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ASSESSMENT OF THE GEO-ECOLOGICAL SITUATION OF HIGH MOUNTAIN LANDSCAPES USING GIS TECHNOLOGIES (IN THE CASE OF THE GREAT CAUCASUS)

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Abstract

As a result of anthropogenic impacts, it is possible to observe changes in landscapes not only in plains, but also in mountainous areas. In particular, the melting of glaciers in high-mountainous areas as a result of global warming and the shrinking of glacier areas are examples of this. In this case, their long-term study is important. In this regard, our study is dedicated to a topical topic. In the 21st century, there are various opportunities to conduct long-term studies using modern methods during the study of the territory. In this article, we have analyzed the study of the geoecological situation in the high-mountainous landscapes of the Greater Caucasus using GIS technologies and its results. At this time, priority was given to modern methods and techniques, modern methods, processing and analysis of satellite images. In addition, field research and materials of previous researchers were also used. When analyzing the geoecological situation of landscapes, we also used the results of the study of vegetation cover, soil cover and surface temperature obtained from our previous studies. As a result of the conducted studies, the landscapes in the study area were regionalized according to their geoecological status and 3 classifications were distinguished: relatively unchanged, weakly and moderately changed landscapes. It was determined that most of the territory belongs to relatively unchanged and moderately changed areas. The main reason for this is that the relief of the area is unfavorable for development. However, considering that the area also has the most productive summer pastures, we also observe problems such as vegetation degradation and soil erosion.

Keywords: *Greater Caucasus, high mountains, GIS technology, landscape, geoecological situation*

Introduction

The study of the geoecological state of natural landscapes in our republic began in the middle of the 19th century. In this field, scientists such as B.A.Budagov, A.M.Mikayilov, M.A.Museibov, M.J.Ismayilov, E.Sh.Mammadbeyov, Y.A.Garibov, M.I.Yunusov and others played a great role. Although A.M.Mikayilov and E.Sh.Mammadbeyov used the decoding of space images in the study of natural landscapes, the method they used has now lost its effectiveness. In modern times, special importance is attached to the study of space images in the GIS environment, using Snap and other methods. Therefore, we have used GIS in the study of natural landscapes of the high mountainous parts of the Greater Caucasus and conducted appropriate analyses. Although the use of the mentioned methods in the world began in the 80-90s of the 20th century, the use of these studies in our republic began at the beginning of the 21st century. The study area is being studied in a GIS environment for the first time. The main goal of our study is to study the geoecological state of natural landscapes existing in the high mountain geosystems of the Greater Caucasus using GIS technologies.

Using GIS technologies, it is possible to study the landscape-geoecological state of the territory (Chen & Han, 2015). Each landscape type is directly or indirectly exposed to anthropogenic influences (Apostol & Chelaru, 2011). When systematically studying the geoecological state of natural landscapes, it is possible to determine the natural potential in the highlands and the current use of these resources.

When determining the landscape-geoecological state in the highlands of the Greater Caucasus, natural and natural-anthropogenic landscapes are considered as a whole Natural Territorial Complex. Therefore, a systematic approach is extremely important.

Using GIS, we can determine each landscape type, species and other parameters. Images obtained from satellite images make it possible to determine the degree of transformation of high-mountainous landscapes under the influence of natural and anthropogenic factors. Through space images, it is possible to detect the boundaries of geological structures, lithological differences of bedrock and Quaternary sediments, orographic steps, relief forms, natural boundaries of soils and plant communities. The use of these images is carried out in three stages: foreground, field, and camera.

Processing of space images using geoinformation methods Analysis and assessment of the state of the vegetation component of geocomplexes is based on the analysis of spectral reflectance (Connolly, (2017). During land cover classification, image pixels form an elementary territorial unit with fixed dimensions (for Landsat - 30x30 m). The purpose of the classification is to group the classification elements into groups (classes) so that the differences in decoding characteristics between groups are greater than the differences within the groups (Huan et al., 2019). The reliability of the classification determined by discriminant analysis decreases with each level. At the fourth level (16 classes), the classification result can be considered almost 94% reliable (Ma et al., 2019). When using GIS in mapping, their resolution is important, which determines the degree of representation of the main territorial unit - landscape type, landscape type, etc. (Leblois et al., 2017). Scientists noted that individual tracts or facies do not provide a complete description of the landscape environment and cannot be considered as basic taxonomic units of the landscape hierarchy, therefore the use of satellite images with centimeter resolution is not always appropriate (Li et al., 2017).

Materials and methods of the study

During the study, existing fund materials, thematic maps, and modern geoinformation mapping methods were used. Relevant maps were compiled on the basis of these materials. Thematic map materials are a structural element of a landscape and ecologically balanced environmental management model, which is necessary for territory management under conditions of increasing anthropogenic pressure. The software platform for creating maps of environmental users and forestry stations is the ArcGIS program developed by ESRI. Satellite images are a useful and important source of information when studying the properties of geocomplexes.

Research results and discussion

Our study area covers the high mountain geosystems of the Greater Caucasus (Figure 1). The total area is 321,544 ha, and 5 landscape subtypes are distributed.

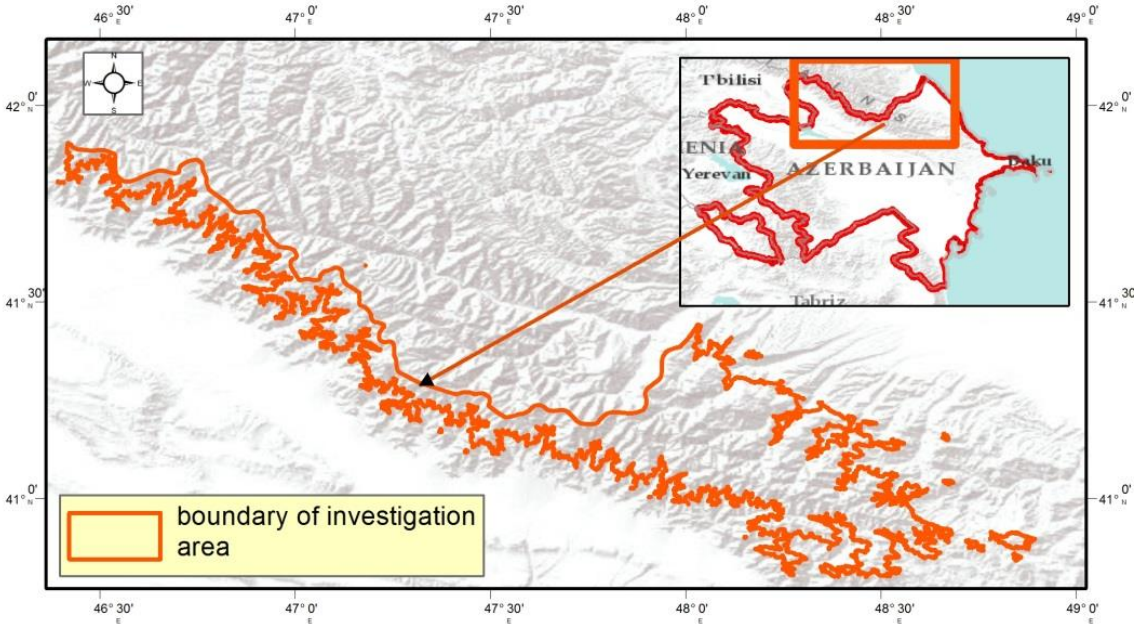

Figure 1. Location of the study area

In determining natural landscapes, we first focused on the study of vegetation. Because vegetation is the main indicator in determining natural landscapes in the GIS environment. To analyze and evaluate the plant component of geocomplexes, methods of linear combination of spectral channels or vegetation indicators are used. The method of vegetation indices provides a quantitative assessment of projective vegetation. The determination of phytomass is based on the use of a simple zonal ratio coefficient or vegetation index, which is calculated by dividing the brightness coefficient in the near-infrared part of the spectrum by the brightness coefficient in the red part of the infrared spectrum. NDVI is useful in this study, where the difference in zonal brightness coefficients is normalized to their sum. NDVI increases the contrast of green vegetation with other cover objects, such as soil and dry vegetation.

The second most important parameter in the study of natural landscapes through space images is the morphometric index of the relief. The three main parameters of the relief - the distribution of heat and solar radiation, hydrological runoff and glaciers, allow us to determine the landscape-geochemical mechanisms of material transport. Morphometric indicators include surface slopes, absolute height, horizontal and vertical fragmentation, water catchment area, radiation balance and slope orientation.

These indicators provide the energy of the landscape. Landscape energy refers to its activity in the absorption, transformation, accumulation and release of energy. Vertical relationships in geocomplexes and many horizontal formations are directly or indirectly related to the conversion of solar energy. The conversion of incoming solar radiation begins with its absorption, although part of it is reflected from the earth's surface. Radiation losses due to reflection vary depending on the nature of the surface. Energy conversion is an important indicator of the intensity of operation and associated stability of geocomplexes. Their annual cycle of activity depends on the periodic supply of solar energy. The cyclical nature of their activity processes is accompanied by changes in the vertical structure.

During the study, the current state of the territory, including the degradation of the components of the landscape environment, was comprehensively studied. Data on the natural conditions and technogenic loading of the study area were collected during the current period, as well as geological, engineering-geological, hydrogeological, climatic, landscape, soil, geobotanical, zoogeographical and geoecological data, including existing thematic maps, were analyzed. Their processing allows us to create a complete picture of the geoecological characteristics of the landscapes of the territory. The list of characteristics determined on the basis of available materials includes parameters of the ecological state of the components of the landscape environment and components of anthropogenic impact. The nature and characteristics of their impact on the ecological state of the territory were determined on the basis of stock materials and maps, satellite images for each of the analyzed components. The analysis of the available materials was supplemented with data from the decoded satellite image.

At the same time, the image was correlated with topographic maps, as well as with existing thematic schemes and maps, man-made objects and infrastructure (industrial facilities, transport routes, pipelines, quarries, etc.) that affect the state of the natural environment were identified, areas of development of dangerous natural-man-made processes and events were determined, the negative consequences of direct anthropogenic impact were initially assessed (pollution areas, burned areas, deforestation, land acquisition and other violations of vegetation and soil cover), planning of ground works was carried out, including the location of key areas and control routes. A preliminary map was compiled taking into account the analysis of reserves and published materials, preliminary interpretation of satellite imagery, etc. At the same time, the nature of land use, the location of existing man-made sources of impact and designed objects, sanitary-protective and water protection zones, protected areas, places where environmentally unfavorable processes for the natural environment occur were taken into account. In the absence of the necessary primary data, additional field studies were also conducted with the required level of detail.

The study of vegetation and soil cover was carried out in three aspects. These are:

• as an indicator of natural conditions and their change (degradation) under the influence of anthropogenic impact;

• as a biotic component of the natural environment, playing a decisive role in the structural and functional organization of ecosystems and determining their boundaries;

• as an indicator of the level of anthropogenic load on the natural environment (burned areas, overgrazing, mechanical damage, damage from technogenic emissions, changes in species composition, reduction of vegetation cover, productivity).

The result of the work was the transformation of the components of the analysis of the current geoecological state of the territory into a single measurement system - a scoring system. Extrapolation of spatial data was carried out in the Golden Software Surfer program. When calculating the surface and its description, the boundary of the territory of an arbitrary configuration was determined. The resulting contour map was exported to ArcGIS, and the layers of borders, infrastructure, rivers, lakes, settlements, peaks, etc. were combined. This made it possible to create a single cartographic product.

Natural differentiation determines the genesis of modern landscapes of the territory, which were subsequently subjected to anthropogenic differentiation or evolved naturally. We consider it appropriate to include a new typological unit in it - a landscape subtype, which would indicate the degree of anthropogenic transformation of the landscape type. Within each landscape type (for example, the main moraine plain), according to the characteristics of anthropogenic differentiation of the environment, we have identified three main subtypes of landscapes: conditionally natural (almost unchanged), their appearance is associated with natural features (relief, quaternary and basic rock beds, etc., and the structure of all layers of the composition is preserved), cultural (modified by man) or recreated by him – artificial landscapes.

Conditionally natural landscapes include high mountains, bare rocks, glaciers, which are not affected by any type of human activity. The other two types can be further divided by settlement and land use systems, since their appearance and structure are determined by the characteristics of human activity.

Cultural landscapes are those that have been transformed by human activity, usually as a result of the development of agriculture, forestry, and settlements. Among these landscapes, it is necessary to distinguish between purposefully created and accidentally (spontaneously) modified (most often disturbed) landscapes. This category also includes natural landscapes whose state is regulated by humans. These include protected areas, ecological corridors and junctions, as well as technogenic parks, forest plantations, and others. In most of them, human activity changes one or more components of the original landscape and is limited to the local and regional scale of landscape genesis.

Artificial landscapes include landscapes created entirely by man, where natural conditions are often limited to a geographical location, and the proportion of artificial components of the landscape exceeds the proportion of natural ones. Artificial landscapes can also include landscapes of large cities and their agglomerations, where all components of the landscape have undergone transformation and the introduction of newly created human components has occurred both on the surface of the original

landscape and in its depth (underground). In this case, the creation of an artificial landscape by man can consist both in the addition of artificial components to the landscape composition (as occurs during above-ground construction), and in the removal of huge masses of the lithogenic base, where the upper floors are built, and the landscape composition also disappears (table 1).

Table 1. Modern landscape subtypes and their structure

Degree of anthropogenic changes (in points)	Landscape subtypes				
	Conditionally natural	cultural			Artificial
		adjustable	converted		
	1	2	3	4	5
Features of anthropogenic changes in the original natural landscape	The structure of the original landscape is completely preserved, minor changes in fauna are possible	The original natural or previously modified structure is preserved, changes in biocenoses are possible (the main features of the zonal vegetation are preserved)	The structure of the original landscape has been altered: the main features of the vegetation have been changed or lost, the soil cover has been changed, the microrelief has been altered.	The structure of the original landscape has changed significantly: natural soil and vegetation have been lost, replaced by anthropogenic changes, and the relief has been altered.	The structure of the original landscape has been lost down to the relief and lithogenic base.
Functional cohort example	Nature reserves (strictly protected areas)	National parks, elements of the ecological framework	Agricultural and forestry landscapes, rural settlements, recreational facilities	Small and medium-sized cities, transport infrastructure facilities	Large cities and agglomerations, quarries, large structures (dams, etc.)

In landscape areas with low socio-economic conditionality of modern landscape genesis, conventional natural landscapes prevail, in areas with a high degree of cultural and artificiality (Table 2):

Table 2. Proportion of landscape subtypes in areas with different socio-economic conditions (I – indicator value)

Type of modern landscape area	Content of landscape subtypes within a landscape area		
	Conditional natural landscapes	Cultural landscapes	Artificial landscapes
Naturally designated areas (I<13)	≥ 50%	10–50%	< 1%

Mixed fields (I = 14-16)	25–50%	50–75%	1–5%
Socially defined areas (I>17)	<25%	>75%	>75%

Taking into account the above, we conducted a zoning of landscapes in our study area according to their geoecological status. At this time, we distinguished 4 criteria: landscapes whose geoecological status is conditionally unchanged, landscapes with weak changes, medium changes, and strong changes (Figure 2).

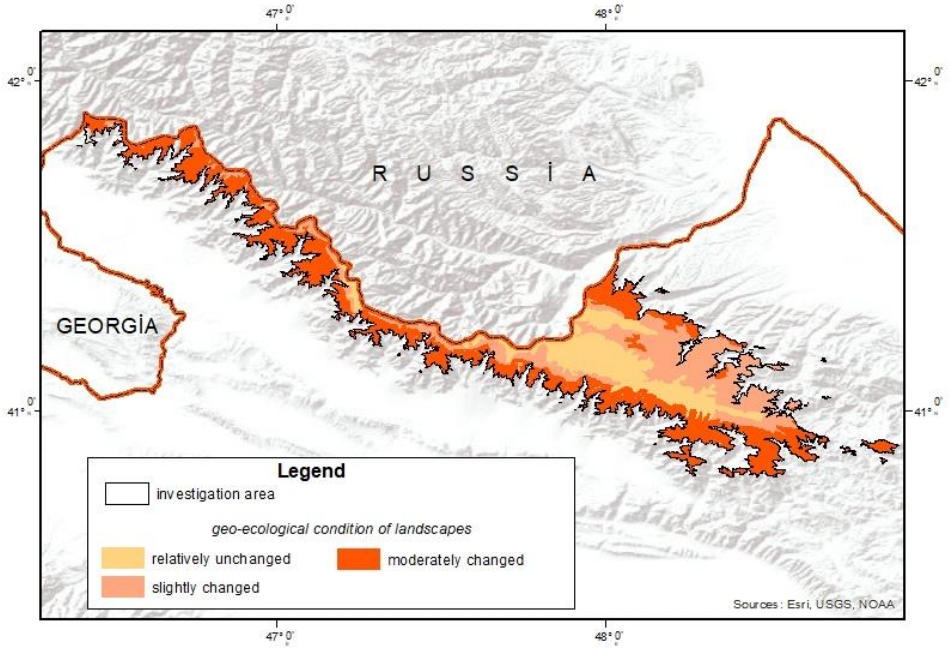

Figure 2. Zoning of landscapes according to geoecological status

According to these analyses, 96,596 ha of the study area belong to landscapes with conditionally unchanged geoecological status, 78,265 ha to landscapes with weakly changing status, and 146,683 ha to landscapes with moderate changing status (Table 3).

Table 3. Results of zoning of landscapes according to geoecological conditions

№	Geoecological situation	Area		Areas covered	Appropriation	Transformation state
		ha	%			
1	unchangeable	96596	30	Upper boundary of nival and subnival landscapes	Seasonal exploitation, important areas for mountain tourism	Relatively untransformed
2	slightly changed	78265	24	The lower limit of subnival landscapes and the upper limit of alpine meadows	Summer pastures	Weakly transformed, partial erosion of soils, partial degradation of vegetation cover
3	average changed	146683	46	Lower border of alpine	Summer pastures, settlements,	Vegetation degradation,

				meadows, subalpine meadows and mountain forests	partially cultivated areas	erosion dominance
4	Total	321544	100			

Conclusion

Our research, within the framework of the system paradigm and using GIS technologies, allowed us to study the main opportunities and ecological problems in the development of the high mountain landscapes of the Greater Caucasus. Based on the conducted research, a map of geoecological zoning of landscapes was compiled. It was determined that 30% of the total area belongs to landscapes whose geoecological state is conditionally unchanged, 24% to landscapes with weak changes, and 46% to landscapes with moderate changes.

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XÜLASƏ

YÜKSƏK DAĞ LANDŞAFTLARININ GEOEKOLOJİ VƏZİYYƏTİNİN CİS TEXNOLOGİYALARI İLƏ QİYMƏTLƏNDİRİLMƏSİ (BÖYÜK QAFQAZ TİMSALINDA)

Ülviyə Qasımova

Antropogen təsirlər nəticəsində nəinki düzənlik, hətta dağlıq ərazilərdə də landşaftlarda baş verən dəyişiklikləri müşahidə etmək mümkündür. Xüsusilə qlobal istiləşmə nəticəsində yüksək dağlıq ərazilərdə buzlaqların əriməsi, buzlaq sahələrinin kiçilməsi buna nümunədir. Bu zaman onların uzun müddətli tədqiqi vacibdir. Bu baxımdan tədqiqatımız aktual mövzuya həsr edilib. XXI əsrdə ərazinin tədqiqi zamanı müasir metodlardan istifadə edərk uzun müddətli tədqiqatlar aparmaq üçün müxtəlif

imkanlar var. Biz də bu məqalədə Böyük Qafqazın yüksək dağ landşaftlarında geoekoloji vəziyyətin CİS texnologiyaları ilə tədqiqi və onun nəticlərini təhlil etmişik. Bu zaman müasir metod və üsullara, müasir mənələrə, peyk şəkillərinin emalı və təhlilinə üstnülük verilmişdir. Bununla yanaşı çöl tədqiqatı və bizdən öncəki tədqiqatçıların materiallarından da istifadə edilmişdir. Landşaftların geoekoloji vəziyyətinin təhlili zamanı öncəki tədqiqatlarımızdan əldə edilən bitki örtüyünün, torpaq örtüyünün və səth temperaturunun tədqiqinin nəticələrindən də istifadə etmişik. Aparılan tədqiqatlar nəticəsində tədqiqat ərazisində landşaftlarn geoekoloji vəziyyətinə görə rayonlaşadırılması aparılmış və 3 klassifikasiya ayrılmışdır: nisbi olaraq dəyişilməyən, zəif və orta dərəcədə dəyişilən landşaftlar. Müəyyən olunmuşdur ki, ərazinin əksər hissəsi nisbi olaraq dəyişilməyən və orta dərəcəd dəyişilən ərazilərə aiddir. Bunun əsas səbəbi ərazinin mənimsənilməsi üçün relyefinin əlverişsiz olmasıdır. Lakin ərazidə ən məhsuldar yay otlaqlarının da olduğunu nəzərə alsaq, burada bitki örtüyünün deqradasiyası və torpaqların eroziyası kimi problemlərin də olduğunu müşahidə edirik.

Açar sözlər: *Böyük Qafqaz, yüksək dağlıq, CİS texnologiyası, landşaft, geoekoloji vəziyyət*

РЕЗЮМЕ

ОЦЕНКА ГЕОЭКОЛОГИЧЕСКОЙ СИТУАЦИИ ВЫСОКОГОРНЫХ ЛАНДШАФТОВ С ПОМОЩЬЮ ГИС-ТЕХНОЛОГИЙ (НА ПРИМЕРЕ БОЛЬШОГО КАВКАЗА)

Ульвия Гасымова

В результате антропогенного воздействия можно наблюдать изменения ландшафтов не только на равнинах, но и в горных районах. Примером этого, особенно в результате глобального потепления, является таяние ледников в высокогорных районах и сокращение площадей ледников. В настоящее время важно их долгосрочное изучение. В связи с этим наше исследование посвящено актуальной теме. В 21 веке при изучении территории открываются различные возможности для проведения долгосрочных исследований с использованием современных методов. В данной статье мы также с помощью ГИС-технологий проанализировали геоэкологическую ситуацию в высокогорных ландшафтах Большого Кавказа и ее результаты. На этот раз были представлены современные методы и приемы, современные средства обработки и анализа спутниковых изображений. Кроме того, были использованы полевые исследования и материалы предыдущих исследователей. При анализе геоэкологического состояния ландшафтов мы также использовали результаты исследований растительного покрова, почвенного покрова и приземной температуры, полученные в результате наших предыдущих исследований. В результате проведенных исследований ландшафты района исследований районировались по геоэкологическому состоянию и были разделены на 3 классификации: относительно неизмененные, слабо и умеренно измененные ландшафты. Определено, что большая часть территории относится к относительно неизмененным и умеренно измененным участкам. Основная причина этого в том, что рельеф местности неблагоприятен для разработки. Однако, если принять во внимание, что в этом районе также есть наиболее продуктивные летние пастбища, мы увидим, что существуют и такие проблемы, как деградация растительности и эрозия почвы.

Ключевые слова: *Большой Кавказ, высокогорье, ГИС-технологии, ландшафт, геоэкологическая ситуация.*