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Influence of Temperature and Precipitation Changes on Desertification

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***Abstract*—**The purpose of this paper was separation and study of the part of structure regime, which directly affects the process of desertification. A simple scheme was prepared for the assessment of desertification process; surface air temperature and precipitation for the years of 1936-2009 were analyzed. The map of distribution of the Desertification Contributing Coefficient in the territory of Georgia was compiled. The simple scheme for identification of the intensity of the desertification contributing process has been developed and the illustrative example of its practical application for the territory of Georgia has been conducted.

***Keywords*—**Climate change, aridity, desertification, precipitation.

I. Introduction

THE study of drought and desertification in Georgia has long history. In the middle of XX century Davitaya conducted an important work [1], investigated the frequency of droughts in the former Soviet Union, estimated the negative impact of drought on agriculture, in particular desertification process and outlined ways to reduce it. Having examined the drought and desertification favorable synoptic-aerological conditions; [2] characterized the regime of the dry and the moisture deficit situation and pointed the possible risks of desertification. Dry periods were explored in Georgia as a looming desertification previous ones and given its territorial distribution [3]. The so-called hot (arid) days' (days when at 13p.m. the air temperature ≥ 25°C and relative humidity ≤30%) characteristics were studied and revealed intra annual distribution of such days [4], [5]. The characterization of drought and desertification processes has been carried out by so-called dryness radiation index [6]. As the authors conclude, in the Kakheti region, desertification process is already underway. In [7], the drought and desertification process are viewed as a complex phenomenon, which depends on the atmosphere, soil and plant structure. For the assessment of the aridity, which allows the determination of the intensity of desertification, we used the so-called modified hydrothermal coefficient and relative number of soil productive moisture reserves.

The aridity quantitative evaluation complex method is given in [8]. The method of aridity evaluation has been treated by the use of Selianinov's hydrothermal coefficient and Shashko's moisture indicator. Activation of drought and desertification processes, first of all, should be promoted by the increase of temperature and reduction of rainfall. This is the basis of the works of a group of authors [9]-[11], where there are considered simultaneous instances of the norm on high temperature and low precipitation and defines the activity of the desertification magnitude with 6 criteria in Georgia. In [12], [13], the structural originality of the surface atmosphere temperature and precipitation regime are characterized, their impact on the process of desertification intensity during the strong climate warming period (1980-2009) in Georgia was assessed. Reference [14] describes global warming, characteristic of climate parameters favorable for the desertification, droughts, strong winds and the so-called variations on the hottest days. It is estimated to be a significant increase in recent decades, which leads to the activation of a process of desertification.

Conducted analysis of the trials of the desertification process in the territory of Georgia shows that describing desertification intensity of territorial distribution giving a mixed picture. In this case, instead of searching a method determining the desertification process, it is better to define the parameters of the climate regime structure, which can exert a significant influence on the desertification process. As it is known, first of all, such parameters are the surface air temperature and precipitation.

II. Study Method

In the global warming conditions, an empirical study of the structure regime of surface temperature and precipitation has been carried out as an example for the relatively small area of Georgia, where, due to the complex relief, almost all the varieties of the climate are represented. The average monthly surface temperature and precipitation values were taken for six months (April-October) in 28 observation stations for 1936-2009.

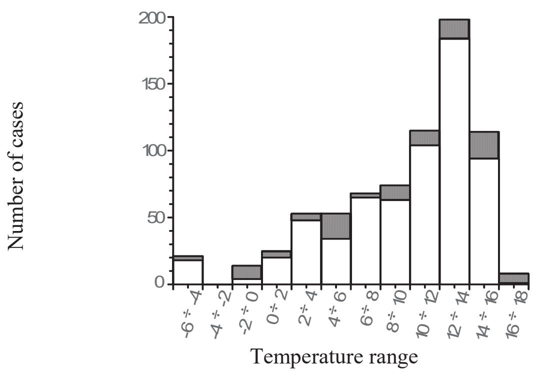

Fig. 1 Distribution of the average annual temperature in Georgia (1936-2009)

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In order to eliminate subjective errors, above mentioned observation materials are analyzed by the method of Obukhov-orthogonal decomposition of random function by the natural components [15].

In 1906-1995, when the climate warming occurred in eastern and southern Georgia, the cooling process was dominant in the western coastal area, while the climate change did not occur in the northern mountainous areas [16]. After the 1990s, the sharp warming period started in the entire territory of Georgia. Table I shows the year average temperature defined by the data of the 28 observation posts in 1936-2009 for three periods. In the first and second period, the temperature almost does not change, in the third period, during 25 years, temperature increased over 0.2 °C. It should be noted that in the same period, the precipitation mainly decreased.

The average annual surface temperature during 1936-2009 is shown on Fig. 1. The horizontal axis is marked on the 2-degree temperature ranges from -6 °C up to + 18 °C. On the vertical axis, the number of cases of the average annual temperature of 28 observation stations is given in the presented range during 74 years. Shaded part defines the few number of cases (The shaded lower boundary) and many (upper boundary) number of cases in the given range.

TABLE I
CHANGES OF TEMPERATURE AND PRECIPITATION IN GEORGIA

Period	Temperature ºC	Standard error	Precipitation, mm	Standard error
1936-1959	9.485	5.004	1108	608
1960-1984	9.492	5.079	1067	586
1985-2009	9.712	5.002	1066	601

The total average values of temperature and precipitation are given in Table I. It shows that in this period, the annual precipitation has reduction tendencies, especially in the first and second periods.

Distribution of the annual sums of precipitation is given in Fig. 2. As can be seen from the drawings, the distribution of temperature and precipitation in Georgia is sharply asymmetric opposite directions and underlines the fact that the temperature increases and at the same time, there is a reduction in the amount of precipitation. For example, the range of probability temperature is 12÷14°C, the main number of cases are in the range of -0.6÷12°C. Probability precipitation range is 750 ÷ 1000 mm, while their absolute majority are in 1000 ÷ 4250 mm range. This fact proves changes of the temperature and precipitation anomalies (deviation from average) in the period considered (1936-2009), which are presented on Figs. 3 (a) and (b).

In order to determine the anomaly changes in time, their linear (polyline) and nonlinear (curve built by the 7th-order polynomials, because it gives smaller standard inaccurate results) approximation has been carried out [17]. The formulas obtained by the linear approximation are (1a) for temperature and (1b) for precipitation.

$$Ta = -2.78 + 0.0014\ n \quad (1a)$$
$$Na = 1493.5 - 0.757\ m \quad (1b)$$

where N is a year, and it changes from 1936 to 2009.

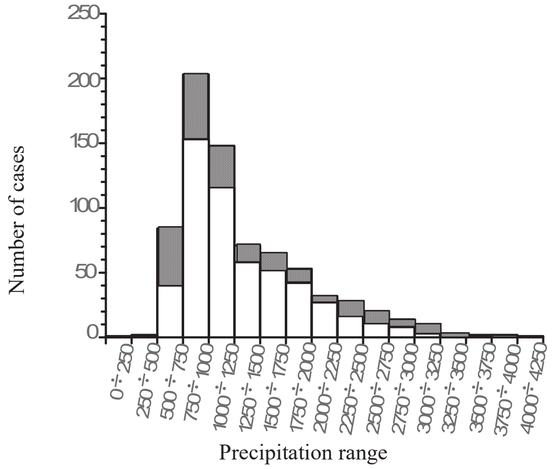
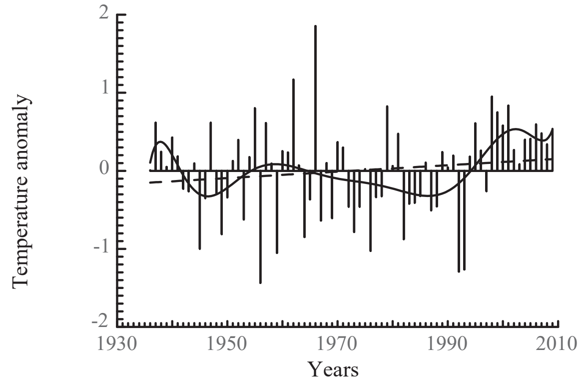
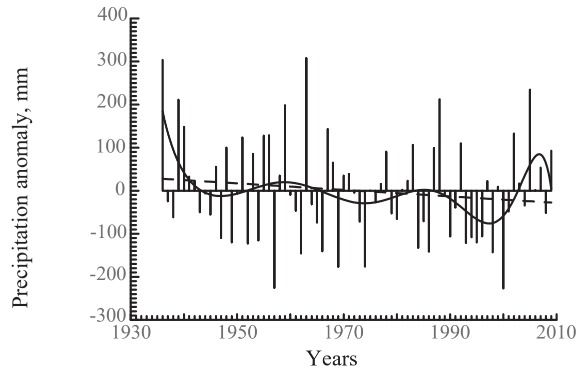


Fig. 2 Distribution of the annual sums of precipitation in 1936-2009



(a)



(b)

Fig. 3 (a) Temperature anomalies (b) Precipitation anomalies

Formulas show that the average annual temperature growth to + 0.0014°C in 1936-2009 years, while the average annual precipitation reduced to -0,757 mm. As for the non-linear approximation, it shows that cooling process (from 1960 to 1990) changed with sharp warming. The precipitations in recent years have the upward trend.

Because desertification may exert adverse impact on agriculture instead of whole year data, used the data of vegetation period (May-October). Thus, for the assessment of desertification process will be used database only 6 months. In particular, only cases when the positive temperature anomaly corresponds to the simultaneous precipitation negative anomaly.

To examine variations of temperature and precipitation between regions within the territory the area divided into four parts: the mountainous area of the southern slope of the Caucasus (North), Eastern plains (East); Meskheti-Javakheti upland (South) and Western foothills (West). There are seven observation posts located in each of them. To determine connection of variations between temperature and precipitation autocorrelation matrices (Table II) were done. As the table shows, only the West is distinguished among the rest of the regions, and there are certain correlations among the other regions.

TABLE II
CONNECTION OF VARIATIONS BETWEEN TEMPERATURE AND PRECIPITATION AUTOCORRELATION MATRICES

	positive temperature anomalies					negative rainfall anomalies			
	North	East	South	West		North	East	South	West
North	1	0.75	0.82	0.64	North	1	0.67	0.71	0.53
East		1	0.90	0.54	East		1	0.84	0.50
Sought			1	0.59	South			1	0.50
West				1	West				1

Thus, the process of desertification assessment was conducted for all four regions. As the relative quantitative impact of temperature excess and precipitation deficit on desertification process is unknown, the same weight of impact on desertification was given to the both parameters. For example, if the temperature positive anomalies sum of the 28 observation stations was $\sum_{i=1}^{n}(Ta)_i$ during the six months (warm seasons) of the 74 years, and the negative precipitation anomalies sum of the corresponding precipitation was $\sum_{i=1}^{n}(-Na)_i$, then their quantitative equalization can be made by the coefficient K:

$$\sum_{i=1}^{n}(Ta)_I = -\text{K} \sum_{i=1}^{n}(-Na)_i$$

or:

$$\text{K} = -\sum_{i=1}^{n}(Ta)_i \,/\, \sum_{i=1}^{n}(-Na)_i \qquad (2)$$

For the territory of Georgia, K = -0.03633. By multiplying with this coefficient, all values of the negative anomalies of precipitation were “adjusted” to the corresponding value of the temperature anomaly.

We summed up the warm-season temperature anomalies of each year of all observation posts and added to it the “adjusted” values of corresponding precipitation. We conventionally named these values Desertification Contributing Coefficient - U. The obtained numbers determined the importance of joint impact of ground surface temperature and atmospheric precipitation contributing desertification of the observation post during the warm-season period of the corresponding year.

We averaged the data of 7 observation points of each region. Their values according to the 1936-2009 years are given in the Fig. 4, in the vertical axis of which the Desertification Contributing Coefficient is measured, and in the horizontal – the years. Both the linear and non-linear approximation was also performed with the Least Squares Method [17].

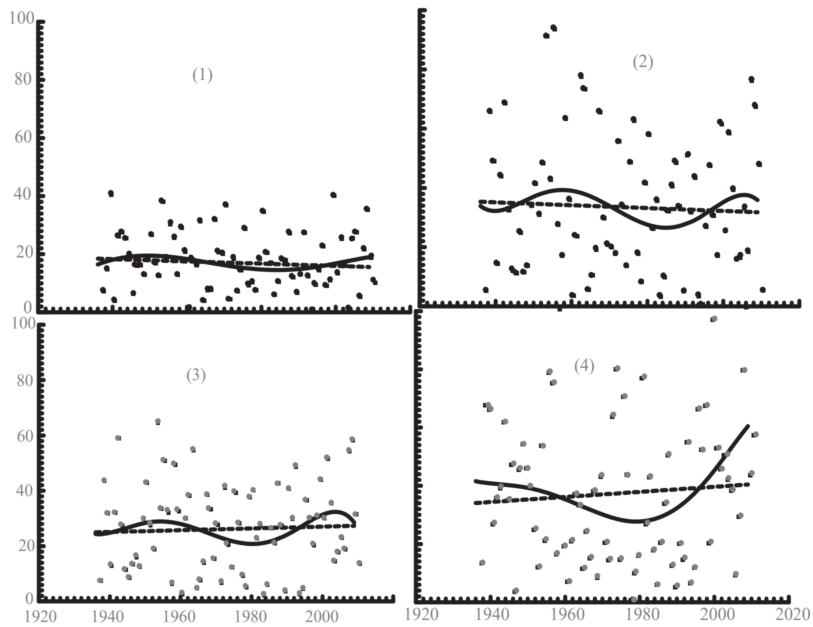


Fig. 4 Desertification contributing factor values of the four regions ((1) -North, (2) West, (3) North-South, (4) West) and their linear change (Dashed line) and non-linear (curve built in the 7th row of the polynomial) approximation

Linear approximation showed a downward trend in the desertification coefficient in the North and East. The reduction average value was 0.039 and 0,049 each year, and increasing in 0,032 was recorded in the South. But, compared with the West, the change is relatively small in all three regions, where the average annual increase of U reached 0.087. This was led by the fact that in the West, in the last century, until the 1980s, the cooling process was the dominant, which was then replaced by a sharp warming [16].

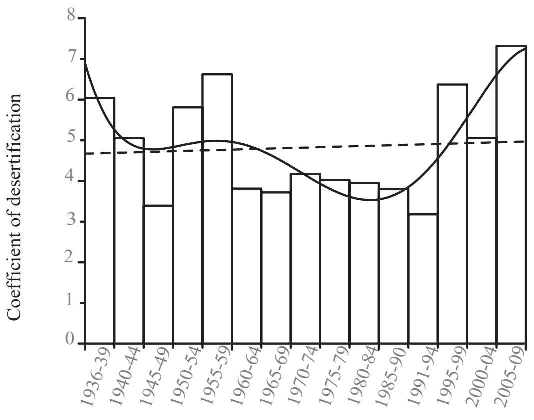


Fig. 5 Coefficient of desertification

The average values of the desertification coefficient of each 5 year in the four regions were identified in order to characterize the change in the time of the desertification contributing process over the entire territory of the country and Fig. 5 was built by the obtained values. The linear and non-linear (by the 7-th order polynomial) approximation of the data was conducted to determine the trend of changing.

The equation derived from the linear approximation has the following form:

$$U = 4.67 + 0.02\ n \quad (3)$$

where the "n" is the five-year period. As (3) shows, the environmental temperature excess and the precipitation deficit impact is negligible. During the 74 years, the desertification coefficient increased only by 6.4% on the entire territory of Georgia.

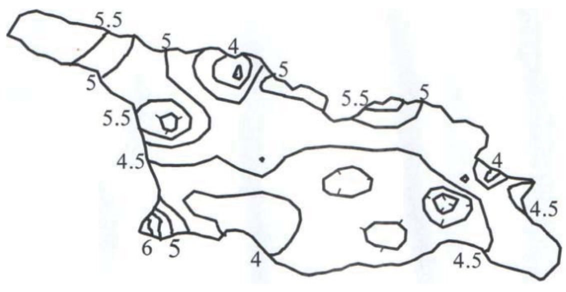


Fig. 6 Distribution of the desertification contributing coefficient

The non-linear approximation explains the changes in the desertification contributing process within the considered period. As can be seen Fig. 6, mainly a reduction in the desertification coefficient in Georgia is observed before the 1980s. And the next period indicates the sharp increase in the process.

In order to identify the territorial distribution of the Desertification Contributing Coefficient, its mean multiannual value was identified for the 28 observation points in Georgia. By the obtained values, the map of distribution of the Desertification Contributing Coefficient in the territory of Georgia was compiled (Fig. 6).

III. Conclusions

As the map shows, the values of the coefficient U are greater in the regions, where the cooling (in the West) took place in the initial period or the climate was not changing (in the North). Thus, the simple scheme for identification of the intensity of the desertification contributing process has been developed and the illustrative example of its practical application for the territory of Georgia has been conducted.

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