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Risk of Natural Hazards in Georgia

[1,2] Emil D. Tsereteli, [1]Nana R. Bolashvili, [1,2]George M. Gaprindashvili, [2]Merab V. Gaprindashvili, [1]Nino G. Machavariani

[1]*Vakhushti Bagrationi Institute of Geography of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia*
[2]*National Environmental Agency, Department of Geology, Tbilisi, Georgia*
gaprindashvili.george@gmail.com

ABSTRACT

Two groups of completely different phenomena and consequences can cause natural hazards. Those are dangerous meteorological processes in the atmosphere and geological processes, which take place on the earth surface and its crust. However, in spite of very different nature and development conditions of these phenomena, there is quite often a synergetic liaison between them, which determines the level of activation/reactivation of the given phenomena.
Natural Hazards become more topical in the beginning of XXI century, as the pressure of them on human environment becomes much heavier. Background of global climate change processes immeasurably increases the risk of uncontrollable disasters.
Taking into account that the South Caucasus region and especially Georgia, belongs to the regions distinguished among the world mountainous areas by natural hazards large scale development processes, frequency recurrence, and negative impact on population and engineering/economic facilities, South Caucasus is recognized as one of the most vulnerable regions.

Key Words: *Natural hazards, landslides, climate change, geology.*

Introduction

Natural hazards become more topical in the beginning of XXI century, as the pressure of them on human environment becomes much heavier. Background of global climate change processes immeasurably increases the risk of uncontrollable disasters.

Taking into account that the South Caucasus region and especially Georgia, belongs to the regions distinguished among the world mountainous areas by natural hazards large scale development processes, frequency recurrence, and negative impact on population and engineering/economic facilities, South Caucasus is recognized as one of the most vulnerable regions. Besides that, the territory of Georgia is located within the limits of 7 – 9-point intensity earthquake risk area. The earthquakes are directly connected with stimulation of landslide-gravitational and debris/mudflow phenomena. Major part of Georgian population, agricultural lands, roads, oil and gas pipe-lines, hydro-technical and irrigation facilities, electric transmitting lines, and mountainous tourism facilities periodically endure the attacks of natural phenomena. Georgia hosts a great variety of morphological and climate conditions - from the humid, subtropical coastlines to highland-alpine-nival areas; whenever natural disasters strike the country, this usually leads to a great number of casualties, also due to very populated human settlements all across Georgia [1 - 5] However, the majority of geo-ecological cataclysms take place in mountain zones, which represent 71% of the country territory and which are occupied by 20% of population. At the same time, the mountainous zones have enormous potential in geopolitical and economic development of the country. 2/3 of landslides observed in the country took place in mountain zones, while debris/mudflows, snow avalanches, rockfalls, rock avalanches took place almost exclusively in mountains. Economical damage caused by natural hazards, as well as casualty and ecological migration in 80% of cases take place in mountain areas followed by devastation of mountain villages and settlements.

Among the multi-spectral geological processes in Georgia the most impressive phenomena are gravitational landslides and debris/mudflows, washing out of marine coasts and river banks within the limits of settlements.

The spatial distribution of landslide and mudflow events over the territory encompasses both the seaside and the highlands. Out of the 70 municipalities regarded as affected by landslide hazards, 29 are included in the average-hazard zone (41%) and 35 (50%) in the high-hazard zone. According to recent data (2011–2018) from 8229 families (Source: Department of Geology of Georgia 2019), as a result of this monitoring activity, 1545 families were given the recommendation to relocate to safer houses/settlements [6].

Risks of geological phenomena

The geological processes developing in mountain regions are characterized by high heterogeneity. Origination or re-activation of them depends on integrated interrelation of multi-spectral factors. Study of development mechanisms of such extremely complex phenomena and determination of that relevant dominant factor (or a group of factors), which can move the geological environment out from homeostatic state and triggers origination/re-activation of this or that kind of processes (or groups of processes), would be impossible without well developed methodology and the well-thought-out systemic approach.

Taking into account that processes are considered as a consequence of interaction of large number of factors (components) in the open equifinal system, where origination/re-activation of geological processes at certain stages of their development should be determined as the final (concluding) action of the whole system. Hence, the assessment of development regularities of contemporary elemental processes and the re-activation trends in the multi-spectral system of triggering factors, should be based on the basic determinative factors.

Presumably, there are certain multi-spectral natural factors triggering processes (some authors define nine different levels [7]), which determine regional and zonal regularities of development of elemental destructive processes and phenomena. The most important factors among them are geological environment (lithologic composition, state, features, tectonic activity, and earth crust movement), relief morphology and its energy potential constant, and the climate, as the unity of meteorological conditions of a given area with the established regime [8]. The scale of development processes and their activation speed depend on sensitivity level of landscape-geological environment of a given space.

Climatic conditions, which in geological past played determinative role in modification processes of the earth surface, as well as in forming of sediments and the landscape-geographic zones, are determining also current correlation of the development time and space of exo-geological processes and the regime of development/re-activation.

However, the role of climate in the relief morphogenesis is quite well investigated. Climate related methodological and theoretical issues are included in a new direction of earth sciences of second half of XX century – “Climatic geo-morphology”. The role of climate factor in engineering geo-dynamics and in the development of contemporary geological processes, especially the issues of forecasting of geological processes in terms of time and space is much less investigated.

Professor A. Shcheko [9,10] who is one of the founders of research methodology on forecasting of elemental geological processes related to the development and activation trends of exogenous geological processes regime, includes the climatic conditions into the main group of changeable factors. This problem is especially important for such complex and vulnerable (in terms of geological processes) mountain regions as

Caucasus and especially Georgia. All zones starting from sea coastal zone and ending with high mountain-nival belt, from humid sub-tropical climate to dry arid climate, are represented in the landscape-ecological environment of Georgia. Each zone is characterized by special type of geological processes, the regime, intensity, and activation level different in accordance with observation conditions of geological environment. Meteorological elements able to provoke certain processes (atmospheric precipitations, humidity, temperature, etc) through deviations from limit values of perennial mean norms can cause changes in the above-mentioned parameters. At the same time, the more syncretic is geological environment, as the receptor and synthesizer of atmospheric precipitations, the higher is activation level of the processes in short time interval.

It should be noted that climate conditions (through increased 'humidity effect') stimulate landslide processes at the slopes which are generally predisposed to such processes and number of which is over 70% among the total number of landslides of different genesis. Climatic factors have decisive role in generation/reactivation of mudflow transformations, erosive processes, floods, snow avalanches, etc.

29% of the whole territory of Georgia is subject to water erosion processes that significantly threaten the environment in general and especially village economy. In 1957-78 the erosive processes damaged 20 000 ha of lands which were excluded from land fund. Area of arable lands by 1980 in Georgia was 673,2 thousand ha, 30,5 % of which were eroded [11]. Soil erosion is especially intensive under the influence of strong anthropogenic factors in mountain regions with scarce plant coverage. About 150-200 tones of fertile soil per 1 ha area is washed out annually in such areas. In case of highly intensive downpours, these figures are increasing up to 300-500 tones per 1 ha, while the soil regeneration processes take centuries in conditions of optimal climate. In this regard the gravest situation is developed in mountainous areas of Ajara, Svaneti, Racha-Lechkhumi, Meskheti, Kazbegi, and Dusheti [12].

Intensive washing out of riverbanks can be observed on big rivers (Rioni, Tskhenistskali, Enguri, Kodori, Mtkvari, Alazani, Iori) in valley and foothill zones, where the annual values of washed out areas fluctuate within 2 – 3,5 m in average. In cases of extreme flooding, this figure increases up to 10 m, especially in the most vulnerable areas. If we take into account that total length of the riverbanks subject to intensive washing out is over 1000 km, and the annual wash out value is approximately 1,5 m, then the annual losses of lands is 150 ha [11].

In lowland areas of Georgia, the washing out of big riverbanks caused by increased water level usually is followed by flooding of significant areas with all negative consequences. According to historical data, around 30-35% of population was affected by extremely intensive floods on river Rioni in 1811-1812. In 1839 water level on this river increased up to 9,6 m, in 1911 – up to 3 m, and in 1922 – up to 2,8. Area of 13 000 ha was flooded in 1982 caused damage of 12 million USA dollars. During the last period, there were not described such catastrophic floods in Kolkheti lowland, except 1987, when 20 000 ha were flooded, 3,2 000 facilities damaged, 2 000 facilities and 16,5 km of railway destroyed. Total damage was calculated about 300 million dollars [13]. Catastrophic floods were described repeatedly in the past years on river Mtkvari, Alazani and lower segments of their tributaries (1839, 1956, 1967, 1968, 1972), which caused damage of several thousands million dollars and took away tens of lives. Some large floods were observed during the last period (2004-2010) on rivers Rioni, Tskhenistskali, and Alazani. Special kind of water erosion is the intensive washing of the Georgian Black Sea coast, which periodically damages high valued recreational areas. From time to time it becomes necessary to provide reconstruction works or moving of highways or railway. In a number of areas of abrasive segments (Musera, New Athoni, Eshera, Ochamchire, Makhinjauri, Gonio-Sarpi, etc) the washing out processes caused by storms coincide with significant activation of landslide processes. By 1980 total area of washed out and degraded coasts was 220 km. In 1967, 1971, and 1978 the direct damage caused by winter storms to Abkhazian coast was estimated up to 27 million dollars [11]. Expenses for coast protection works conducted in Georgian Black Sea coastal areas in 1961-71 were calculated as 45 million dollars, while in 1972-81 – over 81 million dollars. In spite of the measures undertaken for coast protection purposes, the washing speed is catastrophically high, especially on Abkhazian coasts, where beach forming solid sediments today are being taken in a very unacceptable way.

However, the most dangerous/strong natural phenomena among geological processes due to their potential development scale and recurrence frequency, which keep in stress local population and can cause an irreversible economic damage to the country, are landslides and mudflows. Landslides of all kinds and mechanisms known in engineering-geodynamics can be developed in Georgia, starting with the simplest type, deformation of which remains within the aeration zone, and ending by the deep ones (10 meters) of the volume of million cubic meters. However, according to massive development of the landslide processes and the activation intervals, the most distinguishable are those landslides, which can be directly provoked by the regime distribution of atmospheric precipitations. This type of landslides is called climatic (or consistent), dynamic mechanism of which is determined by consistence of water on the slopes and by 'humidity effect'. Changes in 'consistence' features of rocks, as well as critical decreasing of resistance to shifting depend on these parameters. More than 70% of the landslides in Georgia represent this type of landslides and can be found in all landscape-geo-morphological zones [13, 14].

Large development scale and high recurrence frequency of climatic landslides are the main features of almost all landslides in western Georgia. Black Sea coastal undulate zone, Saguramo-Tsivgombori slopes, low mountainous and foothill zone of Shida Kartli, middle segment of river Aragvi basin, and all those areas of the relief of Georgia in general, the slopes of which have an angle over 8% and are built with clay rocks highly sensitive to landslide processes and which are able to accept certain amount of atmospheric precipitation. Dynamics of landslide processes depend on deviation values of atmospheric precipitation in an intra-annual interval from perennial statistic values of a given landscape-geological environment.

According to analysis of geo-monitoring statistic data, activation or attenuation of landslide processes, or their temporary stabilization is in direct correlation with syncretism of geological environment.

Regional perennial engineering-geological research conducted at the territory of Georgia and geo-monitoring data, as well as analysis of regime observation data, show stabilization of exo-geological processes which directly depend on climatic factors, can be reached when the values of atmospheric precipitation and humidity within the given period of time (year, season, month, 24 hours) is below the mean perennial limit value. At the same time, the higher is deficit within the long-time segment, the higher is safety related to limit risks of geological processes. Together with increasing of precipitations to compare with statistic norms, the level and risk of activation of elemental processes increase proportionally.

Taking into consideration all mentioned above, according to space-time development of the exo-geological processes provoked by climatic factors, they can be divided in 5 categories: 1) below the background (stable); 2) background; 3) stressful; 4) extreme; 5) paroxysmal [14].

In a certain geological environment, where amount of precipitations remains within the limits of perennial norm (coincides with statistic climatic regime), exo-geological processes, if there are not any other additional conditions, develop at the background level. In particular, there is a close correlation between dynamics of climatic landslides and alterations of the precipitation regime. A landslide body 'sleeping' in a geological environment of optimal reception features comes out from homeostatic state.

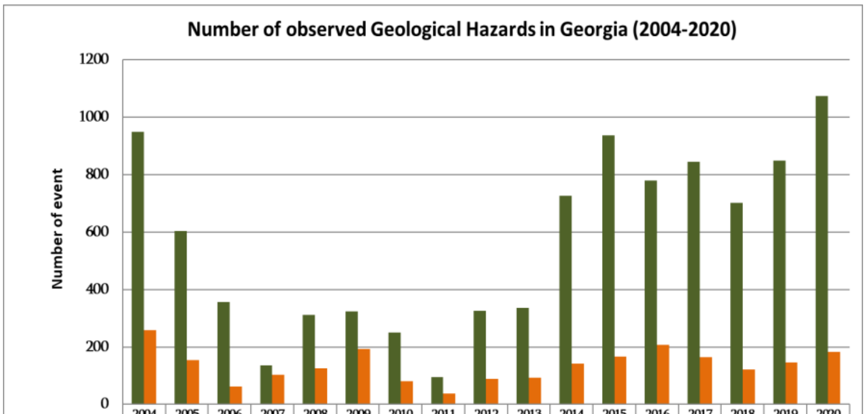
Annual amount of precipitations increased by 100-200 mm to compare with perennial norm, cause activation of landslide processes above the background level. Annual precipitations increased by 200-400 mm provoke activation of the landslide processes and enter the stress state. All landslide bodies which temporarily were in a stable state, as well as new landslides, start activating in those geological environments, deformation horizons of which are characterized by high sensitivity and synthesizing features. Annual precipitations increased by 400-600 mm to compare with the perennial mean value activate the processes entering the extreme stage, when a number of new landslides explode and almost all 'sleeping' landslides start activating. Research data confirm that according to a certain type of macro-circulation regime in atmosphere, extreme activation of elemental processes can gain regional character and later can develop at the global scale. There are number of relevant paradigms in Georgia and in Caucasus in general. For instance, the extreme explosion of landslide processes in West Georgia in 1967-68 which covered area of up to 300 000 ha, damaged and destroyed up to 20 000 living houses. At that time no such extreme activation of the elemental processes was observed in East Georgia. However, in 1987-89 the geological catastrophes of paroxysmal character covered the whole territory of Georgia.

This kind of extreme paroxysms of elemental processes were observed repeatedly all over the country in 1991-1992 and 2004-2005. Total damage caused by these processes was over 12 billion dollars. At the same time, we should take into account that the extreme or paroxysmal elemental processes develop in a very complex way that increases threats to the local population and complicates implementation of the appropriate management measures.

Analysis of perennial data obtained by engineering-geodynamic research and geo-monitoring observation at the territory of Georgia confirm that there is an indisputable correlation between extreme activation of landslide processes and critical deviation from perennial norm of atmospheric precipitations. This correlation is set through ‘humidification effect’ on slopes vulnerable towards landslide processes and because of ability of building rocks to receive atmospheric precipitations, and due to their certain geological features.

During the last period many countries conduct appropriate researches to detect the functional relationship between atmospheric precipitations and those critical values when the landslide, mudflow, and erosion processes, as well as the re-activation extremes start developing. For instance, it is determined for New Zeeland [15], that weak deformation of the slopes takes place in case of daily sum precipitations within the limits 50-55 mm. Mean deformation is observed in case of 60-90 mm and large-scale landslides start developing in case of precipitations over 100 mm. For South-East Asia the critical amount of daily precipitations able to provoke landslides is defined as 100-200 mm [16]. Extreme activation of landslide processes in this region was observed in July of 1996, when during 24 hours 401 mm of precipitations provoked 700 new landsides.

According to the Geology Department of the National Environment Agency, in recent years the quantity and magnitude of landslides and mudflow processes have increased significantly on the territory of the country (Fig. 1). As of 2020, 20% (729 settlements) of Georgia's populated areas were at high risk of geological hazards (Fig. 2-3) – [17, 18].



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Landslide	949	603	356	136	311	323	250	94	325	336	727	936	780	845	702	849	1074
Debris/mudflow	258	155	63	104	126	193	81	37	88	93	141	167	208	165	122	146	183

Fig. 1. Number of observed Geological Hazards in Georgia [17, 18].

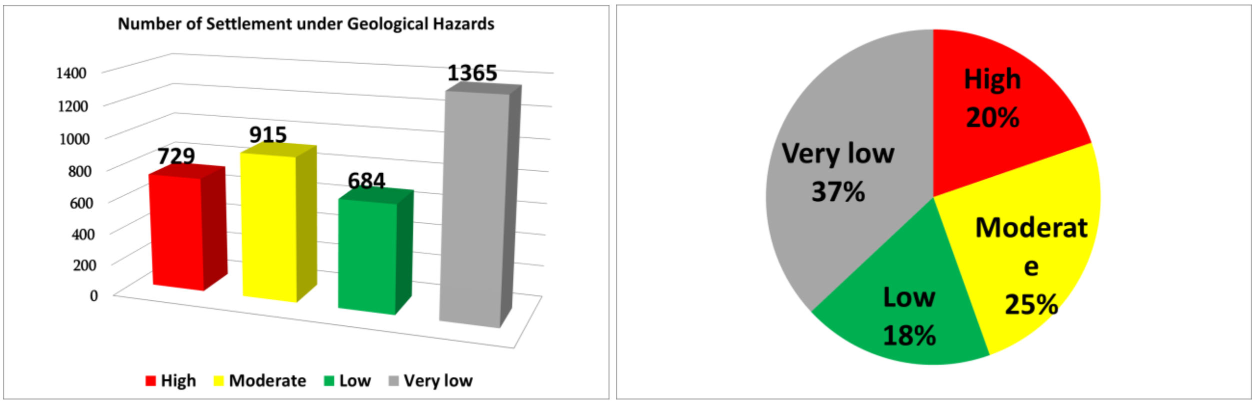


Fig. 2-3. Number of settlements under Geological hazards [17, 18].

Research data confirm that in geological-climatic conditions of Georgia, the humidification level of slopes depend not directly on the amount of daily precipitations, but on the prolonged impact of the same sum amount of precipitations. The exemptions are Mtatusheti low mountainous relief zone of Mtkvari depression built with extremely not-water-proof rocks of molassic rocks, as well as relief forms built with flood-plain and silt facieses, the structure of which can be immediately destroyed by contact with water. Hilly mountainous areas of the Black Sea coastal zone are also characterized by high ability of water penetration and low structural liaison, which in certain conditions can easily loose sustainability.

However, at the territory of Georgia, the landslides which are activating due to certain deviations in amounts of precipitations from maximum permissible values, are the most notable by their development scale. The mentioned deviation has direct effect on humidification level of deformable slopes. Relevant research data show that the maximum value (50-70%) of 'humidity effect' which is able to make move this type of landslides within the limits of deformable horizon is observed in autumn-spring period. It should be noted also, that in summer period the humidity of potentially movable grounds in West Georgia is decreasing by 10-16% in average, while in East Georgia this value is increasing up to 22-30%. Parameters of natural humidity are almost unchangeable below the zone of influence of atmospheric precipitations (below aeration zone) [19, 20].

Activation of landslide processes in accordance with atmospheric precipitation regime clearly indicates the correlation regularities: the intervals between atmospheric precipitations able to provoke landslide processes, fluctuate within 2,5-5 years, while the sequence line between the increase and deficit of precipitations, which represents one cycle of development of the landslide processes, ranges within 3-8 years.

Conclusion

Three main stages, or periods in the dynamics of landslides can be distinguished with regard to regional development of landslides:

1) Maximal re-activation period of landslide processes, which is determined by extreme values of paroxysmal amount of atmospheric precipitations. The intervals between active periods are 4-11 years.
2) Mean activation period of the landslide processes mainly includes intervals of landslide processes between the periods of intensive activation.
3) Background activation period of landslide processes. Number of landslides of this type of dynamics is more than the number of landslide processes performed during previous two activation periods. Usually, the landslide bodies being in this kind of regime, can move to a stress regime, or vice versa, to a stabilization regime, depending on the development of atmospheric precipitation conditions and the connected 'humidification effect' of relevant slopes. The start point of these processes is the moment when 'humidification effect' of slopes vulnerable towards landslide processes does not correspond with the values able to start moving. Analysis of statistic data on atmospheric precipitations in Georgia during last 100 years shows, that the intervals between activation of landslides of the mentioned regime, fluctuate within diapason of 1-5 years.

Note

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სტიქიური უბედურების რისკი საქართველოში

ე. წერეთელი, ნ. ბოლაშვილი, გ. გაფრინდაშვილი,
მ. გაფრინდაშვილი, ნ. მაჭავარიანი

რეზიუმე

ბუნების სტიქიური პროცესები ორი ერთმანეთისაგან სრულიად განსხვავებული მოვლენებითა და შედეგებით წარმოგვიდგება: ეს არის ატმოსფეროში ფორმირებული საშიში მეტეოროლოგიური მოვლენები და დედამიწის ზედაპირზე და მის ქერქში წარმოქმნილი სტიქიური გეოლოგიური პროცესები. თუმცა, ხშირად ამ ორი ერთმანეთისაგან დიამეტრიულად განსხვავებული მოვლენის ფორმირების პირობების მიუხედავად, მათ შორის კავშირი სინერგეტიკულია და განსაზღვრავენ ამა თუ იმ მოვლენის წარმოქმნა-რეაქტივაციის ხარისხს.
ბუნებრივი სტიქიით განპირობებული კატაკლიზმები კიდევ უფრო აქტუალური გახდა XXI საუკუნის გარიჟრაჟზე, როდესაც სტიქიური კატასტროფები ადამიანის გარემოზე მიყენებული ფართომასშტაბიანი პრესინგისა და კლიმატის გლობალური ცვლილებების საერთო ფონზე განუზომლად ზრდის მათი საშიშროების რისკს და ხშირად უმართავი ხდება.
სამხრეთ კავკასია და განსაკუთრებით, საქართველო, მიეკუთვნება იმ რეგიონებს, რომლებიც მსოფლიოს მთიან ტერიტორიებს შორის ბუნებრივი საფრთხეების ფართომასშტაბიანი განვითარების პროცესებით გამოირჩევიან. ხშირი განმეორებადობის, მოსახლეობასა და საინჟინრო-ეკონომიკურ ობიექტებზე უარყოფითი ზემოქმედების გამო, სამხრეთ კავკასია ერთ-ერთ ყველაზე მოწყვლად რეგიონადაა აღიარებული.

Риск стихийных бедствий в Грузии

Э.Д. Церетели, Н.Р. Болашвили, Г.М. Гаприндашвили,
М.В. Гаприндашвили, Н.Г. Мачавариани

Резюме

Две группы совершенно разных явлений и последствий могут вызвать стихийные бедствия. Это опасные метеорологические процессы в атмосфере и геологические процессы, происходящие на земной поверхности и ее коре. Однако, несмотря на очень различную природу и условия развития этих явлений, нередко между ними существует синергетическая связь, определяющая уровень активации / реактивации данных явлений.
Стихийные бедствия становятся все более актуальными в начале XXI века, поскольку их давление на среду обитания человека становится все более сильным. На фоне глобальных процессов изменения климата неизмеримо возрастает риск неконтролируемых катастроф.
Принимая во внимание, что регион Южного Кавказа, и особенно Грузия, относятся к регионам, выделяющимся среди горных территорий мира крупномасштабными процессами развития природных опасностей, повторяемостью и негативным воздействием на население и инженерно-экономические объекты, Южный Кавказ признан единым целым наиболее уязвимых регионов.