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Jafarova Latafat,
PhD Candidate

Ganja State University, Ganja, Azerbaijan, e-mail: ismayilovaletaft@gmail.com,
ORCID ID: 0000-0003-3388-7501

DIFFERENTIATION CHARACTERISTICS OF MOUNTAIN-FOREST, FOREST-SHRUB, AND FOREST-MEADOW LANDSCAPES IN THE NORTHEASTERN PART OF THE LESSER CAUCASUS

Abstract. In the northeastern slope of the Lesser Caucasus, particularly within the mountain-forest and mountain-meadow landscapes, the intensification of human settlement poses serious ecological risks in terms of the transformation of natural landscapes. High population density in steep mountainous areas further exacerbates these risks. This issue represents a significant threat, especially for mid- and high-mountain zones, and is particularly critical in areas characterized by steep cliffs and mountain peaks. The article explores the characteristics of landscape differentiation processes in this region and examines their scientific and theoretical significance.

Methodology and Methods. The study employs several widely used approaches in the investigation of geographical landscapes, including the cartographic method, field research, geographical forecasting, and mathematical-statistical analysis. In the course of the research, extensive use was made of scientific literature on the subject, maps, internet resources, and statistical data.

Key Scientific Contribution. The primary scientific novelty presented in this study lies in the identification of risk factors resulting from anthropogenic differentiation processes within the mountain-forest, forest-shrub, and forest-meadow landscapes in the northeastern part of the Lesser Caucasus. These risk factors have been substantiated with concrete evidence. Based on the analyses conducted, quantitative indicators of the landscapes affected by differentiation have been determined.

Research Findings. The study reveals that in the northeastern part of the Lesser Caucasus, the type, intensity, and structure of anthropogenic activity generally vary in accordance with vertical zonation, shifting from the foothills to high-mountain areas. Based on the degree of differentiation of the natural ecological structure, it was determined that 8% of the landscapes in the studied area have undergone severe differentiation, 46% moderate differentiation, 37% relatively weak differentiation, and 9% have not been affected by differentiation at all.

These landscape complexes are subjected to maximum anthropogenic pressure during the summer season, primarily due to the seasonal migration of large and small livestock to highland pastures. In contrast, anthropogenic interventions in the high mountainous areas are virtually halted during the winter months due to extreme climatic conditions. In this region, subalpine meadows are predominantly utilized as hayfields, while alpine meadows are mainly exploited as grazing lands.

Keywords: Northeastern Lesser Caucasus, alpine, subalpine, landscape, differentiation.

Introduction (Problem statement): In the mountainous massifs of the northeastern slope of the Lesser Caucasus, the risk of landscape transformation increases in parallel with the growth in population size and density. The relevance of this issue in the studied region is intensifying year by year. Therefore, the adverse effects caused by the vertical zonation of landscapes must be systematically investigated. For areas characterized by high ecological tension due to anthropogenic pressures, comprehensive mitigation measures should be developed. These measures primarily include the proper and efficient use of soil and water resources, as well as the incorporation of new landscapes into the production cycle while maintaining environmental balance and sustainable development. Projects dedicated to studying and addressing this problem are being developed across all regions of the country, with the participation not only of ecologists and geographers but also professionals from various fields involved in project design and implementation.

The primary scientific innovation of this study lies in the substantiation, with concrete evidence, of risk factors arising from anthropogenic differentiation processes within the mountain-forest, forest-shrub, and forest-meadow landscapes in the northeastern part of the Lesser Caucasus. Based on the conducted analyses, quantitative indicators of landscapes subjected to differentiation have been determined.

In recent years, the study of the characteristics of differentiation processes in natural landscapes of the northeastern part of the Lesser Caucasus has acquired significant scientific and theoretical importance. Several aspects of this issue have been investigated in modern times by Azerbaijani researchers such as K.S.Agayeva (2015), M.A.Museibov and R.Y.Guliyev (2018), I.E.Mardanov (2008), as well as Y.A.Garibov, N.S. Ismayilova, and R.R. Sadullayev (2011, 2020), G.B.Ahmedova (2016). Some critical facets of the studied topic have been reflected in the works of these scholars. Below, a brief overview of the key points related to the subject as presented in these publications is provided.

Y.E. Garibov`s [2011] study systematically examines the anthropogenic transformation of contemporary landscapes in the Republic of Azerbaijan. The work begins with an analysis of the primary characteristics of the region`s landscape structure in relation to its natural conditions and geographical features. The author provides an extensive discussion on the impact of human activities-particularly agriculture, industry, settlement, and infrastructure development-on landscape structure and functions.

The book analyzes the consequences of anthropogenic transformation across various ecological indicators, including soil erosion, deforestation, and changes in water resources. The work holds significant theoretical and practical importance for addressing environmental problems and ensuring the efficient management of natural resources.

G.B.Ahmadova`s [2016] research systematically examines the natural conditions of the Lesser Caucasus during the Middle and Late Pleistocene, as well as the paleoecological status of humans in that period. The study analyzes climatic changes, landscape development, and their impacts on human activity in the region, based on geological, paleontological, and archaeological materials.

The author provides a comprehensive discussion of the human habitat during the Pleistocene, emphasizing the interactions between humans and natural resources, including hunting, settlement patterns, and impacts on the ecosystem.

The book serves as a significant resource for research in paleoecology, archaeology, and climate change, aiding in the understanding of the interactions between the natural history of the region and human activities.

The joint research work "Geomorphology of Azerbaijan" by M.A. Museyibov and R.Y.Guliyev [2018] provides a systematic overview of the country`s geomorphological structure, formation processes, and surface development characteristics. The book analyzes the geomorphological features of Azerbaijan`s diverse relief zones, including mountainous, lowland, and hilly regions.

The authors provide a comprehensive explanation of the impact of geomorphological processes-such as erosion, denudation, karst formation, and landslides-on the landscape structure of the region. The book also discusses the methodology of geomorphological research in relation to Azerbaijan`s geological structure, the evolutionary stages of the relief, and the current dynamics of geomorphological development.

I.E.Mardanov`s [2008] research analyzes the eco-geomorphological condition of Azerbaijan and the impact of natural balance disruption on regional landscapes. The article highlights the role of geomorphological processes within ecosystems and the anthropogenic pressures exerted by human activity on these processes.

The author emphasizes that the disruption of the natural balance leads to the emergence of various ecological problems, such as soil erosion, landslides, deforestation, and disturbances in the water balance. Additionally, the study analyzes regional differences in the eco-geomorphological conditions across various parts of Azerbaijan and their impacts on the environment.

The ecological risks and threats caused by anthropogenic transformation are generally classified by scholars into four main categories, each with specific evaluation criteria. First, the sources of these risks-such as landslides, rock falls, erosion, desertification, etc.- and their spatial distribution across different landscape types are identified. Subsequently, the impacts of these processes on natural landscapes and their manifestation within socio-ecological systems are assessed. The most severe category of risk is classified as a "disaster," while the least impactful is considered "mild" (Agayeva, 2015). Within the research area, all of these categories can be observed to varying degrees. The natural-geographical conditions of the region, combined with its status as an area of active exodynamic processes, have resulted in the presence of nearly all sources contributing to environmental risk and threat.

Differentiation Characteristics of the Alpine and Subalpine Landscape Belts in High-Mountain Areas. High-mountain meadows in the study region are located between the subnival zones and forest complexes, typically found at absolute altitudes ranging from 1,700–1,800 meters to 3,000–3,200 meters. The relief of these zones is highly fragmented and is primarily composed of weakly differentiated rocks dating back to the Cretaceous, Jurassic, and Eocene periods. These zones are widely shaped by gravitational and erosional-denudational relief forms. The mountain-meadow complexes are particularly widespread in ranges such as Goshkardag, Kapaz, Shahdagh, Murovdagh, and others.

Due to differences in relief, climatic conditions, productivity, and patterns of use, the high-mountain meadows are subdivided into two distinct subtypes: alpine and subalpine meadows. Each of these subtypes has unique characteristics and functions within the region's ecological and agricultural systems.

Alpine Meadows are formed at the upper boundary of mountain meadows, typically between absolute altitudes of 2,700 and 3,200 meters. The development and formation of these meadows are strongly influenced by harsh climatic conditions. In the high mountain peaks, including the elevated areas of Murovdagh, Shahdagh, Goshkardagh, and others, one can observe glacial and recent snow cover exaration relief forms from the Quaternary period, as well as accumulative relief types such as moraines created by these processes. Within this landscape complex, there are numerous small lakes, mostly of glacial origin, formed under the influence of glaciers and other exogenous processes. The largest of these lakes is located on the northern slope of the Gamishdagh massif at an absolute altitude of 3,000–3,100 meters.

Under the influence of the harsh mountain tundra climate, the annual solar radiation in this landscape complex amounts to 140–148 kcal/cm² per year. The average temperature in January ranges between -6°C and -10°C, while in July it averages between 5°C and 10°C. In the high-mountain zones where mountain meadows develop, the absolute minimum air temperature can drop below -30°C (Mardanov, 2008, p.59-60).

Due to their sensitive and fragile nature, alpine meadows contain numerous morphological units formed under the influence of unstable regimes. Dynamic erosion of ancient rocks has resulted in exposed rocky outcrops, glacial relief forms, and erosion products of varying thicknesses, which significantly enhance the differentiation of these landscapes (Ahmedova, 2016).

Subalpine Meadows develop below the alpine zone, typically between altitudes of 1,700–1,800 meters and 2,700–2,800 meters. Depending on the consistent rise in relief, the subalpine meadows form relatively wider belts on the northern slopes of the Shahdagh and Murovdagh ranges.

Due to block-tectonic uplifts between the Kurekchay and Ganjachay river valleys, subalpine meadows in some areas (particularly on high peaks) penetrate into the forest belt. In accordance with the dynamics of anthropogenic impacts, the subalpine complex is subdivided into subalpine meadows and meadow steppes. The meadow steppes of the subalpine zone predominantly develop in the high mountain massifs of Dashkasan and Gadabay.

Subalpine meadows differ from alpine meadows primarily in their higher thermal conditions. In these zones, the annual solar radiation totals 130–140 kcal/cm², with a radiation balance of 26–35 kcal/cm². The average annual air temperature is approximately 4°C, with January averages ranging between -5°C and -8°C, and July averages between 8°C and 15°C.

Due to favorable relief conditions (such as gentle slopes and low differentiation), the high mountain meadows of the northeastern slopes of the Lesser Caucasus have been studied more extensively compared to those in the Greater Caucasus. At altitudes between 1,800 and 2,000 meters, the area hosts not only hayfields and pastures but also cultivated fields for fodder crops, second-crop cereals, small orchards, and other agricultural activities. The high mountain meadows and summer pastures formed on various watersheds and mountain slopes within the region differ significantly in terms of their dynamics and degrees of anthropogenic impact.

The landscape complexes of the Garachadar and Ayibazar summer pastures, which are located near rural settlements, have undergone significant changes. Multiple routes lead to these summer pastures from the villages of Toghanali, Azgilli, Kurdali, and Pirverdi. On the northern side of Toghanali, along the left bank of the Kurekchay River, terraced mountain slopes at altitudes of 1,650–1,700 meters support sparse forests and forest shrubs, where fruit growing, secondary forests, and various hayfield-shaped agricultural plots have developed.

Around Azgilli village, at approximately 1,800 meters altitude, areas of meadows and cultivated fields have formed on former cleared forest lands. Near the watersheds, flat and smooth plateaus are covered with short-statured oak trees and shrubby grasslands (Müseyibov, Quliyev, 2018, p. 84).

The southern and southwestern slopes of Mount Tekilli (1,806 meters) are predominantly covered with tall subalpine meadows. The diverse herbaceous meadows on moderately sloping mountain sides are used as high-quality hayfields and pastures. The vegetation cover is almost complete, approaching 100% (Qasımova, 2023, p.63). In most areas, leguminous and cereal grasses exceed 30–45 cm in height. After mowing, these areas serve as grazing grounds for livestock. In years with high moisture, two hay harvests are performed during the summer season, with tall subalpine meadows extending up to 2,500–2,600 meters in elevation.

Such landscape complexes experience maximum anthropogenic load during the summer, primarily related to the seasonal movement of large and small cattle to summer pastures. It is precisely during this period that the most pronounced landscape changes occur. In winter, anthropogenic

interventions are practically suspended due to the extreme climatic conditions prevailing in the high mountains.

According to our calculations, lightly and moderately degraded pasturelands and hayfields cover an area of 300,000 hectares, while severely degraded pastures and hayfields occupy 149,000 hectares. The majority of the degraded pastures are located in relatively steep mountainous areas. These pasturelands are primarily concentrated in the mountain massifs of the following districts: Dashkasan (29,000 ha), Gadabay (74,300 ha), Goranboy (55,000 ha), Goygol (71,100 ha), and Shamkir (56,900 ha) (Budaqov, 1994, p.142).

Differentiation characteristics of the mountain-forest, forest-shrub, and forest-meadow landscape belts in the mid-mountain zone. In the studied area, the majority of the high-quality and productive forest stands are located within the mid-mountain zone. In several mountain slopes, these complexes differ both in terms of vertical differentiation and in the studied characteristics. In the northeastern part of the Lesser Caucasus, the Murovdag horst anticlinorium, Shahdag horst synclinorium, Bashkend-Dastafur graben-synclinorium, Shamkir horst anticlinorium, Kepaz horst-synclinorium, Goygol anticlinorium, and Gazakh graben synclinorium vary according to their developmental history, age, and differentiation age (Qələndərov, 2018, p.95).

In the indicated morpho-structural units, mountain-forest and mountain-meadow landscapes occupy a wide area within the vertical zonation of landscapes. One of the valleys distinguished by forest complexes is the Shamkirchay valley. Several forest stands of varying productivity are scattered in large masses at absolute elevations of 1200–1800 m on the southeastern part of the Upper Chaykend area, and on the slopes of Goturdag (3048 m), Bugdadag (3101 m), and the northern, north-eastern, and north-western slopes of Agqaya (3057 m). However, the Sarisu river valley consists mainly of low-altitude forests and forest-shrub-meadow complexes extending up to 2400 m, while the Goyyurd valley rises to 2300–2500 m, and the Agqaya valley reaches absolute elevations of 2400–2600 m. Additionally, the forested areas on the northeastern slopes of Kanlidag, Chobandag, and Boyuk Hasan mountain typically cover areas up to 2200–2300 m or higher in absolute altitude.

The Shamkirchay system comprises over 100 small and large rivers and their tributaries. Most of these rivers are 1.5 to 3.0 km in length and flow through sharply dissected deep valleys. Except for rocky, steep cliff slopes, the river valleys are generally covered with alder, pistachio, and birch forests. On the right bank of Shamkirchay, besides several valleys, the widths of other forest masses range from 0.5 to 2.5 km, while on the left bank they reach 3–4 km. The relatively smooth and widely terraced parts of the river valleys have been utilized by human agricultural activities since ancient times and, as a result, deforested. Analysis of historical data shows that the forests in these areas have been intensively destroyed since the beginning of the last century (Məmmədəliyeva, Nəsirova, 2021, p.112]. The integrity of forests in most river valleys has been severely compromised due to the continuous anthropogenic impact. Particularly in the settlements of Gadabay, Deyagarabulag, Aytala, Galakend, Miskinli, and similar zones, forest belts in the south and southeast directions have become excessively deforested, replaced by secondary growth and shrub vegetation.

Currently, in the southern and southeastern parts of the Galakend and Arisuy forests, the number of felled trees exceeds that of standing trees. In certain observation sites (plots), the number of cut trees per hectare (over 300–350) is three times higher than the number of trees regenerating the forest naturally (about 110). In these areas, all forests have been subjected to human disturbances, damaged, and mostly cut down; natural regeneration has led to the growth of new trees, while near residential zones, the forest cover has undergone more severe transformation, often replaced by shrublands and forest shrubs.

The middle and lower reaches of the Asrikchay valley have also been studied and researched. In the area from Cirdakhan village to Shykhheybat and Pelakli villages, forests of varying stability levels have developed on both slopes of the valley. On the right bank of Asrikchay, the forest cover has sharply decreased due to human economic activity, and the composition of the forests in this zone has changed significantly. Here, the forest massif spans a width of 1000 to 2500 meters in most places.

The southeastern and northwestern slopes of Chyngyldag are covered with dense forests. However, there are no forests near the Chyngyldag watershed and its vicinity. The villages of Kiran, Hajıhasanli, Qushchu, Galaboyun, Sofular, and Khatıncan, established within the territory of the ancient forest massif on the leveled area of the mountain, have played a significant role in the transformation of the forests in this region. All the named settlements occupy hundreds of hectares of cleared forest areas. The deforested lands are currently used as hayfields and arable land. The deforested area in Chyngyldag amounts to approximately 1050 hectares and continues to increase over the years.

In contrast, on the left bank slopes of the Asrikchay River, natural regeneration dominates, and the forests remain in good condition. Here, certain steep (40-45°) mountainous slopes with absolute elevations of 1600-1800 meters are entirely covered with forests. Except for rocky and stony relief areas, the remaining territories are densely forested, though some forests have undergone certain degrees of alteration. Severely disturbed forests account for approximately twenty percent of the total forested areas in this region (Heydərova, Əliyeva, Xəlilov, 2008, pp.339-340).

Differentiation characteristics of forest-steppe, steppe, and meadow-steppe landscape belts following the forest zone in the middle and low mountain regions. These complexes cover extensive areas at absolute elevations ranging from 450-500 meters to 1000-1200 meters in the foothills and low-mountain zones under study. Depending on relief features, slope exposures, exogenous activities, and the dynamics of anthropogenic impacts, their upper boundary sporadically rises to 1400-1500 meters in the basins of Zayamchay, Ganjachay, Goşqarchay, and Shamkirchay rivers. The areas where these landscape complexes develop are characterized by a dry-mild-warm winter climate (Qəribov, 2011, p.206).

In most parts, the total annual solar radiation accumulates between 120-130 kcal/cm², the annual number of sunny days ranges from 82 to 104, the average annual air temperature is between 9-13ºC, the mean temperature of the warmest month ranges from 25 to 19ºC, and that of the coldest month ranges from 15 to -15ºC. Annual precipitation ranges from 400 to 800 mm, reaching up to 1000-1200 mm in certain areas.

Denudation and erosion activities characteristic of the landscape type are the primary factors shaping the parent relief. In this region, there exist significant differences in the average temperatures throughout the year and month. The relatively high amount of atmospheric precipitation contributes to the continuous and persistent progression of erosion processes year-round. The mechanical weathering processes in the lower reaches of the Goshgarchay, Zayamchay, and Shamkirchay basins proceed with notable dynamism, leading to the formation of diverse morphological landscape units. Due to the inclined relief, slope exposures, and the elevation of the local erosion base level, contemporary geomorphological phenomena manifest in various forms and with regularity (Mehdiyev, İsmayılov, 2011, p. 92). The area is characterized by well-developed terraces, leveled surfaces, deep river valleys, gorges, ravines, and other relief types.

Between the absolute elevations of 800-1200 meters, carbonate-forest, mountain-brown, and dark brown mountain-forest soils have developed. On low slopes and highly inclined piedmont plains, brown, light brown, and forest-underlying brown soils prevail. Productive black and brown soils dominate in the smooth-shaped plateaus under forests in the Shamkir, Dashkasan, and Gadabay zones. The Murovdag horst anticlinorium and the Shahdag horst synclinorium consist of ridges, uplifts, and plateaus differing from each other by vertical landscape zonation. The Kapaz horst-synclinorium experiences more intensive uplift. All types of vertical zonation characteristic of the region are present here.

In most parts of the studied area, destruction of shrubbery and forests has caused soil aridification and erosion of its upper layers. The anthropogenic transformation characteristics of the region`s shrub-forest and post-forest meadow complexes differ markedly from each other (Qəribov, İsmayılova, Sədullayev, 2020, p. 67-68).

The gently sloping, slightly deformed smooth relief surface between the Kurakchay and Ganjəchay rivers has been thoroughly studied. The leveled plateau with an absolute elevation of 900-1000 m between Zurnabad village and Ganja settlement is divided into two parts by the Damirdik and Ganjachay rivers. In this area, dense mountain brown soils under the forest have a humus layer of 15-20 cm, and the humus content in the upper layers is 4-4.5%. The degree of anthropogenic transformation of landscapes on smooth, gently sloping terrains ranges between 0.8 and 0.9 (Qəribov, 2010, p.122).

Conclusion. It has been established that the type, intensity, and structure of anthropogenic activities generally vary along vertical zonation, changing from piedmont areas to high mountains. According to the level of disturbance of the natural ecological structure, 8% of the area is severely disturbed, 46% moderately disturbed, 37% relatively weakly disturbed, and 9% remains undisturbed natural landscape.

According to our calculations, the areas of pastures and meadows moderately to slightly degraded cover approximately 300,000 hectares, while severely degraded pastures and meadows encompass about 149,000 hectares. The predominantly degraded pasture lands are located in relatively steep mountainous massifs. These pastures are mainly concentrated within the mountainous regions of the Dashkasan (29,000 ha), Gadabay (74,300 ha), Goranboy (55,000 ha), Goygol (71,100 ha), and Shamkir (56,900 ha) districts.

The gently sloping, minimally deformed smooth relief surface situated between the Kurekchay and Ganjachay rivers has been thoroughly studied. The plateau, with an absolute elevation of 900–1000 meters, lying between the village of Zurnabad and the town of Ganja, is divided into two parts by the Damirdik River and Ganjachay. In this area, dense mountainous brown forest soils rising from beneath the forest exhibit a humus layer of 15–20 cm thickness, with a humus content in the upper layers ranging between 4 and 4.5%. In the gently sloping and leveled areas, the degree of landscape anthropogenization ranges from 0.8 to 0.9.

Such landscape complexes experience maximal anthropogenic pressure during the summer months, associated with the seasonal movement of large and small horned cattle to the highland pastures. Conversely, in winter, anthropogenic interventions practically cease due to the extreme climatic conditions prevailing in the high mountain areas. The subalpine meadows formed in this region are predominantly utilized as hayfields, whereas the alpine meadows serve primarily as grazing grounds.

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