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Ecology

Influence of Global Warming on Agroclimatic Indices of Agriculture and Intensity of Droughts in Kakheti Region, East Georgia

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ABSTRACT. Against the background of current global warming the temperature in Eastern Georgia is increased by 0.4-0.5°C, on average, which might increase by 2°C and more in 2050. Such an increase of temperature shows the tendency of change (increase or decrease) in agroclimatic factors (active temperature, precipitations, hydrothermal coefficient) determining growth and development of agricultural plants, their productivity etc. According to the data of the long standing (1949-2008) meteorological observations in Kakheti region, the sums of active temperatures and the period of vegetation are increased, while the atmospheric precipitation (April-October) is decreased in some municipalities. Based on the mentioned observation data the dynamics of agroclimatic factors (sums of active temperatures and atmospheric precipitations) were mapped in trends showing the tendency of increase of the active temperature sums in the region which might improve the growth and development of agriculture in vertical zones. As a result of decreased atmospheric precipitations and the increase of the above-mentioned sums of active temperatures (according to trends) in the active vegetation period the decrease of the hydrothermal coefficient (HTC) is also marked. On the ground of the meteorological observations of sixty years (1949-2008) the hydrothermal coefficients were defined and the arid and humid conditions of the vegetation period were estimated. In particular, different kinds of frequent droughts are marked on most territories of Kakheti that require some measures to be carried out. The above-said studies show that global warming has both positive and negative action in vegetation period. In conditions of certain soil humidity the sum of increased active temperatures will be favorable on the territories, where agricultures suffer heat deficit. The area of plant distribution might extend higher above sea level. The tendency of the hydrothermal coefficient decrease will have a negative influence on the productivity of agricultural plants causing serious problems to agrarian sector because the weak and moderate droughts might intensify. Therefore, given global warming some preliminary activities for climate moderation are necessary. *© 2016 Bull. Georg. Natl. Acad. Sci.*

Key words: global warming, active temperature sum, atmospheric precipitation, hydrothermal coefficient, drought, agriculture

Modern global warming of climate is a serious ecological, social and economic problem. It has an influence on different types of climate formed in the course of years, the change of which causes dangerous hydro-meteorological phenomena: melting of eternal snows and glaciers, floods, storms, tempests,

Table 1. Agroclimatic indices in Kakheti region (1949-2008)

Municipality (meteostation)	Date of air temp. tchange (>10°C)	Date of air temp. rise (<10°C)	t>10°C Duration (days)	Active temperature sum (>10°C)	Active temperature sum >10°C (VI-VIII)	Atmospheric precipitations sum (IV-X)	HTC index (IV-X) sum	Atmospheric precipitations sum (VI-VIII)	HTC index (VI-VIII)
Gurjaani	1.04	4. 11	217	4035	2114	582	1.5	236	1.1
Dedoplistskaro	17.04	21.10	189	3360	1948	426	1.3	185	1.0
Telavi	4.o4	1.11	211	3841	2044	572	1.5	254	1.2
Omalo(Akhmeta)	31.05	18.09	110	1444	1226	344	2.3	264	2.1
Sagarejo	12.04	26.10	197	3490	1953	561	1.6	232	1.2
Kvareli	2.04	4.11	216	4057	2114	702	1.7	299	1.4

droughts causing great damage to many fields of economics. It has an influence on the change of agroclimatic factors determining the growth and development of agriculture and their productivity.

At the end of the 20th century it was noted in [1,2] that against general background of global warming the climate of Eastern Georgia also undergoes warming. The temperature is increased by 0.4-0.5°C, on average, which might increase by to 2°C and more by 2050, which is especially important for relatively lower agricultural zones (300-500m above sea level) because in such places the thermal regime might activate in vegetation period. Therefore, it is necessary to take preventive agrotechnical measures to maintain moisture in the soil under the cultures.

According to the study [3], the foci of intensive warming are in the south part of the Kakheti ridge, where an average rate of annual temperature increase in every 10 years is above 1°C. The moderate (rate 0.06-0.1°C) focus of warming is in the south-east part of the Gombori ridge. In the process of the temperature change the earth resource degradation (expressed in soil salination) caused by global warming is revealed on the example of the valley, on the right hand bank – of the Alazani river (south-east part) Signaghi municipality, for which an appropriate irrigation measures are developed [4]. Along with other extreme hydro-meteorological phenomena, global warming causes intensive and drastic droughts [5].

The goal of the present study is to reveal the tendency of change (increase or decrease) of agroclimatic factors in vegetation period caused by global warming (determining the growth and development of agricultural plants, their productivity, quality etc), in particular, changes in the sums of active temperatures (>10°C) and the atmospheric precipitations, hydrothermal coefficients and duration (days) of vegetation period. To this end we used the longstanding (1949-2008) meteorological observation data (the sums of atmospheric precipitations, mm, and average daily air temperatures per month) of the National Environment Agency obtained from six municipalities of Georgia located at different levels above the sea (Gurjaani 415 m.a.s.l.; Kvareli - 449 m.a.s.l; Telavi-568 m.a.s.l; sagarejo - 802 m.a.s.l; Omalo, Akhmeta-1880 m.a.s.l;). As a result of analysis and processing of the material obtained the sums of annual active temperatures and atmospheric precipitations were calculated. According to the above mentioned indices the hydrothermal coefficients were

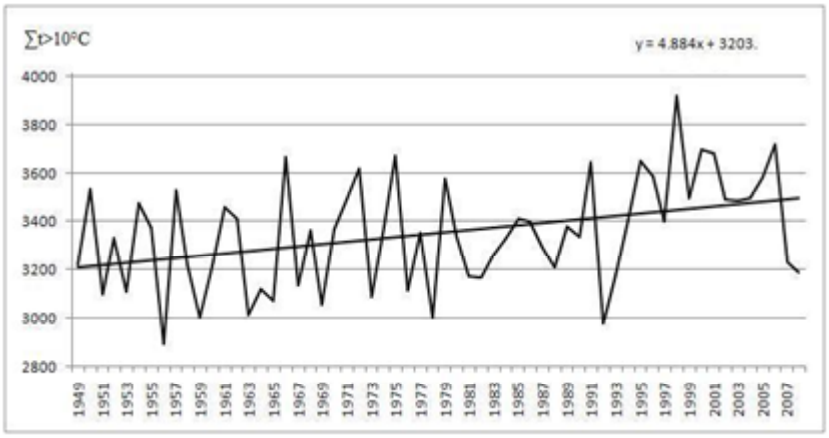

Fig.1. The dynamics of active temperature (>10°C) sums (1949-2008).

defened (G. Selianinov method). Table 1 shows agroclimatic indices.

The Table shows that the air temperature rise above 10°C begins earlier (1-4. April) at 400-600 m a.s.l, a bit later (12-17. April) at 800-1000 m, and even later (31.May) at 1800-2000 m. The dates of air temperature falling below 10°C at the given heights are also recorded. The other agroclimatic indices are given in similar pattern.

The above mentioned long-term agroclimatic indices (1949-2008) cover the period of the beginning of global warming (70-80s of the 20th century), the beginning of its influence on agroclimatic indices. Thus, we divided the data of 60-year observations into two 30-year periods.

The first period covers 1949-1978 and the second 1979-2008. The analysis showed drastic changes in agroclimatic indices observed in municipalities in the second period. For example, the air temperature rise above 10°C begins earlier and the fall below 10°C ends later. The sums of active temperatures is increased and the vegetation period (days) is longer compared to the first one. As to the atmospheric precipitations in the vegetation period (April-October) it is decreased in all municipalities, except Kvareli and Dedoplisckaro. The HTC are also decreased throughout the whole vegetation period as well as in the period of active vegetation (June-August). The dynamics of the above said agroclimatic indices related to global warming was mapped in trends, showing identical tendency of increase of active temperatures sums in all municipalities. For illustration, the trend of the Dedoplisckaro municipality located in relatively arid conditions is provided (Fig. 1).

The trend clearly shows the tendency of the active temperatures sum increase (Table 2).

If the increase of temperature sum continues within the same period (60 years), then in 60-70 years it will double that might improve the development of cultures in vertical zones especially in the North-East and North-West of the region. Due to the temperature increase the plant productivity increase on the territories of Iori plateau, Shiraki and Eldar valleys should be of special concern. The problem can be solved by efficient use of water resources (irrigation system).

The trends also show (Fig. 2) that in vegetation period the tendencies of increase and decrease of atmospheric precipitations are observed in the municipalities of Kakheti region. The tendency of decrease is observed in Akhmeta (Omalo), Gurjaani, Telavi and Sagarejo. The results of the given research are also confirmed in other studies [3].

The sums of atmospheric precipitations (340-580 mm, except Kvareli 700 mm) are not enough from the agricultural point of view. It is even lesser (180-300 mm) in active vegetation period (June-August) (Table 1). Therefore, the trend shows that as a result of de-

Table 2. The changes in HTC indices of the sums of active temperature (>10°C) and atmospheric precipitations (mm) according to the trends in Kakheti region

municipality	active temperature sum(>10°C)				Average rate in every 10 years	
	Beginning of the period	End of the period	Increase	Decrease	Increase	Decrease
Gurjaani	3955	4113	158		27	
Dedoplistskaro	3208	3496	288		48	
Telavi	3715	3968	253		42	
Omalo (Akhmeta)	1338	1549	211		35	
Sagarejo	3364	3610	246		41	
Kvareli	3937	4177	240		40	
Atmosphericprecipitationsums, mm (IV-X)						
Gurjaani	584	561		23		4
Dedoplistskaro	418	445	27		5	
Telavi	577	568		9		1
Omalo (Akhmeta)	357	331		26		4
Sagarejo	621	500		121		20
Kvareli	686	717	31		5	
Hydrothermal coefficientindex (VI-VIII)						
Gurjaani	1.2	1.1		0.1		0.01
Dedoplistskaro	1.0	0.9		0.1		0.01
Telavi	1.3	1.1		0.2		0.02
Omalo (Akhmeta)	2.3	2.0		0.3		0.03
Sagarejo	1.3	1.1		0.2		0.02
Kvareli	1.4	1.5	0.1		0.01	

crease of atmospheric precipitations and increase of the above mentioned temperature sums (Fig. 3) the tendency of HTC decrease in active vegetation period is also observed creating very unfavorable conditions (droughts) for growth and development of agricultures and harvest etc.

It should be noted that hydrothermal coefficients (Table 1) are almost satisfactory in Kakheti region throughout the whole vegetation period (April-October) provided by greater amount of precipitations in April and May as well as in September and October, while it is far lesser in June, July and August. In the period (June-August) when the plant is actively growing and developing, productivity is increasing, perennials are budding etc., the HTC indices are not satisfactory (Table 1) and the droughts are quite frequent. It is especially characteristic of the territories of Dedoplistskaro and Iori plateau, though in certain years the other territories of the region in the East (Kvareli, Lagodekhi) are not safe from droughts either. Work [6] clearly describes water deficit, when the HTC water balance is less than one coinciding with very important months (June-August) of plant vegetation. In that period the atmospheric precipitations are little in the soil (at the depth of 20 cm). Complex action of such conditions have negative influence on the growth, development and productivity of agriculture unless the soil is irrigated.

The arid and humid conditions of vegetation period can be estimated according to HTC. In particu-

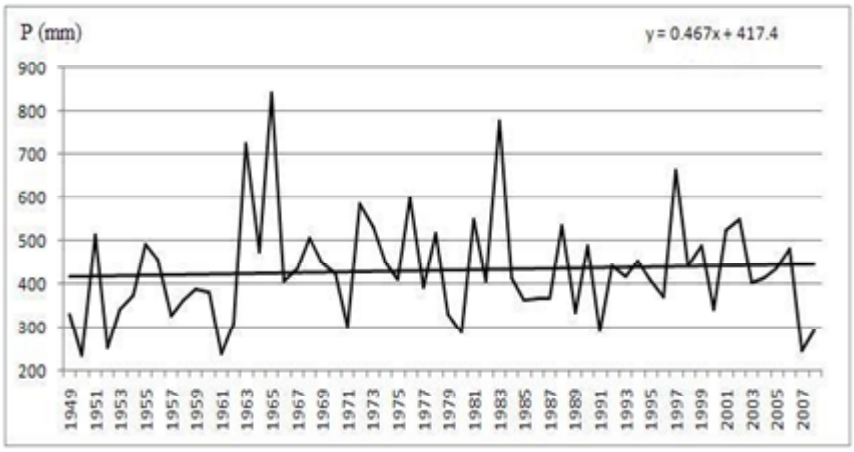

Fig. 2. The dynamics of atmospheric precipitations, mm (1949-2008).

lar, on the territory, where the balance of the water precipitated and evaporated (HTC) - is equal to 1.0, the plants are more or less provided with the moisture in soil and can continue vegetation, though for a short period (annual plants for 12-14 days, perennials 15-20 days). If the water balance (HTC) is less than 1.0 (<0.9-0.7), then there is the moisture deficit indicating a drought of weak intensity. Such a HTC is often observed on the south-west and south-east territories of Shiraki valley, Dedoplistskaro. The territories of Sighnaghi and Tsnori lowlands in the north-west to Dedoplistskaro are less wet, (HTC 1.1-1.3). The territories in Gurjaani, Sagarejo, Telavi and the southern part of Akhmeta are moderately wet (HTC 1.4-1.6). The territories of Kvareli and Lagodekhi (HTC 1.7-1.9) are moderate wetlands while the territories in the North-East to Akhmeta, Omalo are wetlands (HTK 2.0 and more) [7].

The tendency of decrease of the above agroclimatic indices, the atmospheric precipitations (in June, July and August) and HTC causes intensive droughts of different kind on most territories of Kakheti. Therefore, the agricultural workers and farmers should efficiently use maximum water resources of irrigation system and take measures against droughts to moderate it.

On the basis of observation material of 60 years (1949-2008) different hydrothermal coefficients i. e., the type of drought and the number of its occurrence in percents indicating occurrence of different droughts in every 10 years and more were defined in order to estimate intensive droughts of different kind in municipalities of the region under research (Table 3).

For example, in Dedoplistskaro weakly intensive drought (HTC <0.7-0.9) is observed in 32%, i.e., it is anticipated about 3 times in very ten years and more (HTC <0.6), while moderately intensive drought is observed in 13%, i.e. approximately once in every ten years etc. The table shows that the lesser the HTC the greater the drought intensity is. Therefore, in case of intensive drought it is required to increase soil irrigation norm and even intensiveness, if necessary.

The above said researches show that in vegetation period, global warming has an influence on agroclimatic indices and intensity of droughts of the region under study. As it was mentioned above, they have positive and negative influence. In particular, in conditions of relative soil moisture the increase of the sum of active temperatures (>10°C) will be favorable for those territories, where the agricultures suffer heat deficit. In addition, the area of the plant distribution might increase, especially into vertical zones. Decrease of atmospheric precipitations in some municipalities will make unfavorable conditions for normal productivity of agriculture. Also, the tendency of HTC decrease will have negative influence, due to which the weak and moderate droughts might

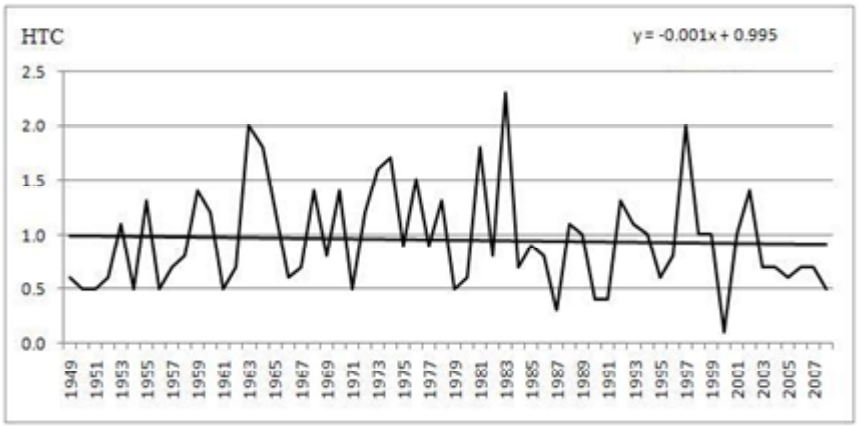

Fig. 3. The dynamics of hydrothermal coefficients (1949-2008).

Table 3. Hydrothermal coeficients and the types of droughts in vegetation periods (1949-2008)

Municipalities	HTC index	Drought type	Number of cases	%
Gurjaani	<0.7-0.9	Weakly intensive	15	25
	<0.6	Moderately intensive	8	13
	<0.5	Very intensive	2	3
Dedoplistskaro	<0.7-0.9	Weakly intensive	19	32
	<0.6	Moderately intensive	8	13
	<0.5	Very intensive	4	7
Telavi	<0.7-0.9	Weakly intensive	16	27
	<0.6	Moderately intensive	1	2
	<0.5	Very intensive	2	3
Sagarejo	<0.7-0.9	Weakly intensive	18	30
	<0.6	Moderately intensive	1	2
	<0.5	Very intensive	2	3
Kvareli	<0.7-0.9	Weakly intensive	10	17
	<0.6	Moderately intensive	1	2

intensify causing serious problems to agrarian sector. Therefore, it is necessary preliminarily to work out the methods and ways of adequate measures for climate moderation. Otherwise irreparable injury to the economics of the country is not excluded.

The above said shows that for production of grain crops it is necessary to take measures against the negative phenomena mainly on lowlands (300-500 m), in particular, Shiraki valley in Dedoplistskaro, in the vicinity of Sighnaghi, Tsnori and Iori plateau as well as on most territories of Gurjaani, Telavi and Sagarejo: to select relative temperature and drought resistant species; to reduce inter-row spacing in sowing of annual cultures to some extent (3-5 cm); wherever it is possible, to arrange terraces on the slopes (>10°) to reduce water flow and intensive discharge of moisture. The soil surface cultivation, tilling, has a good effect (reduces water evaporation). For reduction of water evaporation from the soil it will be efficient to arrange the wind belts. Also, it is very important to use modern irrigation and sprinkler systems.

ეკოლოგია

გლობალური დათბობის გავლენა აგროკულტურების ზრდა-განვითარების აგროკლიმატურ მაჩვენებლებსა და გვალვის ინტენსივობაზე აღმოსავლეთ საქართველოს კახეთის რეგიონში

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კახეთის რეგიონის მრავალწლიური (1949-2008) მეტეოროლოგიურ დაკვირვებათა მონაცემების მიხედვით, მომატებულია აქტიურ ტემპერატურათა ჯამები და გაზრდილია საფეგეტაციო პერიოდის ხანგრძლივობა, ხოლო ატმოსფერული ნალექები (IV-X) ზოგიერთ მუნიციპალიტეტში შემცირებულია. აღნიშნული დაკვირვებების მონაცემთა საფუძველზე გამოსახულ იქნა აგროკლიმატური მაჩვენებლების (აქტიურ ტემპერატურათა და ატმოსფერული ნალექების ჯამები) მსვლელობის დინამიკა ტრენდებით. რეგიონში გამოვლენილმა აქტიურ ტემპერატურათა ჯამების მატების ტენდენციამ, შესაძლებელია გააუმჯობესოს აგროკულტურების ზრდა-განვითარება ვერტიკალური ზონალობის მიხედვით. ასევე (ტრენდებით) გამოვლენილია ატმოსფერული ნალექების მატებისა და კლების ტენდენციები. შემცირებული ნალექებისა და ზემოაღნიშნულ ტემპერატურათა ჯამების მატების შედეგად (ტრენდის მიხედვით) მცენარეთა აქტიური ვეგეტაციის პერიოდში აღინიშნება ჰიდროთერმული კოეფიციენტის (ჰთკ) ინდექსის კლებაც. სამოცწლიანი მეტეოროლოგიურ (1949-2008) დაკვირვებათა საფუძველზე განისაზღვრა ჰთკ ინდექსები და შეფასდა ვეგეტაციის პერიოდის არიდული და ჰუმიდური პირობები. კერძოდ, კახეთის უმეტეს ტერიტორიაზე ფიქსირდება სხვადასხვა ტიპის ხშირი გვალვები. ზემოაღნიშნული გამოკვლევებიდან გამომდინარე, გლობალური დათბობა საფეგეტაციო პერიოდში დადებით და უარყოფით ზემოქმედებას ახდენს. მომატებული აქტიურ ტემპერატურათა ჯამი შესაბამისი ნიადაგის ტენიანობის პირობებში ხელსაყრელი იქნება იმ ტერიტორიებზე, სადაც აგროკულტურები სითბოს ნაკლებობას განიცდიან, ასევე შესაძლებელია გაფართოვდეს მცენარეთა გავრცელების არეალი ზღ.დონიდან სიმაღლის მიხედვით. ჰთკ კლების ტენდენცია ნეგატიურად იმოქმედებს კულტურების პროდუქტიულობაზე, მნიშვნელოვანი გამოწვევების წინაშე დააყენებს აგრარულ სექტორს, რადგან მოსალოდნელია სუსტი და საშუალო ინტენსიური გვალვების გახშირება. ამიტომ გლობალური დათბობის გათვალისწინებით გამოყენებულ უნდა იქნეს კლიმატის შერბილებისათვის წინასწარ შემუშავებულ ღონისძიებათა მეთოდები და ხერხები.

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