MATHEMATICAL MODELING OF SOME PECULIAR PROPERTIES OF REGIONAL CLIMATE CHANGE

T. Davitashvili[1], A. Khantadze[2], K. Tavartkiladze[3]

[1]I.Vekua Institute of Applied Mathematics of
Iv. Javakhishvili Tbilisi State University
University Street 2, 0186, Tbilisi, Georgia

[2]Iv. Javakhishvili Tbilisi State University
Faculty of Exact and Natural Sciences
University Street 2, 0186, Tbilisi, Georgia

[3]Georgian Geographic Institute
Iv. Javakhishvili Tbilisi State University
1/8 M. Aleksidze St., 0193, Tbilisi, Georgia.

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Abstract

In the present work we have collected data of water resources in the territory of Georgia. The specific properties of regional climate warming process in the eastern Georgia is studied by statistical methods and mathematical modeling. The effect of the Eastern Georgian climate change upon risk of desertification is investigated. For the description of desertification favoring processes, the earth surface temperature and precipitations are studied.

Key words and phrases: Climate, desertification, mathematical modelling.
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1 INTRODUCTION

1.1 Some Hydrological Specifications of Georgian Water Resources

Georgia lies along the eastern Black Sea coast, to the south of the Major Caucasian Ridge. About 85 percent of the total land area occupy mountain ranges. The Lesser Caucasus mountains occupy the southern part of Georgia. These two mountain systems are linked by the centrally located Surami mountain range, which bisects the country on the west and east regions. To the west of the Surami Range the relief becomes much lower, and elevations are generally less than 100 m along the river valleys and the coast of the Black Sea. On the eastern side of the Surami Range, a high plateau known as the Kartli Plain extends along the river Kura. The two largest rivers in Georgia, the Kura and the Rioni, flow in opposite directions: the Kura, which originates in Turkey, runs generally eastward through Georgia and Azerbaijan into the Caspian Sea, while the Rioni runs generally westward through the lower Rioni valley and drains into the Black Sea. An average density of the river network in Georgia is $0.6km/km^2$. The density of the river network is conditioned by the impact of physical-geographical, climatic factors. The quantity of atmospheric precipitation plays a special critical role. Generally the density of the river network in Georgia decreases in parallel with the reduction of atmospheric precipitation from the west to the east. In particular, the density of the river network in Western Georgia is about $1.07km/km^2$, while in Eastern Georgia this figure equals to $0.68km/km^2$ and density of the river network in Eastern driest regions of Georgia is very low and it equals to $0.1km/km^2$ ([22]). There is almost no river network in the eastern driest regions of Georgia, where the annual quantity of atmospheric precipitation is very low and equals to 100-250 mm, and the level of evaporation is extremely high. About 99% of the Georgian rivers are less than 25 km. And only one river, the river Kura, is longer than 500 km. Also there are 43 natural and artificial lakes in Georgia, of which 35 in East Georgia, for irrigation or hydropower generation surface water and groundwater resources include numerous thermal and mineral springs. Many snow- and glacier-fed rivers are present in the Greater Caucasus. Groundwater resources are abundant, especially in the lower slopes of the Greater Caucasus and in the lava plateaus of Javakheti mountains ([22]). In Georgia, about 1600 water-suppliers provide a total of 620 million m^3 of drinking water per year. From this quantity 90% is consumed by urban population and 10% by rural ([15]). Main source of drinking water is groundwater, accounting for about 90 of the total amount of water feeding the centralized water-supply networks. No special treatment of groundwater takes place before it is supplied to the users, the water is chlorinated only. When surface water is used as raw material, this water is specially treated - precipitated and chlorinated.

2. Some Peculiarities of Climate Change on the Territory of Georgia

The global cycle of climatic warming in the Earth's atmosphere is the result of a number of natural factors and especially consequence of anthropogenic activity. Beside the natural factors, especially interesting is the impact of increasing concentration of radiation gases, aerosols and dust on the global climate. Their accumulation in the lower atmospheric layer plays the role of the scum, intensifies solar warming of the atmosphere and considerably decreases long-wave flow directed from the Earth to the outer space ([21]). In the physical system with strong non-linear heat parameters (heat content, heat coefficient of turbulent exchange, coefficient of heat inflow and loss, etc.) of the system will become dependent on the temperature and non-linear heat process (during a definite cooperated action) induces the growth of characteristic temperature of the system by the time and creation of "greenhouse effect" in the system ([21]), ([16]). Now in the atmosphere non-linear heat sources are already acting, and their intensity may increase in the future. The "greenhouse effect" is the direct result of the accumulation of radiation gases, caused by human activity, rapid development of industrialization of oil, gas, coal, and other types of organic resources. This process was followed by the accumulation of combustion products (radiation gases): carbon dioxide , nitrogen, peroxide , methane , freons , ozone in the lower layer. Against the background of global climate change, climate change of Georgia is characterized with strongly expressed regional peculiarities. There are observed as warming as well cooling processes on the territory of Georgia. Namely statistical treatment of data of average climate temperature of 1905-1995 years has shown simultaneously sharp process of warming in the Eastern Georgia and climate cooling in the Western Georgia. There are also exposed the micro regions, where the average climate temperature does not change according to time. The mentioned changeability of the climate on the whole territory of Georgia corresponds to the picture of climate change on the territory of Georgia obtained by the observations conducted according to the program of the global climate investigation and model calculations of global climate ([12]).

Since on the whole territory of the Western Georgia takes place the climate cooling process, it is necessary to find such constantly acting thermal and advective-dynamic sources, which will be periodic according to time, its periodically will have the order of the year and the characteristic horizontal and vertical scales will be equal accordingly to 200-300 km and 3-4 km. Among many atmospheric circular processes, which take place in the Western Georgia, only the circulation of the monsoon type is characterized by spatial and time parameters ([20]) , that is caused by the irregular warming of the territory of Black Sea and Kolchida lowland during the year. This circulation (which can not exist in the Eastern Georgia), must be caused by the action of constantly acting two heating mechanisms, in which the Kolchida lowland plays the role of heating and the Black Sea - the role of refrigerator during the summer, but in winter - conversely: Kolchida lowland is a refrigerator and the Black Sea - heating. It is natural, that this alternation of the sources gives rise to the changes of temperature by the annual period. According to ([20]) , the variety of general circulation of the Earth atmosphere and the failure in zonal regularity is caused by the thermal and cool sources (ocean - land), which are known as thermal machines of "second order" in atmosphere thermodynamic.

To the existence of the monsoon circulations in Georgia point the investigations ([11]), but there is mentioned, that the horizontal component of the monsoon velocity, the magnitude of which does not exceed 1-3 m/s, is insignificant in comparison with the dominating winds (5-10 m/s) and its exposition needs the statistical treatment of climate parameters during long time. Unfortunately, Georgian meteorologist-experimentalists have not carried out large-scale investigations in this direction.

Since the reality of the existence of sources generating the monsoon circulation in the Western Georgia has no alternative and analogously are daily and nightly sources of breeze and valleys and mountains circulation, we assume as a priori the compulsory existence of the circulation of such type in the Western Georgia, the real exposition and detailed description of which must be the actual subject of the future research. The monsoon circulation, which is the most large-scaled among the daily and nightly breeze and valley and mountains' circulations existing in the Western Georgia, easily can comprise all the territory of the Western Georgia till Surami Range. This circulation, which in winter generates the monsoon circulation rotating clockwise and the up flow stream in the Black Sea sufficiently far from the shore , is characterized by the down flow streams at Surami Range ([11]). In summer, the circulation has the opposite direction of rotating and at Surami Range the up flow streams change by down flow ones in the Black Sea. The distance of up flow and down flow streams from the shore and the spatial scales of generated circulations depend on the contrast (intensity) of summer and winter seasons during a year ([7]).

The problem of the forthcoming climate change resulting from natural and growing anthropogenic factors acquires a particular importance for Georgia. As we have mentioned above Georgia's climate oscillates from subtropical conditions on the Black Sea coast to continental conditions, with cold winters and hot summers, in the extreme east, with dry lands. Activity of anthropogenic factors resulted in the considerable change of the area of underlying surface in Georgia. Namely there are observed decreasing of the following units owing to increasing of the production and building: mowing; arable; unused lands; shrubs and forests. Transformation of one type structural unit into another one, naturally, results in local climate change.

3. Some peculiarities of droughts on the territory of Georgia

Droughts in Georgia is characterized by special extra conditions of the weather, with high temperature, low humidity and absence of atmospheric precipitations for a long period of time, i. e. when a daily norm of atmospheric precipitations are less than 1mm. Genesis of droughts is determined by numerous natural phenomenon, but on the territory of Georgia atmosphere currents play an great importance. Namely when air currents are invading from the east, or south-east regions, they bring dry air masses on the territory of Georgia. Namely during the influence of the Asia Depression, the currents of summer thermal cyclone are extending from the south-east and as a result dry and hot air masses are formed over the territory of Georgia. Minimum temperature of the lowland dos not fall below $+20°C$, and a daily maximum exceeds $+38°C$. Recurrence of the influence is the highs in July (25,1%). During the development of various influences in Georgia change of air temperature regime takes place. Invasion of hot and dry air masses on the territory of Georgia is very dangerous for the development of draughts. For example on the steppe valley of Gardabani region lock of rain. (dry weather period) are observed 3-4 times in year, when the ground is demanded watering, while at the Black Sea coast arias only one time in 10 years. In the dry regions of eastern Georgia 15-20 days with dry weather is observed 5-6 times in year and some times dry weather period exceed 80-100 days. Reiteration of the eases the amount of atmospheric precipitations is less then 150 mm. For example in Shiraki it is equal 19% and in Gardabani area 44%. That is way there is observed desertification processes in Gardabani and Shiraki regions([17]). It is known that in Georgia the most drought regions are lower Kartli and lowland of Eldary, where possibility of the severe drought is about 40Shiraki Valley - 20-40% and in the vest regions of arid East Georgia probability of the severe droughts is 10-20%. Also investigations have shown that during XX century in every ten years annual average temperature has increased in average about $0.02° - 0.07°$ C, which is closed to the velocity of global average annual temperature rise ([5]).

Investigations have shown that in lower Kartli and Shiraki Valley from the middle of XIX century to the beginning of XX century average annual temperature has increased only significantly. Namely in every ten years from 1920 to 1940 value of the temperature increased on $0.3° - 0.4°$ C, from 1940 to 1955 the value of the temperature decreased in average on $0.25° - 0.29°$ C, from 1955 to 1960 increased on $0.21° - 0.34°$ C, from 1960 to 1980 the temperature decreased about $0.26° - 0.30°$ C, and then from 1975 to nowadays value of the temperature speedy increased with the velocity $0.32° - 0.40°$ C in every 10 years ([5]).

Desertification occurrence depends on complex interactions among a large number of factors. Namely a decrease in the total amount of rainfall in arid and semi-arid areas could increase the total area of drylands , and thus the total amount of land potentially at risk from desertification. Many dryland areas face increasingly low and erratic rainfalls, coupled with soil erosion by wind and the drying up of water resources through increased regional temperatures. In addition such areas also suffer from land degradation due to over-cultivation, overgrazing, deforestation and poor irrigation practices.

The analysis of perennial regional research material and the data of regime observation in the territory of Georgia showed that there exists very close dynamic connection between activation from the perennial norms. When the precipitation amount is about 700 mm mean perennial index, then activation of desertification processes remains at the general background level. When atmospheric precipitation is about 500 mm the tendency of activation of desertification processes is registered above mean level, but when precipitation less than 200 mm then there begins catastrophic development of desertification processes. It is not yet possible, using computer models, to identify with an acceptable degree of reliability those parts of the Earth where desertification will occur. But below we are going to use new simply physical-mathematical model of desertification for the purpose of to study, one of the main characteristics of desertification process, soil upper layer's temperature's temporary and spatial variations by analytical solution.

4.On The Thermodynamic Model of Desertification Process

As we have mentioned Georgia's climate oscillates from subtropical conditions on the Black Sea coast to continental conditions, with cold winters and hot summers, in the extreme east, with dry lands. Activity of anthropogenic factors resulted in the considerable change of the area of underlying surface in Georgia. Namely there are observed decreasing of the following units owing to increasing of the production and building: mowing; arable; unused lands; shrubs and forests. Transformation of one type structural unit into another one, naturally, results in local climate change. Problem of desertification takes one of the important places in the cycle of climate global warming problems. Desertification is the most complicated and mathematically less studier problem of present meteorology.

Conditions, which stipulate the surface layer desertification are so versatile that their simultaneous consideration in a general desertification problem meets unsolvable mathematical difficulty. So, while discussing indicated problem by mathematical modelling it is necessary to separate out these main factors, which essentially condition surface layer desertification process. As well as in other physical problems desertification problem should be brought down to the creation of a certain desertification theoretical model, in which main physical mechanism causing desertification will be preserved. So that to find out whether what kind of physical process is going on during the baring of soil surface, it is necessary to proceed from soil, as a physical environment, conception. According to ([13]), ([10]) any simple soil fraction represents a conglomerate of elementary particles composing the soil. Since these particles have irregular geometrical shape, their direct contact with each other occurs merely in certain points or on very small areas. Therefore, elementary soil particles are mainly connected with each other by air layer or a water film. The richer the soil with water contact, then more particles is connected with each other by water layer. Since the air is a bad heat conductor in comparison with water (air heat conductivity coefficient is $\lambda = 5.6 \cdot 10^{-5} \frac{\text{cal}}{\text{cm.sec.deg}}$, for water $\lambda = 1.3 \cdot 10^{-5} \frac{\text{cal}}{\text{cm.sec.deg}}$) these particles connected with each other by air layer badly transmit heat, obtained through solar radiation to each other, while between particles connected by water film intense heat exchange is taking place and temperature gradients between them are rapidly decreasing. While decreasing vegetation and precipitation (these two factors may be conditioned by many reasons) radiation load upon soil active layer is intensifying. Number of particles connected by air layer is intensively increasing and each particle becomes the source of heat accumulation due to bad air heat - conductivity. This time so called "greenhouse effect" develops in the active layer, when soil has a function of semi conduction : it actively gets heat through solar radiation and extremely passively gives it out. This physical phenomenon occurring in the active soil layer may be safely called as a soil desertification process and the following consideration may be made. In fact, soil desertification process of a specific region starts due to precipitation decrease and degradation of vegetation cover. This time , average annual intensity of solar radiation action in the given region sharply increases, causing drying (aridity) of soil active layer and gradual change of its structure. In particular, soil physical parameters such as density ρ, specific heat capacity C_p , transfer soil heat - conductivity coefficient λ, become dependent upon temperature (otherwise, changing of soil structure and its transformation into a new fraction will not occur) and a heat transfer mechanism in the soil gets a non-linear nature, as a result of which strong a heat accumulation and growth of temperature in time are observed in the active soil layer during the entire desertification process. Indicated process, as mentioned, which represents the "greenhouse effect", continues until arid soil structure gets quite a new appearance, with new physical parameters (e. g. heat conductivity coefficient of one the soil fractions, that of moist sand at $+10°C$ is equal to $\lambda = 3.71 \cdot 10^{-5} \frac{\text{cal}}{\text{cm.sec.deg}}$ and dried out sand to $\lambda = 0.7 \cdot 10^{-5} \frac{\text{cal}}{\text{cm.sec.deg}}$). This completes the desertification process and in a new fraction its physical parameters p, C_p, and λ become dependent upon temperature, and a heat transfer mechanism gets the form of traditional Fourier linear problem ([10]).

If under the influence of external factors, (degradation of vegetation, decrease of precipitation, drought, erosion, advection, etc.) radiation load on the soil intensifies and on the active layer of soil, the structural change begins (desertification process) with physical parameters, dependent upon temperature, the heat conductivity mechanism gets a non-linear nature. Here, the superposition principle no longer is observed and generation of various harmonics, their intensified interaction with each other and increase of heat process in the soil, i.e. "greenhouse effect" occurrence, take place, accelerating structural process in the active layer of the soil. Therefore, "greenhouse effect", which, in fact, represents a growing thermal process in limited time interval, is stipulated by a non-linear mechanism of heat conductivity. If radiation load upon the soil decreases, heat transfer process will get a linear nature and the "greenhouse effect" disappears. Following the articles ([19]), ([18]), one should mind that it is impossible to measure by means of experimental methods the soil intrinsic parameters (p, c, λ) that structurally change during the desertification process. The soil temperature is the only, main characteristic parameter, which submits to accurate measurement. It should be mentioned that in normal conditions (in terms of vegetation coverage and adequate amount of precipitation) in the active soil layer the water content functions as the complex parameter q, which prevents the sharpening of the radiation processes and origination of "greenhouse effects". Meanwhile, heat obtained from the solar radiation intensively scatters among the elementary soil particles that are linked to each other with water pellicle and the stationary temperature field forms with the stationary temperature T_{st}. The link between the stationary temperature T_{st} of the soil and the parameter q can be easily arranged for different types of soil in natural terms in case if the water content evaporates per unit of the soil. It will not be exaggerated to note that this type of work for the soil in Georgia should become a precondition in the study of the desertification process in this country.

In natural conditions the value of the parameter q significantly decrease and the soil thermal activity increase because of structural change of internal parameters. In these terms only by means of artificial, soil-conservational methods is it possible to raise the parameter q to such a value, that in the given geographical and climatic conditions is necessary for conducting thermal processes in the same way as it proceeded before the origination of the desertification process.

The parameter q can be defined us: water mass m_b per soil unit divided by sum of the soil and water masses in the same volume:
$\dfrac{m_b}{m_n + m_b}$, where m_n is the soil mass per unit of volume, thus represents dimensionless parameter and is always below 1 in soil.

As it was mentioned, the parameter q prevents the sharpening of the desertification process in the soil, while the structural change of the internal soil parameters causes heat accumulation, origination of "greenhouse effect" and its further development. Thus in natural conditions the process of desertification always proceeds on the basis of two opposite processes: the first one promotes the growth of the "greenhouse effect" in the soil according to the time (p, c, λ) and the second one disturbs it and causes extinction of the "greenhouse effect" q.

Below we will review a real case when the thermal sources resulting in desertification are located in the soil active layer.

If we generally mark the heat flow and loss functions by $Q(t)$ and $R(t)$ functions, the equation of soil heat conductivity formula will look as ([10]), ([13]), ([6]), ([3]):

$$pc\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\lambda\frac{\partial T}{\partial z} + Q(T) - R(T). \tag{4.1}$$

where parameters (p, c, λ) represent the power functions of temperature T ([10]). Generally the equation (4.1) is solving with the initial and the boundary conditions:

$$T(0,t) = \varphi(t); \quad T(z,0) = f(z), \tag{4.2}$$

where the quantities $\varphi(t)$ and $f(z)$ represent the functions depended on the solar radiation and the intensity of Earth radiation. Certainly, the temperature change caused by the solar radiation at the considerable depths of the soil $(z \to \infty)$ should tend to zero.

Let us consider a thermal function of volume and the heat conductivity coefficient ([10]), ([13]):

$$du = pcdT; \quad f = \frac{\lambda}{pc} = au^n. \tag{4.3}$$

The result of equation (4.1) and the relation (4.2) gets the following form:

$$\frac{\partial u}{\partial t} = \frac{a}{n+1}\frac{\partial^2 u^{n+1}}{\partial z^2} + Q(u) - R(u). \tag{4.4}$$

$$U(0,t) = \Phi(t); \quad U(z,0) = F(z), \tag{4.5}$$

where $a = f_0 u_0^{-n}$; $f_0 = \frac{\lambda_0}{p_0 c_0}$; the coefficient n shows the nonlinear character of desertification process; p_0, C_{po} and $\lambda_0$are values of density and heat transfer coefficients , respectively, when $t = t_0$.

5. Analytical Consideration

In order to solve the task, the thermal sources should be identified. Let us consider the case when the difference between heat flow and loss functions represents the power function of the function

$$Q(u) - R(u) = \alpha u^{\sigma}, \tag{5.1}$$

where α and u^σ are the parameters of the thermal function.

The representation of thermal functions $Q(u)$ and $R(u)$ by means of power formula of u function is justified by the fact that they represent the complex temperature function in the thermodynamic tasks of the soil. The aforementioned appropriateness changes from the appropriateness of Newtonian thermal function ($\sigma = 1$) to the appropriateness of the Boltsman thermal function ($\sigma = 4$) according to the value $\Delta T = T - T_e$, where T_e is the temperature of environment. According to the relation (5.1), the equation (4.4) get the following form:

$$\frac{\partial u}{\partial t} = \frac{a}{n+1}\frac{\partial^2}{\partial z^2}u^{n+1} + \alpha u^\sigma. \tag{5.2}$$

The first term in the right part of the equation (5.2) expresses the nonlinear heat transfer process, and the second member marks the action of the nonlinear thermal sources in the soil.

An exact solution of equation (5.2) was obtained by us in case when $\alpha = 0$ ([2]). It is easy to demonstrate that considering the thermal source the equation (5.2) preserves the mechanism of "greenhouse effect" in case when we assume that $\sigma = n + 1$. Consider also that the parameter must include the effect of the thermal activity resulted by the change of internal soil parameters (p, c, λ). The intensification of this thermal activity effect promotes the sharpening of "greenhouse effect", and the growth of q parameter, which prevents the development of "greenhouse effect" in the soil. Out of the aforementioned let us introduce parameter α as a difference

$$\alpha = \alpha_1(p, c, \lambda) - \alpha_2(q) \tag{5.3}$$

and rewrite the equation (5.2) in the following way:

$$\frac{\partial u}{\partial t} = \frac{a}{n+1}\frac{\partial^2 u^{n+1}}{\partial z^2} + (\alpha_1 - \alpha_2)u^{n+1}. \tag{5.4}$$

By direct insertion it is possible to show that the nonlinear solution of the equation (5.4), which includes the "greenhouse effect" will look like ([4]), ([9]):

$$u(z,t) = u(0,0)\cos^{\frac{2}{n}}\left(\frac{\pi}{2}\frac{x}{|\Delta|}\right)\left(1 - n\frac{t}{|t_f|}\right)^{-\frac{1}{n}}, \tag{5.5}$$

where Δ and t_f are defined by the formulas:

$$\Delta = \frac{\pi}{n}\sqrt{n+1}\sqrt{\frac{f_0}{\alpha_1 - \alpha_2}}; \quad t_f = \frac{2(n+1)}{(n+2)}\frac{u_0^n}{u^n(0,0)(\alpha_1 - \alpha_2)}. \tag{5.6}$$

The formula (5.5) shows that desertification process develops in time in three stages:

1. If the water content q is sufficient to satisfy the condition $\alpha_1(p, c, \lambda) = \alpha_2(q_1)$ then $|\Delta| \to \infty$, $|t_f| \to \infty$, is obtained from (5.6) formulation, and the stationary temperature distribution can be obtained from the formula (5.5):

$$u = u(0,0), \quad \text{that is } T = T_{st}^{(1)}. \tag{5.7}$$

This kind of thermal condition of the soil takes place before the desertification process begins, when the vegetation coverage and the precipitation amount is sufficient for normal functioning of the thermally active soil layer;

2. If the thermal activity coefficient is higher than the heat loss coefficient, which represents the water content function, than the following equation will be obtained from $|\Delta| = \Delta > 0$, $|t_f| = t_f > 0$ and formula (5.5):

$$u(z,t) = u(0,0) \cos^{\frac{2}{n}} \left(\frac{\pi}{2} \frac{z}{\Delta} \right) \left(1 - n \frac{t}{|t_f|} \right)^{-1/n}, \tag{5.8}$$

which includes the "greenhouse effect" - thermal process that is space limited ($z < \Delta$) and grows by time for the $t < \dfrac{t_f}{n}$ interval. This type of appropriateness of soil temperature field should take place in desertification process.

3. If by human active interference in the desertification process the water content q grows up so as to satisfy the condition $\alpha_1 < \alpha_2$ then, $|t_f|_f$ in the formulation (5.8) will be negative and equal to $(-t_j)$ and imaginary $|\Delta|$ to $|\Delta| = i\Delta$. Therefore (5.5) solution will have the following form:

$$u(z,t) = u(0,0) \cos^{\frac{2}{n}} \left(\frac{\pi}{2} \frac{z}{\Delta} \right) \left(1 + n \frac{t}{|t_f|} \right)^{-1/n}, \tag{5.9}$$

The formula (5.9) demonstrates that the thermal function of soil will be space limited in this case as well ($|z| \leq \Delta$), and will have the form of time reducing function. This kind of thermal process will develop in the soil under the soil-conservation methods accomplished by a man. At this time the $u(z,t)$ function achieves zero for a long-term interval and the "greenhouse effect" extinct. Out of the above mentioned it may be concluded, that analytical formula (5.5) quantitatively well describes the three stages of desertification process and includes the basic physical mechanism which is the basic reason of desertification. This physical mechanism proceeds in cooperation of two opposite process (sharpening of the "greenhouse effect" because of the structural change of the soil and thermal activity on the one hand and the weakening of the process resulted by man's active interference).

6. Estimation Method of Desertification Process

We have elected such long-term climatic observation station in the region of expected desertification, which has been characterized by the increased drought frequency in recent years. We have studied the temperature of soil surface in the selected station and variations of precipitation and established the climatic parameters, which can be regarded as the beginning of desertification. In the region of climatic warming we have examined the anomaly variation of soil surface average monthly temperature from January 1936 to December 1990 in order to reveal the most clearly expressed increasing of the surface temperature. Such observation station was selected in Shiraki.

Variation of temperature by seasons as it known ([23]), happens in different ways. For instance, according to years the warming process is conditioned by an increase of temperature in cold period of the year.

Only the temperature variation of the warm period might have a main effect on the desertification process. Therefore, it is necessary to examine the action of cold and warm season variations on the average annual variation of anomalies according to the soil surface temperature as well as precipitation anomalies. For this purpose, normalized autocorrelation matrix was determined for Shiraki according to the soil surface temperature and average annual and seasonal precipitation anomalies (Table 1).

Normalized correlation matrix for Shiraki, according to the soil surface temperature and average annual and seasonal precipitation anomalies

Table 1.

		1	2	3	4	5	6
Average annual temp.	1	1	0.83	0.67	-0.34	-0.06	-0.3
Cold season's temp.	2		1	0.14	0.01	-0.06	0.31
Warm season's temp.	3			1	-0.6	-0.07	-0.58
Total of the annual precip.	4				1	0.24	0.89
Total of Cold seas. precip.	5					1	-0.22
Total of Warm seas. precip.	6						1

As it is seen from the Table 1, the anomalies of the soil surface average annual temperature are mainly determined by cold season (correlation coefficient-0.83), but warm season also has rather great share (correlation coefficient-0.67) in temperature increase according to the years. As to the precipitations variation it occurs almost completely on the expense of warm season (correlation coefficient-0.89).Comparatively high correlation link between temperature and precipitation anomalies is revealed in conditions of warm season (correlation coefficient-0.6), which is one more index of desertification process development.

This dependence is well expressed by the curve constructed with the method of least squares which analytical form is:

$$\Delta N = 21.9 - 108.2\Delta T + 32.6(\Delta T)^2$$

Where ΔT and ΔN are the anomalies of temperatures and precipitations of correspondingly.

Thus, as criteria of quantitative estimation of desertification process the anomalies of soil surface temperature and the amount of precipitation were selected. For determination of the criterion the following procedure seems to be reasonable: temperature anomalies are determined by 40-50 year, monthly complete data of soil surface temperature of observation station.

Table 2 Drought years stimulating desertification and the criteria of their estimation for Shiraki

Drou ght years	Period, when the anomaly of soil surface temp. $> 0.5°C$	Num of mon ths	Anomal. of aver. month temp. of soil surf. in drought period	T. excess stimul. deser tific. $°C$	Precipit. aver. month anomal. in drought period, mm	Lack of precipit. stimulat. desertif. mm
1941	Febr-Sept	8	1.63	13.0	-19.0	-152.0
1950	March-May	3	1.4	4.2	-32	-96.0
1951	March-Sept	7	1.7	11.9	-12.0	-84.0
1953	April-Aug	5	1.14	5.7	-2.0	-10.0
1957	Febr-May	4	0.62	2.5	-6.0	-24.0
1961	April-Aug	5	2.12	10.6	-30.0	-150.0
1962	May-Dec	8	1.36	10.9	-12.0	-96.0
1966	June-Dec	7	2.54	17.8	-3.0	-21.0
1971	July-Dec	6	1.92	11.5	-9.0	-54.0
1975	March-Sep	7	1.47	10.3	-24.0	-168.0
1977	Febr-June	5	1.58	7.9	-4.0	-20.0
1986	June-Oct	5	1.48	7.4	-9.0	-45.0
1989	March-Aug	6	2.45	14.7	-23.0	-138.0

Those years are selected in warm period of which three or more months anomalies (one by one) are positive and each one is not less than 0.5 C. According to corresponding periods precipitation anomalies are determined and according to temperature from selected years those will be left when positive anomalies of temperature will be followed synchronically only by negative anomalies of precipitations. The anomaly of month average temperature and precipitations of drought period is determined. Their product on the amount of the given months period determines the values of temperature excess stimulating desert and lack of precipitations. Let's take practical example according to the data from Shiraki. In the 1936-1990, in

Shiraki 13 years appeared too droughty by anomalies of soil surface temperature and precipitations. These years are given in Table 2. As is seen from the Table 2, the greatest excess of soil surface temperature was recorded in June-December, 1966 and made 17.8°C . The lack of precipitations in the mentioned period was 21 mm. If the average annual value 2.3°$C/$ year of temperature excess stimulating desertification. Correspondingly, the value of precipitations lack will be 19 mm.The same approach can be applied to determine the values of the mentioned parameters for other stations, which help to determine numeric values of the parameters characteristic for the beginning of desertification.

7. Droughts, desertification and its mitigation

The challenges facing the science community include better understanding the soil surface and meteorological processes that lead to desertification and determining how new technology and techniques might be applied to reduce the risk of desertification. Solution of these challenges usually supposes composition of drought hazard zone maps and then attempt to predict probabilities of droughts and associated consequences. To help with this scientists can take advantage of advances in satellite remote sensing and other data sets in the development of landslide susceptibility maps based on satellite-based digital elevation maps, satellite land cover information, soil characteristics and high time resolution multi-satellite precipitation analysis with sufficient accuracy and availability to be useful for detecting rare rainfall events that provoke droughts. The combination of these products potentially provides information on the "where" (susceptibility) and "when" (rain events) of desertification process occurs and the potential to detect or forecast drought areas.

Method of dripping irrigation needs 3 times less water compared with surface natural irrigation, giving up to 67 irrigation water economy, and thus resulting in much more rational irrigation water consumption. Therefore, the introduction of indicated method in the basins of rivers with irrigation water deficiency may be considered to be as an important anti-drought measure([1]).

The danger of global biosphere disaster could be given to the Service of complex ecological monitoring, one of directions of which is the early warning system . Aiming the coordination of scientific investigations it is necessary to establish Scientific center in the system of Academy of Sciences, which will summarize the ecological monitoring information obtained from different sources, analyze it and create models of biosphere processes that could serve as a basis for the elaboration of forecasts, guaranteeing successful implementation of sustainable development programme ([8]).

8. Conclusions

As our conception about climate cooling has the general form, climate cooling must take place in other regions of the Earth; particularly, where the monsoon flow and the adjective - orographic factors are sharply expressed. For verification of this conception we can take the picture of global climate warming, which has a mosaic structure. There are given cooling and warming regions of the Earth caused by big variety of the regional factors. It must be mentioned, that the fact of climate cooling in the Western Georgia can become the important conception of Georgian governmental policy and in the balance of green house gases' expansion all over the world according to the regularity mentioned above. From this result, it can be stated two economically and strategically important problems for future: to estimate the effect that the propagation of greenhouse gases will have on the global balance of existing gases in the atmosphere; it will be reasonable strategically if the development of industry in the future connected with green house gases takes place in the Western Georgia.

Out of above considered theoretical model of desertification it proceeds that to halt the desertification process, first of all it is essential to stop nonlinear thermal process occurring in the soil, causing its structural change due to the "greenhouse effect". In order to achieve this aim, the measures, that will decrease solar radiation load upon the soil and will cause naturally the "greenhouse effect" extinction in its active layer, should be conducted. This needs to use a system of drip irrigation and well-known methods of hydroponics basing upon a many-year experience of the scientists from Israel. The first of them allows to get a maximum irrigation effect with a minimum water use, the second one permits to get a vegetation cover by means of water rich in various salts, essential for soil, in fact without its direct participation. This time it is necessary to sow such heat-resistant wild plants, which in several months form the vegetation cover of the soil are characterized with deep and branchy roots and even in case of their upper part burning, they should preserve vitality and biological activity. As a result of conducting multiple indicated measured (the frequency should be determined experimentally for a specific soil area) the intensity of radiation load upon the soil surface will decrease and the introduction of salts, necessary for soil by a method of hydroponics and the soil biological enrichment (as a result of wild decay) with the mass, accumulated at the expense of wild plants, will result, in our opinion, suspension of desertification process and extinction of the "greenhouse effect" in the soil active layer. Finally, it should be indicated, that elaboration of a general model of desertification and working out effective recommendation against desertification should be carried out by means of close co-operation of meteorologists, biologists, soil and irrigation specialists.

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