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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

ASSESSMENT OF THE GEOECOLOGICAL SITUATION OF THE MOUNTAIN FOREST LANDSCAPES OF THE NORTH-EASTERN SLOPE OF THE GREAT CAUCASUS BASED ON GIS TECHNOLOGIES

Speciality: 5408.01 – Physical geography and biogeography, soil geography, geophysics and geochemistry of landscapes

Field of science: Geography

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GENERAL CHARACTERISTIC OF THE WORK

The relevance of the topic and the degree of elaboration. Optimizing the use of nature based on the assessment of natural and anthropogenic factors affecting the landscape-ecological conditions in all mountainous countries is considered one of the urgent problems. In particular, the formation of soil, vegetation, and relief under the influence of geomorphological factors, and biodiversity protection issues are the focus of many specialists working in this field. In this regard, the mountain-forest landscapes of the northeastern slope of the Greater Caucasus, which are characterized by the manifestation of complex exodynamic processes, are no exception.

Systematic analysis of the factors influencing the formation of landscapes in the mountain-forest belt of the studied area, including the determination of the composition and properties of soil and vegetation, the spatial and temporal dynamics of the forest areas, the characteristics of transformation, the determination of morphometric indicators and environmental stress have been carried out relatively poorly and/or covered separate parts of the territory in previous studies. For this reason, the effective use and protection of soil and plant resources and the assessment of exodynamic conditions in the area are very relevant in the conditions for the formation of a renewed economic system in the mountain-forest landscape belt of the northeastern slope of the Greater Caucasus.

Foreign scientists such as A.M.Aleynikova, M.N.Petrushina, E.S.Sukhoruchkina, S.S.Chernomorech (2005), N.S.Evseeyeva, N.V.Osincheva, Z.N.Kvasnikova (2012), M.A.Ivanek (2018), and Azerbaijani scientists A.A.Mikayilov (2008), I.I.Mardanov, N.Sh.Eldarov (2017), Sh.F.Mutallibova (2005) and A.A.Mikayilov (2008), and others played a great role in the study of the impact of exodynamic processes and environmental stress on the mountain-forest belt of the northeastern slope of the Great Caucasus.

The object of research is the mountain-forest belt covering the low, medium and partly high altitude of the northeastern slope of the

Greater Caucasus, which has been subjected to various natural and anthropogenic factors, especially changes in the economic structure in recent years. Within this territorial system, separate mountain massifs are characterized by the different intensity of horizontal and depth fragmentation, and the manifestation of exodynamic processes, which cause a different degree of geoecological stress.

The subject of the study is the structure, state, and dynamics of phytocenoses and other natural components in order to protect, improve, and optimize the use of nature in the mountain-forest landscapes of the northeastern slope of the Greater Caucasus.

The purpose and objectives of the study. The main goal of the study is to evaluate the spatio-temporal transformation of the mountain-forest landscapes of the northeastern slope of the Greater Caucasus under the influence of various factors based on the data of field research and GIS technologies. The following tasks were performed in this direction:

- Determining the impact characteristics of the main natural factors affecting the geo-ecological conditions based on field research, processing of various types of cartographic and satellite images, the research carried out by a number of authors in previous years in the mountain-forest belt of the northeastern slope of the Greater Caucasus;

- Determination of geographical differentiation and the degree of ecogeographic stress of the relationship between morphometric indicators that affect the ecological and geographical conditions in the mountain forest belt, with other natural factors, including the lithological composition of rocks, soil and vegetation, and various exodynamic processes that manifest themselves in the territory together with the anthropogenic influence;

- Assessment of ecogeographical conditions based on the determination of biodiversity, age, and density indicators of tree species and area changes that occurred during the relevant time in the mountain-forest belt of the northeastern slope of the Great Caucasus;

- Assessment of the possibilities and consistency of nature protection measures aimed at improving geo-ecological conditions.

Research methods. To carry out the research work, there were used GIS technologies (Geographic Information Systems), historical-geographical, mathematical-statistical, comparison, observation, systematic analysis, and other scientific methods.

In the course of the study, representative (typical) forest areas were selected that were subjected to varying degrees of anthropogenic impact. Field works were conducted by the route method and satellite images with a resolution of 1 meter were processed together with topographic maps and field survey materials.

The research was carried out in several stages. For the assessment of the geoecological condition of the territory, there were carried out the selection of representative (typical) forest massifs that have been subjected to varying degrees of anthropogenic influence on the basis of primary data, the organization of a route trip, the identification of natural and anthropogenic factors determining the geoecological condition based on field studies, literature, and fund materials, and the determination the leading factor that causes the transformation of natural landscapes.

Depending on the geoecological condition of the natural components, interpretation (deciphering) signs were determined during the research. Processing of aerospace images was carried out on the basis of established features and special computer programs.

In the next stage, on the basis of field studies and visual and instrumental processing of aerospace materials, the compilation of various cartographic materials was performed, which allowed determining the differentiation in the geoecological situation.

In order to carry out a quantitative and qualitative assessment of the changes in the geoecological conditions in the area, detailed field studies were performed using large-scale maps, and information was obtained on the biochemical composition and properties of individual natural components.

The main provisions of the defense:

1. Determining the impact of the natural-geographical conditions of the Greater Caucasus mountain-forest belt on its

creation, distribution, biodiversity, abundance, and species composition.

2. Determining the dynamics in the area of the mountain-forest belt and changes in density indicators over a certain period of time as a result of natural and anthropogenic impacts.

3. Determining the ecological condition of the mountain-forest complexes and their economic evaluation typical for the north-eastern slope of the Greater Caucasus using aerospace materials.

4. Analyzing the main characteristics of the exodynamic processes typical for the area, evaluating the ecogeomorphological conditions, and improving the cartographic base that allows for the development of nature protection measures.

The scientific novelty of the research consists of the following:

- Based on the assessment of the degree of influence of various natural and anthropogenic factors there were carried out, the species composition of mountain forests, the main edifiers, the age characteristics of trees, and the determination of spatial dynamics over time;

- Based on the analysis of ecological-geomorphological, anthropogenic, and soil conditions there were determined the most dangerous areas from a geodynamic point of view that can affect the sustainable development of mountain forests;

- Depending on the geo-ecological conditions, mainly morphometric indicators, soil cover, and vegetation density, possible ways of solving the problem of effective use of the slope surface, and sustainable development of forest cover were indicated.

- The degree of degradation of the mountain-forest ecosystems of the northeastern slope of the Greater Caucasus was determined based on the samples taken from the soil cover.

- Based on the analysis of individual morphometric indicators of the relief of the area, ecological stress areas were determined in the mountain-forest belt.

Theoretical and practical significance of the research. The results obtained in the research process allow to enrich the available information about the species composition and biodiversity of

mountain forests, help to make appropriate corrections in the selection of the sparsest forest areas and tree species during the implementation of forest restoration works, and help to determine the priority areas during the implementation of these works.

Based on the results of the conducted research, it can be important in choosing the safest and most convenient route lines for the implementation of construction works and the development of ecotourism in order to ensure the development of a large-scale tourism business in the area. It can also be used by relevant state, municipal and private organizations when determining the direction, composition, duration and sequence of nature protection measures.

Approbation and application. The main provisions of the dissertation were presented and discussed at the following scientific-practical conferences of national and international importance: International scientific-practical conference on "Globalization and Geography" (Baku, 2012), Scientific-practical conference on "Human and environmental relations" (Baku, 2017), International scientific-technical conference on "Natural disasters and the safety of human life" (Baku, 2017), XXI Republican Scientific Conference of PhD students and young researchers (Baku, 2017), International scientific conference of Social Geographers (Azerbaijan-Russia) on "Human geography in Azerbaijan and Russia: the main ways of development in the XXI century" (Baku, 2018), Republican scientific conference on "Global trends and modern Azerbaijan" (Mingachevir, 2018), International conference on "Mountains: cultures, landscapes and biodiversity" (Baku, 2019), Republican scientific conference on "Modern problems of geography" (Sumgayit , 2019) and IX international scientific-practical conference "Mountain territories: priority directions of development" (Vladikavkaz, 2019).

Based on the research results, 18 articles and abstracts were published.

The name of the institution where the dissertation was carried out. The dissertation work was performed at the "Geography and its Teaching Methodology" department of Sumgayit State University.

The structure and the volume of the dissertation. Dissertation work consists of introduction, 4 chapters, conclusion, list of used literature and appendices. The total volume of the work is 175 pages. The introduction consists of 8 pages, chapter I of 60 pages, chapter II of 21 pages, chapter III of 27 pages, chapter IV of 32 pages, the conclusion of 02 pages, and the bibliography of 23 pages. The dissertation contains 37 tables, 16 figures, and 26 graphs, including 6 schematic maps and 5 maps. The volume of the dissertation is 192022 characters without a bibliography and appendices (without graphs, tables, and pictures).

THE MAIN CONTENT OF THE RESEARCH

The introduction indicates the relevance of the topic, the degree of study, purpose, objectives, theoretical and methodological foundations of research work, scientific novelty, and practical significance of the work.

The first chapter of the dissertation is entitled "**Characteristics of the main components that form the natural conditions of the study area.**" This chapter discusses all the elements of natural and geographical conditions that affect the formation of the mountain-forest belt.

The mountain-forest belt of the northeastern slope of the Greater Caucasus is distinguished by the complexity of its orography. The absolute and relative heights, the steepness of the slopes, the inclination, and the direction of the watersheds that determine the character of the relief, have a great influence on the formation of the mountain-forest belt. In the Yan Range, which is the largest orographic element of the study area, the mountain-forest belt is clearly manifested. The mountain-forest belt is shrinking in the direction from Yaridag and Shahdag massifs to Beshbarmag peak. The intensity of exogenous relief-producing processes within the zone is greatly influenced by the absolute and relative heights that determine the nature of the relief of the north-eastern slope, the steepness of the slopes, and the direction of waterers. ue to the

decrease in the absolute heights from the northwest to the southeast, there is a reduce in atmospheric precipitation and slope inclinations in this direction. Therefore, differentiation is noticeable in the development of water-erosion and arid-denudation processes on the territory. Avalanches, landslides, water-erosion, gravity, and denudation processes prevail in the middle mountain zone within the mountain-forest belt, and arid-denudation and accumulation processes prevail in the low mountains.

The role of climate indicators in the formation of mountain-forest ecosystems is great. In this zone, the absolute maximum temperature was recorded at 22.4^0C (Gusar dis.), and the absolute minimum temperature was -23.2^0C (Khaltan v.). For the areas where erosion centers are formed in the territory of the Greater Caucasus, the total radiation indicators vary between 140-145 kcal/cm^2. The amount of precipitation has a special importance in the formation of the forest belt, which is mainly observed in the summer and autumn seasons in the studied area. Precipitation trends: annual maximum - 1333.9 mm, annual minimum - 223.6 mm in Khinalyg station, annual maximum - 892 mm, annual minimum - 238 mm in Gyriz station, annual maximum - 706.9 mm, annual minimum - 313, 6 mm in the Khaltan station, the maximum annual - 587.2 mm, the minimum annual - 422.1 mm at the Gusar Reserve, the maximum annual - 779.2 mm, the minimum annual - 284.4 mm at the Altyagach station. The highest precipitation rates are observed in areas at an altitude of 2400-2800 m above sea level[1].

The analysis of meteorological data showed that the vertical temperature gradient on the northeastern slope of the Greater Caucasus is 0.4ºC. The winter months in the foothills and middle mountains are mild, and severe in the highlands. The average monthly temperature during the winter months ranges from 0º to 4ºC in the valleys and foothills. The average monthly temperature drops to -3, -4ºC in Alibey station (1750 m) in winter. The average monthly temperature in the winter period varies between +1ºC and -6ºC in

[1] National Hydrometeorological Service data.

Kyriz station on the northeastern slope of the Greater Caucasus, with an absolute height of 2006 m[2].

In the process of intensive wearing, the daily amplitude of the air temperature, the course of atmospheric precipitations, intense rains, snow avalanches, and flooding events in rivers have a great role.

According to H.A.Aliyev (1964), the total area of brown mountain-forest soils is 50,000 ha on the northeastern slope of the Greater Caucasus. Most of this area is located in Guba region (35000 ha), Gusar region (10000 ha), as well as in Shabran and Khizi regions.

Various subtypes of brown mountain-forest and brown mountain-forest soils are spread in the study area[3]. The typical brown mountain-forest subtype of brown mountain-forest soils developed under beech, beech-hornbeam forests in the middle forest zone. The dark brown mountain-forest subtype develops under beech-hornbeam or hornbeam forests and forms a transition to brown forest soils. The saturated brown mountain-forest subtype is common in areas where typical brown mountain-forest soils are spread. These soils are formed in relatively sparse areas of beech forests or beech-hornbeam forests, mostly at the border of dark brown mountain-forest soils. Carbonate residual brown mountain-forest subtype soils are very common soil types. This soil is most often found in the upper part of the forest, especially on the slopes of the eastern exposure, partly in areas of accumulation of erosion products brought from higher zones and on the edges of broken forests. Gravelly, poorly developed brown mountain-forest subtype soils are formed on the northern slopes of the highlands or rocky areas, outside the forest zone. Meadowed brown subtype soils are formed as a result of grass covering broken forest areas in the upper part of the forests. Typical dark brown mountain-forest subtype soils are distributed in the lower part of the forest zone, mainly under low oak forests. Mountain-

[2] National Hydrometeorological Service data.

[3]Babayev M.P., Jafarova Ch.M., Jafarova A.M., Huseynova S.M., Gasimov Kh.M.. Modern soil map of North-Eastern and South-Eastern parts of Greater Caucasus. Scale: 1:100000 // – Baku, – 2010.

forest semi-type soils with light brown and buried horizons are mainly formed under oak forests and are found in most parts of the study area. Brown mountain-forest semi-type soils developed under forest cover in the past and later underwent a certain transformation under the influence of human activity.

In the middle mountainous part of the mountain-forest belt, brown mountain-forest soils are spread under beech and hornbeam forests, and dark brown mountain-forest soils under oak forests. As a result of the destruction of the lower borders of the forests, the soil cover here has been degraded and lost its original condition. To determine the degree of degradation, soil samples were taken from 8 specially selected sites. The first 5 stations are located between the basins of the Valvalachay, Shabranchay, Zeyvechay, Ajicay, Khotadarechay, Dalichay, Turgachay, and Gilgilchay rivers, and the other 3 stations are located along the right bank of the Valvalachay - between the villages of Gorkhmazoba, Isnov, Velvele, and Gedik. The mentioned areas are the zones between 260-1400 m above sea level where the forests are mostly cut down and the soils are more eroded. As a result of the analysis of the collected soil samples, it was determined that the carbonation of the soil in specially selected areas varies from 1.86 to 6.3 mg, and the amount of humus fluctuates between 3.2 and 10.8%. This indicator (carbonation - 2.3 times; humus - 3 times) is quite low compared to previous years' studies.

The forests of the north-eastern slopes of the Greater Caucasus are formed under certain climatic, soil, and geological-geomorphological conditions, creating different and unique phytocenoses. The study of these senoses, including the landscapes created by them, was the subject of the work of a number of researchers[4]. It was found that beech forests are spread from an altitude of 550-600 m in the Guba and Shabran regions of the studied area. Here, it is possible to find beech forests in the form of a large area, three kilometers west of the Galaalti village. A tree-shaped

[4]Mamedov G.Sh. Ecological assessment of soils of agricultural and forest lands in Azerbaijan. Abstract of a doctoral dissertation. - Dnepropetrovsk: 1991, - 31 p.

Persian juniper (*Juniperus polycarpos*) species is common in the Gilgilchay and Tigchay river basins on the northeastern slope of the Greater Caucasus. The oak and its species, the Georgian oak (*Quercus iberica*), should be specially mentioned, whose border extends to the Republic of Dagestan. We can observe the anthropogenic replacement of oak with lentisk (*Pistacia lentiscus*) in the Gilgilchay and Tugchay river basins. On the northeastern slope of the Greater Caucasus, natural walnut forests are spread up to 1600 meters above sea level. In the valleys protected from the wind, beech, hornbeam, poplar, maple, etc. grow mixed with different tree species, and sometimes they form a dense forest in small areas. The Warty birch (*Betula verrucosaEhrh*.) together with Litvinov's gorse (*Betula litwinowii*) covers a wide area at absolute altitudes of 1500-2100-2200 m, especially in Guba and Gusar regions[5]. Hook pine (Pinus hamata L.) forests mainly grow well in more unfavorable, rocky, bare areas. Therefore, hook pine should be widely used for the purpose of erosion control in areas unsuitable for other tree species. The forest of this pine species has been established in the Altiaghaj massif. L.I. Prilipko (1954) showed that the hook pine grows at an altitude of 1800-1900 m above sea level near the village of Laza, Gusar region, on the northeastern slope of the Greater Caucasus. As a result of the conducted research, it was determined that the eastern border of the pine on the northeastern slope of the Greater Caucasus is located near the village of Kuzun on the left bank of Gusarchay river. Yews forests (Taxus L.) are less common on the northeastern slope of the Greater Caucasus than on the southern slope. In this area, they are found singly or in groups at a considerable distance from each other. The most important yews forest area is located near the village of Yukhari Khanegah at an altitude of 900-1000 m above sea level and covers the understory of the beech-hornbeam forest. Another yews area is located 3 kilometers north of Khaltan village of Guba district. To the east of the Gilgilchay basin, the yews are rarely

[5]Mammadov G.Sh., Khalilov M.Y. Forests of Azerbaijan / G.Sh. Mammadov, M.Y. Khalilov - Baku: "Science" Publishing House, – 2002. – 472 p.

found in the Atachay and Tikhchay river basins. Its eastern border passes through the basin of the Karabulag river, a tributary of the Tikhchay river. On the left bank of this river, in the area between the former villages of Gars and Garabulag, at an altitude of 1000-1200 m above sea level, on the steep northern slopes, under the canopy of an oak-hornbeam forest, yews can be found singly, sometimes in groups.

The second chapter is called "**Theoretical foundations of the research and sources of primary data**". A number of studies show the change of the mountain-forest landscapes of the Greater Caucasus under the influence of various gravitational processes and forms - landslides, debris, and sprinkles. The catastrophic scale of these processes and forms creates great barriers to human activity in an intensively used area[6]. It should be noted that these processes are created under the influence of flood flows. These streams, in turn, leave a heavy imprint on the life of the inhabitants of the mountainous and foothill regions[7].

Spectral indicators of plant and soil cover of mountain forests depend on the phenological development characteristics and structure of forest phytocenoses, the composition and properties of the soil mass, the degree of illumination at the time of measurement, and a number of other factors. According to the data obtained, the natural structural characteristics of mountain forests, such as species composition, degree of projective cover, height, density, and layering, are interdependently related to the productivity of forest ecosystems. Close interrelationships were also established between indicators of forest vegetation condition (primarily biomass) and soil surface condition (erosion rate).

[6]Guluzade V.A., Aliyev Y.G. Exomorphogenesis processes causing ecological stress in mountainous regions and measures to combat them // Baku: Proceedings of the Azerbaijan Geographical Society. Modern geographical studies in Azerbaijan, –2007. Vol XI, – pp. 80-84.

[7]Pashayev N.A. Economic-geographical problems of the impact of natural disasters on the economy in the Republic of Azerbaijan: Abstract of the dissertation of Doctor of Geographical Sciences. / Baku: 2017. – 45 p.

Geobotanical studies and research on the development of exogenous processes carried out in different parts of the Greater Caucasus prove the fact that soil degradation processes necessarily lead to the deterioration of the species composition of the vegetation, its biochemical indicators, and, as a result, to the complication of the agrarian and social situation, causing a decrease in its economic value.

Based on preliminary data, representative (typical) forest massifs exposed to various degrees of anthropogenic influence were selected for the assessment of their geoecological condition. Analysis of field studies, literature, and fund materials allowed us to determine the natural and anthropogenic factors that define the geoecological situation and the leading factors that conduct the transformation of natural landscapes[8]. On the basis of field studies and visual and instrumental processing of aerospace materials, the compilation of various cartographic materials was performed, which allowed determining the differentiation in the geoecological condition. These materials, in turn, made it possible to monitor the differentiation of the ecogeographical conditions. In order to carry out a quantitative and qualitative assessment of the changes in the geoecological conditions in the area, comprehensive field studies were carried out using large-scale maps, and information was obtained about the biochemical composition and properties of individual natural components - soil and vegetation.

At the last stage of the study, generalization, and systematization of the collected fund and literature data, and field research data were carried out. At this time, the most recent and detailed information has been selected. These data were compared with the data collected in previous years and made it possible to assess the spatio-temporal changes in geoecological conditions in the area. As a result of the

[8]Mikayilov A.A. Ecogeochemical characteristics of landscape complexes on the northeastern slope of the Greater Caucasus / A.A.Mikayilov, G.I.Rustamov, A.M.Rustamova [et al.]. // Proceedings of Baku University, Natural sciences series, – 2013. № 4, – pp. 152-160.

conducted research, forest areas were identified, where the most intense ecological situation is observed, and environmental measures that can improve the geoecological situation and their sequence.

By summarizing the results of the research carried out in this field, there were chosen the optimal way of assessing the degree of degradation of landscapes in the mountain-forest belt and geosystem analysis of the state of low and medium mountainous landscapes in general.

The research can be divided into several stages:

1. Collection and processing of literature materials about the soil-vegetation cover, relief, climatic conditions, etc. of the research area.

2. Comparative analysis of methods used in research.

3. Decoding of aerial images and generalization of field research materials.

The third chapter analyzes "**The reasons for the transformation of the main natural complexes in the research area"**. In this section, the transformation sources and territorial characteristics of mountain-forest complexes are studied. Various reasons have influenced the transformation of mountain forests, and the analysis of these reasons is of great importance for the optimization of the use of forests.

Mountain-forest complexes in the study area can be grouped according to the degree of transformation as follows:

1. Moderately modified landscapes. These landscapes include mountain-forest, forest-shrub-meadow complexes of the middle highlands, and forest-shrub complexes of the low highlands. In most of these complexes, the anthropogenic factor is less than 0.5. It should be noted that the soil-vegetation cover of landscapes and animals is subjected to intensive changes, and climatic conditions, relief, lithology, etc. are relatively less exposed. These complexes are characterized by natural regeneration and self-regulation.

2. Severely modified complexes. These complexes cover large areas in the agricultural regions of the country. They are mountain-forest, forest-shrub, steppe, forest-steppe, arid sparse forest and shrub, plain forest-meadow complexes, semi-deserts, hydromorphic

meadow-swamp, thicket-meadow, etc. represented by irrigated garden-plantation, seliteb-garden, etc. units. Depending on the intensity of anthropogenic activity, these complexes are affected by economic activity to varying degrees, but regularly, and are constantly regulated by humans. Various genetic types of these complexes are formed in mountain-forest, mountain-steppe, forest-steppe, arid sparse forest, shrub-steppe, depression-forest, forest-meadow, and semi-desert landscapes.

3. Completely transformed complexes. These complexes are widespread in sloping plains, and medium, and low mountains. They occupy a very small area in the middle highlands and are distinguished primarily by linear habitats. Such complexes include roads, quarries, ravines, gobos, etc. These complexes have been completely changed and turned into completely deforested agro landscapes.

The forests of the lower mountain-forest belt are more disturbed by human economic activity than the forests of the middle mountain belt.

The forests of the middle mountain-forest belt are mainly beech forests and beech-hornbeam mixed forests. The forests of this zone create large forest massifs compared to the lower and upper mountain-forest areas. They are also superior in quality.

Available materials show that during the years 2000-2010, although the total area of the forest within the existing area did not decrease in the Guba administrative region, there was a noticeable decline in the density of forests. This can be directly attributed to the felling of trees for firewood and poor reforestation.

During the analysis of the development of landslides and soil erosion in the area, there was used visual processing of aerial photographs. It allowed determining the quantitative data about the landslides formed within the mountain-forest belt of the northeastern slope of the Greater Caucasus, their morphological elements, and the degree of fragmentation and homogeneity of the landscape contours separated in the landslide areas.

Remote sensing of aerial photographs has determined the presence of a number of destructive landslides in the study area, especially in the Valvalachay river basin. At this time, sometimes there is a transition from one process to another. For example, as in the case of the Atuch landslide, an avalanche is observed to move into a landslide, and the landslide materials cause flood flows. During the Atuch, Ruchug, Yerfi, and Garabulag landslides, the formation of hills, steps, and cracks in the relief, uneven surface moisture, and violation of the integrity of the soil and vegetation are observed.

One of the important exogenous processes manifested in the study area is soil erosion. Along the Gudyalchay valley and in the Valvalachay basin, there are widespread areas severely eroded as a result of anthropogenic activity and flood flows that have a devastating effect on the soil cover.

The fourth chapter is entitled "**Ways of research and optimization of forest complexes based on GIS technologies**". In this chapter, the temporal dynamics of mountain forest transformation is analyzed based on data from Forestry Enterprises and Global Forest Watch (GFW). In the area, young forests are 10,546 ha (20%), middle-aged forests are 39,312 ha (76%), maturing forests are 270 ha (1%), and old-aged forests are 1,508 ha (3%). As it can be seen, the main place in the area is occupied by middle-aged forests. After a certain period of time, these forests can be classified as maturing or old-aged forests. This situation may lead to environmental degradation in the area in the future.

On the basis of Global Forest Watch (GFW) data, the dynamics of forest cover changes in the mountain-forest belt of the northeastern slope of the Greater Caucasus were monitored in the period 2001-2017 (Fig. 1, 2)[9]. During this time, the forest area decreased from 147 thousand ha to 137 thousand ha. At the same time, during the years 2001-2012, the newly formed forest area was 64.6 ha, and the destroyed forest area during the years01.01-2001-31.12-2017 was 465 ha (Graph).

[9]Global Forest Watch (GFW) satellite data.

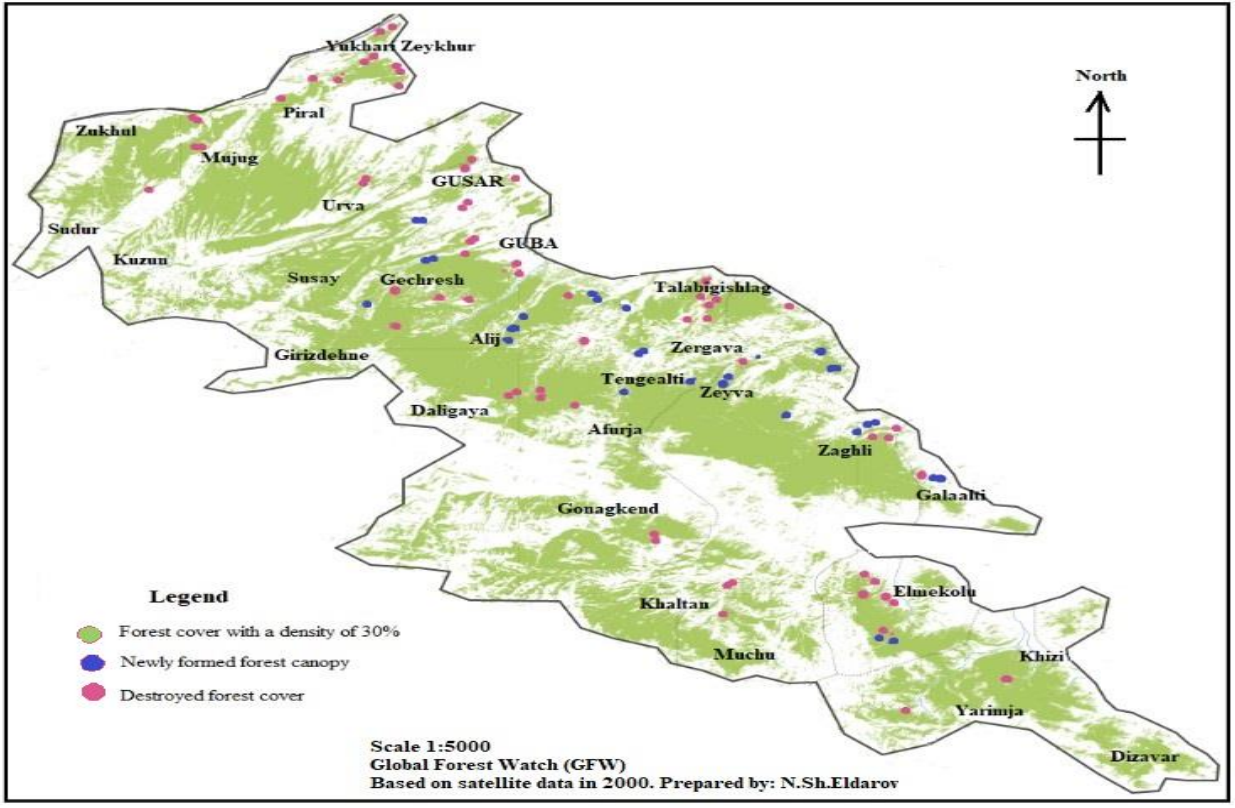


Figure 1. Map-scheme of the state of forest cover in the mountain-forest belt of the northeastern slope of the Greater Caucasus (2000)

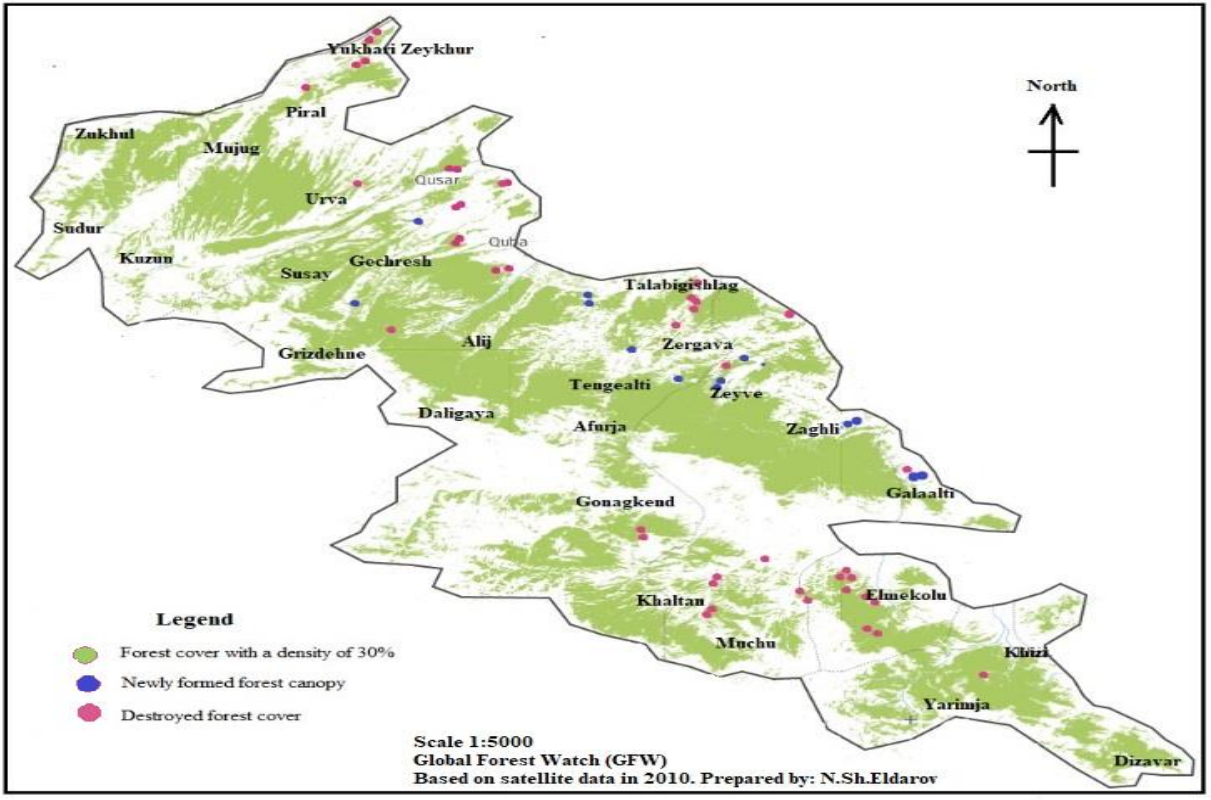
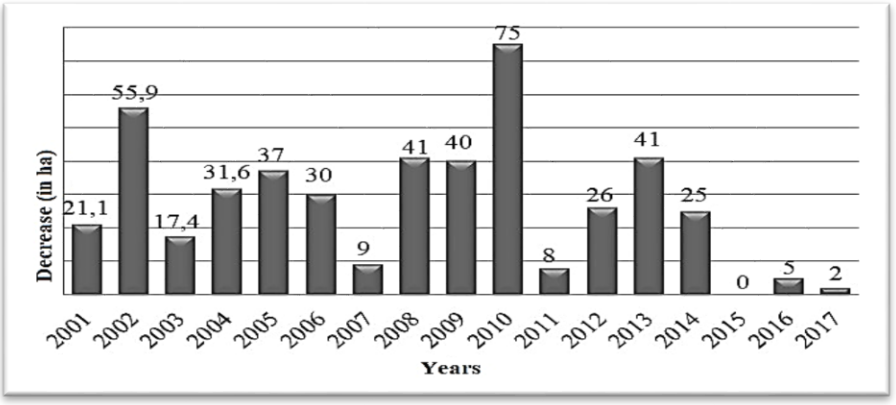


Figure 2. Map-scheme of the state of forest cover in the mountain-forest belt of the northeastern slope of the Greater Caucasus (2010)



Graph. The annual dynamics of forest cover in the mountain-forest belt of the northeastern slope of the Greater Caucasus in the period 2001-2017

Based on our research, we have determined that the reduction of forests in the studied area occurs as a result of both natural and anthropogenic influences. For this purpose, it is extremely important to protect and maintain the mountain-forest belt of the Greater Caucasus, which is of great importance in our republic. Taking into account the above, we have compiled an eco-geomorphological map of the region. At this time, we determined the exodynamic conditions of the northeastern slope of the Greater Caucasus on the basis of GIS technologies and satellite images. In order to study the exodynamic situation, we have studied the hypsometric height of the area, the slope, inclination, and horizontal and vertical division of the slopes.

We have determined that 43.5% of the mountain-forest belt has a hypsometric height of 1000-1500 m, 42.8% has a slope of 10-20 degrees, 49.2% has a horizontal division of 1000-1500 m/km^2, and 48% has a vertical division of 200-400 m/km^2, which makes the natural-geographical conditions of the studied area favorable for the development of various economic fields. For this reason, the mountain-forest belt is more exposed to tree felling and anthropogenic loads. Also, the morphometric indicators of the terrain

once again prove the activity of exodynamic processes. Analyzing the above-mentioned indicators, we divided the mountain-forest belt into 5 criteria (conditionally stable, weakly unstable, moderately unstable, severely unstable, and anomalously unstable areas) and compiled an eco-geomorphological map (Fig. 3).

1. Conditionally stable areas (296 km^2) include areas with a hypsometric height of 500-600 m, with slope inclination below 10^0, horizontal fragmentation below 500 m/km^2, a vertical distribution below 200 m/km^2, and slopes with a north-east direction. The indicated areas have a fairly large area in the north-west and south-east of the studied area. The mentioned areas are mainly selected for their suitability for agriculture, which reduces their sustainability.

2. Weakly unstable fields (1874,6 km^2) include areas with a hypsometric height of 600-1000 m, with slope inclination 10^0-20^0, horizontal fragmentation 600-1000 m/km^2, a vertical distribution 200-400 m/km^2, and slopes with a north-east direction. The presence of favorable natural conditions leads to deforestation by various farms, which results in their poor sustainability.

3. Moderately unstable areas (629 km^2) include areas with a hypsometric elevation of 1100-1300 m, the inclination of 20^0-30^0, horizontal fragmentation of 1100-1500 m/km^2, vertical fragmentation of 200-400 m/km^2, and northeast-facing slopes. Moderately unstable areas cover the upper part of the forest zone and river valleys. This also increases the danger of developing exodynamic processes, which are a problem for the development of the expanding tourism business in the area.

4. Severely unstable areas (5,8 km^2) include areas with a hypsometric elevation of 1400-1600 m, the inclination of 30^0-40^0, horizontal fragmentation of 1600-2000 m/km^2, vertical fragmentation of 600-800 m/km^2, and northeast-facing slopes. It covers a small part of the total mountain-forest belt, especially forest areas that are spread in sharply divided parts of the terrain where exodynamic processes are active. The reduction of the area of forests in these regions occurs as a result of the activity of natural processes.

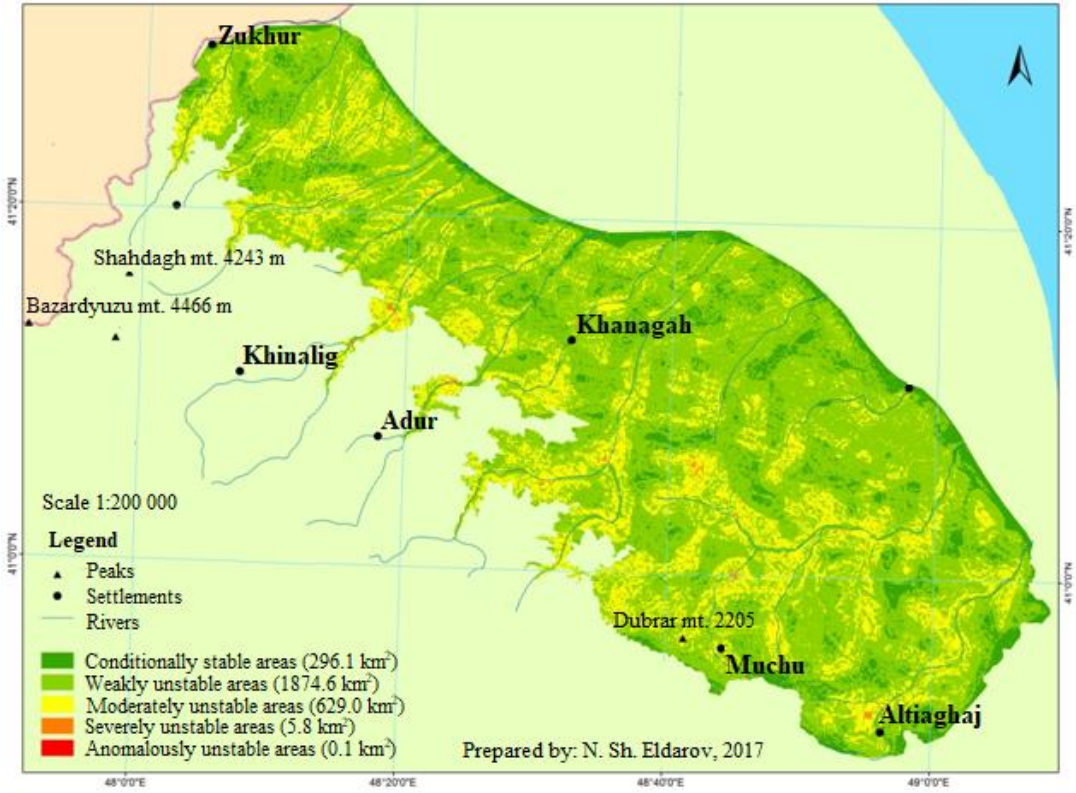


Figure 2. Ecological stress map of the mountain-forest belt of the northeastern slope of the Greater Caucasus

5. Anomalously unstable areas (0,1 km^2) include areas with a hypsometric elevation above 1600 m, inclination of the slopes – more than 45^0, horizontal fragmentation above 2000 m/km^2, vertical fragmentation above 200-400 m/km^2, and northeast-facing slopes. It covers forest areas spread on steep cliffs in the form of small areas and dominated by natural processes. The forests spread in the mentioned areas are mainly beech forests.

As a result of the analysis of the relevant situation for the protection and improvement of forest complexes, it was determined that in the upper parts of the mountain-forest belt of the Greater Caucasus and the areas of the mountain-meadow zone adjacent to them, linear and surface washing of the soil cover occurs due to a number of reasons. At the mentioned height, both natural and anthropogenic influences lead to the intensification of the erosion process. The natural-geographical conditions of this place create difficulties for the implementation of anti-erosion measures and prevent the restoration of the land.

In contrast to the upper border of the forest, the natural-geographical conditions are very favorable for maintaining the fertility and efficient use of the brown mountain-forest soils, which occupy a large area in the low mountainous parts. For this purpose, as the main measures, it is possible to recommend the banning of tree cutting, the prevention of grazing, and the planting of tree plants typical for the area in that zone, especially relict plants that develop in fairly dry climates.

The conducted studies show that, just as trees were cut down in the lower part of the forest for the needs of agriculture, deforestation in the upper forest belt was also carried out to expand pastures. As a result, anthropogenic activity has emerged as the main cause of the steppe process within the forest zone (Table).

The goals and tasks of optimizing the use of mountain forests have been defined under the conditions of the development of exodynamic processes. The mountain-forest belt of the northeastern slope of the Greater Caucasus is attractive for the creation of tourist routes due to the presence of natural and historical monuments.

Table

The scheme of erosion control measures in the mountain-forest belt of the northeastern slope of the Greater Caucasus

The degree of erosion	Measures
Not eroded	A) regulation of tree cutting, application of plantings
	B) implementing the conservation regime, monitoring the state of biological diversity and the chemical composition of soil-plant groups
Weakly eroded	A) creation of small dams in inclined (15^0-20^0) areas, prevention of surface runoff and formation of furrows, application of park regime
	B) surface improvement (grass seeding, cleaning of gravel and scrap material, prevention of surface runoff and furrowing)
Moderately eroded	A) grass seeding in low-slope areas, fertilizing, construction of small protection dams, temporary prohibition of cutting trees in less inclined areas, reclamation of ravines, and prevention of their development
	B) creation of small dams in sloping areas, prevention of the formation of ravines and their melioration, prohibition of tree cutting
Severely eroded	A) stop cutting of trees, create hydrotechnical facilities to limit surface runoff, and prevent the development of ravines and their reclamation
	B) Implementation of tree plantations in low-sloping areas, mainly on north-facing slopes that are less affected by rainfall

In addition to the protected areas, the mountain forest areas of the Greater Caucasus are a zone of active use of nature and play a major role in providing the population with agricultural products. For this reason, prevention of soil erosion is also important from an economic point of view.

One of the important tasks is the implementation of fire prevention measures. The active involvement of the territory in the implementation of tourism business requires the implementation of security measures.

In order to weaken or prevent the degradation processes and their resulting flood flows, it is very important to expand phytomeliorative control measures aimed at restoring the integrity of the vegetation of mountain forests. A radical measure against erosion for the mountain-forest belt is the prohibition of any felling.

CONCLUSION

The following results can be listed on the basis of the considered characteristic features of the geographical differences and dynamics of the condition of the mountain-forest belt of the northeastern slope of the Greater Caucasus under the conditions of the interaction of natural and anthropogenic factors, and its geoecological assessment:

1. As a result of the irrational use of the mountain forests of the northeastern slope of the Great Caucasus and the exceeding of the sustainability limit of geocomplexes, the biological productivity of the ecosystem decreases, the species composition of plants deteriorates, and the share of old trees increases, and the share of valuable tree species and the density of forests decrease. Therefore, young forests in the area are 10,546 ha (20%), middle-aged forests are 39,312 ha (76%), maturing forests are 270 ha (1%), and old-aged forests are 1,508 ha (3%).

2. It was determined that as a result of the impact of the anthropogenic factor on mountain-forest landscapes, the area of forests decreased by 10 thousand ha in 2000-2010 and reached the crisis level. Especially in the limits of the mountain-forest landscapes covering the low, medium, and partially high mountain belts of the northeastern slope of the Greater Caucasus, the inefficient use of individual areas for a long time has led to the intensive depletion and thinning of vegetation and the expansion of less productive areas.

3. Over the past 25-30 years, the mountain-forest landscapes of the Greater Caucasus have been subjected to intensive anthropogenic influence as a result of the expansion of settlements, the increase of agricultural areas, and the development of tourism. These processes became more pronounced in the Valvalachay basin, causing the emergence of new landslides and serious environmental problems.

4. The dynamics of forest massifs in the research object were determined in time and space based on comparative methods, including the analysis of repeated space images of the area taken in 2000 and 2010. Also, horizontal and vertical fragmentation, genesis and dynamics of exogenous factors, flood sources, landslide areas, and soil-vegetation conditions were determined based on space images with a resolution of 1 m.

5. The morphometric indicators of the relief of the mountain-forest belt on the northeastern slope of the Greater Caucasus (hypsometric height, inclination of the slopes, steepness of the slopes, horizontal and vertical division of the relief) were analyzed separately and an eco-geomorphological map of the studied area was drawn up. The mentioned area is divided into 5 criteria - conditionally stable, weakly unstable, moderately unstable, severely unstable and abnormally unstable areas. 66.8% of the mountain-forest belt of the northeastern slope of the Greater Caucasus is weakly unstable, and 0.01% is abnormally unstable.

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