

Geoecological Monitoring of Dangerous Natural Processes

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ABSTRACT

The article presents the structure of monitoring (3 stages). For each stage, there have been defined the methods of monitoring. For mapping and zoning of dangerous processes, principles of territory division there have been developed: a creation of the so-called hydrograph-geomorphological framework. There has been made the classification of dangerous processes, conditions of their formation, types of land holding. For certification, there have been presented the parameters of estimation of the influence of processes on the landscape components. There have been given classifications of elementary units of formation of processes on the example of snow avalanches. To create a monitoring network, there have been given criteria for the distribution of monitoring objects (elementary units) according to the order and frequency of the investigation. The proposed monitoring methodology allows to develop measures that reduce the level of impact of processes on the territory to a reasonable minimum.

Keywords: geo-ecological monitoring, dangerous natural processes, geosystems, landscapes, inventory, certification, ranking

Mathematics Subject Classification: 86A05 86A30 86A40 86A60 97R50 97R60

Journal of Economic Literature (JEL) Classification: Q01 Q54 Q56

1. INTRODUCTION

Mountain territories have a number of physical and geographical peculiar properties that lead to a wide development of dangerous natural processes. Therefore, for the sustainable and safe development of mountain areas, it is necessary to conduct geoecological monitoring of mountain geosystems (landscapes), taking into account dangerous natural processes (Akselevich, V. I. 2015 and Gunya, A. N. 2016). At the same time, when monitoring is carried out, it is very important to take into account the geographical and environmental components of the natural environment (Bhattarai, G. R. at el., 2006; Nagabhatla, N., at el., 2007; Salvati, L. at el., 2009 and Ginko, V.I. at el., 2015). For this case, it is very important to create a state system of geoecological monitoring, which will unite all existing systems of observations of the natural environment. At the same time, the study of the natural environment of mountain territories requires an integrated geoecological approach (ZHerdev, V. N. at el., 2000 and Kyul, E. V. at el., 2016). This approach was used by the author to study the geoecological consequences of avalanches (Kyul, E. V., 2017), and later other dangerous processes.

The main goal is to develop the methodology of geoecological monitoring. This statement of the problem should solve the problem of assessing the transformation of landscapes, taking into account dangerous processes and development of the territory. At the same time, the development of each mountain area requires an ecosystem approach (Boranbayev, S., 2007 and Sarkar, A. N., 2013). To do this, it is necessary to develop a system of environmental norms and rules to take into account the development of mountain territories of their physical and geographical features (Fongwa, E. A. 2012 and Nondo, C. at el., 2014).

2. STATEMENT OF THE RESEARCH PROBLEM

A number of components are allocated: plant, soil, water, - when carrying out monitoring of the natural environment (Akselevich, V. I., 2015). All together these components make up the landscape. In the study of landscapes in the course of geoecological monitoring (Ginko, V.I.at el., 2015), it is important to describe all the components with a set of all the main characteristics for each of them. The main task is to study the degree of transformation of landscape with the help of new technologies, such as GIS. And it is important to assess both natural and anthropogenic changes in landscapes. Geoecological monitoring is divided into several stages: 1) preliminary (exposure of landscapes to dangerous processes); 2) field (inventory of landscapes taking into account dangerous processes and anthropogenic component); 3) final (allocation of sites with different degree of transformation of landscapes). The monitoring methodology proposed by the author allows to give further recommendations on reducing the negative impact on the landscape.

3. METHODS AND MATERIALS OF RESEARCH

Geoecological monitoring begins with the analysis of scientific and cartographic materials available in the study area. In addition, the data obtained by interpretation space images are used. Image processing is carried out in MultiSpec program (<http://gis-lab/info/qa/multispec-sat.htm>). As a result, the obtained data on the condition of landscapes are specified in the course of field studies. Cartographic method has long been successfully used in geographical, as well as geoecological (landscape) studies of mountain regions of the world by a number of foreign and Russian researchers (Nagabhatla, N., at el.,2007; Ajibefun, I. A., 2008; Bedunah, D. at el.,2012; Gentili , R. at el., 2013; Gunya, A. N., 2015 and Sinickas, A. at el., 2016). The convenience, simplicity and versatility of the method using GIS technology to present maps in electronic form made it even more perfect. Mapping of the territory with the use of GIS technology allows to solve most of the problems in geographical research (Ajibefun, I. A., 2008 and Hashirova, T. Ju. at el., 2017). Approbation of the monitoring methodology is carried on the territory of the Kabardin – Balkar Republic within the framework of the budget theme of the Center of geographical studies of Kabardin - Balkar scientific center of the Russian Academy of Sciences.

4. RESEARCH RESULTS AND DISCUSSION

The basic concept is the landscape. We accept it as a natural-territorial complex of any rank – "a set of interdependent and interrelated objects and natural phenomena that appear before us in the form of certain historically developed continuously developing geographical complexes" (Ginko, V. I. et al., 2015). In our case, «landscape» is a natural geocomplex or natural geosystem, which includes not only the geographical but also the environmental component of the natural environment. In this case of mountain landscapes, dangerous natural processes play an important role. They affect all components of the landscape and sometimes change it completely. Natural avalanche, mudflow and other complexes are formed, for example. Geoecological monitoring is carried out in several stages. At each stage, the main methods and techniques of monitoring are determined.

4.1. Stage 1. Office stage. Zoning of the territory on the basis of the principles of division developed by the author

First of all, zoning of the territory by height is carried out accordingly, on the basis of method the author (Kyul , E.V., 2004). The whole mountain part is divided into low (up to 1000m), medium (up to 2000 m), high (up to 3000 m) and the highest (over 3000 m) mountains. This is the vertical division of the territory.

Below is the zoning of river basins from the 1th to the 4th order or so-called morphosculpture. In this case, the river basin are divided into the main basin – basin of the 1th order and its tributaries, basin of the 2th order. In this case, the river basin are divided into the main basin – basin of the 1th order and its tributaries, basins of the 2th order. Tributaries of basins of the 3th order respectively will be tributaries of the 4th order and so on. Consider the zoning of the river basin on the example of the Ganges river (Table 1, Fig. 1)

Table 1. Hydrographic zoning of the Ganges river

№ n n	The name of the river	River basin order	Other rivers of this order	Note
1	The Ganges river	Basin 1-th order	-	
2	The Kosi river	Basin 2-th order	The rivers Gandhak, Chaghra, Yamuna, Tons, Son, Hoogly	All these rivers are tributaries of the Ganges river
3	The Sarda river	Basin 3-th order	The rivers Chambal, Sindx, Betwa, Richand	The Sarda is a tributary of the river Chaghra
4	The Banas river	Basin 4-th order	-	The Banas is a tributary of the river Chambal

The main characteristics of river basins are as follows:

1. The order of the basin.
2. Catchment area.
3. The length of the watercourse.

Usually these indicators are taken from the State water register or removed from space images. In the future, according to the above indicators, hydrographic areas are allocated.

This is the division of the territory horizontally.

Then geomorphological zoning is carried out. In the latitudinal direction in the territory allocated geomorphological provinces, subprovinces, regions and districts (Fig.2).

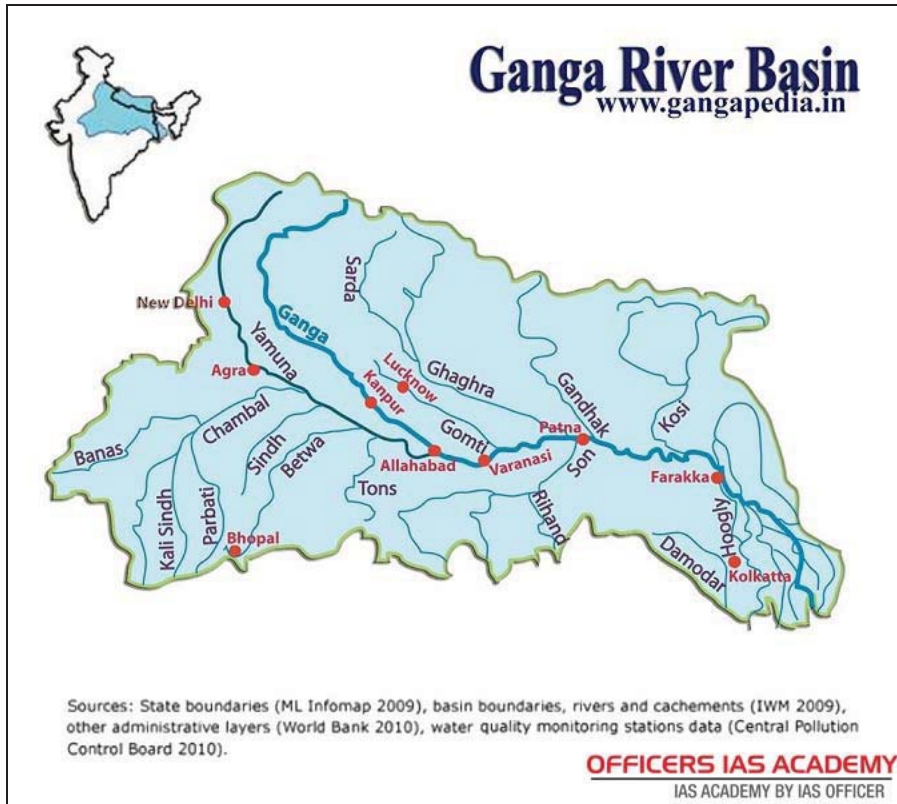


Figure 1. The basin of the Ganges river

To determine the type of dangerous process, there was developed a classification, which was performed according to the General genetic classification of exogenous geological dangers by A. I. Sheko with author's additions (Anisimova, N.G. et al., 2002).

The level of landscapes changes is so great that as a result of this in the highlands the so-called natural avalanche, mudflow and other complexes are being formed. Each landscape is assessed by the sum of conditions and factors of formation of dangerous processes, as well as types of dangerous processes and land use. The so-called method of the leading factor is used. Each of these factors can be divided as a priority into: the main, additional and leading at the moment (the main are those factors without which it is impossible to do, the additional are those that increase the probability of the

process, the leading factor is the one that at the moment is the cause of the descent of a dangerous process).

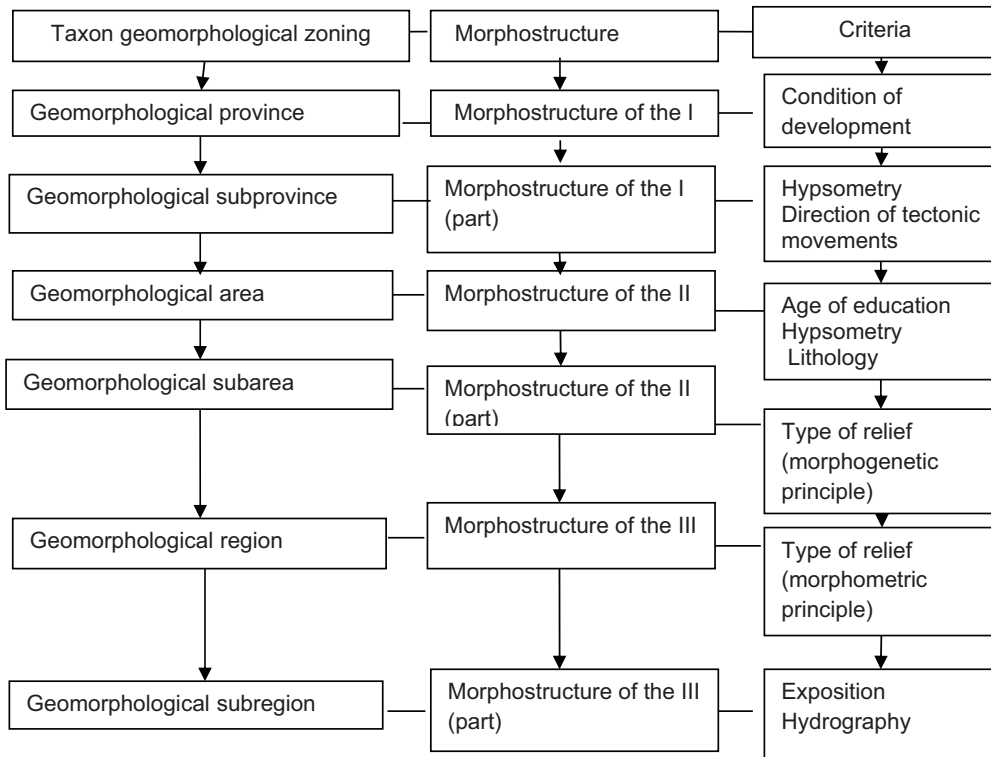


Figure 2 . The scheme of geomorphological zoning

4.2. Estimation of dangerous natural processes

As an example, the choice of exogenous geological processes for the study of the territory of Kabardino-Balkaria for avalanche and mudflow activit. In addition to this factor, another one is introduced: the mode of formation of the process, i.e. the time period of the descent of the dangerous process. The General genetic classification of exogenous geological processes of A. I. Sheko is applied here (Anisimova, N. G., et al., 2002).

Criteria for selection of the main dangerous processes for the study area (mountain part of the territory of Kabardino-Balkaria, horizontal 800m):

1. The name of the process (according to A. I. Sheko): group, class and type of dangers .The relationship with the energy of the relief (gravity, the so-called gravitational processes). Movement of rocks without loss of contact with the slope or with a small loss of contact. For example, snow avalanches. The relationship with the energy water. Channel processes. For example, floods or mudflows.
2. Estimation of the formation of the process: qualitative and quantitative, in %.

For example, snow avalanches (mountainous part of the territory, horizontal 2000 m). There is a strong degree of avalanche danger. 50-75% of the territory is avalanche-prone. Snow avalanches descends all year round in the mountainous part (more than 3000 m). Further, with regard to mudflows (mountainous part, from 2000 to 3000 m; average, from 2000 m and less. More than 75% of the territory is under the influence of mudflows. Mudflows are now flowing from April to September. Due to the increased tectonic and seismic activity of the territory, the impact of avalanches and mudflows can be increased to a maximum

3. Natural danger for estimation (the leading process in a certain period of time is included in the estimation). For example, snow avalanches occur in winter and spring, and mudflows occur in summer and autumn.

The criterion for choosing the so-called "leading factor, for example, are the critical values of a condition that leads to the descent of a dangerous process.

The author has developed a *classification of the conditions of formation of dangerous natural processes* for the component-by-component estimation of the landscape:

2 groups: I-constant and II- variable conditions of formation.

Classes: constant, I₁, endogenous and I₂, exogenous conditions, changeable –climatic (meteorological) conditions, II₁. Subclass. Endogenous conditions . I 1-1, geochronological, I 1-2, structural-lithological,, I 1-3, volcanic, I 1-4, tectonic and I 1-5, seismogenic. Exogenous conditions .I 2-1, geomorphological, I 2-2, geobotanical, I 2-3, soil, I 2-4, water. Climatic conditions. II 1-1, solar radiation, II 1-2, air, II 1-3, temperature, II 1-4, precipitation.

Types. Endogenous conditions: type 2 in the 2nd subclass of: I 1-2, structural-lithological: I 1-2-1, structural and I 1-2-2, as well. Exogenous conditions. 1st subclass-I 2-1, geomorphological, 3 types (according to the landforms): I 2-1-1, morphogenetic, I 2-1-2, altitudinal-exposition, I 2-1-3, morphometric. 2 type, 2 subtypes: I 2-1-2-1, altitudinal (hypsometric) and I 2-1-2-2, exposition. 3 type, 4 subtypes: I 2-1-3-1, depth of relief dissection, I 2-1-3-2, density of the relief dismemberment, I 2-1-3-3, the intensity of the dismemberment of the relief, I 2-1-3-4, the value of the surface slope. 4 subclass – I 2-4, 2 types (according to the depth): I 2-4-1, surface waters, I 2-4-2, groundwater. Climatic conditions. Types in the 3rd and 4th subclasses. 3rd division - II 1-3, temperature, 3 types (according to the landscape components): II 1-3-1, air temperature, II 1-3-2, soil temperature, II 1-3-3, snow temperature. 4th division-II 1-4, precipitation, type 2(physical state of the material): II 1-4-1, liquid and II 1-4-2, solid precipitation. The 2nd type II 1-4-2, solid precipitation. 2 subtypes: II 1-4-2-1, uniform snow and II 1-4-2-2, heterogeneous snow. Thus when carrying out the own studies (Kyul,E.V.,2017 and Hazhmetov, L.M.,at el., 2016) there have been confirmed results of other researchers (Sinickas A.,at el., 2016 and Rixen Ch.,at el.,2007) that are most exposed to dangerous processes such landscape components as topography, vegetation, soil, surface water, and to a lesser extent, climate.

Factors of formation of dangerous processes is a complex of natural and climatic conditions with certain critical values at the given moment leading to immediately process .For example, for snow

avalanches it is required a slope with defined morphometrical characteristics. At the same time, constant factors of formation play a major role in the formation of snow avalanches (in our case, for example, it is the slope angle and the height of the snow cover). Additional conditions and factors here can serve as constant (for example exposure) and variable factors of formation (temperature, wind, etc.). The leading condition and factor that separates a potential dangerous threat to the process from the factual, generally for snow avalanches is the snow cover and its structure and condition. There is a principle: the more we take into account factors, the more accurate the assessment of the degree of danger.

To estimation the appropriation of the territory in the landscape analysis is to determine the type of land holding. The concept of "land holding" can be defined as " ... the form of land disposal with the purpose of extracting useful properties from the land or income " (Aksenova, E.G., at el., 2017). All the lands on the basis of the relevant land legislation are divided into categories by functional purpose.

On the basis of the above categories of land (Aksenova, E.G., at el., 2017) there has been made the classification of landscapes according to types of land holding that is landscape: agricultural, residential, industrial, engineering and communication, recreational, environmental, historical and cultural, forest, water and so-called reserve lands. Each type can be divided into subtypes, for example, industrial can be divided into mining and other industries. On the basis of this classification, according to the leading type of land holding are areas with different types. In the future, the impact of development on the activation of dangerous processes is taken into account.

4.3. Stage 2 .Field stage. Certification of elementary units of formation of dangerous natural processes with different classes of danger in the study territory

According to the results of the territory estimation on the basis of the inventory, geosystems with a high degree of exposure to dangerous processes are identified. To do this, GPS-survey of landscapes is carried out within the designated areas of formation of dangerous processes. The degree of transformation of the landscape by processes is estimated here (Table.2).

Further, for the certification of elementary units of formation of dangerous processes, it is necessary to develop a number of classifications. For example, in avalanche studies, when assessing the relief of avalanche formation, there are such elementary units of avalanche relief as simple and complex, as well as avalanche basins.

Table 2. Parameters for assessing the impact of dangerous processes on individual components of the landscape

<i>№ n/n</i>	<i>Landscape component</i>	<i>Impact of (on the example of avalanches)</i>
1.	Relief	The number of elementary units of education of dangerous processes
2.	Vegetation:	The projective coverage of avalanche collections, %
	-projective cover;	
	-composition of rocks;	Replacement of primary vegetation on the secondary, %
	-condition;	Mechanical damage, %
	-inversion	Presence of plants-bioindicators of landscape from a different belt
	-another	Delay of the phases of vegetation, the time period
3.	Soils:	The Presence of primary soil, %
	-projective cover;	
	-composition;	Change in mechanical composition;
	-condition;	The Degree of disturbance of soil horizons Changes in soil temperature, degrees.
	-inversion	Mixing of soils of different types
4.	Climate:	The change in temperature, degrees
	-air temperature	
5.	Surface waters:	Change of the regime:
	-hydrological regime	-flow rate

Note: the impact of dangerous processes on the last two components is virtually unexplored and requires further ad hoc studies

Below there are the classifications developed by Kyul E. V. on the basis of the classifications by V.P. Blagoveshchensky (Seversky, I.V., at el.,1983) :

Classification of avalanche basins:

1. Groups. According to ecological condition of the natural environment. 1.1. Natural. 1.2. Natural - anthropogenic. 2. Subgroups. According to the degree of their complexity (the number of elementary units of avalanche relief) in the basin. 2.1. Of little difficulty (two elementary units of avalanche relief). 2.2. Of medium difficulty (three elementary units of avalanche relief). 2.3. Of great difficulty (more than three elementary units of avalanche relief). 3. Classes. According to the location of elementary units of avalanche relief on the boards of the river valley. 3.1. On one side. 3.2. On opposite sides. 4. Types. 4.1. According to the concealment of zones of elementary units of avalanche relief. 4.1.1. Of the transit zone. 4.1.2. Of the stopping zone. 4.1.3. Combined (of the transit and the stop zones). 5. Subtypes. The intersection and location of elementary units of avalanche relief to each other. 5.1.1. With overlapping elementary units of avalanche relief. 5.1.2. With a parallel articulation of elementary units of avalanche relief. 5.1.3. With the lateral articulation of elementary units of avalanche relief. 5.1.4. With a consistent arrangement of elementary units of avalanche relief.

Classification of complex elementary units of avalanche relief:

1. Groups. According to ecological condition of the natural environment. 1.1. Natural. 1.2. Natural-anthropogenic. 2. Subgroups. According to the degree of their complexity (the number of areas of contact in elementary units of avalanche relief). 2.1. Of low difficulty (one zone). 2.2. Of medium difficulty (two or three zones). 2.3. Of great difficulty (more than three zones). 3. Classes. According to the structure of the avalanche hearth. 3.1.1. A single-chamber avalanche hearth and one transit area. 3.1.2. Two-chamber hearth. 3.1.3. Three-chamber hearth and more. 4. Subclasses. According to the number of transit zones. 4.1.1. With one transit area. 4.1.2. With two transit areas. 4.1.3. With three or more transit zones. 5. Types. According to the location of the contact zone. 5.1. In the avalanche hearth. 5.2. In the transit area. 5.3. Combined (in the avalanche hearth and the transit zone).

Classification of simple elementary units of avalanche relief:

1. Groups. According to ecological condition of the natural environment. 1.1. Natural. 1.2. Natural-anthropogenic. 2. Classes. According to the geomorphological type of avalanches. Elementary units of avalanche relief. 2.1. With slope type avalanches. 2.2. With tray type avalanches. 3. Subclasses. In size of elementary units of avalanche relief. 3.1. Small. 3.2. Average. 3.3. Large. 4. Types. By type of avalanche hearth. 4.1. Gutter. 4.2. Erosive slit. 4.3. Erosive pothole. 4.4. Snow collecting funnel. 4.5. Kar. 4.6. Deformed car.

4.4. Stage 3. Final stage. Ranking of monitoring objects based on the results of certification and inventory of the territory. Creation of a monitoring network based on the ranking of monitoring objects

At this stage, it is necessary to distribute the main units of the formation of dangerous processes according to the order and frequency of the survey. For this purpose, there are gradations of elementary units according to 2 parameters: the size of the descending process (in terms of the size of removal of the demolished material, m^3) and the class of danger of national economic objects in the process exit zone. *Gradations* of dangerous processes by the amount of material to be demolished are as follows: with a small volume of removal (up to 10 thousand m^3) average (10 – 100 thousand m^3) large (100-500 thousand m^3) catastrophic (more than 500 thousand m^3).

Classes of danger of economic (dangerous production) facilities are allocated in accordance with the Federal Law "On industrial safety of dangerous production facilities" 116-FL (Akselevich, V.I., 2015). All dangerous production facilities, depending on their level of danger, are divided into 4 classes: I class of danger-objects of extremely high danger; II class of danger-objects of high danger; III class of danger-objects of medium danger; IV class of danger– object of risk facilities. For example, the study area contains gas pipelines and petroleum products, which can be classified as a class III danger – for objects intended for the transportation of natural gas under pressure of less than 1.2 megapascal or liquefied petroleum gas under pressure of less than 1.6 megapascal. Also dangerous are: a) objects that use fixed hoisting mechanisms, in our case, these are ropeways, III class of danger; b)

objects conducting mining operations, for example, quarries, where open mining operations are carried out, the size of the development of the mountain mass of which is less than 100 thousand cubic meters per year, IV class of danger. Also on the territory there are hydraulic structures of the pressure front, which, depending on the possible consequences of their destruction are divided into classes. In our case, these are hydroelectric power plants with a capacity of less than 1.5 million m³, which belong to II–IV classes. Also, to the objects of increased danger are closely connected road tunnels and bridges.

Thus, a *monitoring network* is being created, where the elementary units of foundation of the process and economic objects in the area of their action are divided into 4 classes (from 1, where are the objects, which are examined first, several times a year, and then). The creation of such a network allows the most complete monitoring of the dangerous process, to refine and add the data for the presentation of materials in the form of Atlases, Inventories and Databases. This mapping provides an opportunity to conduct a numerical evaluation of the natural danger at the present time.

5. CONCLUSIONS

The author proposed the methodology of geoeological monitoring, which allows on the basis of the study to determine a set of measures to prevent, control and protect against dangerous processes. In this case, the author has developed a classification of conditions and factors of formation of processes, as well as the principles of division of the territory, which reveal the spatial patterns of distribution of dangerous processes over the territory.

This methodology allows to determine the leading types of processes and land use in assessing the susceptibility of the territory to dangerous processes. In addition, the classification of elementary units of formation of dangerous processes developed by the author allows to rank the territory according to the degree of danger. In this case, the degree of danger will be determined more accurately. According to the results of the evaluation it is possible to identify areas with a high degree of natural danger. Certain economic activities that lead to the activation of certain types of processes should be prohibited in such territories. At the same time, the best option of measures to combat dangerous natural processes has been chosen. This will allow more competent to develop recommendations for sustainable development of the mountain area, taking into account dangerous processes. With this geoeological approach, the territory acquires the status of potentially safe.

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