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Baltica

BALTICA Volume 37 Number 1 June 2024: 47–58
https://doi.org/10.5200/baltica.2024.1.5

Landscape-geomorphological factors of the development of mudflow centres in the Goychay River basin

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Tarikhazer, S., Karimova, E., Kuchinskaya, I. 2024. Landscape-geomorphological factors of the development of mudflow centres in the Goychay River basin. *Baltica, 37 (1)*, 47–58. Vilnius. ISSN 1648-858X.
Manuscript submitted 25 December 2023 / Accepted 26 April 2024 / Available online 27 May 2024

Abstract. In recent decades, as a result of global warming and increased development of mountain areas, which are highly sensitive to anthropogenic impacts, there has been a rapid increase in the number and scale of natural disasters accompanied by material damage and even death of people. An increase in anthropogenic impact on the mid- and high-mountain geosystems is also characteristic of the mountainous territories of Azerbaijan, especially, because this is pronounced within the southern slope of the Greater Caucasus. Here, along with such dangerous processes as avalanches, landslides, etc., mudflows are intensively manifested. New methods of dealing with them should be developed to mitigate their effects. In this regard, the problems of studying the development and mapping of mudflow centres become very relevant. On the southern slope of the Greater Caucasus, the basin of the Goychay River is one of the most subject to mudflow processes, which in recent years has caused significant economic and social losses. The article gives a complete description of the landscape-geomorphological factor as one of the main factors in the formation of mudflow centres and traces their development dynamics. In the course of the study, with the aim of using the ArcGİS software for 2018, the area was calculated and the dynamics of the development of a number of mudflow centres was revealed. In addition, a land use map of the Goychay River basin was compiled with the help of statistical, cartographic (digital topographic and maps of the use of past years) and remote sensing (RS) data (interpretation of aerospace images (ASS) 2002–2019 from the Landsat satellite (scale: 1: 60,000). On the basis of field research and landscape mapping in the "key areas", the influence of mudflow processes on the differentiation of landscapes in the basin of the Goychay River was studied.

***Keywords**: mudflow source; mudflow hazard; anthropogenic impact; remote sensing; landscape; landslide*

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INTRODUCTION

The subject of the study is the landscape and geomorphological factors of the development of mudflow hearths in the Goychay River basin. The importance of the study is that the basin of the Goychay River is located on the southern slope of the Greater Caucasus, which is one of the most mudflow-dangerous areas within Azerbaijan. It occupies a leading position in the number of mudflow basins, the frequency of passage of various types of mudflows, their power, the volume of removal and the complexity of the conditions for their formation, and the amount of damage caused to economic facilities and residential buildings (Tarikhazer 2020). According to Makhmudov (2008), more than 400 mudflows occur here. The basin of the Goychay River belongs to the Mountainous Shirvan zone, where there are 70 settlements with a population of 171.2 thousand people in the mudflow zone, and Mountainous Shirvan has been actively developed for recreational purposes in recent years.

We conducted research in such mudflow-prone river basins on the southern slope of the Greater Caucasus as Kurmukhchay, Mukhakhchay, Kishchay, Shinchay, etc. (Tarikhazer 2021, 2022).

The difference between this work and previous studies is that for the first time the influence of mudflow processes on the differentiation of landscapes in "key areas" of the Goychay River basin was studied. Strong anthropogenization in the zone of accumulative terraces and on the detrital cone on the Goychay River was revealed.

Azerbaijan is one of the regions of the world that are often affected by mudflows. Approximately 572 settlements with a population of about 2 million and numerous infrastructure facilities are at risk of mudflows. The territory of the Greater Caucasus is ranked among the most mudflow hazardous in terms of the number of mudflow basins, the frequency of flow of diverse mudflows, their thickness, the volume of debris cone, and the complexity of the conditions for their development, the amount of damage caused to residential buildings and economic facilities (Tarikhazer 2019, 2020). Currently, 70 settlements with a population of 171.2 thousand people are located in the mudflow zone in the Shamakhi–Ismayilli region. According to Makhmudov (2008, 2015), there are more than 400 mudflows in the Greater Caucasus. There are four mudflow-bearing rivers in the region under study, among which the most mudflow-prone is the basin of the Goychay River (Table 1, Fig. 1).

The recreation and tourism sector has been intensively developing in the mountainous regions of the southern slope of the Greater Caucasus in recent years. It has led to the establishment of a large number of infrastructure facilities, namely buildings, transport routes, and communication lines in areas where dangerous exodynamic processes are actively manifested, including mudflows. In addition to anthropogenic factors, geomorphological, hydrogeological, and climatic factors significantly influence the formation of mudflow processes (Guliyeva *et al*. 2019). At present, increasing the accuracy of forecasting the development of mudflow processes, which provides for the availability of not only the data on the structure of individual mudflow basins but also information on the specifics of their dynamics, is of great importance (Karavayev, Voskova 2012, Widjaja 2015). According to Revzon (2012), it is necessary to study not only the water regime and the morphology of mudflow-prone basins but also the processes by which river valleys are replenished with loose-clastic material while exploring the mudflow process: seismo-tectonic, landslides, avalanches, screens, etc. Thus, a mudflow hazard assessment should be studied based on a complex geodynamic analysis of a mudflow-prone

Table 1 Dates of passage of the most dangerous mudflows of the Goychay River

No	Date of the mudslide	Aftermath of mudslide
1.	20.05.1919	20 houses, 21 shops, water pipes, and 17 rooms of a leather factory were destroyed. The damage amounted to 50 million rubles
2.	15.07.1945	The villages of Vigur and Vyalyasi were damaged. There were human casualties
3.	30.05.1972	42 houses, water supply, power grid, communication line, bridge across the Goychay River and Baku–Tbilisi highway damaged
4.	22.05.1982	1 person died
5.	21.04.2009	17 pedestrian bridges destroyed, 94 houses damaged in Gakh city
6.	24.06.2010	3 houses of Mirzabeyli village of Gabala region destroyed, 68 houses damaged
7.	10.06.2012	A short-term mudflow on the Goychay River
8.	30.05.2013	Damaged houses in the villages of Kurd, Arabjabir, Shahadet. 100 hectares of sown area damaged
9.	13.06.2013	Damage was caused to agricultural land, about 100 residential buildings in Goychay region
10.	06.07.2013	The hydroelectric power station on the Goychay River was destroyed. The village of Sumagally was flooded. Roads, power lines, pedestrian and automobile bridges were destroyed. 30 houses damaged
11.	11.07.2013	Agricultural land destroyed, more than 100 houses destroyed. 6 bridges were demolished in 4 villages of the Ismayilli region. The granary supplying the villages with drinking water was destroyed. Power poles damaged. Communication on the Baku–Shamakhi–Yevlakh road was interrupted for several hours
12.	02.09.2016	In the villages of Istisu, Chaigovushan, Galajig and Sumagalli of the Ismayilli region, damage was caused to sown areas and vegetable gardens. The bridge over the Shirvanchay River (a tributary of the Goychay River) was destroyed (Fig. 1). Poultry died
13.	03.06.2018	Two two-story residential buildings and several private houses were damaged. 45 families evacuated
14.	12.06.2018	Mudflow demolished the Goychay bridge on the Baku–Shamakhi–Yevlakh road
15.	28.09.2021	The bridge in the city of Goychay was destroyed

According to Makhmudov (2008, 2015), with the addition of Tarikhazer (2019, 2020).

Fig. 1 The bridge over the Shirvanchay River (a tributary of the Goychay River) destroyed on 2 September 2016 by a mudflow in the village of Galajig, Goychay region (photo 12 October 2019)

basin, one of the results of which should be an assessment of the endo- and exodynamic potential of the study area (Tarikhazer *et al*. 2022; Somos-Valenzuela *et al*. 2020).

STUDY AREA

Most of the Goychay River basin is located within the Goychay district of Azerbaijan. Goychay district is one of the 66 districts of Azerbaijan. It is located in the centre of the country and belongs to the Central Aran Economic Region.

Goychay region is located in Shirvan valley, at the footsteps of the Greater Caucasus Mountain range. It stretches for about 25 km from north to south and 40 km from east to west, making up 726 km^2 in total. Geographically, the region is divided into a mountainous terrain and lowlands. The Bozdag Garamaryam mountain range makes up the mountainous part.

In the territory of the district, the dominant climate is mild hot semi-arid and dry subtropical. This climate type is characterized by mild and moisture winters and dry and warm summers.

The Goychay River originates on the western slope of Govdag Mountain (2435 m) from a height of 1980 m (Fig. 2). In the area from Buynuz village, the river enters the Ganikh–Ayrichay valley, where the villagers use the river's water for irrigation. Below the village of Sumagally, the river splits into two independent branches, flowing in parallel until it flows into the Ayrichay River. Near the city of Goychay, the river is divided into many branches, and a wide fan of irrigation canals is used for irrigation. From its source to the exit to the Ganikh–Ayrichay valley, the valley of the Goychay River has a V-shape. The slopes of the river valleys 300–500 m high have a steepness of 20–30^o. The slopes of the river valleys 100–150 m high have a steepness of 60–70^o, being bare and steep in some places. The forest vegetation covering the slopes in the area of Buynuz village descends to the very bottom of the valley.

The length of the Goychay River is 115 km, while the catchment basin makes 1770 km^2. The primary sources of mudflows are located in the rocky zone of the basin above the upper border of the forest. Mudflows are predominantly incoherent in nature. All tributaries of the Goychay are mudflow-bearing. The Goychay River is characterized by slopes intensively dissected by gravitational denudation, with block displacements in bedrock and loess deposits. Large landslide massifs (Figs 3, 4) and blocks in both bedrock and loess deposits (Tarikhazer 2020) complicate the slopes of this river.

MATERIALS AND METHODS

The purpose of the conducted work was to reveal the geomorphological and landscape conditionality of the development of mudflow sources in the basin of the Goychay River, as well as indicate the reasons for their formation and propose measures to combat them based on materials from researchers' field geomorphological and landscape studies and fund literature. During the research, the study used topographic maps at a scale of 1:100,000 (1973) and satellite images (SI). We compared the SI from the Google satellite using the ArcGIS software for 2018, calculated the area and revealed the dynamics of the development of several mudflow origination sites. In addition, we have compiled a land-use map of the Goychay River basin using statistical, cartographic (digital topographic and maps of the use of past years), and Earth

Fig. 2 Space image of the Goychay River basin

remote sensing (ERS) data (interpretation of satellite images (ASI) 2002–2019 from the Landsat (Scale:1: 60,000)). The results of the research will allow using the obtained data for the development of the program for the safe and sustainable functioning and development of the hard-to-reach mountainous geosystems of Azerbaijan for the recreational and touristic development.

The study used CNES/Airbus, Maxar Technologies (GeoEye-1) high-resolution airspace (ASP) pictures and Sentinel-2A and 2B medium-resolution airspace (ASP) pictures. Visual and semi-automatic decoding (classification with training) was carried out in the ArcGIS environment.

A landscape-geomorphological assessment of the mudflow river basins was carried out, and cal-

Fig. 3 Landslide processes on the slope of the Goychay River valley (photo 12 October 2019)

culations of the areas of formation of mudflow centres were carried out based on the interpretation of the ASP 1996–2020 years from the Landsat satellite (Scale 1:60,000) for the period 1990–2020.

RESULTS

Complex morphostructural features characterize the relief of the study area, where there is a combination of significant positive and negative structures and discontinuous faults with different severity on the surface. The lithology of rocks is of great importance in morphogenesis. Here, clayey rocks of various ages are mainly developed, resulting in the formation of an intensely dissected landslide relief of the river basin due to the outcrops. Large morphostructures determined the modern plan of the Goychay River channel, confined to large contact zones and profound disturbances.

Tectonically, the study area is located within the Zagatala–Govdag synclinorium, occupying its eastern part – the Lahij synclinorium. Separate linearly elongated folds are distinguished within this enormous structure, determining the morphostructural features of the relief. This zone simultaneously corresponds to the zone of the transverse Goychay uplift of the Greater Caucasus. Thus, the severity of tectonic steps is associated with this uplift. Clearly traced, these steps – Babadagh and Govdag, determined the formation of the relief with a complex lateral and linearly elongated plan of morphostructures. Large tectonic units, the boundaries of which correspond to faults and ruptures, also determine large orographic units – the Main Caucasian and Govdag ridges. Such

Fig. 4 Typical landslide areas within the mountain-meadow landscape of the Goychay River

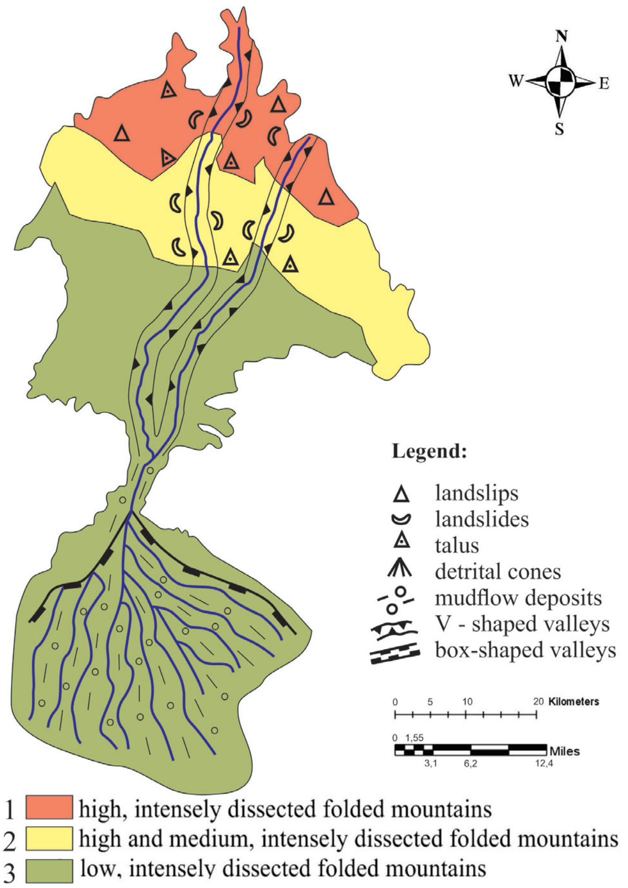

Fig. 5 Geomorphological map of the Goychay River

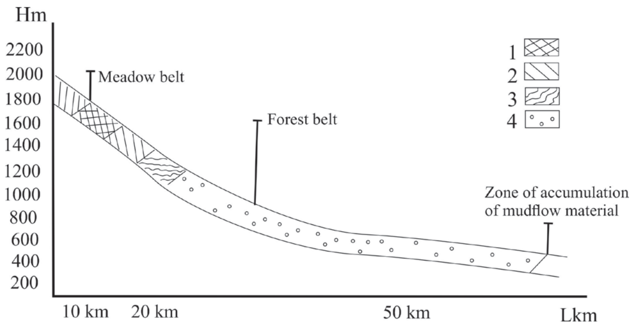

Fig. 6 Geological and geomorphological longitudinal profile of the Goychay River. Meadow belt and mudflow zone: accumulation of materials at the bottom of narrow sections of valleys in the form of deluvial plumes. Forest belt: zone of passage of mudflows, their enrichment with tributary materials and channel sediments

significant and regional tectonic faults and thrust faults as Gozduchay, Zangin, and others delimit large morphostructures or complicate their structures with smaller morphostructures. The Gozluchay fault is the boundary between the Babadagh and Govdag stages, while the Zangin thrust, located between the Govdag zone and the Lahij trough, stretches for a considerable distance. The block character of tectonic movements of the Goychay River basin led to some solidity of morphostructures and their weak differentiation. Due to this, the Govdag and Babadagh steps do not generally break up into smaller morphostructural units, although they are torn apart primarily by the transversal West Caspian fault.

Tectonic faults and fissures occurring along their movements play a significant role in the modern relief of the Govdag Range. They are expressed by a stepped arrangement of individual significant elements, almost levelled surfaces of denudation levels in the relief. Such are the surfaces of the Govdag Ridge, located between the Goychay and Girdimanchay rivers.

Despite a great intensity of modern tectonic movements and the development of landslides, landfalls, screes, and other exogenous processes, faults framing large morphostructures in the modern relief are not obscure. The height of the ledges separating the individual blocks – mountain ranges, massifs, and basins, mostly exceeds 200–300 m, and in some places, it reaches 400 m.

In the plan view, the valley of the Goychay River corresponds to the lines of tectonic faults, along the strike of which the basins are lowered to considerable depths (Figs 5, 6).

For instance, the features of the block origin of morphostructures include a straightened section of the bed of the Goychay River, traceable in the relief, from the confluence of its main tributaries from the Chaygovushan village to the Bighir village. The confinement of large knee-shaped bends of the Goychay River valley to a single line and orientation should be considered one of the clear indicators of the block-discontinuous genesis of morphostructures. For instance, large bends along the Goychay River border the Govdag Ridge from the east and west, thereby creating a large inversion morphostructure – the Govdag synclinal ridge.

Global climate changes also affect the Goychay River basin. In recent years, the amount of precipitation has shown a tendency to decrease, but at the same time it is of a torrential nature. Landslides occur during prolonged (up to several hours) rains, which are accompanied by short downpours. When a large amount of precipitation falls, the pore pressure in the slope grounds increases, its stability decreases and the earth mass shifts.

The enormous landslide blocks are encountered in the upper reaches of the Goychay River. The displacement amplitude of individual blocks in bedrock reaches 70–100 m, the width of the block surface is 50–60 m, while the surface slope reaches 30–35°. The thickness of the blocks does not exceed 20–130 m, which indicates the gravitational nature of landslide blocks. Separate landslide mudflow or active landslide flows are formed in the area of the giant landslide blocks. In addition, ravines, gullies, furrows, and ruts dissect the right slopes of the Goychay River.

Fig. 7 Mudflows areas of the Goychay River basin and threatening the village of Galajig

Fig. 8 Bridge destroyed by a mudflow in the Goychay region (photo 2 June 2018)

Besides, landslides are observed in small areas within the steep parts of ledges of high accumulative and erosion-accumulative terraces in the Goychay River basin.

Rock outcrops of numerous dense and denudation-resistant bedrocks create ledges in the relief. Numerous screen heaps accumulate at the foot of these ledges. For example, well-rounded pebbles characterize river terraces in the village of Galajig with 120–150 m in height. The accumulation of such thick strata, well-rounded pebble formations at absolute heights of 1100–1400 m leads to the conclusion that this, apparently, is associated with changes in the hydrographic network in terms of the Neogene–Quaternary time, as thick layers of well-rounded sediments in such proximity to the watershed could not have been deposited. In all appearances, these deposits are products of other older paleogeographic and paleohydrographic changes.

Mudflows are predominantly incoherent in nature. All tributaries of the Goychay River are mudflow-bearing. The main mudflow-forming foci of the Goychay River basin are located at an altitude of more than 1800 m in the rocky zone of the basin above the upper border of the forest. However, mudflow centres are also encountered in the forest zone at an altitude of 1500–1800 m. Three large mudflow centres near the Galajig village serve as an example of this (based on the Statistical data for 2019, the population was 1700 people) (Figs 7, 8, 9).

The study compared the SI from the Google satellite for 2002 and 2019. Based on these results, the area was calculated, and the dynamics of the development of these mudflow centres were revealed. The area of the first and second centre (located on the left bank of the Shirvanchay River – the right tributary of the Goychay River) in 2002 was 13 hectares and 12.9 hectares, while in 2019, their area was 15 hectares and 15.7 hectares. For 17 years, the area of the first mudflow centre increased by 2 hectares and the second by 2.8 hectares. The third mudflow centre is located on the left bank of the Goychay River. Its area was 43.6 hectares in 2002 and 49.4 hectares in 2019. For 17 years, its area increased by 5.8 hectares (Tarikhazer 2020).

Based on field research and landscape mapping in the “key areas”, the research studied the influence

Fig. 9 Goychay River valley after mudflow (photo 2 June 2018)

of mudflow processes on the differentiation of landscapes in the basin of the Goychay River (Fig. 10).

The development and spread of landslide zones strictly follow the laws of altitudinal zoning of all landscape-forming factors. Within each altitude landscape belt, the character of these phenomena and the clarity of their differentiation vary depending on the spatial orientation of the slopes. The areas of intensive development of landslide zones are the nival-subnival and mountain-meadow belts, the physical-geographical features of which are most conducive to their development. If gravitational, gravitational-infiltration, and glacial types of landslide zones prevail in subnival and mountain-meadow landscape complexes, then in the mountain-forest landscape belt, fluvial and gravitational-infiltration types predominate (accumulative terraces, lateral tributary cones, and gullies, floodplain and channel deposits).

Fine contours and varying resistance characterize the landscapes of the Goychay River basin. The fine contour of the landscape is due to intensive dissection and large slope slopes, while resistance is due to the age of landscapes and the intensity of manifestation of modern geomorphological processes (Karimova, Kuchinskaya 2018). The landscapes of the mountain-meadow zone are the least resistant ones, where the processes of slope renewal are most intensive, as well as the landscapes of the river valley, subject to the destructive effects of mudflows (Guliyeva *et al*. 2014). Rocky-exposed slopes occupy about 10% of the basin area (Fig. 11).

The average amount of precipitation falling on the surface of the catchment basin is 685.1 mm, evaporation is 1127.2 mb, and air temperature is 13.8^{o}C (Mammadov *et al*. 2020). Natural landscapes in the basin occupy 46.7% of the area, while anthropogenic modifications cover the rest 53.3%.

The studied region is largely anthropogenized (Kuchinskaya 2011). The highest anthropogenic load coefficient is encountered in the zone of accumulative terraces and on the peripheral fan. Due to favourable orographic conditions, there are individual buildings with household plots (gardens and orchards) on the accumulative terraces of the Goychay River.

On the flat part of the territory of the river basin, almost the entire economic part of the zone is concentrated. The mountainous part is mainly represented by forests and summer pastures. A significant amount of debris deposits accumulates on the cones of river outflow. The territory of the outflow cones of the Goychay River basin, carried by mudflow deposits, is 20.3 km^3. As a result, there is a reduction in the area of arable land in agricultural turnover.

DISCUSSION AND CONCLUSIONS

Summarizing the above-mentioned findings, geomorphological and landscape factors are one of the main conditions in the formation of mudflow centres and the passage of mudflows. The vertical zonality of the relief of the southern slope of the Greater Caucasus and the confinement of geomorphological proc-

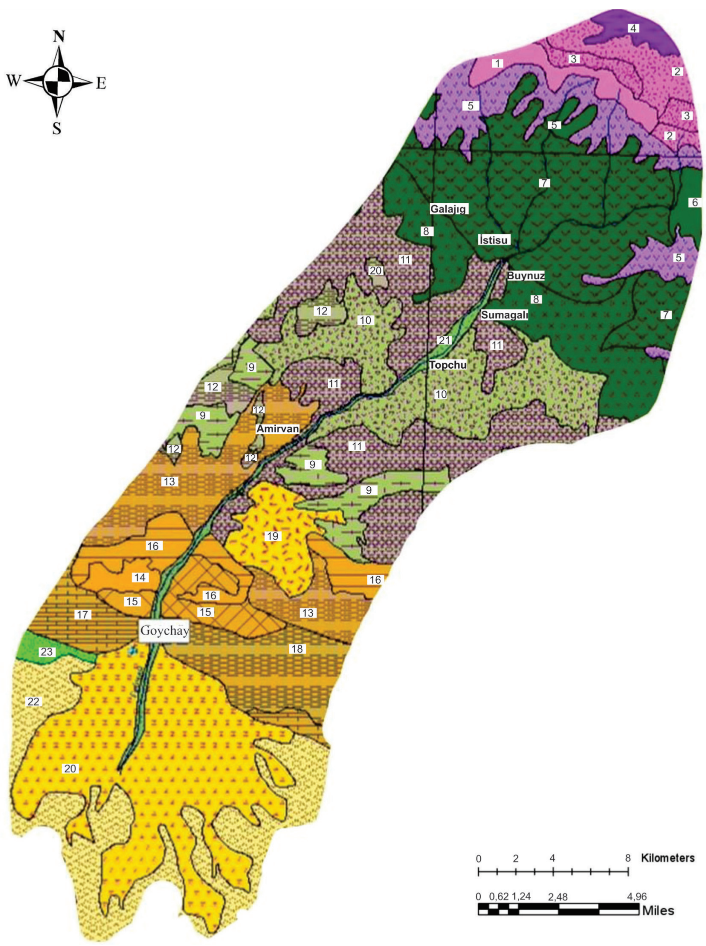

Fig. 10 Landscape map of the Goychay River basin:

A. Landscapes of high mountains with a cold temperate humid climate

I. Subnival landscapes

1. Weakly and moderately dissected slopes of high mountains with bedrock outcrops and disturbed soil and vegetation cover
2. Medium and intensely dissected steep slopes of high mountains with accumulation of weathering materials and areas of alpine meadows on thin, poorly developed mountain meadow soils
3. Intensively dissected steep rocky steep slopes of high mountains, devoid of soil and vegetation cover

B. Mountain-meadow landscapes with a humid and moderately humid climate

II. Alpine meadows

4. Intensively dissected steep strongly eroded slopes of steep mountains with fescue, thyme, clover, Koster on thin washed-away mountain meadow soils

III. Subalpine meadows

5. Weakly dissected landslide slopes with clover, fescue and bluegrass on mountain meadow-soda soils

C. Moderately humid mountain forest landscapes

IV. Beech-hornbeam and oak-hornbeam forests of middle and partially high mountains

6. Intensively dissected slopes of high mountains with oak-hornbeam forests on brown-forest soils
7. Medium-dissected medium sloping slopes of medium and low mountains with beech-hornbeam and oak-hornbeam forests on brown forest soils
8. Medium-dissected medium sloping slopes of medium and low mountains with beech-hornbeam-oak forests on gray-brown forest soils

D. Landscapes of moderately humid accumulative plains

V. Forest, forest-steppe and meadow-steppe, shrub landscapes of accumulative plains

9. Weakly dissected high proluvial plains with post-forest shrubs (gold tree, wild rose, blackberry) and sagebrush-forb plants on brown soils
10. Medium-dissected low, slightly sloping alluvial-proluvial plains with oak-hornbeam forests on brown soils
11. Weakly dissected alluvial-proluvial low plains with oak-hornbeam forest-shrubs and meadow-steppes on brown soils, transformed into agricultural landscapes
12. Intensively dissected terraced plains with oak-hornbeam forests and shrubs on alluvial and alluvial-meadow soils

E. Arid and semi-arid landscapes of low mountains

VI. Dry steppe, steppe landscapes of arid low mountains

13. Undivided, slightly sloping slopes of low mountains with sagebrush-bearded steppes and bushes of chervil, black flower, pomegranate on mountain dark brown soils

VII. Arid-forest, forest-shrub and shrub steppe landscapes of low mountains

14. Intensively dissected badland slopes with light forests of juniper and pistachio on light chestnut soils
15. Intensively dissected slopes of low mountains with rare bushes of pistachio, juniper, and chervil tree on chestnut soils
16. Medium-dissected slopes of low arid mountains with forest-shrubs of pistachio, juniper, wild rose, and Christ's thorn on chestnut mountain soils
17. Intensively dissected steep badland slopes with sparse sagebrush, ephemera, and bushes of the Christ's thorn on mountain brown and chestnut soils
18. Medium-dissected badland slopes of medium-sized arid-denudation mountains with sagebrush-ephemeral vegetation and bushes of Christ's thorn, black flower on gray-brown soils

VIII. Post-forest steppe landscapes of denudation-accumulation plains

19. Weakly dissected flat, slightly sloping plains with sagebrush-bearded and sagebrush-ephemeral vegetation on chestnut soils
20. Undivided flat plains and surfaces of alluvial fans with shrubs, meadow-steppes on alluvial-meadow soils

IX. Intrazonal landscapes of accumulative plains

21. Medium-dissected river valleys with meadow-steppes, meadow-marsh and meadow-shrub vegetation on alluvial-meadow soils

F. Semi-desert landscapes of dry and moderately dry subtropical plains

X. Semi-desert landscapes of accumulative plains

22. Weakly dissected flat plains and intercone depressions with ephemeral and primal-meadow vegetation on gray meadow soils

XI. Intrazonal landscapes of alluvial and marine plains

23. Undissected gently sloping plains with sagebrush-ephemeral vegetation on gray-brown soils

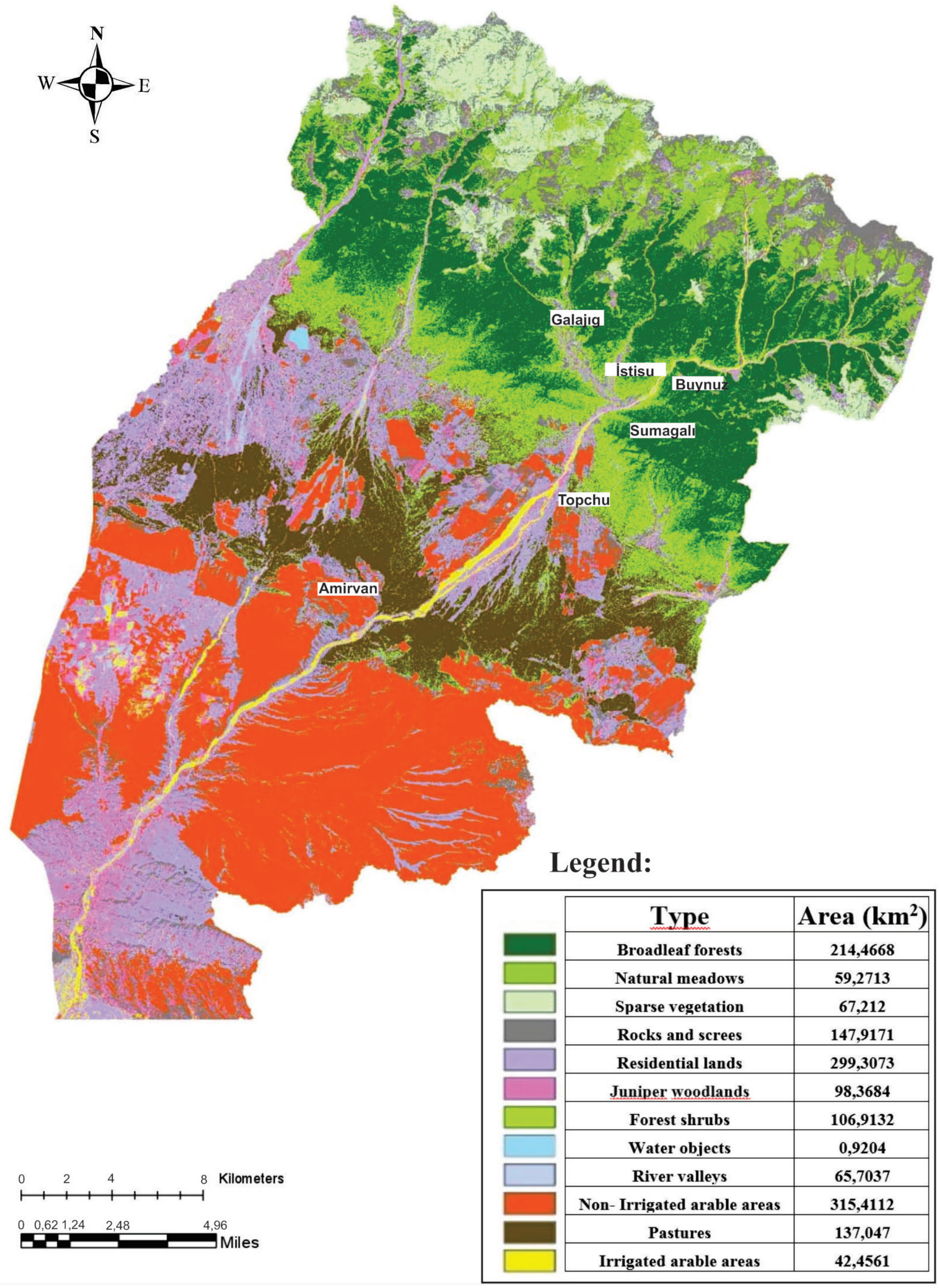

Fig. 11 Land use map of the Goychay River basin

esses to these belts determine the intensity of denudation processes. This indicates the predominance of the process of accumulation of loose material on mountain slopes, which, at high parameters of heavy rainfall, are eventuated in mudflows.

Recent tectonic movements in the formation of mudflow centres play an essential role. Tectonic fracturing is of particular interest, the manifestation of which is due to young movements that contribute to the fragmentation of rocks and are the sources of the formation of mudflow centres and the flow of mudflows.

The Goychay Fault passes through the study area. It is the reason for the increased seismicity of the region. The strongest earthquakes were the events of 4 June 1999 (magnitude 6 points, the source was at a depth of 21 km) and 6 March 2013 (magnitude 4 points, the source was located at a depth of 18 km).

The study has revealed that the formation of mudflows in the basin of the Goychay River flows in different conditions. Thus, bedrock materials on the southern–south-eastern slopes of the Govdag Ridge mainly feed mudflows, while they are associated with landslides and landfalls on the southern–south-western slopes. Therefore, mudflows passing along the tributaries of the Goychay River are different from one another. There are water-stone mudflows on the southern–south-eastern slopes, while mud-stone mudflows are encountered on the southern–south-western slopes.

The formation and passage of mudflows on the Goychay River are highly dependent on the valley's shape and the basin's structure. The slopes of the Goychay River are characterized by a steep fall, a strict orientation to the south, a narrow channel with a funnel-shaped expansion at the source, and easily destructible rocks forming the river's catchment area – shale and sandstone. The material of the destruction of accumulative terraces and terraced alluvial fans of tributaries also plays an essential role in feeding mudflows in the Goychay River. The study has revealed this feature on the Shirvanchay River, the tributary of the Goychay River in the area of the Galajig village.

Recommendations

The study recommends several measures to combat the formation of mudflow centres and the development of mudflows in the basin of the Goychay River, taking into account climate change and the ever-increasing human-induced disturbance on the mountainous geosystems of the southern slope of the Greater Caucasus:

1. It is necessary to categorically prohibit livestock grazing in the rocky belt – in the zone of development of mudflow centres. At the same time, it is recommended to observe the norms of livestock grazing per unit area and to significantly reduce it in the zone of alpine and subalpine meadows.

2. It is necessary to completely prohibit the cutting down of tree vegetation in the forest belt, which leads to bedrock exposure.

3. It is recommended to build anti-mudflow and mudflow-directing barrages and dams in the riverbed of the Goychay River and its tributaries.

4. It is recommended to restore engineering structures destroyed by previous mudflows in the area of mudflow outlets to the foothill zone to ensure the protection of the villages of Galajig, Sumagally, Vigur and others.

Timely information about the threat of mudflow development in the future will make it possible to reduce the risk and the amount of damage from it. The compiled geomorphological and landscape maps make it possible to identify the zones of development of mudflow centres in detail, which will allow studying the features of the accumulation of mudflow material and their readiness for demolition in the future. The land-use plan is helpful in planning the use of resources in the region's current planning and future development. All this will make it possible to use the data obtained for the development of the programme for the safe and sustainable functioning and development of the hard-to-reach mountainous geosystems of Azerbaijan for recreational and touristic development.

ACKNOWLEDGMENTS

We express our deep gratitude to our reviewers for their comments on the article. Their valuable remarks and constructive comments helped us improve the material and make it more informative and useful for readers. We are grateful to the reviewers for their contributions to our work.

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