Determination of the dynamics and development trends of geosystems

Mirmuhan J. Ismayilov, Fuad Z. Zamanov

Institute of Geography named after acad. H.A. Aliyev, Ministry of Science and Education Republic of Azerbaijan, Baku, Azerbaijan, mirnuh.ismayilov@yahoo.com

Abstract. In the research, the optimization of natural and anthropogenic landscapes on the northeastern slopes of the Lesser Caucasus is investigated in order to achieve sustainable development. The research is oriented towards three main directions of landscape planning: ecological balance, continuous management of natural processes, and preservation of natural components through protected areas. The NDVI (Normalized Difference Vegetation Index) was used to study the dynamics of changes in natural landscape characteristics. The comparative analysis of Landsat 5 and Landsat 8 images demonstrates a strong correlation between landscape changes and the structural and functional characteristics of the region’s agrolandscapes. Although the terrain and favorable climate of the area create suitable conditions for the development of agriculture, significant transformations in NDVI occur due to seasonal changes. Human activities, especially agriculture, have an impact on the increase in the area of non-vegetated lands. Seasonal comparisons highlight the necessity of considering ecological aspects in planning land use on the northeastern slopes of the Lesser Caucasus to ensure sustainable landscape management and environmental conservation. In the researched area, there are existing problems such as desertification, soil degradation, and deforestation. Natural and ecological conditions are assessed by considering the differentiation of the relief, anthropogenic activities, and compliance with ecological principles. Based on this evaluation, modern landscapes are classified into groups according to their ecological stress levels. Protected areas, including Goygol National Park, play a crucial role in preserving the ecological integrity and biodiversity. Research in the direction of landscape optimization and planning aims to enhance natural biodiversity and the ecological potential of the region. The research emphasizes the necessity of eliminating intensive anthropogenic impacts in various areas that negatively affect natural landscapes. Landscape optimization and planning are highly important to ensure ecological balance and sustainable development. During the research, the analysis of theoretical issues related to geographic forecasting, proposed with the purpose of effective implementation of landscape planning, has shown that the principles and methods of forecasting in the research area should be based on the structural-dynamic characteristics of natural and anthropogenic landscapes. Implementing landscape planning measures emphasizes the understanding of landscape changes and contributes to environmental conservation and the importance of sustainable development.

Keywords: Lesser Caucasus, sustainable development, dynamics of geosystems, anthropogenic activities, ecological balance.
Introduction

In modern times, the conservation and improvement of the natural resource potential of landscapes mainly depend on human agricultural activities. The preservation and optimization of the natural and ecological potential of landscapes in the context of intensive development and rapidly increasing production is well-documented in the existing scientific literature, drawing upon modern achievements in science and experience. In the field of optimization of natural and anthropogenic landscapes, a series of successful research studies has been conducted (Epps et al. 2007; Doody et al. 2016; Ismayilov, 2022). However, it can be said that there is a lack of unified and specific scientific-methodological principles in the scientific research carried out in this area. Currently, the intensive development of productive forces and the widespread expansion of human activities also demand efficient utilization of soil, water, biological, and mineral resources in the northeastern region of the Lesser Caucasus, taking into account the specific landscape-ecological conditions. Additionally, it requires the implementation of environmental protection measures and framework landscape planning for the area.

R.M. Mammadov (Mammadov, 2016) outlines three main directions of framework landscape planning: the first is to achieve ecological balance between the natural environment and its use, the second involves ecoameliorative measures for the sustainable management of natural processes in the landscape, and the third is the establishment of conservation of natural landscapes. The mentioned measures, which reflect the framework landscape planning in a general sense, lead to significant changes in landscape typological units in the specific area. Indeed, it is crucial to consider the natural-territorial differentiation of the landscape, as well as the type, character, and regularity of anthropogenic activities while implementing framework landscape planning. Studying and applying the research and practical methods of natural landscape optimization and planning enhances its ecological integrity and resilience potential while enabling sustainable utilization of natural resources. The complexity of the relief and climate conditions, diversity in soil-vegetation cover, variability in the lithological composition of rocks, and distinct elevation variations in landscape formations require different geographical technologies for the optimization of natural, natural-anthropogenic, and anthropogenic landscapes in the studied area.

For the purposes of framework landscape planning in the northeastern slopes of the Lesser Caucasus, we have identified three main directions:

I. Assessment of ecological balance and the implementation of ecological management.

II. Optimization of anthropogenic impact on natural ecosystems.

III. Effective conservation of natural components or complexes at regional and local levels.

The implementation of these measures will help optimize the future development trends of geosystems, enhance biodiversity, and ensure the sustainable management of the region’s natural resource potential.

Study area

The studied area encompasses the modern landscapes of the northeastern slopes of the Lesser Caucasus mountains within the territory of Azerbaijan (see Fig.1). The total area of the territory is 8174.5 km². The central coordinates are 46°22’32.7”N, 40°40’41.5”E. The elevation difference in the research area ranges from 350 to 3724 meters above sea level. The region is characterized by high mountain peaks, including Gamishdag (3724 m), Hinaldag (3367 m), Goshgar (3361 m), Kapaz (3066 m), and others. The main cities within the research area include Gandja, Shamkir, Tovuz, Gazakh, Gadabay, Dashkasan, Goygol, and Samukh.
Methodology of the Research

Landsat 5 and Landsat 8 images were obtained for the area on three dates: 02.09.1995, 20.07.2020, and 24.10.2020, to examine development dynamics over the years and seasons (USGS). The acquired satellite images were subjected to radiometric calibration and atmospheric correction to remove noise and atmospheric interference, ensuring the accuracy of the subsequent analyses. NDVI was then calculated using the widely used formula: \( \text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})} \), where NIR represents the Near-Infrared reflectance values and Red represents the Red band reflectance values from the Landsat images (Carlson, 1997). The time series of NDVI values were analyzed using ArcGIS to study the development dynamics of the study area across the three dates. Seasonal variations in NDVI were also explored to understand vegetation changes. To identify significant vegetation changes over time, statistical methods were applied to the NDVI data using ArcGIS (Jingyong, et al. 2003).

The identification of natural landscapes in the researched area was conducted using the Landscape Map of Azerbaijan (scale 1:600,000) (Landscape map, 2017). As a result, 11 types of landscapes were identified in the study area (Fig. 2). The ecological stress level of natural landscapes was determined by considering the degree of relief fragmentation, slope inclination and direction, as well as the character and intensity of anthropogenic impacts, while evaluating the natural-ecological conditions.

Fig. 1. Study area

Fig. 2. Landscape map of the study area

Legend.
Landscape types:
1. Subnival-rocky landscapes
2. Alpine meadows
3. Subalpine meadows
4. Beech-Hornbeam and Oak-Hornbeam forests of the mid-mountain and partially high-mountain areas
5. Low and mid-mountain forest and forest-steppe landscapes
6. Arid low mountain dry steppe and steppe landscapes
7. Low Mountain xerophyte shrubs and dry steppes
8. Arid-denudation semi-desert landscapes of accumulative plains
9. Post-forest steppe landscapes of denudation-accumulative plains
10. Forest-meadow and shrub landscapes
11. Semi-desert landscapes of accumulative alluvial-proluvial and coastal plains
Analysis and Discussion

In order to track the changes in the structural-functional characteristics of natural landscapes on the northeastern slopes of the Lesser Caucasus and assess their impact on the ecological conditions, NDVI indices from different periods have been compared in terms of their dynamic aspects.

The vegetation cover (NDVI) index has been comparatively analyzed over time to study the dynamics of processes and changes in the functional structure of geosystems within landscapes, considering variations and trends occurring across different seasons and periods (Pettorelli et al., 2005). In order to analyze the changes in the dynamics of the differentiation of the vegetation index over the last 25 years, digital maps (Figure 3) and the corresponding table were compiled (Table 1). The analysis of the relationship between NDVI values and landscape characteristics reveals that: NDVI values in the range of 0 to 0.2 correspond to semi-desert and steppe landscapes, 0.2 to 0.4 are associated with low mountain shrubs and steppe landscapes, 0.4 to 0.6 are indicative of forested areas and forest-steppe landscapes, also alpine meadows, 0.6 to 0.8 are suitable for forest ecosystems. The analysis of the table and maps reveals that the dynamic changes in vegetation cover are closely related to the structural-functional characteristics of the agrolandscapes in the researched area during the study period. The relief zone suitable for cultivation lies between elevations of 1800 to 2000 meters on the northern-eastern slopes of the Lesser Caucasus, permitting the development of agriculture, particularly dryland cultivation. Additionally, the region’s climate and moisture conditions are favorable for the advancement of agricultural activities. The main climatic type in the region is a mild and warm climate with dry winters. Approximately 55-60% of the atmospheric precipitation in the area coincides with the vegetation period of cultivated plants in agrolandscapes. This leads to sharp differences in the NDVI index over the seasons and complicates the research into the changes in the natural geosystems that occur during this period. Especially during the plowing period, the areas without plants or barren areas tend to expand. It should be noted that the significant decrease in the area of barren landscapes with NDVI index values below 0.1, from 957.4 km² in 1995 to 17 km² in 2020, is directly attributed to human agricultural activities. In the researched area, during the months of September and October, harvest activities are carried out in several agrolandscapes (such as cotton, potatoes, etc.), and extensive plowing occurs. This leads to an increase in barren areas. On the contrary, during the active vegetation period of plants in the months of June and July, the barren areas sharply decrease in the researched mountainous area. Relatively unchanged barren areas are mainly located in the districts of Gadabay and Dashkasan, primarily occupied by the mountain-mining industry, road infrastructure, and various constructions. In the studied area, landscape areas with NDVI index values of 0.1-0.2, 0.2-0.3, 0.3-0.4, and 0.4-0.5 increased from 1267.5 km² to 2533.3 km²; from 1261 km² to 1640.2 km²; from 1087.7 km² to 1654 km²; and from 902.1 km² to 1488.6 km², respectively, during the compared periods. However, the area of landscapes with NDVI index values greater than 0.5 has sharply decreased, from 740 km² to 269 km². It becomes evident from the comparison that the increase is closely related to the dynamic changes in the structural-functional characteristics of agrolandscapes. To confirm these findings, the NDVI indices of the summer and autumn seasons in 2020 were compared (Figure 2 and Table 1). It has been revealed that the degree of vegetation cover demonstrates seasonality clearly. The changes observed in the indices reflecting the degree of forest cover can be attributed to selective logging activities carried out in forest ecosystems and the shedding of leaves and branches of trees during the autumn season. We can see what has been said more clearly when we analyze the changes in the NDVI index according to the altitude landscape zones of the area. This approach allows us to observe how different factors, such as elevation and topography, influence the vegetation dynamics and landscape patterns in the area. The studied area is divided into four main altitude landscape zones: 1. Xerophytic shrubland and steppe (400-1600 m); 2. Mountain forests (700-2100 m); 3. Alpine and subnival meadows of high mountains (1800-3300 m); 4. Rocky-subnival zone of high mountains (above 3200 m).

The analysis of NDVI changes according to the altitude landscape zones reveals that 70-80% of the seasonal variations occur in the xerophytic steppe of low mountains and the steppe landscape zones’ post forested areas of the mid-mountains. This indicates a strong correlation between the development of agricultural landscapes and the mentioned altitude zones.

One of the main factors causing ecological tensions in the dynamics of geosystems on the northeastern slopes of the Lesser Caucasus is the degradation of soils, reduction of biodiversity, steppe formation, and desertification resulting from human agricultural activities. One of the most pressing current issues is related to global climate change and the hazardous impacts it creates on ecosystems. According to scien-
tists’ calculations, the average annual temperature of the Earth is expected to increase by more than 1.5°C in the 21st century (Masson-Delmotte et al., 2022). As a result, this process may intensify the differentiation of precipitation over the terrain, lead to desertification, increased soil erosion, and degradation of natural landscapes, among other undesirable consequences. More than 40% of the Earth’s surface is already

**Fig. 3.** Development dynamics of the vegetation index (NDVI) in the northern-eastern slopes of the Lesser Caucasus over the years and seasons.

**Table 1.** The temporal and spatial dynamics of the distribution of vegetation index indicators in the researched area

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km²</td>
<td>%</td>
<td>km²</td>
<td>%</td>
<td>km²</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>&lt; 0</td>
<td>957.4</td>
<td>11.7</td>
<td>17</td>
<td>0.2</td>
<td>72.1</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>0 – 0.1</td>
<td>1958.6</td>
<td>24</td>
<td>571.6</td>
<td>7</td>
<td>2244.2</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>0.1 – 0.2</td>
<td>1267.5</td>
<td>15.5</td>
<td>2533.3</td>
<td>31</td>
<td>3619</td>
<td>44.3</td>
<td></td>
</tr>
<tr>
<td>0.2 – 0.3</td>
<td>1261.2</td>
<td>15.5</td>
<td>1640.2</td>
<td>20.1</td>
<td>1870.3</td>
<td>22.9</td>
<td></td>
</tr>
<tr>
<td>0.3 – 0.4</td>
<td>1087.7</td>
<td>13.3</td>
<td>1654.8</td>
<td>20.2</td>
<td>322.2</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>0.4 – 0.5</td>
<td>902.1</td>
<td>11</td>
<td>1488.6</td>
<td>18.2</td>
<td>45.2</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>0.5 – 0.6</td>
<td>572.9</td>
<td>7</td>
<td>266.5</td>
<td>3.3</td>
<td>1.5</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>0.6 &lt;</td>
<td>167.1</td>
<td>2</td>
<td>2.5</td>
<td>0.03</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8174.5</td>
<td>100</td>
<td>8174.5</td>
<td>100</td>
<td>8174.5</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
affected by desertification, and the process continues in 30% of the areas. In the territory of Azerbaijan, desertification is a significant issue, impacting more than 60% of the land, and over 65% of the population living here is facing the consequences of desertification (Mamedov et al., 2016). According to the calculations by M.J. Ismayilov (Ismayilov, 2019), currently, more than 42.5% of the territory of Azerbaijan should be covered by various modifications of mountain and lowland forest landscapes under natural-climatic humidity conditions. However, forests only cover 11% of the country's territory.

The massive deforestation on mountain slopes and foothills has led to significant degradation of the soil cover in the northern-eastern slopes of the Lesser Caucasus. The soil has been severely disrupted, fragmented by erosion, and major gullies have formed on the surface. Modern mountain steppe landscapes, affected by anthropogenic influences, cover an area of 6.5-7% and have been stripped of vegetation, losing their natural potential. If the current intensity and uncontrolled nature of anthropogenic influences persist, it is expected that the area of these landscapes will increase two to three times in the near future. In order to assess the natural-ecological conditions in the studied area, we took into account the degree of relief fragmentation, the slope and direction of slopes, the character and intensity of anthropogenic influences (Abushova, 2014).

According to the mentioned factors, natural landscapes have been classified based on their ecological stress level as follows (Fig. 4):

1. Geosystems with preserved structure-functional characteristics.
2. Geosystems with partially disturbed structure-functional characteristics.
3. Geosystems with moderately disturbed structure-functional characteristics.
4. Geosystems with primarily disturbed structure-functional characteristics.
5. Geosystems with severely disturbed structure-functional characteristics.

- Geosystems with preserved structure-functional characteristics are more commonly found in sparsely populated, temporary, or episodically affected areas, such as alpine and subalpine meadows, subnival and nival landscapes, nature reserves and complex terrain areas with mountain forests and mountain grasslands. 38.1% (5633.8 km²) of the territory in the northern-eastern part of the Lesser Caucasus is estimated to be covered by these types of landscape. As the elevation increases in the mountains, the area of landscapes that maintain their natural ecological condition also increases. However, in the mentioned direction, the ecological diversity of natural landscapes sharply decreases. This is due to the increased fragmentation of the relief and the increasing severity of the climate. The mentioned landscape type is commonly found within the territory of the Goygol National Park, in the northeastern and northern slopes of the Shahdag and Murovdag ranges near the watersheds, as well as in the upper parts of the Zeyemchay, Shamkirchay, Goranchay, and Kurakchay river basins. It is also observed on the steep fragmented slopes of the Gaflangala and Chingildagh ranges, which encompass the Baskend-Dastefur depression from the north. Especially in the territory of Goygol National Park, after implementing a strict conservation regime in mountain forests, alpine meadows, and mountain steppes, this landscape type has managed to preserve its own ecological diversity and natural landscape structure. During the landscape ecological optimization measures to be implemented in the northern-eastern slope of the Lesser Caucasus, the areas around Goygol and Maralgol lakes can serve as natural “standards” for various levels of natural complexes, preserving the natural structure of the landscape units. The forest and mountain meadow landscape types in this area have been compared with different landscape units observed in other areas with similar natural climate conditions, and the degree of degradation of the structure of these natural complexes has been determined. It is essential to preserve the identified natural standard areas as the basis for future national parks to be established in the region.

2. The second group of landscape is composed of geosystems with partially disturbed structure-functional characteristics. These landscapes mainly include pastures, grasslands, and similar areas of the mountain-meadow complexes. The total area of natural-anthropogenic landscapes in the studied area is calculated to be 409,935 hectares. The distribution of this area across administrative districts is as follows: Dashkasan 44,952 hectares, Goranboy 78,377 hectares, Gadabay 32,320 hectares, Tovuz 66,706 hectares, Gazakh 20,536 hectares, Agstafa 14,447 hectares, Goygol 47,545 hectares, and Shamkir 90,025 hectares. The total loading coefficient of the studied area with partially changed natural-anthropogenic landscapes is equal to 0.4.

As mentioned in the previous section, the rich landscape reserves of the Lesser Caucasus have been instrumental in the development of pasture-grassland complexes here since ancient times. Unlike other anthropogenic landscapes, the pasture-grassland complexes in the studied area have preserved their natural
ecological structure from ancient times to the present day. The development of animal husbandry in the area was not only influenced by the changes in the natural landscapes of mountainous and lowland grasslands but also by the changes in forest, forest-steppe, and other landscapes. As the number of livestock, i.e., the intensity of grazing, increased, local landscape disturbance was replaced by large-scale changes in individual areas. This is most evident in the sharp changes in the upper and lower boundaries of the forest due to grazing.

In modern pasture-grazing complexes in the area, proper attention should be given to the grazing norm, and, sometimes, rotational grazing. At the same time, changes in the composition of vegetation due to grazing on pastures should be prevented. In order to maintain the productivity and ecological balance of pastures in the area, it is important to create cultivated pastures and meadows on a large area in semi-deserts and dry steppes.

3. The third group of landscapes belongs to the mountain-meadow, post-forest, meadow-steppe and forest-steppe geosystems with moderately disturbed structural-functional characteristics. This covers 27.5% of the total area (4072.9 km²). This type of landscape includes partially irrigated and mainly rain-fed field complexes, pastures, as well as gardens and residential areas. In the mentioned geosystem, the soil-vegetation cover has undergone drastic changes, the ecology of animals has been disrupted, and ultimately, biodiversity has almost disappeared. The overall development of landscapes in large areas has accelerated. To enhance ecological sustainability in such landscapes, it is necessary to preserve and enhance ecotones (areas between different habitats such as forest edges, meadows, water channels, unused areas, water reservoirs, ponds, natural forest remnants, etc.), apply crop rotation, adhere to agricultural techniques, and increase the amount of unused areas between cultivated fields.

4. The fourth group includes geosystems with primarily disturbed structural-functional characteristics, such as settlements, partially urban areas, road-communication networks, and artificial water bodies (reservoirs, ponds, etc.) where xerophytic shrublands, dry steppes, arid-denudation semideserts, etc. are widely spread. The main characteristic of such landscapes is the significant impact of technogenic cover, leading to substantial changes in the natural ecological structure and complete destruction

Fig. 4. Grouping of geosystems based on their ecological stress levels in the study area
of biodiversity. In the studied area, this group of anthropogenic landscapes covers 6.5% of the territory. Currently, in the northeastern part of the Lesser Caucasus, seliteb (residential) complexes cover an area of 12.6 thousand hectares (1.0% of the total area), areas under reservoirs and canals cover 56.1 thousand hectares (1.5%), and areas under roads and various constructions cover 7.5 thousand hectares (0.8%).

The geosystems with mainly degraded structural and functional characteristics are distributed in the area according to vertical zonation. Their distribution is more extensive in the foothills, sloping plains, wide river valleys, and intermountain depressions, while their area decreases significantly in high mountains and steep slopes.

It should be noted that recently the area covered by road infrastructure and residential complexes has been rapidly increasing. Considering this, a system of measures should be implemented and prepared to enhance landscape-ecological diversity in these complexes.

5. Geosystems with severely disturbed structural-functional characteristics (22.7% of the total area). This group includes anthropogenic landscapes such as areas affected by mountain-mining industries, areas disturbed by industrial and domestic waste, eroded rocks, areas degraded by ravines, areas polluted by industrial enterprises, and so on. In these areas, the main landscapes are post-forest steppes, shrubs, and semi-deserts. Taking into account the significant recreational and tourism potential of the studied area, it is essential to carry out substantial reclamation measures in this group of anthropogenic landscapes and implement environmentally friendly industrial technologies.

The analysis of the natural and anthropogenic influences on the modern landscapes of the northeastern slopes of the Lesser Caucasus shows that in recent times, the process of landscape xerophytization is continuing in all altitude zones of the area. As a result, the majority of the studied area’s semi-deserts, steppe, mountain-steppe, forest, forest-steppe, subalpine, and alpine meadow complexes have undergone significant changes due to anthropogenic influences.

The research shows that the main direction of recent changes in the modern landscapes of the northeastern slope of the Lesser Caucasus is the intensive development of various industries and activities, especially characteristic to the region, such as mountain mining industry, agriculture, tourism, and so on. Intensive anthropogenisation of natural landscapes gradually leads to the increase of cultivated areas, the construction of roads, hydrotechnical and industrial facilities, the construction of new settlements. As a result of this, forest and forest-shrub areas have decreased, degradation areas in pastures have expanded, and the washing process of slopes has increased.

The nature of quantitative and qualitative changes in natural complexes must be determined in advance during their use from nature. The lack of sufficient research on the development, dynamics, and tendencies of natural complexes, as well as their resilience to anthropogenic impacts, leads to the disruption of geosystem’s landscape-ecological balance and normal functioning. Exactly for this reason, it is necessary to forecast a set of parameters of various landscape complexes in the studied area to determine the trends in the development of landscapes.

The prediction of the development trends of modern landscapes is one of the challenging and unresolved issues in the field of geography. Various research studies have been conducted to address the issues of landscape and land use development forecasting (Tilman, 2001; Nemani, 2009).

Geographical forecasting plays a pivotal role in understanding and predicting the dynamics and development trends of geosystems. Complex interactions between various components of the environment are dynamic and subject to constant change, driven by natural processes and human activities. To gain insights into the future of geosystems, it is essential to employ forecasting methods that take into account a range of geospatial, environmental, and socio-economic factors (Januschowski, 2020).

One of the primary objectives of geographical forecasting in the context of geosystem dynamics is to anticipate how these systems will evolve over time (Rudko, 2021). This can be achieved through a multi-disciplinary approach, combining geospatial data, environmental modeling, and statistical analysis. Various tools and techniques are employed in this process, including Geographic Information Systems (GIS), remote sensing, climate modeling, and data analytics. These tools provide researchers with the means to monitor and analyze the current state of geosystems, as well as to extrapolate trends into the future.

For example, in studying the dynamics of geosystems such as watersheds, geographical forecasting can help predict changes in hydrological patterns, such as rainfall, river discharge, and groundwater levels (McCull, 2007). This information is invaluable for managing water resources and mitigating the impact of droughts or floods. Additionally, geographical forecasting can aid in assessing the effects of climate change on geosystems by projecting future temperature and precipitation trends, which are crucial for informed decision-making in various sectors (Yer-
Furthermore, geographical forecasting can be applied to monitor land-use changes and their consequences (Márquez, 2019). Urbanization, agriculture expansion, and deforestation are key factors influencing geosystem dynamics. By forecasting land-use changes, we can assess their potential impact on ecosystems, biodiversity, and natural resources, enabling policymakers to implement sustainable land management practices.

Regarding the nature of geographical forecasting, conclusions can be drawn from the research of the aforementioned and other scientists which shows that geographical forecasting involves pre-determining both the natural development trends of the area and the changes that anthropogenic factors can bring.

The analysis of theoretical issues related to geographical forecasting shows that during forecasting, the main focus is on the evolution and dynamic trends of natural complexes. However, forecasting changes that may occur in a geosystem during purposeful use of natural landscape complexes holds particular significance. From this perspective, predicting the changes that may occur in the course of recreational activities in the northern-eastern slopes of the Lesser Caucasus, gains special importance. The principles and methods of landscape-geographical forecasting are based on the structural-dynamic characteristics of geographical events. In this context, the structural-dynamic characteristics of the landscape provide the possibility to determine the forecast of future changes that may occur.

According to A.G.Isachenko (Isachenko, 1980), geographical forecasting is divided into 5 types based on the time frame: very short-term (up to 1 year); short-term (3-5 years); medium-term (10-15 years); long-term (several decades); very long-term (thousands of years or more). It should be noted that the categorization of forecasting into different types based on the time frame is determined by the specific characteristics of landscape usage.

In our opinion, the most suitable types of forecasts for predicting landscapes over a certain period of time are the medium and long-term forecasts. During these periods, the effects of natural, socio-economic, and technological factors on landscape changes become more evident and noticeable.

The forecasting of landscapes on the north-eastern slope of the Lesser Caucasus for recreational purposes takes into account not only the ancient historical development of the area but also the degree of sustainability against modern anthropogenic pressures. These characteristics have been observed in various levels in the semi-deserts, steppes, forest, and forest-steppe, subalpine, alpine, and subnival zones of the studied area.

Conclusions

1. On the northeastern slopes of the Lesser Caucasus Mountains, like other areas, issues related to the use of soil, water, biological, and mineral resources, as well as environmental conservation, are widespread. The implementation of measures in the direction of optimizing the natural environment in anthropogenic ecosystems will allow effective management of the future dynamics and development trends of geosystems, strengthening ecological diversity, and improving ecological potential.

2. For the first time, three main directions have been established for the objectives of landscape planning to be implemented on the northeastern slopes of the Lesser Caucasus, based on the dynamics and development trends of geosystems: the assessment and provision of natural-ecological balance in geosystems, optimization of anthropogenic pressure on geosystems, and the allocation of areas for the application of ecological management. Implementing measures in these directions will make possible the optimal management of the future dynamics and development trends of modern geosystems, enhance biodiversity, and improve the natural resource potential of the area.

3. Comparative analysis of the NDVI, which reflects the dynamics and seasonal changes in landscapes, was conducted over time to study the variations and functional structure of geosystems with a focus on plant cover. The analysis revealed that the dynamic changes in plant cover are closely related to seasonal dynamic processes in the agricultural landscapes within the studied period. Therefore, it was determined that approximately 70-80% of the variation in the NDVI index corresponds to low mountain xerophytic-steppe, forest-steppe, and mid-mountain steppe landscapes, which are suitable for agriculture.

4. In the studied area, natural ecological conditions were assessed by considering the morphometric indicators of the relief and the character and intensity of anthropogenic influences. Based on the structural-functional characteristics of natural landscapes, they were categorized as practically unchanged, partially disturbed, moderately disturbed, primarily disturbed, and severely disturbed landscapes. Corresponding large-scale (1:200,000) digital maps were created. The analysis of the maps revealed that 38.1% of the landscape in the research area remains practically unchanged, 5.2% is partially disturbed, 27.5%...
is moderately disturbed, 6.5% is primarily disturbed, and 22.7% is severely disturbed.

5. It has been determined that against the backdrop of global urbanization and intensifying anthropogenic impacts, ecological threats such as desertification, aridification, seasonal regime disruption, soil degradation, water scarcity, etc., will be the predominant characteristic features in modern landscapes.

References


1-6. European Association of Geoscientists & Engineers.

