Georgian Geographical Journal

Risks of Sustainable Environmental Management for the Purpose of Developing Regional Tourism (on the Example of the Lankaran Natural Region)

Georgian Geographical Journal, 2024, 4(1) 17-25

DOI: https://journals.4science.ge/index.php/GGJ

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Citation: Tarikhazer, S.; Kuchinskaya, I.; Karimova, E. Risks of Sustainable Environmental Management for the Purpose of Developing Regional Tourism (on the Example of the Lankaran Natural Region). *Georgian Geographical Journal* 2024, 4(1), 17-25. https://doi.org/10.52340/ggj.2024.04.01.03

Received: 1 November 2023
Revised: 25 January 2024
Accepted: 5 March 2024
Published: 1 June 2024

Abstract

Currently, reconstruction and redevelopment of inhabited areas is taking place in the natural area of Lankaran, and the area of construction work is also increasing in new, previously undeveloped areas, primarily due to the intensive development of the tourism and recreational industry. The high-quality functioning of the territory is unrealistic without taking into account the factors and patterns of manifestation of landslide processes, the dynamics and forecast of their development. During the study, a pattern of expansion of landslide processes was identified and the intensity of their manifestation was analysed. To study landslide processes, in addition to expeditionary geological-geomorphological, landscape work and stock materials, remote sensing data was used. When conducting landslide hazard analysis, high-resolution satellite images (CNES/Airbus, Maxar Technologies (GeoEye-1), and medium-resolution Sentinel-2A and 2B satellite images were mainly used. Visual and semiautomatic decoding (classification with training) was carried out in the ArcGIS environment. The compiled map for assessing the recreational potential of landscapes is recommended to use as monitoring and timely response to the state of the landscape-geological-geomorphological situation in the Lankaran natural area.

Keywords: landslide processes, anthropogenic impact, landslide hazard, ArcGIS technologies, recreation

Introduction

In recent decades, recreation has taken a significant place within the economy in the development of the regions of Azerbaijan. The main condition for the development of recreation is the assessment of resource potential, taking into account the numerous areas of its use (Tarikhazer, 2020). Natural and recreational resources are the geological and geomorphological structures of a territory, lithology, seismicity, landscapes, climate, mineral springs, water areas, etc., and are distinguished by limited self-healing capabilities (Solovova, 2007).

The biological and landscape diversity of the natural region of Lankaran significantly distinguishes it from other regions of Azerbaijan — proximity to the Caspian Sea, humid subtropical climate, the presence of mineral springs (Istisu, etc.), relict plants (ironwood, boxwood, chestnut oak, etc.) and many others. In addition, this region is a growing area for citrus fruits, tea and rice. Consequently, the natural conditions and resources of this region are favourable for the development of such types of tourism as sanatorium treatment, health and educational tourism, and recreation. However, ensuring the long-term sustainable use of natural resources for the purpose of developing recreation is a problem. It is well known that the tourism sector causes significant damage to landscape complexes, which can ultimately lead to the development of a wide range of exogenous geomorphological processes (EGPs), specifically landslides (Mammadov & Tarikhazer, 2023; Tarikhazer et al., 2023). The relevance of this problem is that it is necessary to promptly develop plans for the technical and engineering protection of various objects to carry out monitoring work to predict the formation, reduction and even prevention of landslides, which will ultimately reduce risks and reduce material damage (Tarikhazer, 2020; 2019).

Landslide processes in the region under study are the most common but are also the most complex, long-lasting and multifactorial. In the natural region of the Lankaran Plateau in recent years, the largest number of landslide processes in developed or newly populated areas are associated with increased anthropogenic activities (e.g., cutting woody vegetation, pruning slopes, laying linear structures—roads, power lines, gas and water pipes, sewerage networks, expanding existing and establishing new settlements, increasing the area of household plots and crops, and excessive watering and overgrazing of livestock), which are carried out without considering the geological and geomorphological conditions of the area. Most of the numerous objects are located in low- and mid-mountain zones, and this requires increased attention to the conditions and areas of formation and potential development of landslides. Dangerous road zones include the Sadatli landslide section in the Jalilabad district, the Veri-Aliabad section in the Lerik region, the Goravench landslide section in the Lankaran region, the landslide section 17–19 km from the Lankaran–Lerik road (Fig. 1), the Gullutepe landslide section in the Masally region and many more.

In the regions of Azerbaijan located in landslide-prone zones, the number of settlements in the Lankaran region is 8%, and the number of people is 11.1%.

The main conditions and factors for the development of landslides in the Lankaran natural area are geological and geomorphological structures, relief and lithology, and climatic and anthropogenic factors.

Figure 1. Active landslide processes at 17–19 km of the Lankaran–Lerik highway (photo 07.03.2021)

Methods and Materials

In recent years, numerous studies have been conducted to assess landslide hazards in various regions of the world (Akgun & Bulut, 2007; Asadian et al., 2010; Guzetti et al., 2005; Lee& Jones, 2014; Metternicht et al., 2005). To study landslide processes, in addition to expeditionary geological-geomorphological, landscape work and stock material, and statistical and cartographic sources, we used remote sensing data. When conducting the landslide hazard analysis, high-resolution satellite images (CNES/Airbus, Maxar Technologies (GeoEye-1)) and medium-resolution Sentinel-2A and 2B satellite images were used. Visual and semiautomatic decoding (classification with training) was carried out in the ArcGIS environment.

Results

Geological and geomorphological conditions

The large orographic unit of the Lankaran natural region is the heterogeneous morphostructure of Talysh, which is part of the larger morphostructure of the Western Asian Highlands, which is a complex fold-block mountain system. In general, the relief of Talysh is in accordance with the prevailing physical-geographical conditions and geological structure. The formation of the main features of the relief is due to endogenous factors of morphogenesis. Volcanic activity played a significant role in the formation of the Talysh relief, which experienced its greatest development in the Eocene. The block structure of Talysh, caused by discontinuous tectonics, is manifested in the step-by-step nature of its relief. The first stage, 800–900 m high, corresponds to the watershed of the Burovar ridge, the eastern slope of which is cut off by the pre-Talysh deep fault. The second stage, which rises above the first, with a height of 1400–1600 m, occupies the basin of the right tributaries of the river. Lankaranchay in its middle reaches.

İt is limited by a deep fault separating the Lerik synclinorium from the Astara Ridge from the southwest. The third stage, with heights of 700-800 m in the southeast and 2200 m in the northwest, corresponds to the high peaks of the Peshtasar Ridge. There is also a deep fault in the southwest. The fourth stage, at 2400 m high, corresponds to the Talysh Ridge, which is limited from the northeast by a deep fault. Consequently, the morphostructures of the ridges of the Talysh Mountains have a block structure, determined by the features of their relief.

According to the structure of the surface, Talysh is divided into two parts: mountainous, where denudation processes predominate, and lowland, where accumulative processes predominate. The Talysh Mountains descend stepwise to the Lankaran lowland, from which they are separated by a deep fault. The structure of the Talysh relief is closely related to the altitudinal zone. There is no high mountain belt here and is represented by individual peaks of the Talysh and Peshtasar ridges in the watershed strip with heights of 2400–2450 m. Here, the slopes of the river valleys are steep, and their bottoms have large slopes. The mid-mountain belt occupies altitudes of 1400–2200 m and is characterized by deep incision of river valleys. The river valleys are narrow and steep, and erosion terraces have developed. The low mountain belt covers a significant part of the territory and is characterized by significantly flattened relief. The river valleys that cross it are wide and flat-bottomed, accompanied by a series of accumulative and erosion-accumulative terraces. Here, intermountain basins are characterized by large thicknesses of continental sediments filling them.

The main mountain ranges of Talysh extend in the northwestern (Pan-Caucasian) direction and are represented by the Talysh, Peshtasar, and Burovar ranges and the intermountain basins separating them—Yardimli, Dyman and Gosmalyan.

The Talysh Ridge is the highest (Kemurkey Mountain, 2493 m; Gyzyurdu Mountain, 2433 m) and longest (length, 100 km; width, 10–15 km). Its relief is rugged and characterized by intense erosional dissection. To the northeast, at a distance of 7–10 km in the northwest direction, the Peshtasar Ridge extends (maximum height of Tylykh, 2342 m). Due to long-term development, the watershed part and the slopes of the ridge are intensively dissected. On the extreme northeastern periphery of the mountainous Talysh, which is more than 70 km long, is the Burovar ridge, which is intersected by the valleys of the river. Bolgarchay, Vilyashchay, etc. The heights of the ridges range from 600–1000 m.

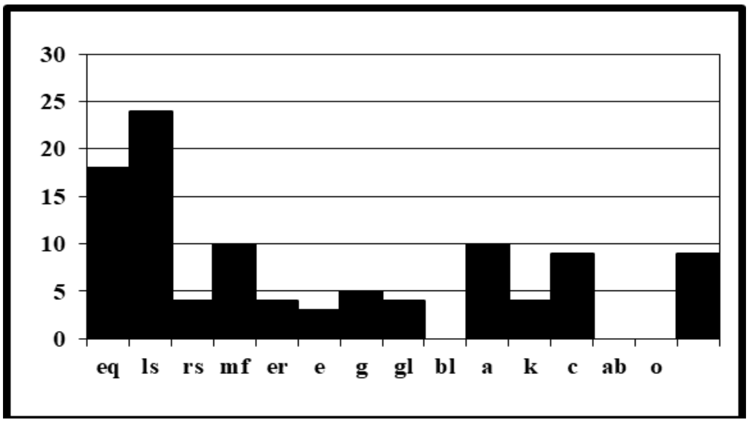

Figure 2. Structure of modern dangerous geomorphodynamic processes within the boundaries of the Talysh Mountains; Processes: eq — earthquakes; c — caves; ls — landslides; k — karst; rs — rockslides; gl —glacial (exaration and accumulation); mf — mudflows; bl — badland; er — erosion; a — avalanches; e — eolian; ab — abrasion; g — gullying; o — other processes.

Within Talysh, intermountain basins of erosional, erosional-tectonic and volcanogenic-tectonic origin have developed. Within their boundaries, the river valleys are wide and are characterized by better preservation of terrace levels of accumulative genesis. The most expanded sections of river valleys correspond to intermountain basins, where rivers, after forming an erosional base, filled the bottom with loose sediments and then cut into their own sediments and formed their own valleys with a series of nested terraces. Landslides are also widespread. The slopes of river valleys are terraced and complicated by landslide processes. Landslides developed on the northeastern slopes of the Peshtasar ridge and in the zone of its transition to the Yardimli intermountain depression. The Yardimli Basin, most of the northeastern slopes of the Burovar Ridge, which is composed of sandy-clayey deposits, is characterized by the widespread development of landslide processes, giving the areas of landslide development a typical landslide landscape.

The Gosmalyan intermountain basin is located in the upper reaches of Konjavuchay. The relief is intensively dissected and characterized by good terracing, with a strong accumulation of proluvial and colluvial deposits. In the northwestern part of the Talysh Range, a large geomorphological element is the Dyman intermountain basin, in which the rivers are wide and terraced. The central part is filled with alluvial-proluvial deposits, into which the river valleys are shallowly cut.

Here, at an altitude of 1480 m, the source of the upper reaches of the Vilyashchay River is concentrated.

The eastern part of the study region is occupied by the Lankaran Lowland, which is limited from the west by the steep northeastern slope of the ridge foothills of the Burovar Range. Along the Burovar ridge, a narrow intermittent strip stretches a zone of deluvial-proluvial deposits, forming alluvial cones, deluvial plumes, etc.

The change in the landscape belts of Talysh from humid subtropical regions in the low mountains and adjacent plains to semidesert regions in the northwestern part of the Talysh and Peshtasar ridges (landscape inversion) determines the vertical azonality of the manifestation of exogenous geomorphological processes (EGP) of relief formation. Consequently, the development of the EGP depends on the altitudinal zone of the relief, the latest and modern tectonic movements (seismicity up to 8 points), slope exposure, climatic conditions, etc. (Fig. 2).

Climatic conditions. Relief and the Caspian Sea have a great influence on the distribution of precipitation in the study area. The difference in precipitation distribution is very large, reaching 1100–1200 mm. The greatest amount of precipitation falls in the foothills of the southeastern part of Talysh (1700 mm). If 1400 mm of precipitation falls in the foothills of Talysh, then in the middle mountains, it decreases to 200–300 mm. In mountain depressions (especially in the Deman and Diabar depressions), up to 300 mm of precipitation falls. The reason for the uneven distribution of precipitation is the mountains.

Table 1. Changes in climate elements by landscape type in the Talysh Mountains

Types of landscapes	Absolute height (m)	Amount of solar radiation (kkal/sm2)	Number of hours of sunshine	Average annual precipitation (mm)	Average annual temperature (C^0)	Average annual evaporation (mm)
Dry steppe landscapes of low mountains	200>	120–130	2000–2200	300–450	14–14,7	800–1000
Forest landscapes of low mountains	200–700	132–136	<2000	400–1200	12–14	600–700
Forest landscapes of the middle mountains	700–1800–2000	130–135	2000–2200	600–1600	8–12	600–800
Mountain xerophyte landscape of the middle mountains	2000–2500	125–135	2200–2400	300>	6–8	400–600

The number of sunny hours in the Talysh Mountains is 2200–2400, and in low-mountain and mid-mountain areas, it is 2000–2200. The distribution of total solar radiation is 128–132 kcal/sm2 at the peak of Kemurgoy-Gyzyurdu 140–144 kcal/sm2. The radiation balance decreases from 35 kkal/cm2 during the year to 10 kkal/sm2 towards the high part of the middle mountains (Table 1).

The average annual relative humidity for the region is 70–80%. The maximum relative humidity is observed in the foothills (Table 2).

Table 2. Relationship between moisture conditions and differentiation of landscape types

Landscape types	Absolute height in meters	Average annual precipitation (in mm)	Average annual evaporation (in mm)	Humidification coefficient	Humidification type

Dry steppe landscapes of low mountains	200>	450	1000	0,45	Arid
Forest landscapes of low mountains	200–700	1200	700	1,7	Extreme Humidity
Forest landscapes of the middle mountains	700–1800–2000	1600	800	2	Extreme Humidity
Mountain xerophyte landscape of the middle mountains	2000–2500	300	600	0,5	Arid

In the region under study, landslide processes become more active during periods of heavy rainfall. For example, from November 7 to November 10, 2015, heavy rains occurred in the Lankaran-Astara zone. In total, 69–122 mm of precipitation fell here (44–72% of the average monthly average). The amount of precipitation in the summer months and early autumn is sometimes 3–4 times greater than the amount of precipitation in the winter and autumn periods, and this increase mainly falls on the share of rainfall precipitation. Therefore, it is no coincidence that landslide processes occurred precisely during this period. As noted by Madatzade and Shikhlinsky (1968), showers are observed in both lowland and mountainous zones. The differences between them lie not in the intensity but in the frequency of rainfall. In the mountainous areas of the Lankaran Plateau, an inversion of atmospheric precipitation has developed: in the mountains, showers are observed less frequently—especially the most prolonged and intense ones—and in lowland areas—much more often (Fig. 3).

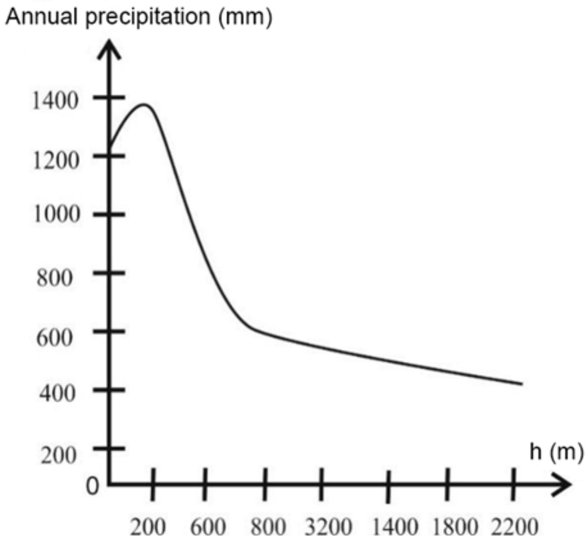

Figure 3. Change in the annual amount of precipitation with height in the central part of Talish (according to A.A. Madatzade, E.M. Shikhlinsky (1968)

The role of climatic factors in the development of landslide processes is undeniable. To reveal the role of climatic factors, a graph (Fig. 4) of the development of landslides in the Lankaran natural area was constructed by month. The maximum number of landslides is observed during periods with the greatest frequency of maximum precipitation, i.e., if the maximum frequency of precipitation occurs in spring and autumn, then the maximum occurrence of landslides occurs during the same period.

In addition, a graph of the frequency of landslide processes in the Lankaran natural area was drawn (Fig. 5). The statistical analysis of the landslides revealed that for the period of 2010–2022. On average, 6 of the most dangerous landslides occur annually.

It follows from Fig. 5 that the highest frequency of landslides is observed in 2015–2017. The trend line (dynamics) proves this, i.e., in recent years, landslide processes have been intensifying; however, we consider the main reason to be geological and geomorphological factors, as well as increased anthropogenic impacts. However, despite this, the role of climate factors cannot be denied. Climatic factors do not form the landslide itself, but they are a kind of trigger.

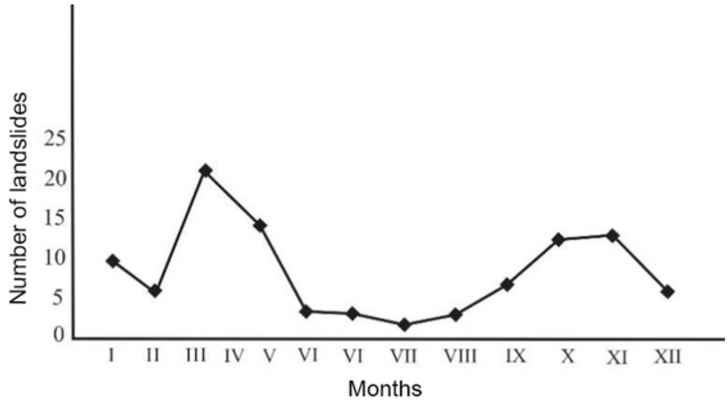

Figure 4. Distribution of landslides in the Lankaran natural area

Anthropogenic factors

It is known that during the anthropogenic development of a territory, it is of no small importance to assess the stability of the relief, its individual forms, or the risk of the occurrence of exogenous geomorphological processes (EGPs), in this case, landslides, which pose a danger to human life and the functioning of tourist and recreational complexes. Common types of anthropogenic impacts include cutting and overloading of slopes, artificial watering and waterlogging of constituent rocks due to leaks from water pipelines and excessive watering of lands (Gulieva et al., 2014). Naturally, they are confined to the most urbanized territories and linear infrastructure facilities. For example, unplanned deforestation during the construction of tourist facilities such as the Lankaran Springs Wellness Resort and Hirkan Park Hotel led to the formation of landslide processes on the slopes of the mountains of the Lankaran natural region. Slopes cut as a result of laying road surfaces such as Lankaran–Lerik, Lerik–Yardimli, and Degedi–Pelikesh in the Astara region (Fig. 6) also led to the formation of new centers for the development of landslides.

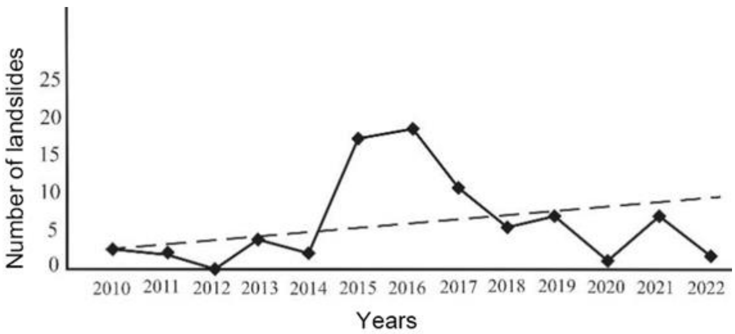

Figure 5. Frequency of landslides in the Lankaran natural area

When analysing the landslide hazard and creating a map for assessing the recreational potential of landscapes, high-resolution satellite images (CNES/Airbus, Maxar Technologies (GeoEye-1)) and medium-resolution Sentinel-2A and 2B images were used. Basically, visual and semiautomatic decoding (classification with training) was carried out in the ArcGIS environment (Fig. 7).

In the Talysh Mountains, the lowest landscape zone begins with forest, followed by mountain steppes and mountain-dry steppe landscape zones. Therefore, the main reason for this event is that, on the one hand, the highlands and internal depressions here are under the influence of the arid climate of the Iranian Plateau, and on the other hand, the mid-mountain Peshtasar ridge, which creates a barrier landscape in the Talysh Mountains and retains moisture generated by humid northeastern winds. Thus, moist air masses coming from the Caspian Sea pass over the narrow Lankaran Plain and on their way into contact with the steep slopes of the Talysh Mountains, resulting in a large amount of precipitation (1400–1600 mm). Air masses moving in the western and southwestern directions gradually lose moisture, and the amount of precipitation in the highlands sharply decreases. The reason for the formation of landscape inversion in Talysh is orography and associated climatic conditions. This led to the formation of unique landscape types at corresponding altitudes (Guliyeva, 2018).

Figure 6. Landslide on the Degedi–Pelikesh road, Astara district (photo May 28, 2023)

From the analysis of the landscape map, field research and other literature, it is clear that if the forests on the northern slope are dense and highly dense and occupy a large area, then the forests on the southern and western slopes are less dense, occupying a relatively large area. a small area and, in some places, even replaced by forest and shrubs.

One of the most important factors determining landscape differentiation in the study area is the formation of river valleys, gorges, and landslides. During your field survey, we observed active landslides on the right bank of the Alasha River, including between the villages of Sors, Aliabad and Shingedulag.

Conclusion

In this study, we analysed all the factors contributing to the development of landslide processes in the natural Lankaran area. The main factors are the geological and geomorphological structure, seismicity and anthropogenic factors. The remaining factors, namely, climate, are a trigger in the formation of landslide processes.

To reveal the role of climatic factors, a graph of the development of landslides in the Lankaran natural area was constructed by month. The maximum number of landslides is observed during periods with the greatest frequency of maximum precipitation, i.e., if the maximum frequency of precipitation occurs in spring and autumn, then the maximum occurrence of landslides occurs during the same period. In addition, a graph of the recurrence of landslide processes in the Lankaran natural area was compiled. The statistical analysis of the landslides revealed that for the period of 2010–2022. On average, 6 of the most dangerous landslides occur annually.

A map was constructed to assess the recreational potential of the landscapes of the Lankaran natural region, from which it follows that most landslides are confined to the plain-mountain contact zone, low mountains and middle mountains. Monitoring work has shown that in the study region, the number of landslides is increasing every year. Based on the results obtained, ArcGIS technology has advantages over traditional (cartographic) methods for studying landslide processes.

Based on the above, we believe that the current environmental situation can lead to a decrease in the productivity of natural ecosystems and further restoration potential in the future. This can subsequently lead to a decrease in the attractiveness of landscapes due to their powerful transformation. Currently, there is already an increase in environmental tension in the region. It is obvious that it is necessary to switch to a new system of environmental management, which, in the future, will ensure the long-term environmentally sustainable functioning of the Lankaran natural area with the aim of developing tourism.

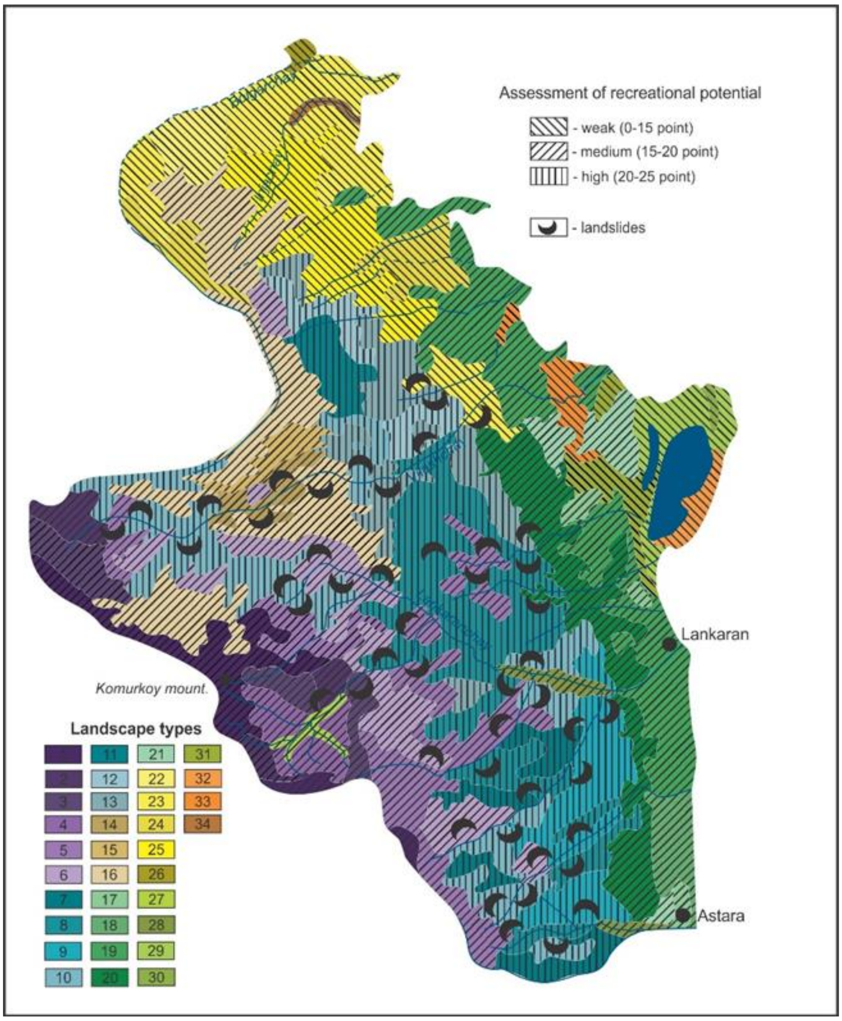

Figure 7. Map of estimation of the recreational landscape potential of the Lankaran region (taking in account the landslide hazard of the territory); Legend A. Temperate-humid mountain-forest landscapes; I. Intrazonal xerophytic mountain landscapes (1–6); II. Hyrcan type humid subtropical forests of low and medium highlands (7–13); B. Landscapes of medium and low mountains with a temperate-humid climate; III. Forest-steppe, steppe and mountain-meadow landscapes of low and medium highlands (14–16); C. Landscapes of temperate-humid accumulative plains; IV. Forest, shrub-meadow and forest-steppe landscapes of accumulative plains (17–21;); D. Lowland arid and semiarid landscapes; V. Dry-desert, desert landscapes of the arid lowland (22–25); VI. Lowland arid-forest, forest-shrub and shrub-steppe landscapes (26); VII. Dry desert and xerophyte-desert landscapes of denudasion-accumulative plains (27); VIII. Intrazonal landscapes of accumulative plains (28–31); E. Semidesert landscapes of arid and temperate-arid subtropical plains; IX. Semidesert landscapes of accumulative plains (32–34)

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors provided critical feedback and helped shape the research, analysis and manuscript.

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