption of harmonic ecological balance in the biosphere as a result of an unforeseen anthropogenic effect.

Upon wide use of mineral resources (oil, coal, etc.) ample emissions of heat and carbon dioxide gas (CO_2) are taking place. The mechanism of impact of the latter on the climate resembles the creation of the so-called "hothouse effect". A process like the action of carbon dioxide gas leads to global warming of air temperature [1, 2]. G. I. Budiko [3] notes that a 6% annual growth of industrial energy can cause a rise in temperature up to 3°C, in about a century. Obviously, the said rise in temperature will change the existing climate and affect a whole number of sectors in the country, particularly the agricultural strategy. Therefore, a significant increase in carbon dioxide in the atmosphere as a result of the burning of the abovementioned mineral resources, emissions by a great number of factories and plants and motor transport are worth noting. If the process continues, then according to preliminary analysis [4], by 2030 the carbon dioxide gas in the atmosphere will double and the air temperature will rise by 2-3°C, which will speed up global warming. At present, such global warming on the planet is observable, and the air temperature is increased by a 0.6°C, on the average. Therefore, climate change should be given proper attention in order to specify the agricultural crop-distribution zones and to make appropriate amendments [5]. According to [6], even one degree rise in temperature might be of great practical importance. It can lead to a shift of isotherms on the earth surface by 260 kilometers and result in a change in the latitudinal strike of different regions, under whose conditions the growth and development of the already adapted agricultural crops or other plants are taking place.

In connection with the rate of global temperature increase, we refer to 4 interesting scenarios of global climate change developed by the World Meteorological

Society. According to the first scenario, the rate of global temperature increase in the current century will be 0.25°C in contrast to the last century. In the case of the second scenario, the rate of increase will account for 0.15°C, while upon implementation of the third and fourth scenarios – 0.05°C [7].

It should be noted that by estimates of researchers [8], Eastern Georgia has been found to reveal a more active tendency towards temperature increase than Western Georgia. Proceeding from global warming and according to altitude of locations in Western Georgia, a 1°C temperature rise is being projected for the agroclimatic zone scenario of the distribution of agricultural crops, and a 2°C rise in Eastern Georgia. Based on the above, agroclimatic zones with active temperature sums over 10°C at a 1000°C gradation have been marked out and scenarios for distribution of farm crops in the agroclimatic zones have been developed, being implemented for the first time in Georgian agriculture. To direct the problem along the right course, the data of long-term observations conducted at the hydrometeorological stations existing in Georgia have been analyzed [9]. In particular, the dates of temperature rise above 10°C and active temperature sums together with the locations' altitudes above sea level, which have been processed by a mathematical statistics method [10]. A close correlation has been detected upon temperature rise of 1 and 2°C (respectively) under the developed scenarios: R=0.99 for Western Georgia, R=0.98 for Eastern Georgia and R=0.97 for all Georgia. Based on the established correlation, regression equations were formulated:

for all Georgia T= -29.294n-0.788h+6081, (1)

for Western Georgia T= -16.7115n-1.127h+5496, (2)

(scenario, at 1°C temperature increase),

for Eastern Georgia T= -44.254n-0.1504h+6742, (3)

(scenario, at 2°C temperature increase).

In the equations, T is the active temperature sum over 10°C, n is the number of days from February 1 to the date when the temperature rises over 10°C, h is altitude above sea level (in m).

The correlation between the date of temperature rise above 10°C and the active temperature sum was first detected by Academician T. Davitaia [11], but not for vertical zonality. In our equations we used altitude above sea level, enabling to compute the active temperature sums at any altitude.

We would like to note that in determining the active temperature sum for a given equation it is necessary that the date of temperature change above 10°C be known. To this end, the data on long-term meteorological observations were processed and relationships between the date of temperature going above 10°C and the altitude above sea level were established. This correlation is rather high in all Georgia (r=0.85), also in Western Georgia under the scenario of a 1°C increase (r=0.87) and in Eastern Georgia - at a 2°C increase (r=0.97); the respective equations were also formulated:

for all Georgia n=0.0282h+57, (4)

for Western Georgia n=0.0275h+5, (5)

(scenario, at 1°C temperature increase);

for Eastern Georgia n=0.0359h+38 (6)

(scenario, at 2°C temperature increase).

In the equations, n is the date of temperature rise above 10°C from February 1 (number of days from February 1 to the date of temperature rise above 10°C), h is altitude above sea level (in m).

By means of the said equations we determined the active temperature sums of the 1000°C gradation; also, under the scenario, upon rise of 1 and 2°C and by means of the given equations, 5 agroclimatic zones of the distribution of agricultural crops were marked out on the territory of Georgia (Table 1).

In the agroclimatic zone I, the active temperature sum totals 4400-4000° C on the average and extends up to 300 m above sea level. The ripening of citrus fruit crops in this zone is ensured by the necessary active temperature sums in every 10 and more years at the 100-200 m altitude.

According to the scenario of the said agroclimatic zone, upon a temperature increase of 1°C the distribution of citrus fruit crops and fruit ripening are ensured by the active temperature sums every year at the 300-400 m altitude.

Under the scenario with a temperature increase of 1 and 2°C, the active temperature sums exceed the active temperature sums in zone I by 200-300°C and 400-500°C on the average, respectively. The difference is almost unchangeable in the rest of the zones as well.

In the agroclimatic zone II, the active temperature sums equal up to 4000-3000C on the average and extend to up to 900 meters. The zone is well suited for cultivating tea, viniculture, horticultural and other crops. It is established that the active temperature sum for industrial distribution of tea culture should be >3400°. Based on the above, in zone II it extends to about 550 m. At a 1°C increase under the scenario, tea cultivation area will spread upwards by 100-150 meters above sea level to cover about 650-700 m. The cultivation in the zone of commercial grapevines (Rkatsiteli, Saperavi, Manavis Mtsvane,

Active temperature sums (>10°) and Agricultural farm crops distribution in agroclimatic zones by vertical zonality (m)

Agro-climatic zone, a.s.l. (m)	Active temperature sums >10°			Agricultural crops distribution at a 1 and 2 °C temperature increase (scenario) according to altitude a.s.l. (m)						
	In all Georgia	In Western Georgia at a 1 °C increase (scenario)	In Eastern Georgia at a 2 °C increase (scenario)	citruses	Tea	Grapevine	Fruits	Grain maize	Winter wheat	Potato, barley, oats, vegetables, fodder root-crops
I 300	4000°	4170°	4540°	distributed at 100-200 m						
II 900	3000°	3210°	3500°	upon a 1 °C increase distributed at 300-400 m	distributed at 550m. Upon 1 °C increase distributed at 1000-700 m	distributed at 750-800 m	distributed at 1300-1350 m Upon a 1 °C increase at 1400-1500 m			
III 1500	2000°	2270°	2450°			upon a 1 °C increase is distributed at 900-950 m; upon a 2 °C increase - at 1000-1100 m	upon a 2 °C increase is distributed at 1550-1600 m	distributed at 900-950 m; upon a 1 °C increase – at 1050-1100 m	distributed at 1400-1500 m	
IV 2100	1000°	1310°	1420°					upon a 2 °C increase is distributed at 1200-1300 m	upon a 1 °C increase is distributed at 1500-1650 m; upon a 2 °C increase - at 1750-2300 m	Distributed at 1500-2100 m
V 2300	700°	1000°	1090°							upon increase by 1 and 2 °C is distributed at 2150-2300 m (respectively)

Tsolikauri, etc.) goes on well under conditions of active temperature sums of 3300-3400°C and above on the average. Such temperatures are noted at an altitude of 750-800 m above sea level. Under the scenario, upon temperature rise of 1°C, the grapevine varieties distributed in Western Georgia – Tsolikauri, Ojaleshi, Chkhaveri, Tsitska – will go upwards to 900-950 m above sea level. Upon the temperature increase of 2°C, the commercial grapevines cultivated in Eastern Georgia – Rkatsiteli, Saperavi, Manavis Mtsvane, Gorula, etc. – might spread up to 1000-1100 m above sea level. The said varieties will be distributed under the scenario in the agroclimatic zone III, where they are not currently cultivated. As regards horticultural crops (apples, pears, etc.), under the scenarios of a temperature increase by 1 and 2°C, they can be cultivated in the area located at up to 1400-1500 and 1550-1650 m above sea level, respectively.

In the agroclimatic zone III, the active temperature sum is from 3000 to 2000°C and extends up to 1500 m above sea level. Distributed here are such crops as wheat, maize, barley, oats, potatoes, etc. Based on the scenario, upon the temperature increase of 1°C the cultivation conditions of the aforesaid crops should improve. The distribution area of grain maize will widen to go up from 900-950 m to 1050-1100 m above sea level, while upon a 2°C increase – up to 1200-1300 m. The ripening of maize kernels at these altitudes will be ensured by the active temperature sums (2400°C on the average).

The cultivation of winter wheat in the said zone upon temperature rise of 1°C will go from 1400-1500 m up to 1550-1650 m above sea level, while upon a 2°C increase – up to 1750-1800 m. The ripening of wheat kernels will be ensured by the active temperature sums (1900-2000°). As can be seen, the wheat distribution area is widened and will transfer to the agroclimatic zone IV.

In the agroclimatic zone IV, the active temperature sum is reduced from 2000 to 1000°C. The zone is located at a 2100 m altitude above sea level. Predominant here are generally barley, oats, potatoes, partially vegetables and haymaking meadows and pastures. Under the developed scenario, upon temperature rise of 1 and 2°C, their growth and development conditions might improve, because the active temperature sums are likely to increase against the available in the zone sums by 300-400°C on the average and result in the widening of the crop distribution area up to 2200-2300 m above sea level.

In the agroclimatic zone V, the active temperature sum is obviously less (1000 to 700°C). The zone is located at a 2300 m altitude above sea level. According to the scenario, upon temperature rise of 1 and 2°C, the active temperature sums will definitely rise to total at an altitude of 2300 m above sea level 1000-1100°C, respectively. As a result, the commercial distribution of barley, oats, early potato, some vegetable crops and fodder root-crops (“kuuziku”, “esko”) as well as the development of meadows and pastures will be possible up to the said altitude.

ეკოლოგია

სასოფლო-სამეურნეო კულტურების გავრცელების აგროკლიმატური ზონების სცენარები კლიმატის გლობალური დათბობის გათვალისწინებით

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ნაშრომში მოცემულია კლიმატის გლობალური დათბობის ანთროპოგენური ზემოქმედების ძირითადი ასპექტები და, ნაწილობრივ, ბიოსფეროს ეკოლოგიური არასტაბილური მდგომარეობა. მითითებულია, რომ

ჰაერის ტემპერატურის თუნდაც 1°-ით მატებას შეუძლია გამოიწვიოს კლიმატური და აგროკლიმატური ზონების გადაწევა არსებული ზონიდან 2-3 ასეული კილომეტრით. გამოვლენილია აღმოსავლეთ საქართველოში ჰაერის ტემპერატურის უფრო მატების ტენდენცია დასავლეთ საქართველოსთან შედარებით. ამიტომ გათვალისწინებულია 2 და 1°-ით მატება (შესაბამისად) აგროკლიმატური ზონებისათვის.

მრავალწლიური მეტეოროლოგიურ დაკვირვებათა მასალების სტატისტიკის მათემატიკური მეთოდით დამუშავების საფუძველზე, მიღებულია მაღალი კორელაციური კავშირები ჰაერის ტემპერატურის 10°-ს ზევით გადასვლის თარიღს, აქტიურ ტემპერატურათა ჯამსა და ზღვის დონიდან სიმაღლეს შორის. აქედან გამომდინარე, შედგენილია რეგრესიის განტოლებები, რომელთა მიხედვით განსაზღვრულია ჰაერის ტემპერატურის 10°-ს ზევით აქტიურ ტემპერატურათა ჯამები 1000°-ის გრადაციით. განტოლებებით განსაზღვრულია აქტიურ ტემპერატურათა ჯამები აგროკლიმატური ზონების მიხედვით, შემუშავებული სცენარების მიხედვით 1 და 2°-ით მატებისას.

სცენარებით, ტემპერატურის 1 და 2°-ით მატებისას აქტიურ ტემპერატურათა ჯამები (10°-ს ზევით) საშუალოდ 200-300°-ით და 400-500°-ით (შესაბამისად) მეტია ამჟამად არსებულ ზონებში აქტიურ ტემპერატურათა ჯამებზე.

საქართველოს ტერიტორიისათვის გამოყოფილია 5 აგროკლიმატური ზონა, რომლებშიც შემუშავებულია სცენარები ტემპერატურის 1 და 2°-ით მატებისას შესაბამისი სასოფლო-სამეურნეო კულტურების გავრცელების მიზნით, რომელიც, საქართველოს მასშტაბით, სოფლის მეურნეობისათვის პირველადაა შესრულებული.

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