LANDSCAPE SCİENCES

ASSESSMENT OF THE GEOECOLOGİCAL POTENTİAL OF SUBALPİNE AND ALPİNE MEADOW LANDSCAPES OF THE HİGHLANDS OF THE NORTH-EASTERN SLOPE OF THE LESSER CAUCASUS

S.M.Abbasova

Ganja State University, Ganja, Azerbaijan

seadet.abbasova.90@mail.ru

DOI: 10.59423/gnr.2026.89.22.004

Article history:

Received: April 25, 2025
Dispatched for revise:
September 19, 2025
Accepted: November 20, 2025

Keywords:

Landscape,
alpine and subalpine meadows,
geoecological potential,
mountain meadows,
pastures,
microlandscape,
pasture plants

Abstract

The article, based on the information obtained from satellite images, analyzes the morphogenetic features, regional differentiation and anthropogenic load of subalpine and alpine meadow landscapes formed in the highlands of the north-eastern slopes of the Lesser Caucasus, as well as their change depending on the absolute altitude. It was determined that more than 80% of the high-mountain forests of the region are located up to 1800 meters, and more than 90% of mountain meadows are located above 2200 meters. These meadows are ecosystems that exist in high-mountain regions and are used as summer pastures, consisting of perennial herbaceous plants. Most of the mountain meadows are restorative in mid-mountain regions where forests have been cut down, and are divided into 4 groups according to the change as a result of anthropogenic impact - virtually unchanged; slightly changed; moderately changed; Radically transformed landscape groups are identified and landscape and ecological features, development and changes in each of them are separately characterized. The analysis focuses on pastures that depend on their natural and geographical features and are particularly vulnerable to environmental degradation due to overgrazing, which leads to low productivity and significant landscape changes.

1. Introduction

The natural conditions of the Republic of Azerbaijan are characterized by complexity, which is reflected in the diversity of its land-scapes. Within the mountainous and lowland areas, a number of landscape types and subtypes are distinguished [4]. In high mountain regions, the upper part of the mountain meadow belt con-sists of alpine meadows, while below them lie subalpine meadows. The elevation of the alpine meadow belt depends on the geographical latitude of the mountain area, the climate, and the orien-tation of the slopes.

On the north-eastern slope of the Lesser Caucasus, high-mountain meadows have been more extensively utilized due to favorable relief conditions, such as gentle slopes and limited dissection. In this area, not only hayfields and pastures, but also other territories differ from one another by their anthropogenic transformation features, such as dynamism and stability. Only in subalpine and alpine meadow landscapes, located above 2000 meters above sea level, due to sharply dissected relief and cold climatic conditions, the population does not settle, and soil-climatic conditions are unsuitable for the development of agriculture. These areas are used exclusively as summer pastures for livestock farming [9].

In research carried out to assess the geoecological potential of the modern natural-anthropogenic landscapes of the north-eastern slope of the Lesser Caucasus, the ecological tension caused by the interaction between natural landscapes and human economic activity is of particular relevance today. Indeed, any anthropogenic impact on a natural component results in changes in its structure and functional activity. From this perspective, ecological-geographical research of landscape complexes, as an integral part of environmental protection and the rational use of natural resources, bears significant scientific and practical importance.

In the study, the transformation and differentiation characteristics of the mountain-meadow landscapes of the Lesser Caucasus, depending on ecological stress, were investigated, and it was determined that this problem is of greater significance in mountainous regions. Within the area, landscapes have been heavily degraded in relatively small spaces and vertical ranges, leading to the emergence of ecologically stressed zones. The high mountain-meadow landscape complexes of the north-eastern zone of the Lesser Caucasus represent the region where morphometric stress is most strongly manifested. Based on the assessment of morphometric stress in these mountain-meadow landscapes, a landscape-ecological classification was carried out.

2.Methods

In carrying out the study, complex physical-geographical research methods were employed, including systematic landscape research methods, observations, field studies, diagnostic approaches, ecological monitoring and assessment techniques, as well as one of the newest methods - the use of morphometric stress in landscape-ecological evaluation. At the same time, through the application of GIS technologies, the interpretation of satellite images was conducted to identify and map ecologically stressed zones.

The morphogenetic characteristics and regional differentiation of the high-mountain landscapes of the north-eastern slope of the Lesser Caucasus, the variation of their anthropogenic load depending on absolute elevation, and the analysis of mountain-forest, mountain-meadow, and meadow-shrub natural landscapes formed in the high and middle mountain zones were determined based on information derived from satellite imagery. Depending on the morphometric stress of the relief, aspects such as the transformation of landscapes, the ecogeographical features of mountain-meadow landscape complexes, and the negative consequences generated by these processes were investigated.

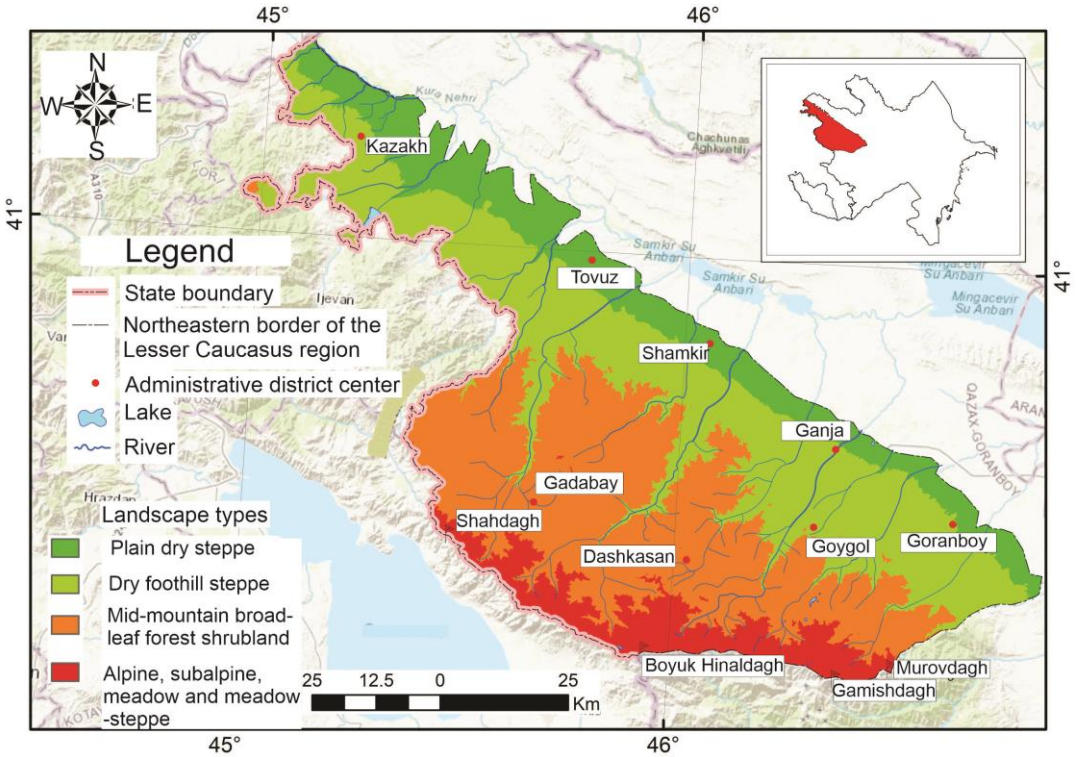
3.Analysis and discussion

The high mountain-meadow complex of the north-eastern slope of the Lesser Caucasus, as a landscape with complex relief conditions and geomorphological structure, covers vast areas and has undergone both vertical and horizontal dissection. Naturally, the mountain-meadow landscape serves as the fodder base for livestock farming; however, pasture erosion occurs here as a result of overgrazing, when cattle graze more intensively than the norm and outside the appropriate season. Trampling of the meadows and the destruction of vegetation, which trigger erosion processes, cover extensive areas. The soil cover, composed of fine-grained weathering materials accumulated in crevices, is located in the lower parts of the relief [10].

In the mountainous parts of the study area, the vertical distribution of landscapes and the associated formation of various exodynamic processes are closely related to slope steepness. The largest areas are those with slopes ranging from 5° to 10°. Only 4% of the total territory has slopes steeper than 30°. The nival and partly nival-glacial landscapes of the high mountains of the Lesser Caucasus (namely the Karabakh volcanic plateau, the Zangezur ranges, and the Murovdag range) cover areas at elevations of approximately 3,000 meters. A somewhat larger area of subnival rocky landscapes is developed on Jamish Mountain (3,724 m) and Omar Pass (3,295 m), as well as in the Koroghlu mountain range (3,462 m). On high mountain passes and watersheds exposed to continuous denudation processes, their extent has gradually decreased, being replaced by subalpine and alpine meadows at high elevations [12]. Within the complex, the accumulation of coarse debris and scree products resulting from physical weathering is observed. In the map-scheme we compiled, the changes occurring in the landscapes of the north-eastern slope of the Lesser Caucasus are clearly reflected.

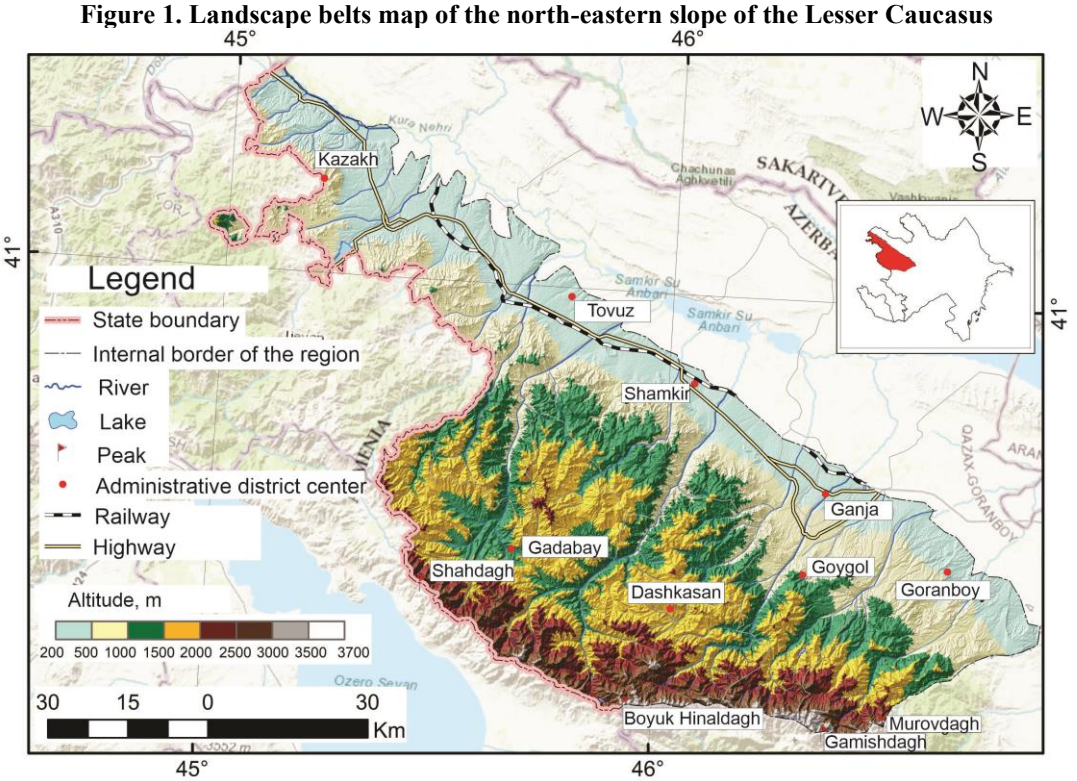
Landscape complexes such as the Ayibazar and Qarajadir summer pastures, located near rural settlements, have undergone significant transformation. Numerous routes lead to these pastures from the villages of Azgilli, Toghana, Pirverdiler, and Kurdalılar. The large number of roads leading to tents and summer pastures in different directions has caused the disturbance of natural landscapes on the slopes. To the north of Toghana village, situated on the left bank of the Kurek River, at an elevation of 1,700 meters, terraced forest-shrub areas, sparse forests, and patches of cultivated lands with diverse grasses, orchards, and secondary forests have formed on the mountain slopes [10].

Mount Ayibazar, covered with highly stable and gently sloping meadows, is extensively used as pastureland. This area represents a fundamentally altered landscape unit with a complex structure. Here, except for the watersheds, thick meadow soils have developed well on smooth-crested mountains, forming a stable cover of low-growing dense meadow grasses.



Source: *The map was compiled using ArcGIS software based on materials from the National Atlas of the Republic of Azerbaijan*

Figure 1. Landscape belts map of the north-eastern slope of the Lesser Caucasus



Source: *The map was compiled using ArcGIS software based on materials from the National Atlas of the Republic of Azerbaijan.*

Figure 2. Altitudinal zonation map

As is known, in areas with elevations of 2,000-2,200 meters, despite intensive grazing, the pastures and hayfields largely maintain their integrity. On some slopes, the rapid recovery of vegetation is due to a significant reduction in grazing intensity compared to previous years. In the summer pastures, climate-related changes - such as annual precipitation and humidity exceeding the long-term norm by 30–40 mm - have contributed to plant growth [2].

In accordance with the characteristic features of the study area, the synthetic methodology of sa-

tellite imagery and complex landscape interpretation was applied, along with the analysis and interpretation of the processed materials obtained as a result. The cosmolandscape methods developed and used for many years have mainly been applied to the study of lowland, foothill, and low-mountain landscapes - those covering large areas and exhibiting limited dissection. However, the study of high-mountain meadow landscapes using cosmolandscape methods had not previously been treated as a specific research subject. In such regions, the interpretation of key landscape units is based on reference indicators (standard parameters). The study of landscapes in inaccessible high-mountain areas requires the application of alternative approaches and methods. Here, pronounced horizontal and vertical differentiation, along with the subdivision of the relief into small individual units, increases the number of small-contour landscapes and strengthens the internal structural complexity of the landscape.

In areas up to 2,500-2,600 meters in elevation, where subalpine meadows are distributed, the landscape possesses a complex structure and varying degrees of human utilization. For example, on the slopes of Mount Chimkir-Chimkir, which has an elevation of 2,029 meters, terraced hayfields can be observed at around 1,900 meters on slopes with gradients of 30–45°. On these terraces, various secondary grasses, as well as small shrubs of wild rose and hawthorn, have developed along the slopes. In addition, remnants of secondary vegetation appear in strip-like formations on the corresponding slopes [9].

Oak shrublands and low-growing meadows dominate the watershed areas. Tall subalpine meadows cover the southern and southwestern slopes of Mount Tashkilli, which has an elevation of 1,806 meters. On the moderately sloping parts of the mountain slopes, diverse-grass meadows are distinguished by their high quality. Various cereal and legume grasses, exceeding 30–45 cm in height, grow across most of these areas and, after mowing, serve as a fodder base for livestock grazing. In years with a humid climate, it is even possible to harvest hay twice during the summer season in these regions.

One of the notable features of the north-eastern slope of the Lesser Caucasus is that subalpine meadows are preserved for mowing from the end of April until the end of July. In particular, the Ayibazar hayfields are protected until the end of June, and the Qarajadir hayfields until the first ten days of July. However, after the grasses are mown, these areas are intensively used as pastures, which accelerates land degradation and exposes the area to various transformations. On steep slopes, continuous grazing leads to the formation of patchy, bare surfaces, creating potential conditions for erosion [5].

Anthropogenic influences have always had an impact on natural landscapes, and the changes observed in the natural components of the study area serve as a clear example of this. The Kapaz and Kurd Yurd summer pastures, which are complex landscape units, differ greatly from one another. Mount Kapaz, located at an elevation of 3,066 meters, has a synclinal structure; its steep slopes and horizontally layered, columnar rock outcrops are bordered by several step-like terraces. Although the southeastern and southern parts of the Kapaz synclinal plateau lie at altitudes of 2,000–2,800 meters, they have relatively gentle slopes. The mountain slopes are covered with soils lacking vegetation and with extensive rocky and stony areas. Large accumulations of rockfall material cover wide areas at the foot of the summit. Massive rock debris has moved along valleys over long distances down to the forest complexes. The forests on the northeastern and northern slopes of Mount Kapaz are located at elevations of 2,000–2,150 meters [8].

The complexity of the internal structure of the landscape can be observed in the numerous small mountain lakes that formed on the slopes of Mount Kapaz as a result of an earthquake in 1139. The pastures located in stony and gravelly areas are mainly found in the southeastern part, while meadows suitable for mowing are found in intermediate zones where there are no landslides. In the studied area, the settlements of Khoshbulaq, Ahmadli, Yolchular, Amirvar, Zoghalli, Dardara, Gazakhli, and others play a significant role in the anthropogenic transformation of natural landscapes. Some settlements are located within the subalpine belt of this mountain massif. The Xoshbulaq plateau, which is one of the most densely populated and elevated summer pastures of the region, has been subjected to intense anthropogenic impacts [1].

In the mountain massif with diverse structures, pastures extend up to the watershed areas. The slopes used as hayfields, situated at altitudes of 2100–2200 m, are located about 2.5 km north of Khoshbulaq village. Here, the meadows that are mowed twice a year in the high-mountain plateaus have high resilience and a stable structure.

Although the pastures have a stable vegetation cover, numerous trails have formed on the slopes due to the intensive movement of livestock. How-

ever, eroded or washed-out slopes are not observed in this area, and tall-grass vegetation covers extensive parts of the meadows. In some places, where rocks are exposed on the watersheds, the soil cover is thin. Various meadow grasses and plants belonging to the families Rosaceae, Cruciferae, Fabaceae, and others are distributed here. These are tall-grass meadows located at absolute altitudes of 2400–2500 m. Weed species such as capsella, thistle, and amaranths are also found in the hayfields [11].

One of the factors contributing to the complete transformation of the mountain meadow landscape is the mining industry at the Alunitdag and Zeylik ore deposits. The pastures of the Amirvar and Gazakhly villages are heavily polluted by mining waste. The relative height of the mining waste cover, which forms large hills in the area, reaches 10-20 m. In some places, sparse vegetation consisting of various weed species, meadow grasses, and isolated shrubs has developed on their surfaces.

The mountain meadow landscape, as a dynamically developing young technogenic landform, is represented in the modern relief by bare hills that form two ridges arranged in an arc shape within the Alunitdagh massif. There are 5–6 steep peaks located approximately 500-600 meters apart, which are rich in alunite ore. The waste materials from ore extraction are scattered stepwise around the area, forming smooth technogenic slopes over the rugged terrain.

The transportation of extracted ore has led to the formation of moderately sloped hills composed of gravelly and stony waste materials on the steep slopes of the mountain. Due to the low stability of these hills, their recovery occurs slowly. However, in moist and gently sloping areas, vegetation and soil can develop relatively quickly on slopes made up of fine waste material. The technogenic hills in the area have formed over the past 30-35 years as a result of mining waste accumulation, particularly on the southeastern side of Alunitdag, and in the southwestern and southern parts of the Amirvar - Gazakhli highland. Here, alongside various meadow grasses, secondary vegetation and semi-shrubs are more prevalent [8].

The mountain-meadow complexes on the northern and northeastern slopes of Mount Goshqar, which has an elevation of 3,361 meters, have been altered to varying degrees. Soil degradation in the area is largely caused by the intensive dissection of the terrain by the tributaries of the Dastafur River and the erosion of the steep slopes of most valleys. On the slopes of Mount Qoşqar, hayfields are located along the river valleys, which, due to intensive grazing, leads to landscape degradation on both sides of the valleys. Additionally, numerous trails formed on the steep slopes have fragmented the terrain in multiple directions.

On stable slopes, intensively grazed alpine meadows on the northeastern part of Mount Goshqar, located on thick meadow soils, represent the most heavily grazed areas in the Lesser Caucasus. Most of the leveled paths on the western side of the summit are cut into small terraces along trails. The alpine meadows are situated on the northwestern slopes, which have gravelly and stony soils with low fertility. Cereals are cultivated along smooth roads at an absolute elevation of 2,200 meters. Nevertheless, the resilient meadows have largely preserved their structure. Across extensive areas, the meadow complexes on relatively steep slopes are disturbed and partially denuded.

As noted above, summer pastures and seasonal shelters (binas) are abundant on the northern and eastern slopes of Mount Goshqar. Each shelter, which is primarily active during July–August, hosts a large number of sheep. On the high slopes, the number of livestock grazing in the pastures far exceeds the recommended norm. This leads to the intensification of erosion processes on the slopes and along numerous trails. Intensive washing and complete denudation occur on slopes disrupted by trails [9].

The rocky and gravelly areas at an elevation of 3,101 meters are practically unused. The more sloping southwestern and eastern slopes of Mount Bughda are stable. On the northeastern slopes, intensively used alpine meadows have developed. The hayfields within the subalpine meadows are distinguished by high resilience and a stable structure. Hayfields are utilized on slopes with absolute elevations up to 2,400–2,500 meters. On the southwestern slopes of Mount Bughda, dissection has developed along the tributaries of the Sarısu River. Here, alpine meadows have been subjected to extensive agricultural pressure.

According to the altitudinal differentiation of natural landscapes, various belts are observed on Mount Qotur, which has an elevation of 3,048 meters. The northern slopes of the mountain, with an absolute elevation of 2,400 meters in the Sansu River basin, are distinguished by their smooth terrain. As a result of anthropogenic impact, dirt roads constructed in the area have sharply fragmented the pasture surfaces. Groups of tall

grasses have formed a thick cover over the soil surface. The gravelly and stony pastures and hayfields in the eastern part of Mount Qotur are relatively less used. Small hummocky hayfields have developed on leveled terraces in the southwestern and southern parts of Lake Zaghalı. Tall hills hinder hay cutting [1].

Subalpine and alpine meadow landscapes cover extensive areas and exhibit varying degrees of differentiation in terms of anthropogenic impact. According to the degree of alteration, weakly, moderately, and severely disturbed landscapes are located in mountainous areas with steep slopes and rugged massifs. Most of the high-mountain summer pastures are concentrated in the Gadabay, Goygol, Goranboy, and Shamkir districts.

In the high-mountain areas of the Murovdagh, Shahdagh, Kapaz, and Goshgar mountain ranges, as well as in the Gadabay and Dashkasan districts, the terrain is characterized by gentle slopes and weak dissection. Considering these features, it is important to implement certain measures based on plan-map materials, such as the organization of areas for pastures and hayfields, the designation of grazing sites and drinking water sources, the location of summer camps, landscape-based management, and productivity assessment projects [2].

According to the degree of disturbance, the landscape components of pastures and hayfields are classified as weakly, moderately, and strongly transformed. Degraded pastures mainly cover large areas within steep mountain massifs. In particular, the vast majority of summer pastures are located in the high-mountain regions of Gadabay, Shamkir, Khanlar, and Dashkasan districts.

Hayfields located at elevations of 2,000–2,300 meters, which are also used as pastures, occupy extensive areas of the Gadabay, Dashkasan, and Goygol districts, where the terrain is gently sloping and mountain-meadow soils resemble chernozems in the mid-mountain zone. The highly anthropogenically transformed high-mountain meadows are used not only as pastures and hayfields but also for rain-fed agriculture. For example, the badland areas near the summit of Mount Kapaz and the high-mountain meadows of the Khoshbulaq summer pastures in the Dashkasan district illustrate such land use [2].

The summer pastures of the sharply transformed high-mountain areas are mainly located within the territories of the Goshgar, Kapaz, Ayibazar, Garachadir, Pant, and Bughda mountain massifs. These landscape complexes, which include subalpine and alpine meadows with complex structures and diverse transformation characteristics, are subjected to the most severe changes. During the summer months, the maximum anthropogenic pressure occurs due to the extensive grazing of livestock in the highlands. Naturally, in the high-mountain areas, especially during the winter months, the cold climatic conditions practically prevent any anthropogenic impact.

The alpine meadows situated on the northwestern and eastern slopes of Mount Goshgar are particularly distinguished by their high intensity of economic use. Intensive grazing here accelerates erosion processes, leading to the exposure of slopes and the formation of numerous trails. The consequences of unregulated grazing are clearly observed in the small hayfields, leveled ridges, and summer pastures located in the southern and southwestern parts of Lake Zoghalli.

4.Conclusion

The subalpine and alpine meadow landscapes of the northeastern slope of the Lesser Caucasus were analyzed using cosmolandscape methods. According to the results, although the anthropogenic coefficient in high-mountain meadows does not exceed 0.4–0.5, intensive land use has caused significant degradation of landscape units and the formation of areas with high ecological stress. The anthropogenic load on the region's natural landscapes, as well as the evaluation of the productivity of pastures and hayfields, should be approached through project-based landscape management, taking into account landscape factors. In the required areas, it is advisable to establish cultural pasture landscapes by enriching the grass cover with seed mixtures, thereby organizing a planned forage supply system for livestock.

REFERENCES

1. Abbasova, S.M. (2022). Assessment of the ecological potential of natural landscapes on the northeastern slope of the Lesser Caucasus. In "Modern Problems of Geography: Integration of Science and Education", International Conference, November 29–30, pp. 165–169.

2. Abbasova, S.M. (2023). The impact of animal husbandry on the transformation of landscapes on the northeastern slope of the Lesser Caucasus. Geography and Natural Resources. Proceedings of the Azerbaijan Geographical Society, "Optimist" Publishing Center, No. 2 (20), pp. 56–61.

3. Abbasova, S.M. (2022). The Impact of the mining industry on the transformation of landscapes on the northeastern slope of the Lesser Caucasus. In "Dialogue of Culture and Sciences in the Modern World",

XXXIII International Scientific Symposium, Bishkek, Kyrgyzstan, pp. 272–276.

4. Budagov, B.A. (2007). Landscapes. Azerbaijan National Encyclopedia, pp. 24–28.

5. Budagov, B.A., & Garibov, Y.A. (2000). Main directions of anthropogenic transformation of natural landscapes. In "Constructive Geography of the Republic of Azerbaijan", Baku: Elm, pp. 159–165.

6. Ismayilov, M.J. (2001). Study of the influence of landscape functioning intensity on its productivity (on the example of the northeastern slope of the Lesser Caucasus). Proceedings of the Azerbaijan Geographical Society, Vol. VII, Modern ecological and geographical problems of mountainous regions, Baku, pp. 27–33.

7. Ismayilov, M.J. (2022). Anthropogenic transformation of landscapes in arid climate conditions and their risks. Journal of Geology, Geography and Geoecology, Dnipro, 31(4), pp. 653–658.

8. Ismayilov, M.J., & Zamanov, F.D. (2024). Determination of the dynamics and development trends of geosystems. Journal of Geology, Geography and Geoecology, Dnipro, Vol. 33(1), pp. 77–87.

9. Garibov, Y.A. (1990). Modern anthropogenic landscapes of the northeastern slope of the Lesser Caucasus. Geography Institute Fund, Baku, 342 p.

10. Garibov, Y.A. (2011). Anthropogenic transformation of modern landscapes of the Republic of Azerbaijan. Baku, 299 p.

11. Garibov, Y.A. (2013). Transformation of modern landscapes of the Republic of Azerbaijan and ways of their optimization. Baku, 250 p.

KİÇİK QAFQAZIN ŞİMAL-ŞƏRQ YAMACINDA YÜKSƏK DAĞLIĞIN SUBALP VƏ ALP ÇƏMƏN LANDŞAFTLARININ GEOEKOLOJİ POTENSİALININ QİYMƏTLƏNDİRİLMƏSİ

S.M.Abbasova

Xülasə. Məqalədə Kiçik Qafqazın şimal-şərq yamaclarının yüksək dağlığında formalaşan subalp və alp çəmən landşaftlarının kosmik şəkillərdən alınan informasiyalar əsasında təhlili nəticəsində onların morfogenetik xüsusiyyətləri, regional diferensiasiyası, antropogen yüklənməsi mütləq yüksəklikdən asılı olaraq dəyişilməsi təhlil olunur. Müəyyən edilmişdir ki, regionun yüksək dağ-meşələrinin 80%-dən çoxu 1800 metrə qədər, dağ-çəmənlərinin isə 90%-dən çoxu 2200 metrdən yüksəkdə yerləşir. Bu çəmənliklər, yüksək dağlıq ərazilərdə mövcud olan, çoxillik ot bitkilərindən ibarət yay otlaqları kimi istifadə olunan ekosistemlərdir. Dağ-çəmənlərinin böyük bir qismi təkrar törəmə mənşəli olaraq meşələrin qırıldığı orta dağlıq ərazilərdə və antropogen təsirlər nəticəsində dəyişilməsinə görə 4 qrupa ayrılması göstərilmişdir - praktiki olaraq dəyişilməyən; zəif dəyişilmiş; orta dərəcədə dəyişilmiş; əsaslı transformasiya olunmuş landşaft qrupları və bunların hər birinin landşaft-ekoloji xüsusiyyətləri, mənimsənilməsi, dəyişilməsi ayrı-ayrılıqda səciyyələndirilir. Təbii-coğrafi xüsusiyyətindən asılı olan otlaqlar heyvanların hədsiz otarılması nəticəsində ekoloji vəziyyətə daha çox məruz qalaraq az məhsuldarlığı, landşaftda böyük dəyişikliyin yaranmasına səbəb olması təhlil olunur.

Açar sözlər: Landşaft, alp və subalp, geoekoloji potensial, dağ-çəmən, otlaq sahələri, mikrolandşaft, otlaq bitkiləri