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Research of Soil Resources Degradation Processes in Georgia

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Abstract: Proper exploitation of soil resourses is one of the significant problem of the adverse impact of climate change. Soil formation is a long process, while its degradation develops much faster. Soil degradation means the process of deterioration of soil resources fertility, as a result of both natural and anthropogenic impact. Significant impact on soil resources take place in East and West Georgia. The results of the present study show that the main reasons of soil resources degradation in Georgia are: salinization, erosion processes and natural disasters impact. In the work the following issues are overviewed, namely: i. The climate components regime and their connection with modern ecological processes. In particular, the temperature and precipitation trends and their possible impact on chemical data are researched. The regression relation between global warming intensity and soil chemical data are revealed. ii. In selected degraded soils total amount of easily soluble salts, the main ions composition for the determination of saline soil's quality, humus and soluble forms of nutrient elements aiming soil fertility definition. iii. The mechanical analysis of the soil referring to research soil physical properties and salt migration in the ground. Natural disasters impact on the soil degradation is considered. Research results defined the territories and types of soils degradation in Georgia. The recommendations to improve the soil fertility are created. The received results could promote the socio-economic development of the districts/ regions in Georgia and introduce considerable material and economic effects, assist the sustainable management of soil resources and alleviation of poverty.

Keywords: Soil Degradation, Sustainable Development, Agriculture, Climate Change, Mitigation

1. Introduction

The area of productive soils in the world is limited and faces increasing pressure from competing uses such as cropping, forestry and pastures/range land, urbanization, as well as energy production and mineral extraction.

The soils represent at least a quarter of global biodiversity, and play a key role in the supply of clean water and resilience to floods and drought. Crucially, plant and animal life depend on primary nutrient recycling through soil processes.

In human terms, soils are a finite resource, of which about 24 billion tons of fertile soil per year is being lost on agricultural lands. Land degradation often occurs in areas that are already characterized by land scarcity and increasing population [1].

The inventory of soil resources for their decsription would be performed [2]. Based on these the urgent actions to improve the health of the world's limited soil resources and to stop land degradation [3] are required, so as to ensure that future generations have enough supplies of food, water, energy and raw materials.

Some stabilization mechanizms are overviewed and studied in [4].

Georgia is a transcontinental country, located along the dividing lines of Asia and Europe in the South Caucasus. Georgia is situated east of the Black Sea, south of Russia, north of Turkey and Armenia and northwest of Azerbaijan. Georgia covers an area of 69.700 km^2.

The climate of Georgia is extremely diverse, there are two main climatic zones, roughly separating eastern and western parts of the country. The Greater Caucasus Mountain range plays an important role in moderating Georgia's climate and protects the area from the invasion of colder air masses from the north.

The Lesser Caucasus Mountains partially protect the region from the influence of dry and hot air masses from the south as well.

Georgia is an agrarian country with small territory, which has the potential to produce high quality and neat agricultural products. Therefore, effective management of land resources is important from the environmental and socio-economic points of view.

Approximately 54% of the territory of Georgia is mountainous. The high mountains and plains occupies respectively 33% and 13% of country's territory. Correspondingly, the 70% of the territory is below the altitude of 1,700 meters [5]. These altitudes contributes to the development of agriculture, and at the greater heights are mainly located only pastures.

Geography of Georgia is diverse: humid, subtropical lowlands and swamps; lakes and numerous rivers and soils; valleys; semi-deserts; hills; mountains covered by forests and glaciers [6]. Some characteristics about Georgia are presented in Table 1.

Georgian population is equal to 4.4 million. According to 2010 data [7] approximately 47% of the population lives in rural areas, 52.3% of this amount deal with agricultural sector. The proportion of the population living in rural areas is more or less stable with respect to the city residents. Agriculture has an important role in Georgia. 43% of the land resources is suitable for cultivation, but certain amount of this soil is degraded and no longer used for agriculture [8].

Table 1. *Some Data about Geography of Georgia.*

Total territory (km^2)	Agricultural lands (km^2)	Forests (km^2)	Mountains (Above 1000 m) (km^2)	Waters (Lakes, Rivers, Reservoirs) (km^2)	Swamps (km^2)	Glaciers (km^2)	Semi Deserts (km^2)
69, 700	30, 258	24, 562	37, 640	8, 351	600	511	100

The soil resources distribution in Georgia is presented in Fig. 1.

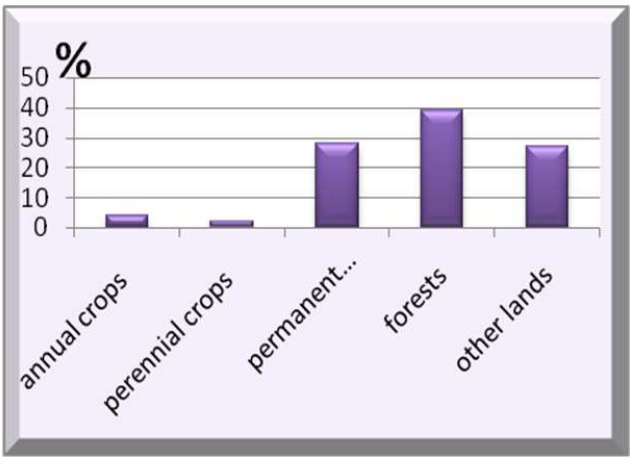

Fig. 1. *The Soil ResourcesDistribution in Georgia.*

According to this Figure soil resources allocation are as follows: annual crops make up 4%, correspondingly perennial crops - 2%; permanent meadows and pastures - 28%; forests - 39%; other lands - 27%. In 2005, 1.07 million hectares of land were processed. From this amount annual crops were planted in the area of 75%, while the rest were occupied by long-term cultures.

2. Study Area & Methods

The study area is the territory of Georgia allocated for the agriculture. Historically soil fertility specified the importance of the agriculture sector as an important part of the Georgian economy. Agricultural productivity is currently limited by soil degradation, which is an important problem. The soil formation is a long process, while its degradation develops much faster. Soil degradation means the process of deterioration of soil resources fertility as a result of both natural and anthropogenic impact.

In Georgia the soil degradation is mainly caused by inefficient management of ground resources and ignoring the principles of sustainable development. It is stipulated by various aspects, namely:

- Significant increase of soil pollution level;
- Substantial decrease of the pastures and forests;
- Expansion of soil erosion;
- Increasing of saline soils.

The tendency concerning deterioration of the quality of soil resources is defined by the change of the economic relations i.e. transition of the country to free economy.

The main reasons are [9]:

i. Considerable shortage of activities to increase soil productivity;
ii. Interruption of the work for soil quality improvement and erosion reduction;
iii. Minimized use of organic and chemical fertilizers;
iv. Full or partial reduction of projects against pollution of soil resources.

As a result of inefficient management we receive:

- Degraded soils due to ground salinization. The typical examples are Georgian districts: Kakheti and Kvemo Kartli;
- Soil erosion caused by water impact. This is well expressed in Lentekhi district;
- Land desertification due to wind erosion. This is spread mainly in Dedoplistkaro district.

Due to these problems the complex study of the soil degradation in abovementioned districts of Georgia is very important.

Modern climate change has significant impact on the development of agriculture. Climate change has significant influence on natural disasters connected with climate, weather and water. The frequency and intensity of these disasters grow considerably. This leads to the soil degradation in large areas.

The ultimate outputs of all above-mentioned are the reduction of agricultural lands and arable areas [10]. That significantly worsens social and economic conditions of life

of the population.

Integrated study of abovementioned issues is the scientific novelty of the research.

Research areas and problems has a broad variation to variety of materials and methods being used. In a monography [9] methodologies and data sets utilized are overviewed. In order to carry out corresponding actions for accomplishment of tasks scheduled by the research it is necessary to carry necessary actions according to standards elaborated by International Standards Organization (acronym ISO). These measures with corresponding standards are:

- Inventory, taking and transportation of soil analysis samples in the districts/regions under investigation implemented according to ISO 10381-1 and 10381-2;
- Preparatory treatment and appropriate preparation (drying, disintegration, grinding, sieving etc.) of soil samples for chemical analysis carried based on ISO 11464 and ISO 565;
- Sampling and transportation of water analysis samples implemented according to ISO 5667-4:1987 standards;
- Determination of turbidity of water samples and suspended load using sedimentation method carried according to ISO 5667-17;
- Determination of humus in soil samples implemented using colorimetric method (at a depths of 0-10,10-20 and 20-30 cm);
- Determination of assimilated forms (N, P, K) in soil carried according to ISO 103041: 2007 and 9964-3:2010.

3. Results & Discussions

In 2009-2010 the production of annual and perennial crops was reduced. This is preconditioned by: a reduction in the sowing area, unfavorable weather conditions, pests and limited use of agricultural practices [7].

The decline in agricultural production are defined due to: water and wind erosion, other anthropogenic and natural agricultural processes that led to the degradation of 35% of agricultural lands [7].

The landscapes of East Georgia are vulnerable towards the climate change [8, 9]. For the last century in most of the territory of East Georgia increase of average air temperature in the range of 0.5 – 0.7 ^{0}C is observed. At the same time the frequency of the droughts grow considerably. The amount of the precipitation in the mentioned territory does not exceed 200-250 mm and the existing reserve of the productive moisture in a meter of thick soil is equal to 50 – 200 mm only. On the background of the global warming due to more rapid draughts, the transformation of the natural landscapes is anticipated.

In South-East of Georgia almost 3 th. sq. km territory located in semi-arid zone is damaged with droughts and wind-erosion and is liable to degradation and desertification. The process of desertification is clearly pronounced in Kiziki, Gare Kakheti and some districts of Kvemo Kartli. The territory of 120 th. ha of Dedoplistskaro district, the territory of 47 th. ha of Sighnaghi and Sagarejo districts, the territory of 32 th. ha of Gardabani district, the territory of 30 th. ha of Marneuli district are liable to the impact of desertification.

Table 2. *The Saline Soils of Georgia in 2012 (Th. ha).*

Region	Saline Soils					
	Arable land	Pasture / hayfield	Pasture / Shrubbery	Forest	Perennials	Total
Signaghi	1.68	5.5	2.25	0.09	0.15	9.67
Gurjaani	0.24	0.47	0.005	-	-	0.72
Sagarejo	2.51	3.8	0.63	0.05	0.06	7.05
Gardabani	5.1	3.29	2.1	0.51	1.1	12.1
Dedoplistskaro	2.21	4.17	0.51	0.67	0.44	8.00
Lagodekhi	2.12	-	-	-	-	2.12
Marneuli	1.59	7.3	1.0	0.04	0.75	10.68
Bolnisi	0.7	-	-	-	-	0.7
Qareli	0.06	0.08	-	0.005	-	0.15
Total	13.39	24.61	6.495	1.365	2.50	48.37

One of the types of degraded lands are saline and solonetz soils. They are mainly spread in Alazani valley. The medium and heavily saline and solonetz soils occupy more than 40 % of the total territory of Georgia. (tables 2-3).

Saline and solonetz soils are spread in the following districts: Sighnaghi (54 th. ha), Marneuli (53 th. ha), Dedoplistskaro (48th.ha), Gardabani (40 th. ha), Sagarejo (23 th. ha), Gurjaani (8 th.ha). In Georgia total area of saline soils is more than 205 th. ha and from this amount more than 84 th. ha are used. Therefore, they are characterized by low productivity.

It is necessary to research erosion processes activated due to temporary climate change. The basic factors that are stipulating the development of erosion processes are climate, relief, surface waters, soils and geological content of the Earth interior.

The problems of water erosion are strongly pronounced in mountainous territories that are mainly stipulated by over pasturing and unsystematic cutting of the forests. At present 50-60 % of the mountainous territory of Georgia are exposed to adverse impact of the water erosion.

The increase of water erosion leads to development of the accompanying processes such as landslides, mudflows, creation of the ravines.

The wind erosion occurs in the cold season of the year in winter-spring months (December-April).

That time North-West winds are predominant and their speed reaches 25-30 m/s. The main factors providing the wind

erosion are: climate, dry up, wind speed, absence of the wind-proof belts, absence of the plants in winter-spring period and irregularity of the precipitation.

Dedoplistkaro district is one of the most vulnerable in Georgia regarding desertification. Natural disasters, such as drought and strong winds have a substantial damage to agriculture.

Table 3. *The Solonetz Soils of Georgia in 2012 (Th. ha).*

Region	Solonetz Soils					
	Arable land	Pasture / hayfield	Pasture / Shrubbery	Forest	Perennials	Total
Signaghi	17.79	20.15	4.6	0.33	1.77	44.64
Gurjaani	2.46	1.89	0.019	0.017	0.51	4.896
Sagarejo	5.87	8.37	0.69	0.11	0.067	15.11
Gardabani	19.9	5.49	1.46	0.65	0.50	28.0
Dedoplistskaro	4.3	24.18	7.02	2.14	0.92	38,56
Lagodekhi	1.7	0.16	0.2	0.012	0.05	2.12
Marneuli	11.3	9.85	0.34	0.03	0.56	22.08
Bolnisi	0.26	0.11	0.32	0.011	0.003	0.70
Qareli	0.34	0.02	0.008	0.01	0.13	0.51
Total	63.92	70.22	14.66	3.31	4.51	156.62

3.1. Land Resources Degradation Due to Salinization

The most saline soils are observed in Kakheti region. The complex investigation of such type of soil degradation was carried for this region [9]. Agricultural soils of 606 thousand ha of Kakheti region the area of 133 thousand ha are saline soils that makes 22 % of total.

The necessary researches on the saline soils conditions were carried. The received results are listed in [9].

Thus:

- The climatic components changes in the Alazani valley and their influence on saline soils;
- The dynamic of the chemical composition changes of saline and alkaline soils;
- The migration of easily soluble salts and the soil productivity alteration;
- The dynamic of the processes of soil salinization - desalinization against: the seasonality, the irrigation, the underground water level, the soil physical characteristics and the climate components;
- The assessment of migration and accumulation in soil of the salts that have the toxic impact on the plants in connection with the climate conditions;
- The chemical content of collector-drainage, underground and irrigation waters are determined.

On Fig. 2- 5 the dry residue or total amount of easily soluble salts in 0-200 cm depths are given in dynamics during 2012 and 2013 for various plots. The analysis of presented graphs shows that in the soils of Dzveli Anaga vineyards salt content is increased in the depth during 2013. The dry residue has a growth tendency in grass soils in a depths of 60-80 cm in 2013.

The total amount of easily soluble salts amount is more during the 2012 in comparison with 2013.

However, total salinization has the growth tendency for plots with drainage and without drainage.

It would be mentioned that total salinization content in drainage plots are more than in the plots without drainage. This clearly shows the positive role of the drainage.

The negative impact of the climate change causes the decrease of some food products production. After caring out necessary activities on the saline lands it is possible to receive crop plants and food grasses that are necessary for the stock-breeding development.

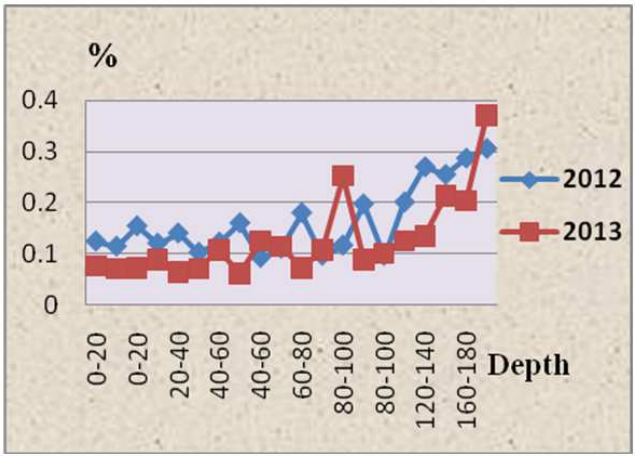

Fig. 2. *DryResidue Total Amount, (%) (Dzveli Anaga, vineyards) for 2012 and 2013.*

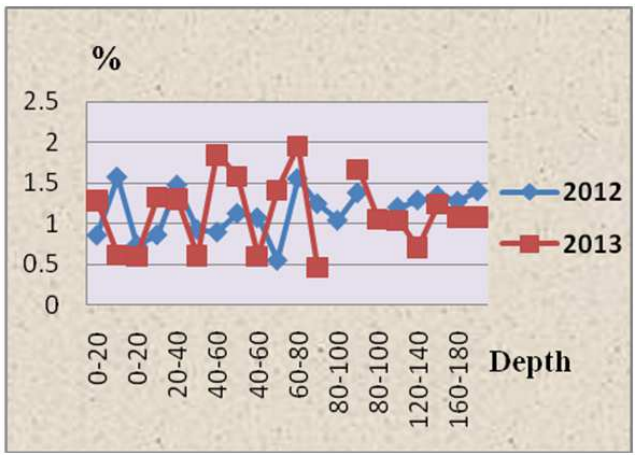

Fig. 3. *Dry Residue Total Amount, (%) (DzveliAnaga, Grass Soils) for 2012 and 2013.*

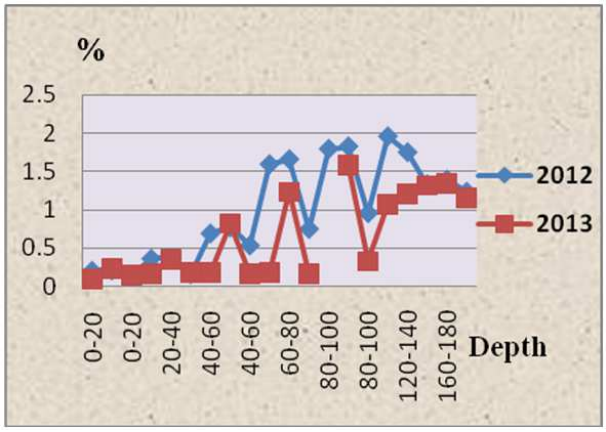

Fig. 4. *Total Amount (%) of Dry Residue Tsnori, drainage plot) for 2012 and 2013.*

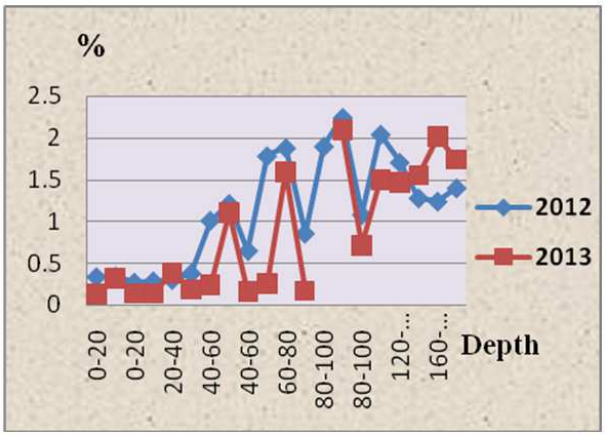

Fig. 5. *Total Amount (%) of Dry Residue (Tsnori, plot without drainage) for 2012 and 2013.*

The nonlinear character of climate change makes the creation of the adaptation measures and their implementation topical. In a new ecological situation characterized by big emmissions of technological pollutants in environment, plants and microorganisms exhibited new capabilities for the absorption and metabolic degradation of toxicants [4, 11, 12].

The analysis of the measures revealed necessity of the following activities fulfillment:

- Development of irrigation systems;
- Introduction of the biotechnologies (selection of drought and salt resistant plants);
- Enhancement of the scientific research in the agriculture.

3.2. Land Resources Degradation Due to Erosion Processes

Research of erosion processes were activated due to temporary climate change. The basic factors that are stipulating the development of erosion processes are relief, climate, surface waters, soils and geological content of the Earth interior. The following land-erosion zones were defined: water erosion in East and West Georgia, the wind erosion in East Georgia and Kolkheti lowland (table 4).

As mentioned above the problems of water erosion are strongly pronounced in mountainous regions that are mainly stipulated by over pasturing and unsystematically cutting of the forests. At present 50-60 % of the mountainous territory of Georgia are exposed to adverse impact of the water erosion. The increase of water erosion caused development of the accompanying processes: landslides, mudflows and creation of the ravines. At present in Georgia 10 th. landslides and 2 th. mudflows causing ecological equilibrium disturbance are detected. Top layer losses make 50-90 t/ha due to water erosion in various land-climate conditions of East Georgia and the same value for West Georgia is in the range of 120-150 t/ha [13].

Table 4. *The Area of Eroded Arable Soils in Georgia.*

Territory	Arable lands		Degradation Level					
			Weak		Middle		Strong	
	100 ha	%	100 ha	%	100 ha	%	100 ha	%
West Georgia	141.9	100	24.0	16.9	15.5	10.9	6.1	4.3 (32.1)
Abkhaseti	36.1	100	3.7	10.2	5.3	14.7	3.1	8.6 (33.5)
Adjara	8.8	100	2.7	30.7	2.5	28.4	0.1	1.1 (60.2)
Total West Georgia	186.8	100	30.4	16.3	23.3	12.5	9.3	5.0 (33.8)
East Georgia	467.7	100	74.6	15.9	45.0	9.6	9.8	2.1 (27.6)
South Osetia	18.7	100	5.5	29.4	6.1	32.6	1.7	9.1 (71.1)
Total East Georgia	486.4	100	80.1	16.5	51.1	10.5	11.5	2.4 (29..4)
Total Georgia	673.2	100	110.5	16.4	74.4	11.0	20.8	3.1 (30.5)
Total eroded soils	205.7 thousand ha - 30.6%							

In West Georgia the erosion processes caused a high magnification of the alluvium amount– up to 30 mln. Metric Ton annually. From this amount approximately 9 mln. Metric Ton fall on r. Rioni basin, correspondingly 9 mln. Metric Ton - on r. Chorokhi basin and 3 mln. Metric Ton - on r. Enguri basin.

As mentioned above the wind erosion occurs in the cold season of the year in winter-spring months (December- April). That time North-West winds are predominant and their speed reaches 25-30 m/s. The main factors providing the wind erosion are: climate, dry up, wind speed, absence of the wind-proof belts, lack of the plants in winter-spring period and irregularity of the precipitation.

Dedoplistkaro district is one of the most vulnerable regarding desertification in Georgia. Natural disasters, such as drought and strong winds have a substantial damage to agriculture. For the last 50 years the severity of these events had increased from 54 to 72 days and the frequency doubled.

The recurrence of strong winds (30 m/s and more) from the beginning of 1980 s increased 5 times.

In the second half of the 20-th century the average annual air temperature increased by 0.6^0 C and annual amount of precipitation grew by 6%. For 2100 the forecasted precipitation would be decreased by 14%. The aridity of the local landscapes would be transformed into semi desert and desert ones.

In Dedoplistskaro district the soil degradation is one of the most topical problems. The thickness of humus layer in arable lands, earlier characterized with high productivity, noticeably decreased due to wind erosion. In Shiraki area the humus amount of black earth soils decreased from 7.5% till 3.2 %. The soil productivity decreased almost twice respectively.

At present degraded soils are spread over 25 300 ha in the Dedoplistskaro district. From this amount the area of 20 000 ha is eroded by the wind. The wind negative impact is spread over 100 000 ha of the territory of East Georgia. More than 80 % of winter pastures are damaged due to over pasturing and partially because of climatic conditions [8]. This process is spread on some areas (Shiraki, Eldari, Iori, Taribana, Natbeuri, Naomari, Ole) fields, sublime localities and significant part of south slopes of Kakheti range [14].

3.3. Land Resources Degradation Due to Natural Disasters

Lentekhi region is one of the most vulnerable regarding natural disasters in Georgia. This is due to the fact that climate change consequences are expressed in increasing frequency and intensity of natural disasters. In the region for the last 50 years the average annual temperature and precipitation increased by 0.4^0 C and 106 mm (8%) respectively. For 2100 the forecasted precipitation would be decreased by 14%. The aridity of the local landscapes would be transformed into semi desert and desert ones.

At present degraded soils are spread over 25 300 ha in the Dedoplistskaro district. From this amount the area of 20 000 ha is eroded by the wind. More than 80 % of winter pastures are damaged due to over pasturing and partially because of climatic conditions [8]. This process is spread in some areas (Shiraki, Eldari, Iori, Taribana, Natbeuri, Naomari, Ole), sublime localities and significant part of south slopes of Kakheti range [11]. The main reason for these facts are that due to the climate change the frequency and intensity of natural disasters are increased considerably.

The time period 1967-1989 is divided into two equal intervals (1967-1978 and 1978-1989) and the analysis of the observation data on flash floods for these time intervals define that for the second period the recurrence of the flash floods doubled. The maximal value of water discharge is increased by 9%. At the same time the duration of flash floods decreased by 25%. That is explaining significant increase of the intensity of flash floods.

Since 1980 the amount of land slides increased by 43% and the slumped sites number reached 117 [15]. The landslides activated since anomalous rich snow winter that took place in Georgia in winter of 1986/87. For the last 2 decades in Lentekhi district increase of plentiful precipitation caused that the frequency of the mudflows doubled. For the last decade the land erosion is increasing due to the increase of frequency and intensity of natural disasters (flash floods, landslides, mudflows, snow avalanches, glacial catastrophes). The land erosion has significant negative impact on the agriculture and damage forests, spoil roads and infrastructure.

Since 1986 the population of Lentekhi district was decreased by 40% due to stirring up of the landslides and flash floods. The Adaptation Fund supported the project "Developing Climate Resilient Flood and Flash Flood Management Practices to Protect Vulnerable Communities of Georgia" (2012-2016). In frames of this project disasters risks are assessed and corresponding adaptation measures are created and carried out for mitigation land erosion in the region.

In addition to the impact of mudflows on degradation processes having place in most vulnerable Lentekhi district it would be useful to overview the heavy catastrophic events that happened in Georgia for the last two years. They are activated mainly by the modern climate change [13, 14].

In 13-14 June 2015 the severe mudflow took place in the river Vere basin. The disaster was connected with long lasted heavy rain. The extreme rain continued 4 hours. The precipitation amount made 49 mm (67 % of the monthly norm). The water level was substantially raised (more than 9 meters). It was accompanied with catastrophic mudflow. The consequences were terrible (see fig. 6). Due to torrential flow (the determined discharge was equal to 259 m^3/s) the human casualties took place, the infrastructure was destroyed, the soil resources were fully degraded. The material losses amounted to several hundred USD.

Fig. 6. *Consequences of Catastrophic Flash flood/ Mudflow in r. Vere Basin.*

The severe catastrophic events (heavy rain and strong mudflows were caused by the ice avalanches occurred in May and August, 2014 from Devdoraki glacier.

High mountains (Big Caucasus Range) are spread at the North of the Georgia. The main problem here are the glacial and hydrological disasters such as glacier falls, the river bed blockage and natural dam formation, with consequent break and passing of catastrophic flash floods and/or mudflows.

Consequently the large areas of land are degraded. To study

these processes the most effective and easy way is assessment of the degraded soil resources from the space i.e. the use of satellite remote sensing [16].

The main reason of the glacial mudflows genesis are consequences of the glaciers subduction. Most of the mountainous glaciers are characterized by rapid pulsing movement. This is a result of the processes going inside the glacier, i.e., fast change of glacier bed conditions and distribution of substances in accumulation and ablation area. In Caucasus there are pulsating glaciers (e.g. Kolka and Devdoraki), which are characterized by sharp advancing of the glacier body the so-called surge accompanied by glacier falls.

When glacier retreats the glacier tongue, due to restricted feeding (result of decreasing of snow precipitation and reduction of its accumulation in firn field) is grinded. The crevices are created on the glacier tongue that make prerequisites for moraine material accumulation (rocks and their debris that falls on glacier surface). In these places due to high temperatures and frequent precipitation on the surface of glacier the certain amount of water is accumulated. It will break the created dams capturing all the remaining ice and moraine material. As a result the destructive mudflows are created.

Obviously, the mudflows that took place in the past were the result of the glaciers such pulsation. At that time periods the characteristics of the Georgian glaciers were mainly increasing.

Last catastrophic events occurred in May and August, 2014 during the period when the characteristics of the Georgian glaciers were steadily diminishing [17].

Based on video, photo material analysis, it can be concluded that the creation of the May 17 and August 20, 2014 catastrophic mudflows are not fully connected with the pulsation of the Devdoraki glacier. In May 17, 2014 from Kazbegi slope at 4, 700 m elevation was cut ice block, with the volume of 5 million cubic meters. This mass fell down along 80-85 degrees inclined slope below 2, 500 m. Then it jumped over the Devdoraki glacier tongue and stroke the left side of the narrow gorge. The ice mass from the mountain slope was accompanied with the volcanic slag. Vice versa can also be considered, i.e., volcanic slag was off first and then it was accompanied with ice.

The red trace of the volcanic slag is well reflected in the area's of the strike of the gorge sides and debris flow trace from the source to the confluence (fig.7). Mudflow material surface that arrived in the r. The Terek valley also was red due to the volcanic slag [17].

The torrential stream generated due to the ice block collapse into pieces. Water/ice masses mixed with moraine material and vulcanic slag (red slag pieces, including andesite & dacite rock material) generated semi-viscous mass. This material passed through narrow Devdoraki-Amali gorge with the speed of 100 km/h in 4-5 min.

Semi-viscous mass stream blocked r.Terek riverbed and artificial reservoir was established (fig. 8).

Fig. 7. *The red trace of the volcanic slag.*

Fig. 8. *The Terek river bed blockage.*

The consequences were heavy. Outgoing pipeline was exploded. Casualties amounted to 9 persons. Established artificial reservoir occupied the area about 2 hectares and the pond was 15 m deep. Luckily water was discharged by under construction derivation tunnel of hydropower station. The outgoing road was closed for a long-term time. The soil resources were fully degraded.

It should be noted that throughout the history of the survey of Devdorak glacier such big scale and strong catastrophe was not observed twice a year.

4. Conclusion

Soils represent at least a quarter of global biodiversity, and play a key role in the supply of clean water and resilience to floods and drought. Crucially, plant and animal life depend on primary nutrient recycling through soil processes.

Proper exploitation of land resourses is one of the main problem of the adverse impact of climate change. Soil formation is a long process, while its degradation develops much faster. Soil degradation means the process of deterioration of soil resources fertility as a result of both natural and anthropogenic impact. The current escalating rate of soil degradation threatens the capacity of future generations to meet their needs.

Research of soil degradation processes were activated due to climate change adverse impact worldwide. The basic factors that are stipulating the development of degradation processes are relief, climate, surface waters, soils, geological

content of the Earth interior.

In Georgia the soil degradation is mainly caused by inefficient management of ground resources and ignoring the principles of sustainable development. The following physical processes are stipulating degradation: salinization, erosion processes, natural disasters impact, substantial decrease of the pastures and forests.

Due to abovementioned the complex study of the soil degradation in connection with climate change tendencies in Georgia were done.

Modern climate change has significant impact on the management of soil resources and development of agriculture.

The landscapes of East Georgia are vulnerable towards the climate change. In most of the territory of East Georgia increase of average air temperature in the range of 0.5 – 0.7 ^{0}C is observed in last century. At the same time the frequency of the droughts grow considerably. The amount of the precipitation in the mentioned territory does not exceed 200-250 mm and the existing reserve of the productive moisture in a meter of thick soil is equal to 50 – 200 mm only. On the background of the global warming due to more rapid draughts, the transformation of the natural landscapes is noted. In South-East of Georgia almost 3 th. sq. km territory located in semi-arid zone is damaged with droughts and wind erosion processes and is liable to degradation and desertification. The process of desertification is clearly pronounced in some districts of East Georgia. The territory of 120 th. ha of Dedoplistskaro district, the territory of 47 th. ha of Sighnaghi and Sagarejo districts, the territory of 32 th. ha of Gardabani district, the territory of 30 th. ha of Marneuli district are liable to the impact of desertification.

Research areas and problems has a broad variation to variety of materials and methods being used. In order to carry out up-to-date accomplishment of tasks scheduled by the research, the necessary measures and actions are carried according to standards elaborated by International Standards Organization.

One of the types of degraded lands is saline soils. They are mainly spread in Alazani valley. The medium and heavily saline soils occupy more than 40% of the total territory of Georgia. Saline soils are spread in the following districts: Sighnaghi (54 th. ha), Marneuli (53 th. ha), Dedoplistskaro (48th.ha), Gardabani (th. ha), Sagarejo (23 th. ha), Gurjaani (8 th.ha). In Georgia total area of saline soils is more than 205 th. ha and more than 84 th. ha are used. Therefore, they are characterized by low productivity.

Soil resources degradation due to erosion processes activated because of temporary climate change is researched. The basic factors that are stipulating the development of erosion processes are climate, relief, surface waters, soils etc.

The wind erosion occurs in the cold season of the year in winter-spring months (December-April). That time North-West winds are predominant and their speed reaches 25-30 m/s. The main factors providing the wind erosion are: climate, dry up, wind speed, absence of the wind-proof belts, absence of the plants in winter-spring period and irregularity of the precipitation. Natural disasters, such as drought and strong winds have a substantial damage to agriculture.

In Dedoplistskaro district the soil degradation is one of the most topical problems. The thickness of humus layer in arable lands earlier characterized with high productivity noticeably decreased due to wind erosion. The content of humus of black earth soils in Shiraki area decreased from 7.5% till 3.2 %. The land productivity decreased almost twice respectively.

At present degraded soils are spread over 25 300 ha in the most vulnerable Dedoplistskaro district. From this amount the area of 20 000 ha is eroded by the wind. The wind negative impact is spread over 100 000 ha of the territory of East Georgia. More than 80 % of winter pastures are damaged due to over pasturing and partially because of climatic conditions.

Modern climate change has significant impact on the management of soil resources and development of agriculture. Climate change has significant influence on natural disasters connected with climate, weather and water. The frequency and intensity of these disasters grow considerably. This causes the soil degradation on large areas.

Lentekhi region is one of the most vulnerable regarding natural disasters in Georgia. This is due to the fact that climate change consequences are expressed in increasing of the frequency and intensity of natural disasters. In the region for the last 50 years the value of average annual temperature and the amount of precipitation increased by 0.4 ^{0}C and 106 mm (8%) respectively.

The analysis of the observation data on flash floods showed that for the active anthropogenic influence period (time period from 1978) the recurrence of the flash floods doubled in comparison with the previous period.

The maximal value of water discharge is increased by 9%. At the same time the duration of flash floods decreases by 25%. That can explain significant increase of the intensity of flash floods.

Since 1980 the amount of land slides increased by 43% and the slumped sites number reached 117. The landslides activated since anomalous rich snow winter (1986/87). For the last 2 decades in Lentekhi district increase of plentiful precipitation caused that the frequency of the mudflows doubled. For the last decade the land erosion is increasing due to the raise of frequency and intensity of natural disasters (flash floods, landslides, mudflows, snow avalanches, glacial catastrophes). The land erosion has significant negative impact on the agriculture and damage forests, spoil roads and infrastructure.

The nonlinear character of climate change makes the creation of the adaptation measures and their implementation topical. In a new ecological situation characterized by big emissions of technological pollutants in environment, plants and microorganisms exhibited new capabilities for the absorption and metabolic degradation of toxicants.

The analysis of the measures revealed necessity of the following activities fulfillment:

- Development of irrigation systems;
- Introduction of the biotechnologies (selection of drought and salt resistant plants);
- Enhancement of the scientific research in the agriculture.

Research results allow the study of soil degradation, improve the soil fertility and create effective methodology and corresponding measures for prevention or/and mitigation of soil degradation.

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