

MODELING THE DEGREE OF ANTHROPOGENIC IMPACT ON THE LANDSCAPES OF THE NORTHEASTERN SLOPE OF THE GREATER CAUCASUS

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Abstract

The anthropogenic transformation index (L_{ant}) of landscapes is used to assess the degree of human impact on natural landscapes. Through this index, the intensity, spatial distribution, and dynamics of anthropogenic loads are determined. The L_{ant} indicator is particularly useful for scientifically analyzing the impacts of urbanization, industrialization, agricultural activities, and transport infrastructures on landscapes, as well as for demonstrating these effects through visual models. This paper explores the determination and modeling of the degree of anthropogenic transformation of landscapes on the northeastern slope of the Greater Caucasus. GIS-based modeling not only reflects the spatial distribution of anthropogenic loads but also identifies the landscapes most and least affected, as well as high-risk zones. The research identifies landscape types impacted by anthropogenic influences based on Geographic Information Systems (GIS), satellite imagery, and field observations. These impacts are assessed using a scoring scale, and the results are presented in visual models. Maps illustrating the classification of natural landscapes based on anthropogenic loading and transformation levels have been created. The results are of significant importance for the formulation of sustainable natural resource management, landscape-ecological planning, and the optimization of anthropogenic loads in the region.

Keywords: anthropogenic transformation, northeastern slope of the Greater Caucasus, landscape, GIS, modeling

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Introduction:

As a result of increasing anthropogenic impacts, natural landscapes are losing their structural and functional characteristics. Anthropogenic factors such as urbanization, industrialization, agricultural activities, and the expansion of transportation infrastructure lead to the degradation or complete transformation of natural landscapes. In this context, the assessment and modeling of the degree of anthropogenic transformation of landscapes is of significant importance for environmental management and the development of sustainable development strategies. Modeling conducted through various Geographic Information Systems (GIS), remote sensing satellite technologies, and statistical methods enables the spatial and temporal analysis of landscape changes. The aim of the

research is to determine the degree of impact of various anthropogenic factors on landscapes and to model landscape-ecological situations for forecasting purposes.

The northeastern slope of the Greater Caucasus features a universal landscape belt formed by the interaction of various natural-geographical factors (ranging from the Caspian coastal semi-desert landscapes to the high mountain glacial-nival complexes). However, observed intense anthropogenic activity has accelerated the processes of loading and transformation in natural landscapes. Therefore, determining the degree of anthropogenic impact on landscapes and modeling these impacts is scientifically relevant.

The research is based on the assessment of the level of exposure to anthropogenic influences on various natural landscape types located on the northeastern slope of the Greater Caucasus. The methodological approach includes the following stages: data collection through Geographic Information Systems (GIS), remote sensing satellite (Landsat) data, digital elevation models (DEM), topographic maps, and field observations as the initial base data. The main types of human activity impacting the study area land use, infrastructure density, population settlement, industrial and agricultural activities were analyzed in terms of anthropogenic factors. The degree of anthropogenic impact for different landscape types was assessed using a specific scoring scale. All this data was integrated into Geographic Information Systems and presented as visual map models (GIS-based modeling).

Discussion and conclusions:

The issues of anthropogenic transformation of landscapes on the northeastern slope of the Greater Caucasus have been addressed in the studies of Y.A. Garibov [3], [4], L.H.Hasanaliyeva [1], I.I.Mardanov [6], N.S Ismayilova [2], [4], R.R. Sadullayev [7], [8], [9], [10] and others.

The anthropogenization index (L_{ant}) of landscapes is used to assess the degree of human impact on natural landscapes. The calculation of the anthropogenization index for the landscapes of the northeastern slope of the Greater Caucasus was performed based on the following sequence:

Categorization of the study area. The northeastern slope of the Greater Caucasus was divided into landscape types according to categories: natural landscapes (forest, mountain-meadow); semi-natural landscapes (croplands, pastures); and anthropogenic landscapes (urban complexes, industrial zones, road-transport infrastructure).

Determination of the area covered by each landscape type. The area (in hectares or km^2) covered by each landscape type was determined. For this purpose, GIS technologies, accurate satellite imagery, and/or topographic maps can be used.

Determination of index values. In this step, the index values are assigned according to the degree of human impact on the landscape type. For the region, the following values can be used as an example: forests – 0.1 (minimal impact); meadows – 0.1; croplands – 0.3; pastures – 0.3; urban-settlement complexes – 0.8 (high impact); road-transport infrastructure – 0.9; industrial zones – 1.0 (maximum impact).

The interpretation of the anthropogenization index (L_{ant}) is as follows: 0-0.2 refers to natural landscapes, i.e., minimal human impact; 0.2-0.5 refers to moderate anthropogenic impact; 0.5-0.8 refers to strong anthropogenization; 0.8-1.0 refers to significant anthropogenic impact, i.e., fully anthropogenized areas.

The calculation of the anthropogenization index (L_{ant}) for the northeastern slope of the Greater Caucasus was performed using this formula:

$$L_{ant} = \frac{\sum(S_i \times A_i)}{\sum S_i} \quad (1)$$

In this case, L_{ant} – the anthropogenization index; S_i – the area of each landscape type; A_i – the anthropogenization index of each landscape type.

If the anthropogenization index (L_{ant}) is close to 0, the landscape is considered to be in its natural state; if L_{ant} is close to 1, the area is considered to be fully anthropogenized.

Calculation of the degree of anthropogenization (1) based on the formula and analysis of the results. For example, if $L_{ant} = 0.25$, it indicates that the studied area is moderately anthropogenized. In other words, approximately 25% of the area has been significantly affected by human activity. In this case, 0.25 indicates a moderate impact, meaning that a significant portion of the landscape remains in a natural and semi-natural state.

To calculate the anthropogenization degree of the landscapes of the northeastern slope of the Greater Caucasus more accurately, several important conditions must be met: 1. Detailed landscape classification of the area; 2. Use of satellite imagery and maps with precise classification capabilities; 3. Consideration of the intensity of anthropogenic activity; and 4. Taking into account the specific characteristics of the region.

Calculation of the anthropogenization degree for the agricultural dominant areas of the northeastern slope of the Greater Caucasus: In such areas, agrolandscapes and semi-natural landscapes predominately prevail. The classification and the calculated areas of the landscape types are as follows: forests – 25 km² (0.1 index); meadows – 15 km² (0.1); croplands – 50 km² (0.3); pastures – 20 km² (0.3); small towns and villages – 10 km² (0.6); roads and agricultural infrastructure – 5 km² (0.7). Calculation:

$$S_{total} = 125 \text{ km}^2$$

$$\sum (S_i \times A_i) = 2,5 + 1,5 + 15 + 6 + 6 + 3,5 = 34,5$$

$$\text{Determination anthropogenization coefficient: } L_{ant} = \frac{34,5}{125} = 0,276$$

$L_{ant} = 0.276$ – This result indicates that the landscape has been subjected to moderate anthropogenic impact. The abundance of agricultural fields and pastures suggests that semi-natural landscapes dominate. The conclusion is that the area has been primarily influenced by agricultural activities, though natural and semi-natural landscapes still occupy a significant portion of the area.

For urban and industrial zone-dominant areas: urban, industrial, and transport infrastructure are predominant. The classification and the calculated areas of the landscape types are as follows: small parks and green spaces: 5 km² (0.2 coefficient); urban area: 40 km² (0.8); industrial zones: 25 km² (1.0); transport infrastructure: 30 km² (0.9). The calculated result: $L_{ant} = 0.85$ – indicating high anthropogenic impact, meaning the landscape cover has been largely altered by human activities. The conclusion here is that natural landscapes are minimal, and urban, industrial, and transport infrastructure dominate the area.

For the determination of the anthropogenic transformation degree of the northeastern slopes of the Greater Caucasus, the following methods were used for the creation of graphical representations and predictive models: **Analysis of changes over time:** The changes in the anthropogenic index over the years were analyzed; **Graphical representations:** Linear graphs and histograms were used to visualize dynamic changes; **Predictive models:** Time series analysis and regression models were used to predict how the anthropogenic index may change in the future.

Changes over time: The areas covered by landscape complexes and the anthropogenic indices for different years (2000, 2010, 2020, 2030) have been shown (Table 1).

Table 1. Changes in the area and index of landscape complexes by year

Years	Forest landscapes (km ²) 0,1 coefficient	Croplands (km ²) 0,3 coefficient	Urban-seliteb (km ²) 0,8 coefficient	Industry Zones (km ²) 1,0 coefficient	Total area (km ²)
2000	40	30	10	5	85
2010	35	35	15	10	95
2020	30	40	20	15	105
2030	25	45	25	20	115

The analysis of the line graph shows the dynamics of the increase in the anthropogenic index over the years: in 2000, the anthropogenic index was 0.307, but by 2030 it rises to approximately 0.476. The main reasons for this increase are the gradual reduction of forest complexes and the expansion of agricultural landscapes, urban settlements, and industrial zones. (Figure 1)

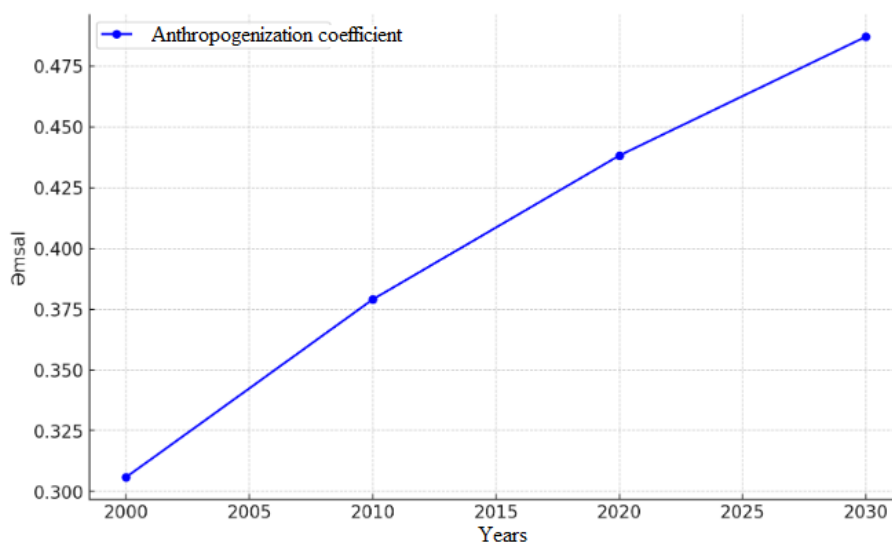


Figure 1. The graph of the change of the anthropogenization coefficient over the years

The analysis of the histogram visually shows the distribution of landscape types over the years; specifically, the area of forest landscapes in the region gradually decreases, while the area of agricultural landscapes and urban settlements continuously increases. (Figure 2)

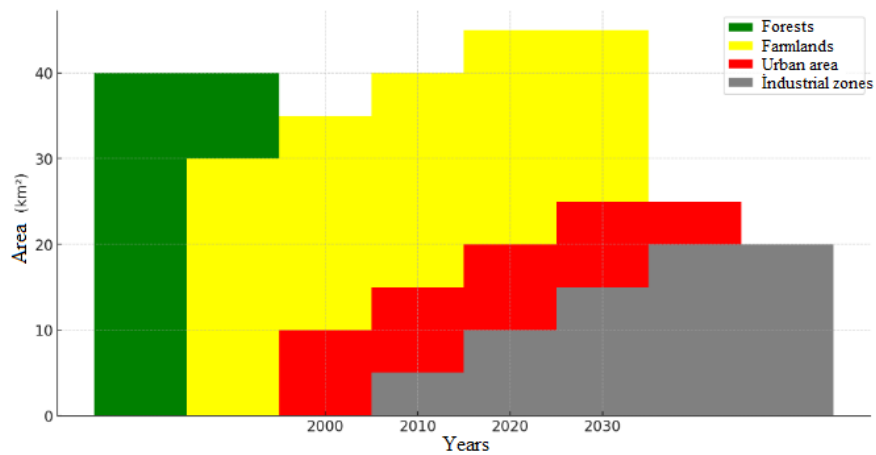


Figure 2. Histogram of distribution of landscape types by year

Forecast models for the northeastern slope of the Greater Caucasus: To predict how the anthropogenization index will change in the future, time series analysis and simple linear regression are useful. Based on current trends, linear regression predicts the values that the anthropogenization index will reach in 2040 and 2050. The forecast graph is important in terms of displaying both current data and future projections. (Figure 3)

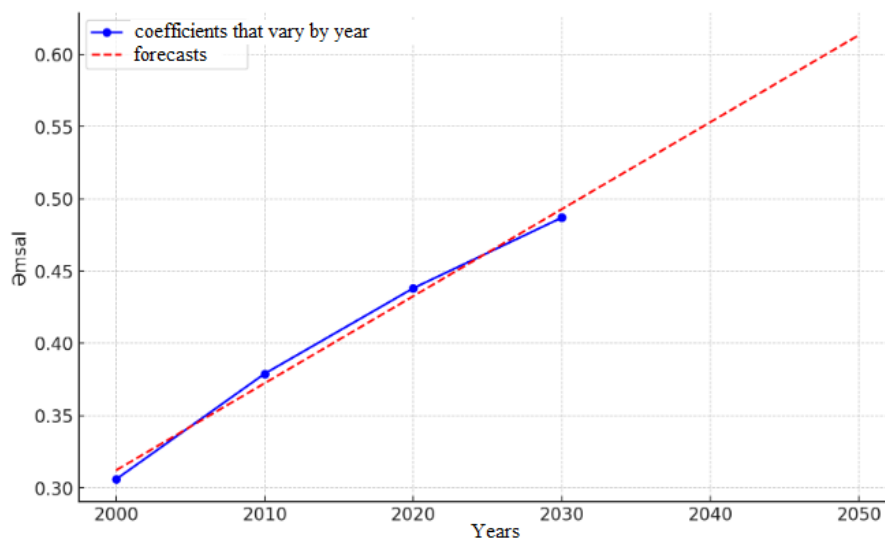


Figure 3. Forecast model of the anthropogenization index.

Based on the results of the developed forecast model, it can be stated that the anthropogenization index for the northeast slope of the Greater Caucasus will be approximately 0.554 in 2040, and this value will rise to 0.615 by 2050. Additionally, the upward trend in the anthropogenization index continues, which is associated with urbanization, industrialization, and the

expansion of agriculture. Such a continuous increase in the anthropogenization index indicates a reduction in the area of natural landscapes and a greater transformation due to human activity. The fastest growth is expected in agricultural cultivation, urban-settlement complexes, and industrial zones. The decrease in forest landscapes may have a negative impact on the stability and biodiversity of related ecosystems.

The research results revealed that the degree of anthropogenization of landscapes located on the northeast slope of the Greater Caucasus varies spatially. The main observations are as follows: In the low mountain and plain areas, the anthropogenic impact is higher. These areas are characterized by widespread agro-landscapes, urban complexes, and settlements [9] (p.56). In the mid-mountain zone, the anthropogenic impact is evaluated as moderate – mainly, grazing areas and some forest landscapes have been affected. In the high mountain and forest zones, the anthropogenic impact is weak, and the landscapes have largely maintained their natural state. Based on this data, zoning according to the level of anthropogenic transformation of landscapes has been carried out. Maps created using GIS clearly reflect the spatial distribution of anthropogenic loading and impact, and allow for the identification of high-risk loading zones. (Figure 4)

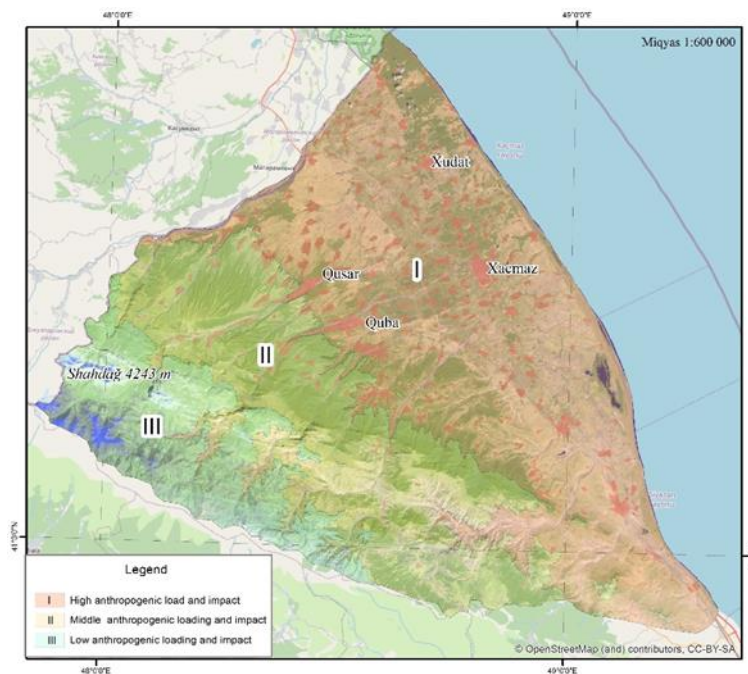


Figure 4. Zoning map based on anthropogenic loading and impact degree

The map of the classification of natural landscapes based on the degree of anthropogenic transformation reflects the classification and spatial distribution of various landscape types, based on the intensity of changes in landscapes caused by human activity. This thematic model map is created considering anthropogenic loads urbanization, industrial activities, agriculture, infrastructure, etc. and is based on GIS and Landsat satellite images. (Figure 5)

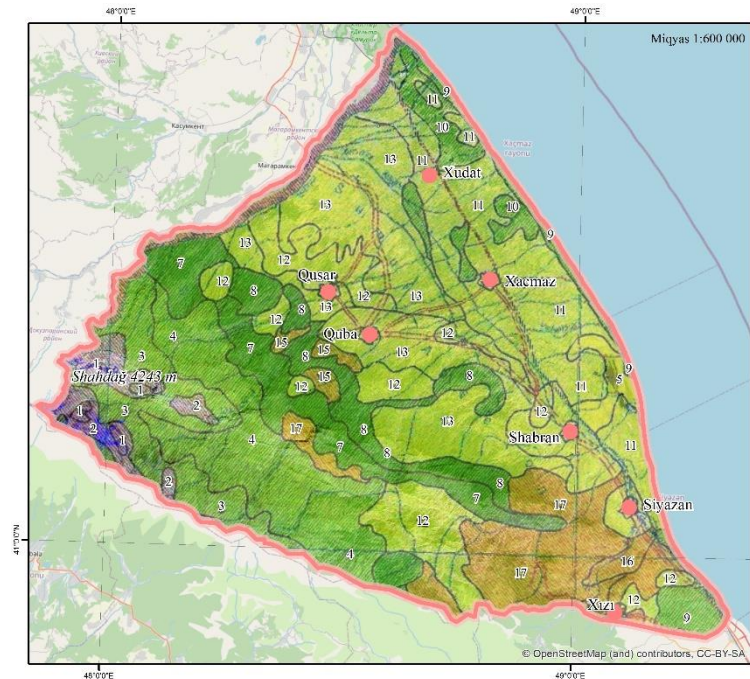


Figure 5. Map of the classification of natural landscapes based on the degree of anthropogenic transformation

Map legend

I. Complexes that preserve natural development characteristics and are practically unchanged: 1. Sharply dissected nival-glacial complexes on high mountain peaks; 2. Sharply dissected subnival complexes on ridges, rocky outcrops, and water divides in high mountain areas.

II. Slightly altered and irregularly impacted by agricultural activities, such as pastures and meadows: 3. Alpine meadows used as pastures in sharply dissected high mountain peat and grassland soils; 4. Subalpine and alpine meadows used as pastures and meadows in sharply dissected high mountain peat and grassland soils.

III. Slightly altered, irregularly impacted winter pastures: 5. Winter pastures in saline, slightly saline semi-deserts with gray-grass and grass-gray soils on rolling hills and hummocky terrains; 6. Winter pastures in sharply dissected low mountain areas with shrub, ephemeral, and frigid semi-desert gray-brown, light gray-brown saline soils.

IV. Slightly altered, episodically impacted mountain-forest complexes: 7. Pine and alder forests in fragmented middle and low mountain brown mountain-forest soils; 8. Oak and alder forests with shrubs in fragmented low mountain and foothill depressions with brown mountain-forest soils.

V. Moderately altered, irregular and partially regular agricultural impacts: 9. Arid sparse forest-shrub, mountain-steppe, and coastal sandy areas with small-scale agricultural plots accompanying pastures and meadows; 10. Oak and alder forest-shrub complexes with small-scale meadow-pasture areas accompanying flatlands.

VI. Severely altered, regularly impacted agricultural complexes: 11. Agro-irrigated landscapes in the plains, semi-desert, dry-steppe, and intrazonal complexes with gray-grass, light gray-brown forest-steppe soils; 12. Agro-irrigated and dryland crops in low mountain and foothill plains, intermountain depressions with semi-desert, dry steppe, forest-steppe, forest-shrub, etc. complexes with brown-gray, grass-gray, light brown-gray, brown-forest, forest-steppe soils; 13. Vineyards, orchard plantations, small-scale urbanized and urban-orchard landscapes in low mountain, intermountain depressions, and foothill plains with semi-desert, dry-steppe, intrazonal, forest-steppe, and forest-shrub complexes with grass-gray, light brown-gray, brown forest, forest-steppe soils.

VII. Severely altered, irregularly impacted agricultural complexes: 15. Recreational forests in sloped and flat plains; 16. Shrub and grass-shrublands accompanied by small agricultural and meadow areas replacing forests; 17. Meadows and pastures on low mountain and foothill plains with post-forest mountain-brown soils.

References:

[1] Hasanaliyeva L.H. The impact of population settlement on the northeastern slope of the Greater Caucasus on landscape transformation:/Abstract of the dissertation of the doctor of philosophy in geography./ – Baku, 2015. – 28 p.

[2] Ismayilova N.S. Modern agroirrigation landscapes of the Samur-Devachi lowland and the Gusar sloping plain./ – Baku: Redline, 2015. – 192 p.

[3] Garibov Y.A., Ismayilova N.S., Hajiyeva A.Z., Sadullayev R.R. Creation of digital mathematical cartographic models of anthropogenic transformation of natural landscapes of the Greater Caucasus// Digital Economy: Modern Challenges and Real Opportunities, Materials of the II International Conference. – Baku: 2022, p. 481-484

[4] Garibov Y.A., Ismayilova N.S., Hajiyeva, A.Z., Sadullayev, R.R. Study of anthropogenic transformation of natural landscapes of the Greater Caucasus using GIS technology./ – Baku: Muallim, 2020. – 190 p.

[5] Sadullayev R.R. Application of Geographic Information Systems (GIS) and study of the differentiation characteristics of seliteb complexes based on space images (on the example of the northeastern slope of the Greater Caucasus)//Materials of the II International Conference on Science and Technology, – Baku: 2021, p.151–154.

[6] Mardanov I.I., Garibov Ya.A., Akhmedova G.B., Alieva R.A., Sadullaev R.R. Analysis of exodynamic processes of high-mountain landscapes of the Greater Caucasus within Azerbaijan // XX scientific and practical conference of young scientists, graduate students and students: materials of the scientific conference –Saransk: 2016, pp. 179-183.

[7] Sadullayev R.R. Research of the differentiation characteristics of seliteb complexes and their impact on the transformation of natural landscapes of the northeastern slope of the Greater Caucasus based on GIS// –Taras Shevchenko National University of Kyiv: Physical Geography and Geomorphology, –2025. Volume 48 Issue 1 p.16–25

[8] Sadullayev R.R. Differentiation characteristics of the modern anthropogenic landscapes of the North-East slope of the Great Caucasus// –Taras Shevchenko National University of Kyiv: Physical Geography and Geomorphology, –2024. Volume 47 Issue 1 p.53–57

[9] Sadullayev R.R., Mammadova Sh. I., Humbatova Sh. Y., Ahlimanov R.M. Research of modern structural–functional characteristics and differentiation regulations of anthropogenic landscapes// – Hyderabad c. Acta Scientific Agriculture. –2024. Volume 8 Issue 2, s.60–65.

[10] Sadullayev R.R., Ahmadova G.B, Abasova N.A, Aktoprak İ.F. Anthropogenic transformations in natural landscapes of the Great Caucasus// –Hyderabad c. Acta Scientific Agriculture. –2024. Volume 8 Issue 6, p.02–07.