

PHYSICAL GEOGRAPHY

Landscape ecology

EXOGENIC RELIEF-FORMING PROCESSES IN THE  
AZERBAIJANI PART OF GREATER CAUCASUS

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**Abstract**

This paper presents the results of various studies conducted in the highlands of the Azerbaijani part of the Main Caucasus and the Lateral Ridges of the Greater Caucasus, utilizing materials from field surveys and the interpretation of satellite images. These findings, in conjunction with an analysis of previous research, allowed for the characterization of highland natural conditions, the identification of highly degraded mountain landscape areas, and the determination of optimal strategies for preserving the natural environment.

**Key words:** landscapes, zones, satellite images, complexity, slopes, vegetation cover, geodynamics

**Introduction.** The natural conditions of the Greater Caucasus and the processes that occur here are characterized by their distribution across altitudinal zones. This zonation, as noted by numerous researchers [1–5], results from recent tectonic movements and the presence of diverse landscape complexes with various exogenous processes. Additionally, the reformation of landscapes is significantly influenced by both endogenous and exogenous processes, such as landslides, debris flows, and others. To prevent potential future catastrophic consequences associated with dynamic processes, a thorough examination of the territory is essential.

In the highlands of the Greater Caucasus, the role of the anthropogenic factor has a specific character. Although there are no large industrial enterprises here,

the development of traditional semi-nomadic animal husbandry, pasture farming, is one of the decisive anthropogenic factors in the development of exogenous relief-forming processes, areas devoid of soil and vegetation cover, accumulations of talus and placers. In recent years, the development of mountain tourism has been added to the factor of pasture and hay farming. The territory attracts both local and foreign tourists due to the presence of centres for active winter recreation as well as rural attractions. The number of ecotourists is also increasing. Such a situation requires a more detailed study of the territory in terms of assessing possible risks when advancing through the terrain, building roads, hotels, and other economic facilities. Uncontrolled passages and neglect of the eco-geographical situation can lead to disastrous consequences. It should be noted that landslide areas are developing in this territory, the constant monitoring of which is necessary from the point of view of ensuring the safety of nearby villages and tourist sites.

**Materials and research methods.** To summarize the results of various studies conducted for the assessment of the natural conditions in the Greater Caucasus region, aimed at the development of diverse economic sectors and effective environmental protection, we have adopted an optimal approach to assess the degree of degradation of mountain landscapes under the influence of geodynamic processes. This approach combines the utilization of aerospace data, visual observations, and laboratory analysis of collected samples.

The assigned tasks dictated a specific research approach. During the collection and organization of existing geological, geomorphological, landscape, hydrometeorological, and soil-plant data concerning the natural conditions of the high mountains of the Greater Caucasus, we processed a substantial volume of research material related to exogenous geodynamic processes conducted over various years.

Furthermore, the compilation of cartographic materials, derived from the interpretation of aerial photographs and statistical data, is of significant importance. These materials depict geodynamic processes, climatic fluctuations that have adverse effects on the mountain landscapes of the Greater Caucasus, and the susceptibility of soils to anthropogenic impacts. The generalization of results regarding the impact of degradation processes on soil and vegetation relied on a combination of field and desk surveys. This comprehensive approach included laboratory analysis of samples collected from key sites and visual interpretations of aerial and satellite photographs. It allowed us to assess the level of degradation in high mountain landscapes on the southern slope of the Main Caucasus Range and the eastern slope of the Greater Caucasus, culminating in the creation of detailed maps of the region. A complex exodynamic situation is particularly evident in the Girdimanchay river basin, which originates from the southern slope of the Greater Caucasus and experiences soil erosion processes (Fig. 1).

We conducted visual interpretations of black and white aerial photographs at a 1:25 000 scale, which provided clear insights into land and vegetation cover

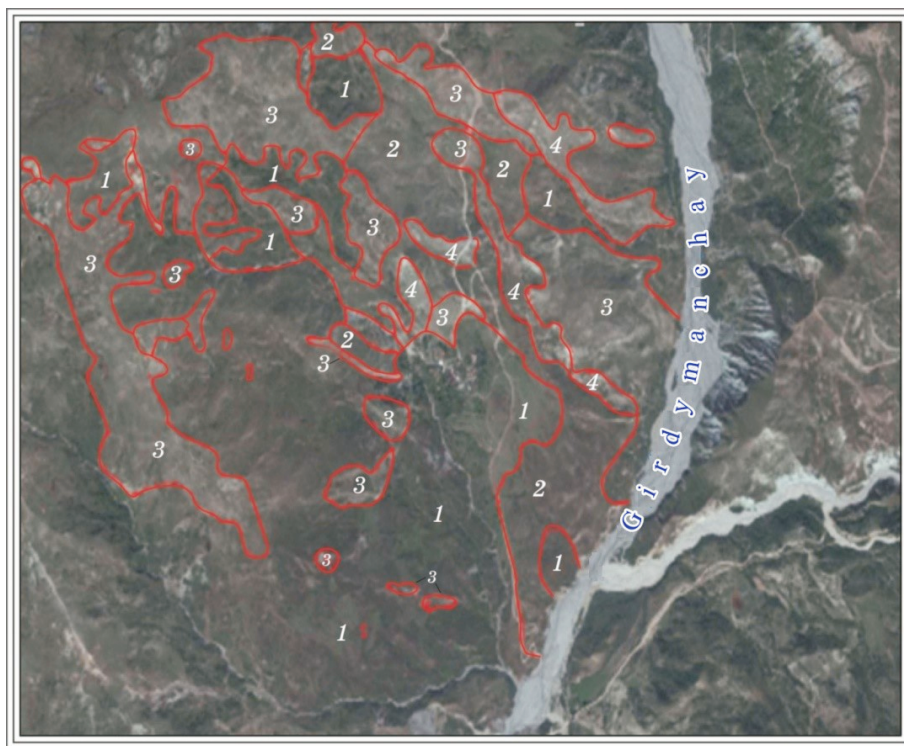


Fig. 1. Satellite image (2010) of the Girdimanchay river basin in the Main Caucasus Range, with highlighted soil erosion contours. Scale: 1:25 000; Key: 1 – non-eroded areas; 2 – slightly eroded areas; 3 – moderately eroded areas; 4 – heavily eroded areas

degradation. These interpretations were performed in distinct high mountain meadow areas located in the Azerbaijani part of the Greater Caucasus, including the basins of rivers such as Shinchay, Kishchay, Gurmukhchay, Girdimanchay, and others.

By combining aerial photography and field surveys conducted in the highlands of the central part of the Southern slope of the Main Caucasus Range, the Southeast slope of the Main Caucasus Range, the Girdimanchay river basin, the Northeast slope of the Greater Caucasus, and the basins of the Gudialchay and Gusarchay rivers, we compiled a range of cartographic data. These data provide insights into the impact of degradation processes on the state of mountain landscapes, enabling a fairly objective assessment of the intensity of these processes over time and space. These findings also allowed us to make appropriate adjustments to the scheme of eco-geomorphological zoning [6–9].

**Results and discussion.** As noted by several researchers [10,11], exogenous relief formation is influenced not only by general climate patterns but also by altitude zonation, as hydroclimatic processes are governed by the hypsometric characteristics of the region. This relationship can be visually observed through

the compiled map of absolute height distribution.

The compiled map of the distribution of absolute heights within the Azerbaijani part of the Greater Caucasus shows that most of the territory lies at the lower levels of the highlands, but this does not at all diminish the influence of natural destructive processes occurring under the influence of both natural and anthropogenic factors (Fig. 2).

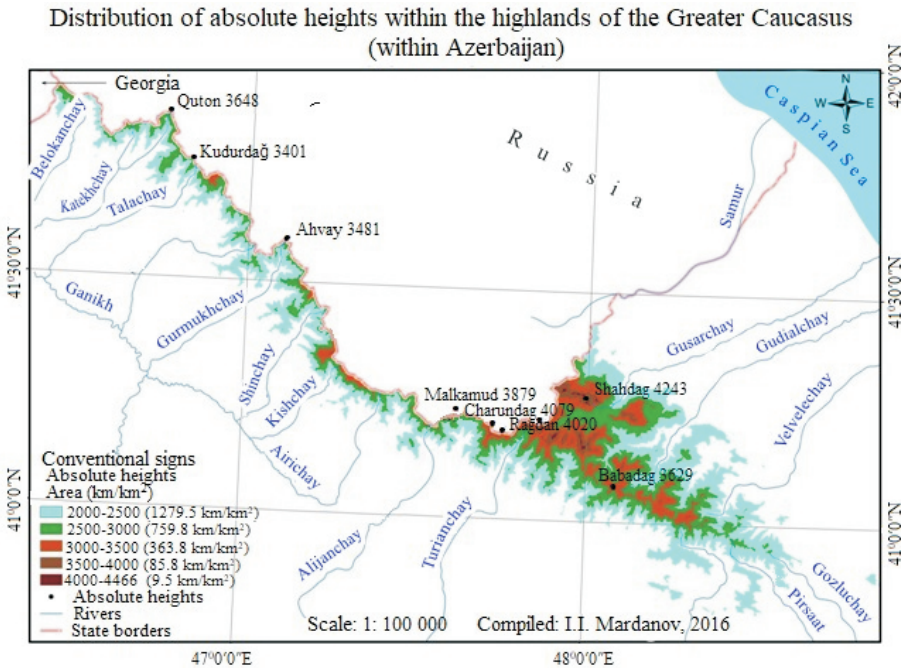


Fig. 2. Map of distribution of absolute heights of the highlands within Azerbaijani part of the Greater Caucasus shows that a small part of the territory is located at altitudes above 3500 m, where frost weathering predominates

In the upper part of the mountain meadow zone, specifically within the alpine meadows, predominant exogenous processes manifest as cryonival relief-forming processes, including solifluction disturbances in loose saturated topsoil, as well as the formation of substantial gravitational relief features such as talus and placers. These processes result in the accumulation of clastic materials that cover both the alpine and subalpine zones. It is within these exposed areas of the mountain-meadow belt that we find the primary locations of mudflow occurrences.

In the mountain-forest belt, large non-forested areas exist, and under sustained intensive human activities, these areas can become potential sites for the initiation of adverse geodynamic processes, ultimately leading to the complete degradation of mountain ranges.

Notably, within this territory, particularly on the southern slope of the Greater Caucasus Mountain Range, gravitational processes play a crucial role in relief

formation. These processes encompass landslides, talus accumulation, and the deposition of large clastic materials [12–14].

The hydrological data we have collected reveal significant variations in sediment discharge in numerous rivers on the northeastern and southern slopes of the Greater Caucasus, including the Gusarchay, Gudialchay, Velvelechay, Talachay, Gurmukhchay, Kishchay, Dashagilchay, Turianchay, Goychay, and others. The high-intensity flushing of sediments from the southern slope of the Main Caucasus Range results from a combination of natural factors that contribute to denudation processes. Additionally, anthropogenic factors, particularly long-distance pastoralism, have a substantial impact on soil erosion and the formation of mudflows, ultimately disrupting soil integrity [15–17].

Atmospheric precipitation plays an important role in the development of exogenous relief-forming processes. As meteorological data show, the greatest amount of precipitation falls between altitudes of 2400–2800 m above sea level, where the main centres of erosion are located, especially on the southern slopes. For example, in the Khinalig point, located on the northeastern slope of the Greater Caucasus, the maximum amount of precipitation according to long-term data is 1333.9 m, and in the relatively lower-lying Gyryz point – 892 m. In Khinalig there are two maximum precipitations, spring and autumn, but at the same time, in both Khinalig and Gyryz, summer rainfalls that fall after the dry period play a large role in the development of erosion processes (Fig. 3).

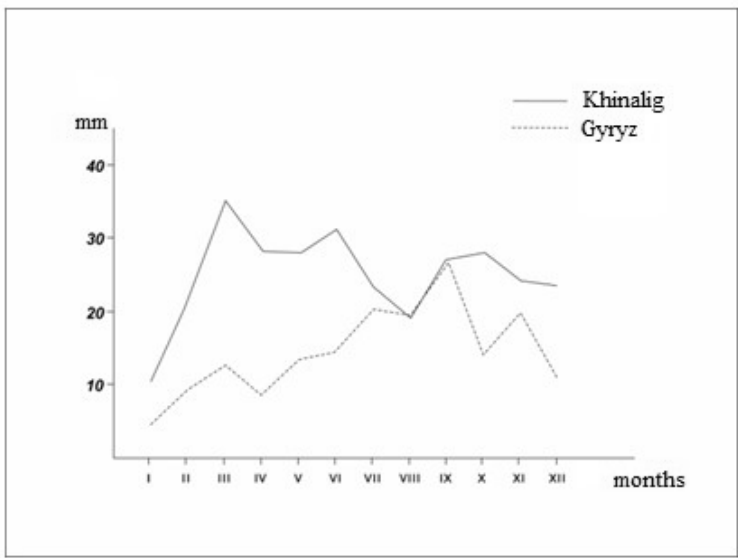


Fig. 3. The highest monthly precipitation is on the northeastern slope of the Greater Caucasus (according to long-term data, 2000–2009). Khinalig village (2301 m), Kyryz village (2006 m)

An analysis of existing literature materials and field-based research on soil erosion and landscapes, conducted over several years, indicates that the uneven sediment flow modulus is a consequence of the intense erosion processes in the Greater Caucasus region (Table 1). This phenomenon is linked to the presence of easily eroded rocks, extensive areas of bare land in the high-mountain parts of the basins, steep slopes, their fragmentation, the pronounced impact of recent tectonic uplifts, and various other contributing factors [18–20].

T a b l e 1

The degree of soil erosion in the mountain-meadow belt of the central part of the southern slope of the Main Caucasus Range

|                    | Non-eroded | Weakly eroded | Moderately eroded | Heavily eroded | Rock outcrops | Total  |
|--------------------|------------|---------------|-------------------|----------------|---------------|--------|
| In km <sup>2</sup> | 26.45      | 106.50        | 72.44             | 77.8           | 47.26         | 329.73 |
| In %               | 8.02       | 32.29         | 21.87             | 23.59          | 14.23         | 100.0  |

Notably, in the Greater Caucasus, the thickness of the erosion layer progressively increases with elevation, signifying the prevalence of vigorous denudation processes in the high mountain areas.

The role of vegetation, when combined with other influential factors, serves to reduce the extent of exogenous processes (Fig. 4). The disruption of the integrity of vegetation cover and the turf layer in mountain meadow soils, in conjunction with other natural destructive processes, results in the withdrawal of considerable areas from agricultural use. A pertinent example is the village of Galaykhudat, located in the Guba administrative district on the northeastern slope of the Greater Caucasus. On the southern slope of the Main Caucasus Range, forest vegetation plays a substantial role in diminishing denudation intensity, synergizing with neotectonics and lithology. In contrast, in the Lesser Caucasus and Talysh regions, the impact of forest vegetation appears to be somewhat mitigated by the contrasting influence of lithological factors, particularly those stemming from igneous rocks.

In the neighbouring countries, landscape-ecological and hydrometeorological studies are being actively conducted to assess the role of the impact of natural and anthropogenic factors on mountain geosystems.

**Conclusions and recommendations.** In identifying the factors contributing to the initiation and progression of degradation processes, we have highlighted key morphoclimatic factors affecting exogenous relief formation. Among these, heavy rainfall stands out as a primary driver, leading to the intensive flushing of the mountain meadow zone’s eroded soil cover.

Our survey results underscore the significance of the underlying rock composition in driving geodynamic processes in the high mountains of the Greater Caucasus. These rocks are susceptible to erosion and denudation, especially in



Fig. 4. Satellite image of the area near Galayxudat village on the northeastern slope of the Greater Caucasus. This image, provided by Google (USA) and captured on October 18, 2013, has a resolution of 1 meter. It displays steep slopes with shading and fresh landslide materials. The surface of the landslide materials exhibits varying degrees of brightness, corresponding to different levels of erosion

the context of heavy rainfall typical of mountainous regions.

Analysis of soil profiles revealed variations in thickness depending on surface slope, which directly influences the extent of degradation processes.

It is important to note that, at this stage, the assessment of degradation degree using aerial and satellite imagery materials alone, without concurrent field surveys, presents significant challenges, and this issue remains unresolved.

## REFERENCES

- [1] ABDUEV M. A. (2010) Reconnaissance Assessment of the State of the River Basins of Azerbaijan on anthropogenic load, Hydrometeorology and Ecology, Quarterly Scientific and Technical Journal, **2**, Almaty, 55–62, (in Russian).
- [2] ALIZADE E., S. A. TARIKHAZER (2010) Dynamics of changes in the structure of the dangerous spontaneous disasters in the Azerbaijani part of the great Caucasus under the conditions of global changes, Sustainable Development of Mountain Territories, **3**(5), 49–56, (in Russian).

- [3] ALIZADE E. K., S. A. TARIKHAZER (2015) Eco geomorphological danger and risk of the Greater Caucasus (within Azerbaijan), MAKS Press, Moscow, 207 pp, (in Russian).
- [4] MARDANOV I. I. (2011) Identification of the main factors in studying the transformation of landslide massifs in the south-eastern tip of the Greater Caucasus, Hydrometeorology and Ecology, Quarterly Scientific and Technical Journal, **4**, Almaty, 132–143, (in Russian).
- [5] ABDUEV M. A. (2011) Denudation in the mountain regions of Azerbaijan according to the data on the run-off of sediments and dissolved substances, Hydrometeorology and Ecology, Quarterly Scientific and Technical Journal, **4**, Almaty, 122–131, (in Russian).
- [6] MAMEDOV R. M. (2016) Landscape planning: essence and application, Elm ve bilik, Baku, 292 pp, (in Azerbaijani).
- [7] MARDANOV I. I., S. N. JUSIFOVA (2017) Geosystem analysis of exogenesis of high-mountainous landscapes of the Azerbaijani part of the Greater Caucasus, Sustainable development of mountain territories, **9**, 1(31), 32–39, (in Russian).
- [8] TARIKHAZER S. A., S. G. MAMMADOV, Z. A. HAMIDOVA (2023) Application of quantitative methods for the assessment of landslide susceptibility of the Aghsurchay river basin, Visnyk of V. N. Karazin Kharkiv National University series Geology Geography Ecology, **58**, 257–273, <https://doi.org/10.26565/2410-7360-2023-58-20>.
- [9] KUCHINSKAYA I. Y. (2011) Landscape-ecological differentiation of mountain geosystems (on the example of the northern slope of the South-Eastern Caucasus), Monograph, Baku, Victor, 196 pp, (in Russian).
- [10] AHUNDOV S. A. (1978) Sediment flow of mountain rivers of the Azerbaijan SSR, Baku, Elm, 98 pp, (in Russian).
- [11] EYYUBOV A. D., X. RAGIMOV (2003) Climatic resources. In: Regional geographical problems of the Azerbaijan Republic, Sheki-Zakatala economic region, Baku, Nafta-Press, 58–63, (in Azerbaijani).
- [12] ALIZADE E. K., I. Y. KUCHINSKAYA, S. Y. GULIYEVA, S. A. TARIKHAZER (2015) Intensity of landslides in mountain geosystems of Azerbaijan and its estimation, International Journal of Scientific Research and Innovative Technology, ISSN: 2313-3759, **2**(10), 1–6.
- [13] MARDANOV I., M. ISMAILOV, E. KARIMOVA, S. TARIKHAZER (2018) The transformations of slope slide landscapes of Great Caucasus: possibilities of discovering of main factors, Konya Journal of Engineering Sciences 6 (Özel (Special)), 787–797, <https://doi.org/10.15317/Scitech.2018.168>.
- [14] GULIYEVA S., I. KUCHINSKAYA, S. TARIKHASER, E. KARIMOVA (2019) Natural and anthropogenic factors in hazard assesment of the Alpine–Himalayan mountain ecosystems (at the example of the Azerbaijan Caucasus), C. R. Acad. Bulg. Sci., **72**(9), 1227–1233, <https://doi.org/10.7546/CRABS.2019.09.10>.
- [15] SHIRALIEV S., R. MAHMUDOV (2008) Hydrometeorological Situation and Dangerous Hydrometeorological Phenomena in Azerbaijan, Baku, Zija-Nurlan, 339 pp, (in Azerbaijani).
- [16] MAMEDOV DZH. G. (2009) Methodology for calculating the variability of the largest expenditures of suspended sediments of the Greater Caucasus rivers (within the Azerbaijan Republic), Hydrometeorology and Ecology, Quarterly Scientific and

Technical Journal, **2**, Almaty, 91–96, (in Russian).

- [17] ABDUEV M. A. (2014) Regularities of the territorial distribution of the module of ion flow of mountain rivers in Azerbaijan, *Meteorology and Hydrology*, **7**, 72–82, (in Russian).
- [18] AGAEV T. D., I. I. MARDANOV, M. F. GADZHIZADE (2013) Ecological aspects of the construction of tourist facilities in the high-mountainous Azerbaijani part of the Greater Caucasus, *Proceedings of the scientific-practical conference on “Risk assessment and security problems”*, April 25–26, 2013, Baku, 189–191.
- [19] TARIKHAZER S. A., I. Y. KUCHINSKAYA, E. J. KARIMOVA, S. O. ALAKBAROVA (2021) Issues of geomorphological-landscape risk (on the example of the Kishchay river), *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of geology and technical sciences, Satbayev University, Almaty*, **6**(450), 133–140, <https://doi.org/10.32014/2021.2518-170X.129>.
- [20] TARIKHAZER S. A. (2020) The geographical prerequisites for the identification and prevention of dangerous geomorphological processes in the mountain geosystems of the Alpine-Himalayan belt (on the example of the Major Caucasus of Azerbaijan), *Journal of Geology, Geography and Geocology, Ukraine, Dnepropetrovsk*, **29**(1), 176–187, <https://doi.org/10.15421/112016>.

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