Analysis of Geodynamic Processes Developed in Georgia

Avtandil Khvadagiani\textsuperscript{3}, Elguja Medzumariashvili\textsuperscript{1,4}, Zurab Laoshvili\textsuperscript{1,2}, Sergo Khomeriki\textsuperscript{1}, Nikoloz Chikhradze\textsuperscript{1,2}, Teimuraz Kikava\textsuperscript{5}, Grigol Shatberashvili\textsuperscript{1,2}, Davit Khomeriki\textsuperscript{1}

\textsuperscript{1}Grigol Tsulukidze Mining Institute, 7, Mindeli St., Tbilisi, 0186, Georgia
\textsuperscript{2}Georgian Technical University, 0175, Tbilisi, Georgia
\textsuperscript{3}State Military Scientific-Technical Center “Delta”, 0144, Tbilisi, Georgia
\textsuperscript{4}Institute Of Structures, Special Systems and Engineering Maintenance, 68b Kostava str., Tbilisi Georgia
\textsuperscript{5}Batumi Shota Rustaveli State University, 35/32 Ninoshvili/Rustavelis str., 6010, Batumi, Georgia

khomeriki_sergo@yahoo.com

Abstract. In the paper, the landscape-geographic disasters, caused by natural spontaneous events (landslide-gravitational, mudflow, rock fall, snow slides), are considered. It has been noted that at such locations, the use of constant monitoring and creation of a single system of communications plays an important role in the activity of state institutions and organizations, the operation of which is associated with control of natural disasters or is used for reduction of the negative effects caused by catastrophic events.

1. Introduction

Geodynamic processes (landslide, mud flow, rock avalanche/rock fall, snow slide and etc.) are natural or natural-anthropogenic processes of large-scale destruction, which, in many cases, are harmful to the human health. They are also denoted as spontaneous-destructive processes (Figure 1).

Systematic collection of the information about above-mentioned processes, their renewal and analysis play the important role in the activity of state organizations the work of which is connected with the control of natural disasters or/and with the reduction of the negative effect of the mentioned processes.

Spontaneous-destructive processes are the result of the interaction of interconnected natural factors (relief, climate, soil-ground, vegetable cover and etc.) The formation-provocation of some of them is associated with the human economic activity (for example, incorrect reclamation of the hillsides, industrial explosions, building of roads, dams and etc.). Along with it one of them may cause the formation of the second one (for example, the landslide body collapsed in the river valley may cause the mudflow). Mentioned processes are highly different from one another by the scales of their reveal and duration.
2. Analysis of Geodynamic Processes

Georgia is the typical mountain country (up to 76% of its territory is occupied by mountain relief). Human activity proceeds in a geographical medium which is extremely sensitive against spontaneous processes. As a result, its geo-ecological complications attain a critical limit. Therefore, Georgia actively participates in international processes for the reduction of harmful effects of natural spontaneous processes.

In Georgia, almost all landscape-geographical zones are in the area of spontaneous harmfulness from the Black Sea coast to high mountains, where the geo-ecological situation is extremely complicated. The negative social-economic, demographic and ecological results, caused, especially, by landslide and mudflow processes, include all spheres of the human activity. Hundreds of the settlements, agricultural lands, roads, traces of oil-and-gas pipes, masts of high-voltage power transfer, hydraulic-amelioration facilities, touristic-recreation complexes and etc. are subjected periodically to their strong effect (in some cases by catastrophic results). In Georgia, only from the 90-th of last century up to nowadays more than 1000 humans became a victim to the spontaneous-destructive processes. Even at the activation of spontaneous phone, the total economic losses comprised tens of million dollars and in the case of its extreme development exceed hundreds of millions.

From this viewpoint, the severe situation is emerging in the mountain regions. As a result, in the case of the extremal activation of the element the relocation of the population is necessary to other locations. Over the last 30 years, up to 60 thousand families were relocated from the aggrieved places.

Extremes of activation of mudflow-landslide processes were subjected, to a greater extent, to the definite cyclicity and, on the basis of local geological-climatic conditions, were repeated over 2-5 and 8-11, years once in average. Though it should be noted that over the last years, the activation of the processes over the average phone is registered almost year after year and the intervals of their extremal reveal are significantly reduced. Along with it, the risk of their harm fullness is increased year after year by geometric progression.
For constant monitoring of harmful geodynamic processes, for avoiding of catastrophic results, for calculation of real losses and for organized control of eco-migrants currents the creation of geo-information system for spontaneous-destructive processes is necessary with single multi-thematic data bank. Formulation of perfect and exact database is a complex and long-term process which implies not only the information about going natural spontaneous processes but also their standardization, revision and systematic renewal of existing data. For this purpose, the technologies of the control of spatial (geographic) data – geographic information systems (GIS) must be used. By its use, the systematization of the data, their organized storage, search, spatial analysis, modeling, thematic mapping, generation of typical reports, statistical analysis and etc. is possible (Figure 2) [1].

![3DGIS model of Akhaldaba landslide](image)

**Figure 2.** 3DGIS model of Akhaldaba landslide

It should be noted that the most of the old data is inaccessible or a failure. On the basis of the latest researches the unknown 700 landslides, 350 mudflows and 100 cases of the rock fall were fixed, though this amount is very small in comparison with the total amount of the processes with were revealed over last decades. In this period at Georgian territory up to 50 thousand landslides up to 3 thousand mudflows transforming erosion watercourses were fixed in dynamics and in the zone of harmful risk because of which up to 3000 settlements are in the harmful area [2, 3].

**Landslide** is the breakaway or replacement of the layer of soil-ground or rocks by the gravitational force on the hillside mainly there, where the hillside and its constituent layers are inclined in one direction.

The reason for the formation of the landslides involves the disequilibrium between the shifting gravitational force and obstructive force. It is caused by the following reasons:

- By increase of hillside inclination caused by washing out;
- Impairment of rock hardness by depletion or by over humidity;
- By action of seismic impacts;
- By incorrect building or agricultural activity.
The system of the landslide monitoring (Figure 3) implies the use of the sensors of various types for determination of the dynamics and intensity of landslide displacement. The information obtained from the sensors of various types is transmitted to the centralized operational system (data logger). Landslide motion is a complex process which depends on many factors. The monitoring of the motion of the landslide body is usually based on the use of the inclinometers.

![Figure 3](image)

**Figure 3.** System for monitoring of various type on landslide processes

Inclinometer, mounted on the borehole, drilled on the landslide, determines the direction of landslide body, displacement velocity and other parameters (Figure 4).

![Figure 4](image)

**Figure 4.** Inclinometer

For landslide observation, the system of global positioning-GPS is also widely used. Its principle involves the following: at one concrete stable place the basic GPS is installed and hereafter so-called reference marks are located at some places of landslide body. Their displacement is fixed by the basic GPS and transmits the information in the on-line regime.

Its advantage lies in the fact that it is not associated with the high sums.
It should be noted that there is no digital (equipment) for landslide processes. Traditionally the record keeping of the information about landslide processes and their mapping is carried out by the department of the control of geological danger of National Agency of the environment (Figure 5).

Mudflow is the complex geological-geomorphological and hydro-meteorological process, the motion of high-concentration water-ground current in the river or ravine bed. Its reveal is determined by a high partition of the relief, by high inclination of hillsides and by an intense development of denudation and erosion processes, by intense snow melting, by the waters overflow from the basins of natural or artificial dams and by intenserainfalls.

Mudflow is formed at intense and long-term rainfalls, at rapid melting of the glaciers or seasonal cover of the snow, as well as owing to collecting of loosed material in large quantities in water collecting bed. Deforestation on mountain hillsides may be the critical factor since the tree roots reinforce the upper part of the soil which reduces significantly the possibility of the formation of mudflow current.

In the places of mudflow danger the avalanched material of large volume, formed as a result of the intense physical depletion, in the conditions of saturation by water and fluidization, is transferred to the currents of mud, stone mud and water stone which, in contrast to usual flood, is characterized by higher water discharge, by higher velocity of the motion, by large volume of solid outflow by high density and respectively, by specific power of the impact (Figure 6). Such currents are characterized by destructive force, this is a serious hazard to the settlements.
Mudflow always was a serious hazard. River Duruji is a classic example of harmful mudflow in Georgia which destroys multiply the city Kvareli (in 1832, 1889, 1904, 1949, 1990, 2002 years). In 1904, mudflow and crushed stone, derived by the river, flushed the whole town. In 1987, at night, the mudflow in the bed of river Chokhelni (Aragvi valley) nearly backfilled 9 families. Over the last period, because of the human intervention in nature, his hazard has significantly increased which determined the necessity of urgent measures.

For example, Devdoraki glacier is well-known for its strong ice avalanche which was fixed in 18-21-st centuries. The ultimate similar catastrophic glacial mudflow at Devdoraki glacier was registered in spring and summer of 2014.

To avoid the tragedy, originated after the mudflow in the valley of Devdoraki-Amali by the initiative of LEPL National Agency of Environment, the modern system of early warning was mounted. The system controls the mudflow source as well as the critical levels of the water in the river valley by means of modern technologies (Figure 7). Also, the single system of communications if the data was created which provides the correct functioning of the system of early warning.

At Georgian territory, the mudflow processes take place in all regions more or less. Their intense reveal is associated which mountain places (Figure 8).
Figure 8. Map of Georgian mudflow danger

Rock fall is characterized by crumbling of the fragments, stone blocks and of the masses of a large stone from the hillside of abrupt mountain. This process is long-term one until the gravitational equilibrium will be attained at the hillside. This process is among the most harmful-gravitational ones in the conditions of mountain relief.

The main frequent reasons, causing the rock fall are water freezing in the rock cracks, as well as melting of the free zed stones under the action of the sun on the massif. Large-scale rock fall may be caused by the earthquake.

Displacement of the human or animal may also provoke mentioned gravitational process at the depleted rock hillside.

Probability of the formation of rock fall is increased in the morning where the melting of overcooled rocks begins under the action of the sun. Morning rock fall is characterized for stone massives, located at the hillsides oriented to east and south-east and for the hillsides oriented to the west — at the second part of the day.

Rainy and warm weather increases the danger of rock fall. Cyclicity of rock fall increases seasonally in the second part of the summer when the stone massive are liberated from the ice and snow cover.

Relatively seldom are destruction centers in stone massives. Fall of large blocks from the center of active destruction occurs every 1-3 hours. Fallen blocks cause the rock fall and the block inertia is so big that they move away from the hillside by high distance at rolling down.

Rock fall is of significant hazard in the river abrupt beds and in various fallen forms of the relief. The moraines, collected on the abrupt ice layer and fallen hillsides are of a serious hazard. As a result of the rock fall, the rods are often failure (Figure 9).
The rock fall is revealed most intensively in the mountain regions of Georgia (Figure 10).

Control of the rock fall in the hazard zone may be carried out by mounting of radar scanners at one specific stable place. It records the potentially harmful places from the viewpoint of the development of the processes of rock avalanche and rock fall. The scanner records the displacement of the masses at the hillside by unit millimeter and allows the distant obtaining of the information about the existing situation (Figure 11).

Snow slide is the rapidly moving snow mass which falls or slides from the mountain hillsides. Frequently it is of catastrophic character. The most advantageous condition is the case when the snow
cover exceeds 20 cm, the inclination of mountain hillside varies from 15° to 50° and it is free from the forest cover, even though there is more than 10 cm of the snowfall takes place. The snow slide action is mainly expected in winter-summer months. Snow volume in the snow slide may attain up to millions of cubic meters.

There are several classifications of the snow slides, for example:
- By the shape of snow slide motion;
- By the character of snow slide motion;
- By the volume;
- By the snow slide collectors relief and snow slide path;
- By the snow consistency.

By the snow consistency the dry, humid and wet snow slides are recognized. Dry snow slides, as a rule, are formed as a result of low adhesive force between large (or displaced) snow mass and fellow located ice crust. The velocity of the motion of dry snow slide, usually, comprises 20-70 m/sec and maximum velocity up to 125 m/sec (450 km/hour). By some data, the velocity of the motion of mentioned slow sides does not exceed 200 km/hour at snow density: 0.02-0.3 g/cm³.

During the motion by such velocity, the displacement of dry snow slide may be accompanied by a snow-air wave, which causes significant failure. The pressure of the shock wave may attain to 800 kg/m². The highest probability of the formation of the snowslides of the mentioned type is the low temperature.

Wet snowslides, as a rule, are formed against the background of unstable weather. The direct reason for their avalanching involves the existence of water interlayer between the layers of the snow of various densities.

Wet snowslides, in comparison with dry ones, move by considerably low velocity: 10-20 m/sec (up to 40 m/sec), though they are characterized by higher density (0.3-0.4 g/cm³, sometimes up to 0.8 g/cm³) which determines the rapid 'closing' of mountain mass. This imparts the performance of life-saving works.

The period, over which an activation of snowslide is expected, is referred to as snowslide harmfulness. In Georgia, such period continues from January to May in the mountains of subtropical and moderate zones.

Mountains, on the basis of snowslide danger and of the height from the sea level, are conventionally divided into several zones: zone of great snowslide danger, zone of high snowslide danger, zone of intermediate snowslide danger and zone of negligible snowslide zone.

Zone of great snowslide danger (3000-4000 m from the sea level) – snowslides avalanche more them once throughout the year, zone of high snowslide danger (2000-3000 m from the sea level) – snowslides avalanche year after year; zone of intermediate snowslide danger (1500-2000 m from the sea level) –
snowslides avalanche nearly year after year; zone of negligible snowslide danger (1000-1500 m from the sea level) – snowslides avalanche rarely.

In Georgia, 56% of the territory is snowslide danger. Along with it, at 20% the snowslides are registered year after year and they are referred to as systematic snowslides. This process is especially intense at intermediate and high mountain places. Up to 5000 centers of avalanche danger are fixed at the country territory from which more than 1100 are harmful to more than 100 settlements, main roads, masts for transmission of high-voltage power and for other engineering structures. In the country, the west and central parts of the Caucasian chain and Guria-Adjara plateau are characterized by the highest coefficient (up to 0.7-0.8) of snowslide danger (Figure 12, 13).

Figure 12. Map of Georgian snowslide danger

Figure 13. Svaneti, Jvari-Mestia road
3. Conclusions
At high-risk landslide-gravitational, mudflow, rock fall, snow slides locations of mountain Georgia the use of constant monitoring and creation of a single system of communications plays the an important role in the activity of state institutions and of the organizations, the operation of which is associated which the controls of natural disasters or is used for reduction of the negative effects caused by catastrophic events.

References
[1] Atlas of hazards and risks of natural spontaneous events characteristic of Georgian territory. CENN/ITC, Tbilisi, 2012.
[2] Comparative analysis of climate change adaptation and disaster risk reduction architecture and recommended actions in Georgia. Swiss Agencyfor Development and Corporation SDC, Tbilisi, 2018.
[3] G. Gaprindashvili, “Geodynamic processes at South plateau of Georgia and expected geoecological complications,” Doctoral thesis, Tbilisi, 2016.