Integrity of risk indicators of hazardous natural processes (on the example of the Krasnodar Krai)

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Abstract. The problem of assessing risk indicators of hazardous natural processes as the basis for sustainable development of the region arises due to the peculiarities of the geological structure of the territory of Krasnodar Krai. The work is based on a comprehensive assessment of the geological conditions of the territory of Krasnodar Krai with the use of a systematic approach. A list of characteristic natural processes that pose the greatest danger to capital constructions was determined: in the mountainous part – erosion processes, on the plain – soil subsidence and associated landforms. Then, schematic maps were compiled and the geological component of the risk (its spatial-areal indicator) was determined. Subsequently, to compare these maps, overlay operations were performed, as a result of which the spatial characteristics of ARC/INFO layers were combined into a new layer and relational join of their attribute data was carried out. Adding the risks of each parameter made it possible to rank the territory into 4 zones according to the degree of integral risk of manifestation of natural processes.

1. Introduction
The beginning of systematic research aimed at assessing the danger of natural processes and risk analysis falls on the middle of the 20th century. A review of modern views on the problem of assessing environmental risks both in foreign and Russian literature [1–5] shows that until now there is no unified methodology for their assessment. So, the terms “risk” and “risk assessment” are still ambiguous. There is domestic experience in assessing risk indicators of endogenous and exogenous processes, experience in developing methodological foundations for assessing the risk of exogenous geological processes when considering regional features, some approaches to assessing natural and anthropogenic factors in relation to urbanized areas were proposed [6–8].

Krasnodar Krai is one of the main economic, recreational and tourist centers in the south of Russia. The expansion of economic activity is inevitably associated with the impact on the environment, but the natural environment itself can become a source of risk and pose a threat to life and health of the population and economic entities. In this regard, finding the solution of issues of sustainable and effective development of society, protection of territories, buildings and structures from hazardous geological processes come to the fore in the region.

Assessment of the integral seismogenic risk for the Black Sea coast is scarcely developed. This risk includes hazard factors caused by both direct seismic effects and subsequent "slow" threats associated with the structural features of the upper part of the geological profile, geomorphological and geological-engineering conditions [9].
One of the ways to solve natural risk management issues is a comprehensive assessment of the geological conditions of the territory of Krasnodar Krai on the basis of geological-engineering zoning. Over the past decade, big volume of survey work has been carried out in Krasnodar Krai, and a large amount of new engineering and geological information has been accumulated. Using these data, potential risk of such exogenous geological processes as landslides, erosion processes, flooding, etc. has been assessed [10].

The purpose of this work is an integral assessment of the risk indicators of natural processes for the territory of Krasnodar Krai. The main tasks of the study come down to assessing the degree of activity of certain geological processes, compilation of a set of maps that have theoretical and applied value, as well as ranking the territory according to the degree of risk using modern geographic information systems.

2. Materials and research methods

The spatial position of the territory of Krasnodar Krai is associated with such tectonic structures as the North-West Caucasus and the Scythian plate, which determine the nature of manifestation of endogenous and exogenous geological processes. Endogenous processes are due to the crustal stress, active tectonic disturbances, and high seismicity. The diversity of types of exogenous geological processes is determined by the geological and geomorphological structure and climatic factors. The most common are processes driven by surface waters. They are flooding, rainwash and soil subsidence in the northern part of Krasnodar Krai, river erosion, rainwash and landslides – in the central part, landslides, mudflows, river, ravine and sheet erosion – in the southern part.

To assess the territory according to the degree of potential risk, the scoring method was used within the framework of evaluative engineering-geological zoning [11] carried out using the ArgGis programs where each estimation parameter is a separate GIS layer of the digital map. By expert analysis, weights were assigned to the established criterion factors depending on their importance and an ordered scoring scale was created according to the increase (decrease) of the properties. The final assessment is the average weighted risk index of the manifestation of the process based on the integral index (in points) and the values of the area of each process development. This method makes it possible to overcome the complexity of assessing non-uniform parameters.

When assessing the seismic hazard of the territory of Krasnodar Krai various methods were used: compilation of seismotectonic diagrams, historical materials on paleoseismicity, micro-seismic zoning, seismogeodynamic modeling based on the dependence of the maximum magnitude of possible earthquakes in the area of the seismogenic block of the Earth's crust. Figure 1 shows a map of the general seismic zoning of Krasnodar Krai used in this work.

In the course of studying the complex of hazardous exogenous processes, the most significant factors were identified: distribution of specific soils, extent to which the territory is affected by subsiding landforms, ruggedness of relief and affection of the territory by gully erosion. To reflect the extent to which the territory is affected by each process, coefficient K was calculated, expressed as a percentage based on the total area of the affected territories. In this work, a pairwise compilation of schematic maps (M 1: 2500000) of the density of the gully network and degree of erosion of temporary

![Figure 1. Map of general seismic zoning with a degree of seismic hazard (1%).](image-url)
streams as well as of distribution of loess-type rocks and location of subsiding landforms was carried out. As a result, the geological component of the risk (its spatial-areal index) was determined.

For example, in figure 2, which shows the degree of erosion of temporary streams the territory of Krasnodar Krai, 12 regions are identified. A schematic map (figure 3) of the density of the gully network shows 6 areas with difference in ruggedness index. In figure 4, according to the total area of subsiding landforms, expressed as a percentage of the area of a unit square, 9 regions were identified. Figure 5 shows the zoning distribution of subsidence rocks.

Figure 2. Schematic map indicating the degree of erosion of temporary streams.

Figure 3. Schematic map is a diagram of the density of the gully-beam network.

Figure 4. Schematic map is a diagram of the distribution of subsidence landforms.

Figure 5. Schematic map of the distribution of loess-like rocks.
Subsequently, to compare these maps, overlay operations were performed, as a result of which the spatial characteristics of ARC/INFO layers were combined into a new layer and relational join of their attribute data was carried out.

3. Results
Figure 6 shows a map that provides information on the intensity of erosion forms and the density of the gully network distribution. Similarly, a map of loess-type rocks and the location of subsiding landforms in an integral form was created (figure 7).

![Figure 6](image1.png)

**Figure 6.** Combined schematic map is a diagram of the intensity of erosion forms and the density of the gully-beam network.

![Figure 7](image2.png)

**Figure 7.** Combined schematic map of the distribution of loess-type rocks and the location of subsiding landforms.
Adding the risks of each of the considered parameters by summing the above maps made it possible to rank the territory according to the degree of integral risk of manifestation of endogenous and exogenous processes. Figure 8 shows the results of zoning the study area according to the risk indicators with the allocation of relatively homogeneous parts and division of the criteria into classes. Areas with similar natural conditions were combined into four regions (zones) according to the level of potential risk of hazardous endogenous and exogenous processes: low, medium, increased and high.

**Figure 8.** Map of the integral risk of endogenous and exogenous processes in Krasnodar Krai. The intensity scale of the levels of potential risk of hazardous natural processes: 1 – low, 2 – medium, 3 – increased, 4 – high.

4. Conclusion
The performed integral assessment of hazardous endogenous and exogenous geological processes makes it possible to assess potential natural risks at the regional level. The lowest potential risk of natural hazards is characteristic of the plain territories the territory of Krasnodar Krai, the highest potential risks are typical for mountainous areas, for which the development of risk management measures will be required, since their consequences may require significant material expenses and time to be eliminated.

References

[1] Kosinova I and Kustova N 2008 Theory and methodology of geoecological risks *Vestnik VSU, Series Geology* 2 pp 189–197
[2] Osipov V, Eremina O and Kozlyakova I 2017 Assessment of exogenous hazards and geological risk in urbanized areas (review of foreign experience) *Geocology, Engineering geology, Hydrogeology, Geocryology* 3 pp 3–15
[3] Cascini L and Ferlisi S 2014 Introduction to the thematic set of paper on the quantitative analysis of landslide risk *Bull. of Engineering Geology and Environment* 73 2 pp 207–208
[4] Sharma V 2006 *Engineering Geology for Tomorrow’s Cities, IAEG 2006, 6–10 Sept.* Zonation of landslide hazard for urban planning: case study of Nainital town, Kumaon Himalaya, India pp 3–191
[5] Vranken L, Van tilt G, Van Der Elkshaut M, Vanderckhole L and Poesen J 2019 Landslide risk assessment in densely populated hilly area *Landslides, 2015* 12 4 pp 787–798
[6] Burova V N Features of zoning of urbanized areas for risk assessment from hazardous natural processes *Geocology, Engineering geology, Hydrogeology, Geocryology* 6 pp 106–111
[7] Larionov V, Frolova N and Ugarov A 2017 Seismic risk assessment *Geocology, Engineering geology, Hydrogeology, Geocryology* 2 pp 22–37
[8] Osipov V, Larionov V, Sushchev S, Frolova N, Ugarov A, Kozharinov S and Barskaya T 2015 Assessment of the seismic risk in the territory of B. Sochi *Geocology, Engineering geology, Hydrogeology, Geocryology* 1 pp 3–19
[9] Stognii G and Stognii V 2019 *Proc. VII Int. Sci. and Pract. Conf. The problem of assessing the seismogenic risk of the Black Sea coast of the Krasnodar Territory (Krasnodar, Kuban: State University)* pp 226–229
[10] Lyubimova T, Bondarenko N, Stognii V and Pogorelov A 2017 Map of the integral risk for manifestation of exogenous geological processes as a basis for solving various theoretical and applied problems in the Krasnodar Territory Natural and technical sciences 2 114 pp 140–145

[11] Bondarik G and Pendin V 1982 Methodology of quantitative assessment of engineering-geological conditions and special engineering-geological zoning Engineering geology 4 pp 82–89