

ANALYSIS OF THE REGULARITY OF DISTRIBUTION OF
NATURAL LANDSCAPES IN THE GREATER CAUCASUS
DEPENDING ON PHYSICAL-GEOGRAPHICAL
CHARACTERISTICS USING GIS TECHNOLOGY

Afag Z. Hajiyeva[✉], Firuza M. Jafarova

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Abstract

Natural geographic conditions play an important role in the formation and development of landscapes. Various factors of natural conditions, especially the absolute height of the relief, slope, aspect, horizontal and vertical fragmentation, have been widely studied since the 20th century. Nowadays, these factors are studied through geographic information technologies, on the basis of satellite images and Remote Sensing materials. Therefore, our research is dedicated to the actual topic. We also conducted analyses based on modern methods in the Great Caucasus natural region, which is our research area. At this time, we have analyzed the absolute height of the relief, aspect and inclination of the slopes using the Digital Elevation Model of the area. As a result of the conducted research, we have determined that desert and semi-desert landscapes were formed in areas with low absolute height and inclination, and forest, alpine, subalpine, nival and subnival landscapes were formed in areas with high absolute height and inclination. Forests are mostly found on the northern slopes, and semi-desert and desert landscapes are widespread on the southern slopes.

Key words: Greater Caucasus, geographic information systems, aspect, slope, differentiation

Introduction. As we know, geocomplexes are formed and developed as a system. The elements of this system are geographical components and their

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elements. The stability of the landscape depends on these components being constantly stable and resistant to the environment within the geosystem [1]. If one of the components that make up the geosystem does not participate in this system, then a weakening occurs within the system and its stability decreases [2]. If the connection between most of the components is weakened, then geosystems change from one form to another. As an example, we can say that semi-deserts become deserts, forests turn into steppes. All these changes depend on the slope of the natural landscape, the aspect and the hypsometric structure [3].

If the connections of the leading components of geosystems become too weak, then after a while the geosystem will lose its structure and another complex will be formed in its place [4]. For example: if a forest is completely destroyed, a steppe or forest-steppe is created in its place. In the modern stage of development of landscape complexes, anthropogenic factors, along with natural-geographical factors, dominate their change [5].

Any anthropogenic impact directly or indirectly increases morphological differentiation within a natural landscape [6]. Complexes of anthropogenic origin cause a qualitative change in the structure of the landscape with the creation of new morphological units. Therefore, the changes occurring in the structure of each territorial complex should be systematically studied, along with the historical path, various aspects and traces of human influences. It is on its basis that optimal loading of landscapes, systematic management and balanced development of each natural complex should be determined [7]. In order to assess the ecological conditions of the natural landscapes of individual regions of Azerbaijan, it is of great importance to study the laws of anthropogenic transformation of landscape types. The natural landscapes of the Greater Caucasus, which have complex orographic conditions and ecogeomorphological stress, have been drastically changed as a result of centuries-old human influences. Most of the natural landscapes, especially the steppe, forest-steppe and forest landscapes of the foothills, lowlands, intermountain depressions, have been subjected to anthropogenic transformation and to varying degrees of stress [8].

Each natural and anthropogenic landscape complex is formed as a result of long-term natural-historical processes. The anthropogenic factor plays a leading role in the replacement of forests, grasslands, steppes, forest-deserts and others with artificial complexes. Therefore, modern natural and anthropogenic complexes cannot be separated from each other by sharp boundaries. Modern anthropogenic landscapes have a unique pattern of anthropogenicization of farmlands, garden plantations, agricultural complexes, and various infrastructures. The systematic study of these regularities has both practical and great scientific importance [9].

The modern landscape map of the Greater Caucasus, i.e., the map depicting the transformed territorial units of natural landscapes in a modern form, was compiled as a result of long-term research (2000–2013) based on the analysis of

both visual and satellite images. In the following years, the anthropogenization and transformation of natural landscapes were clarified with GIS technology and the obtained scientific results were systematized.

Material and methods. Data on both quantitative and qualitative characteristics of landscapes and their components are collected by mathematical statistical methods and analyzed based on special criteria. Through mathematical methods, a number of patterns of differentiation, structural-functional characteristics, quantitative and qualitative characteristics of landscapes are evaluated more accurately.

The Digital Elevation Model (DEM) (<https://earthexplorer.usgs.gov/>) was used to determine the dependence of natural and anthropogenic landscape transformation patterns on relief and its morphometric indicators in the studied region. The Digital Elevation Model of the study area is freely downloaded from the <https://earthexplorer.usgs.gov/> website. This time, the Shuttle Radar Topography Mission (SRTM) satellite image from the first half of 2023 has been downloaded. Based on it, a map of the absolute height of the relief was prepared.

Later, it was processed using the slope formulas shown in the results part of the study, and a corresponding map was prepared with the ARCGIS software, and analyses were carried out.

Also, by applying relief exposure, horizontal and vertical division formulas, relevant maps of the area were prepared and analyses were carried out.

Results. *Distribution of natural landscapes depending on hypsometry and analysis based on GIS.* As a result of research, it was determined that the formation of landscape complexes in different types of morphostructures characteristic of the Greater Caucasus is contradictory. Thus, depending on the height in the mountain massifs and ridges, the differentiation of landscapes as a whole is strengthened or weakened. Landscapes of mountainous plateau morphostructures are characterized by a type of landscape compared to mountain range morphostructures. This is due to the fact that the mountainous plateaus have a relatively smooth surface, as a result of which they do not create a barrier against air masses. Since intermountain depressions are surrounded by morphostructures of different genesis from all sides, and have different absolute heights, they create special landscape types and subtypes. The analysis of the orotectonic features of the studied area allows us to distinguish a number of longitudinal and transverse morphotectonic steps and their corresponding landscape types.

In addition, morphosculpture relief forms such as gorges, ravines, valleys and depressions, protruding slopes, wide and narrow watersheds, pseudokarstic depressions and others are characteristic of the mentioned area. The abrupt change of relief creates complexity and leads to differentiation of landscapes. Accordingly, it can be noted that the dry-desert landscape, which is mainly characteristic of the area, is found not only in the upper part of the low highlands, but also at the bottom of a number of depressions in the middle highlands (Fig. 1).

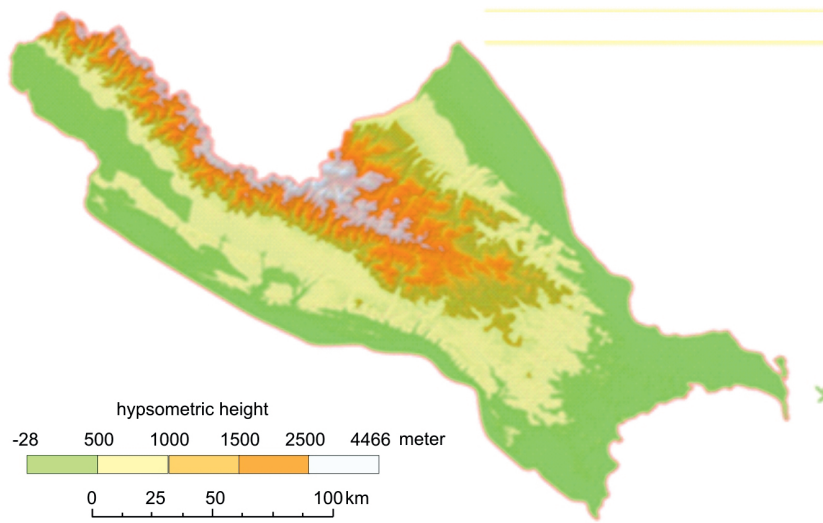


Fig. 1. Hypsometric elevation map of the Greater Caucasus and the surrounding plains

A hypsometric elevation map of the Greater Caucasus and its surrounding regions was prepared based on the ArcGIS software to determine the regularity of the distribution of landscapes on hypsometric levels. At this time, the classification was carried out in the order of -28 – 500 m, 500 – 1000 m, 1000 – 1500 m, 1500 – 2500 m, 2500 – 4466 m.

The analysis of this map shows that semi-deserts, dry deserts and steppes spread in areas up to 500 m absolute height. Mountain forests between 500 – 1500 m absolute altitudes, subalpine and partially alpine meadows at 1500 – 2500 m absolute altitudes, and subnival and nival landscapes spread in higher areas.

At the same time, the vast majority of fundamentally changed landscapes were formed at absolute altitudes from -28 m to 500 m, and weakly changed landscapes were formed in areas higher than 2500 m.

Distribution characteristics of natural landscapes depending on inclination. The role of morphometric elements of relief in the formation of landscapes in the mountainous parts of the studied area has been widely studied by researchers. However, depending on the planetary and regional position of the mountains, the role of morphometric elements in landscape development can change to a unique extent. For example: in the Azerbaijani part of the Greater Caucasus, its southern slope region receives more precipitation mainly because it is turned towards humid westerly air currents, and mountain-forest landscapes are widespread here.

The following slope formula was used to determine the slope:

$$i = \frac{h}{d} \operatorname{tg} \alpha,$$

where h denotes the hypsometric curves (the maximum and minimum hypsometric difference of the slope), and d is the distance between two horizontals.

With its help, the data taken from the <https://earthexplorer.usgs.gov/> resource was analyzed using the Spatial Analyst/Surface/Slope sequence in the Arcmap 10.3 program to prepare the slope map. This operation is calculated by the following formula:

$$\alpha = \operatorname{tg}^{-1} \left(\sqrt{\left(\frac{dz}{dx} \right)^2 + \left(\frac{dz}{dy} \right)^2} \right) * 57.29578,$$

where α is the inclination angle, $\operatorname{tg}^{-1} = 1/\operatorname{tg}$, dz/dx is the value of change of the surface in the horizontal direction from the central raster cell, and dz/dy is the value of change of the surface in the vertical direction from the central raster cell.

The analysis of the inclination map shows that the areas with $0-5^\circ$ inclination cover more territory in the Greater Caucasus (228 000 ha). Here, steppes of foothill plains, forest-steppes, sparse forest thickets prevail. Areas with a slope of $5-10^\circ$ are mainly located in the low mountains and foothills (104 000 ha). Forest and forest-meadow landscapes mainly spread in these regions. In the mentioned areas, the surface of the relief is weakly and moderately fragmented. Morphological differentiation of landscapes increases according to surface fragmentation on slopes with an inclination of $10-15^\circ$ (71 000 ha).

The activity of exodynamic processes increases at absolute heights (74 000 ha) with greater inclination ($15-20^\circ$, $20-25^\circ$). The weak stability in the development

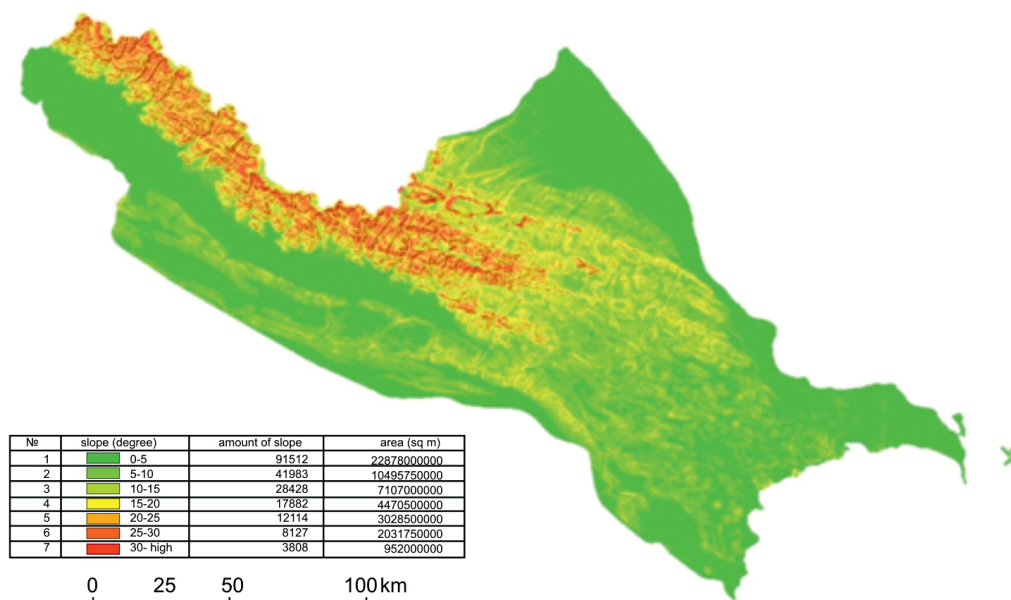


Fig. 2. Slope map of Greater Caucasus and surrounding plains

and formation of mountain meadow, subnival and nival landscapes with an inclination of 25–30° (20 000 ha) and more than 30° clearly indicates high dynamism in the morphogenetic characteristics of landscapes.

Analysis of the characteristics of changes in natural landscapes depending on the aspect of the relief. When preparing the aspect map of the area, the DEM (Digital Elevation Model) file was taken from <https://earthexplorer.usgs.gov/> and the analysis was performed on that file using ArcMap 10.3 in the order of Spatial Analyst-Surface-Aspect.

The analysis of the aspect map prepared by ArcGIS 10.3 program for the Greater Caucasus shows that the vertical differentiation of natural and anthropogenic landscapes is highly dependent on the aspect of the slopes. In the vast studied region, slopes with a smooth surface occupy only 3% of the area (13 800 ha). A large part of them covers the north-east of the Greater Caucasus, the Gusar sloping plain and Absheron-Gobustan areas. In the region, the southern slopes (south, southeast and southwest) cover a wider area. This type of slopes cover more than 212 000 ha of the region, and arid sparse forests and bushes (on the south-eastern slope, Ajinohur-Jeyranchol, Absheron-Gobustan), oak and oak-forest-shrub landscapes prevail here.

The northern slopes mainly cover the north and north-eastern expansive moist slopes of the region (more than 54 800 m). More than 50% of these slopes are covered with peanut and peanut-hornbeam forests.

The horizontal distribution map was prepared on the basis of the topographic map on a scale of 1:100 000 (Fig. 4a). For this purpose, the lengths of the stream

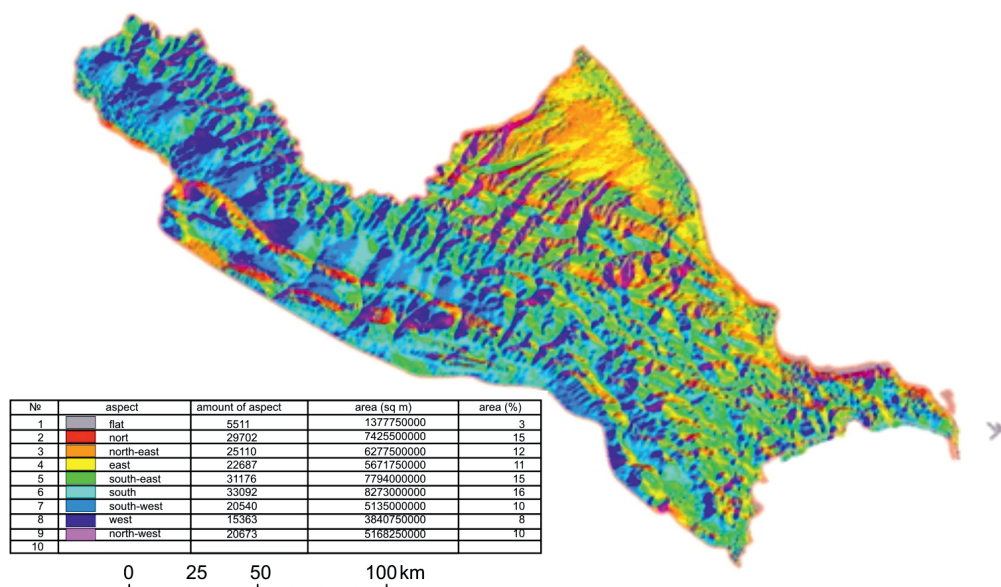


Fig. 3. Aspect map of the Greater Caucasus and the surrounding plains

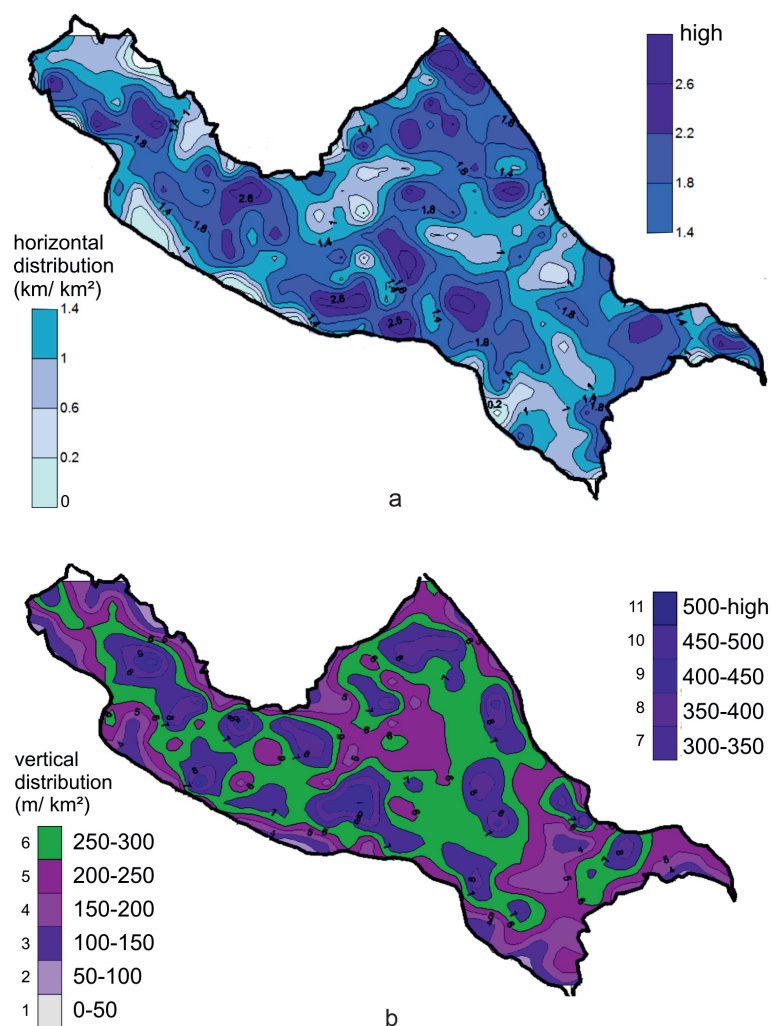


Fig. 4. a) Horizontal and b) Vertical distribution maps of the Greater Caucasus and the surrounding plains

network falling on a single area are measured on the map and divided by the area of that place. The horizontal split is determined by the following formula:

$$K = L/S,$$

where L is the length of the river-valley-ravine-gorges complex in km, S is the area of the square in km^2 , and K is the amount of fragmentation.

After determining the value of fragmentation, isolines are drawn at certain intervals and maps are prepared based on the Arcmap 10.3 program, covering the same quantitative indicators.

The vertical distribution map was calculated according to the hypsometric differences of the area based on Arcmap 10.3 software (Fig. 4b). The amount

of fragmentation is calculated according to the ratio of the difference between the absolute height of the lowest point of the erosional relief element, such as a gorges, valleys, ravines, etc., per unit area, and the highest absolute value within that area:

$$\Delta H = H_1 - H_2.$$

Here H_1 is the highest value within the square, H_2 is the lowest value, and ΔH is a quantitative indicator characterizing the depth of vertical splitting.

Conclusion. It is known from our research that the differentiation of anthropogenic landscapes in the territory of the Greater Caucasus depends on the relief of natural landscapes, the development characteristics of the economy, the level of settlement, and others. Mathematical relationship graphs show that the value of the asymmetry coefficient of the landscape contours per unit area is directly proportional to the coefficient of variation. Digital mathematical-cartographic map models clearly show that the differentiation of anthropogenic landscapes depends on the relief, the development of the economy and the level of settlement.

A vector map model was created for the modern landscapes of the studied region using geoinformation technologies, and a regional geoinformation model of landscape differentiation was given based on that model.

REFERENCES

- [1] DOVLÉN S. (2016) A relational approach to the implementation of the European Landscape Convention in Sweden, *Landsc. Res.*, **41**(8), 950–965, <https://doi.org/10.1080/01426397.2016.1174771>.
- [2] MELNYCHUK A., O. GNATIUK (2018) Regional identity and the renewal of spatial administrative structures: The case of Podolia, Ukraine, *Morav. Geogr. Rep.*, **26**(1), 42–54, <https://doi.org/10.2478/mgr-2018-0004>.
- [3] BREUNIG M., P. E. BRADLEY, M. JAHN et al. (2020) Geospatial data management research: Progress and future directions, *ISPRS Int. J. Geo-Inf.*, **9**(2), 95, <https://doi.org/https://doi.org/10.3390/ijgi9020095>.
- [4] MACIAS A., S. BRÓDKA, M. KUBACKA, W. PINIARSKI (2020) Physical and geographical regionalization and environmental management: A case study in Poland, *Pol. J. Environ. Stud.*, **4**(29), 2753–2762, <https://doi.org/10.15244/pjoes/110756>.
- [5] MATTEUCCI S. C., G. F. CARTEI (2022) The impact of the European Landscape Convention on landscape planning in Spain, Italy and England, *J. Environ. Law*, **34**(2), 307–330, <https://doi.org/10.1093/jel/eqac004>.
- [6] SILVA-COIRA F., J. R. PARAMÁ, S. LADRA, J. R. LÓPEZ, G. GUTIÉRREZ (2020) Efficient processing of raster and vector data, *PLoS ONE*, **15**(1), e0226943, <https://doi.org/10.1371/journal.pone.0226943>.
- [7] DE MONTIS A. (2014) Impacts of the European Landscape Convention on national planning systems: A comparative investigation of six case studies, *Landsc. Urban Plan.*, **124**, 53–65, <https://doi.org/10.1016/j.landurbplan.2014.01.005>.

- [8] HAJIYEVA G. N., A. Z. HAJIYEVA, F. M. JAFAROVA (2023) Ecological problems associated with land cover in the Great Caucasus and important aspects for efficient use, *Revista Universidad y Sociedad*, **15**(1), 277–284, <https://rus.ucf.edu.cu/index.php/rus/article/view/3540>.
- [9] AMANOVA SH. (2022) Geo-ecological situation and forecasting of coastal cities of Azerbaijan, *Grozny Natural Science Bulletin, Earth Science*, **7**, 1(27), 5–13.

State University of Economics (UNEC), 6 Istiglaliyyat St, AZ1001, Baku, Azerbaijan
e-mails: afaq.adu@mail.ru, jafarova_firuza@mail.ru