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Relief morphometry as a factor of formation and spatial differentiation of highland landscapes of the major Caucasus

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Abstract

The article analyzed the morphometric indicators of the topography of the highland part of the Greater Caucasus (hypsometric height, slope and aspect of topography, horizontal and vertical division). The height amplitude in this zone is high, leading to the mentioned parameters' diversity. The fact that topography plays a vital role in the formation and distribution of the landscape makes the analysis of morphometric indicators relevant in the investigated area. Landscapes spread in the mountainous zone are divided into different facies and zones depending on the slope and aspect of the topography both horizontally and vertically. The reason for this is that the topography affects climate change. Modern methods were used during the research. For this, the Digital Elevation Model of the area was processed. As a result of processing, height, slope, and aspect maps were compiled. The main goal of the research is to analyze the factors affecting the formation of the landscape, the morphometric elements of the topography based on modern methods and analyze the results. As a result of the study, it was determined that the morphometric indicators of the topography play an important role in the formation of landscapes. As a result of our analysis, it was determined that different half-types of nival, subnival, alpine, and subalpine landscape types are distributed in the research area.

1. Introduction

The relief is recognized by all researchers as the main factor in the landscape differentiation of the territory. Due to the development of digital technologies and the wide availability of remote sensing data, a detailed assessment of the relief as a landscape-forming factor has become possible. Thus, the use of digital elevation models has simplified the morphometric analysis of the relief. The relief and its parameters are recognized as the most important in the selection of natural-territorial complexes of the highest classification ranks. To identify the NTC of different levels and create a landscape map, it is necessary to analyze the relief: first of all, the distribution of heights, steepness, and exposure of slopes. Heat and water balances depend on these factors in mountainous conditions. They, in turn, directly impact the distribution of soil and vegetation cover (Budagov, 1973, 1988, Solntsev, 2001).

2. Method

Morphometric relief analysis is one of the methods of geomorphological research, in which the quantitative characteristics of landforms are studied using special measurements. Usually, the absolute and relative heights of individual landforms or their complexes, slope angles, exposure of theories, areas occupied by positive and negative forms, and some others are measured (Kirillova, 2010).

3. Results

A significant number of works are devoted to the problems of quantitative description of the relief (Kuchinskaya, 2011, Hajiyeva, 2017). Morphometric analysis of the relief today is carried out using a digital elevation model (DEM). The creation of DEMs of different resolutions has begun, which in GIS technologies perform, to a certain extent, the functions of map scales.

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The territory of the high-mountainous Greater Caucasus was analyzed using the ArcGIS package based on the DEM. The Shuttle Radar topographic mission (SRTM) radar survey results, designed to build a high-precision global DEM network, were used as a basis. Its root-mean-square error is estimated at a height of about 16 m, and the accuracy of the position of the three-second grid nodes is about 20 m, while in mountainous terrain these indicators become higher. Such accuracy of the DEM corresponds to the goals set in the work.

4. Discussion

The corrected SRTM image with a resolution of about 60 m is suitable for performing morphometric analysis and building corresponding maps in a GIS environment. Image editing, related to the identification and subsequent elimination of minor errors, was carried out using the tools of the ArcGIS package and its Spatial Analyst module. The same program was used in the primary calculations and mapping. The map of slope steepness (angles of inclination of the earth's surface) was built using the Special Analyst function and its Surface analysis option. Initially, the map was obtained in raster representation and then it was converted to vector. As a result of the conversion, polygons of different steepness were obtained in the vector map of slope steepness. At the same time, a hypsometric map was initially built with given height steps, then the minimum and maximum slopes and areas of polygons were calculated by height steps. The slope exposure map was built in a similar way. According to this method, a hypsometric map and a map of the steepness of the slopes were compiled for the territory of the high-mountainous Greater Caucasus on the basis of digital elevation models. Further, thematic layers were superimposed on these maps - rock lithology (geological), distribution of climatic parameters (temperature, precipitation, moisture - Ku), hydrographic network, vegetation, soil cover, as well as available landscape maps.

Greater Caucasus major range of the Caucasus Mountains extending west-eastern for about 1200 km from the Taman Peninsula on the Black Sea to the Absheron peninsula on the Caspian Sea. Our investigation territory is a highland area of the Greater Caucasus. The territory of this area is 313486 km^2. As can be seen from the above data, the foothills occupy 35% of the entire area of the high-mountainous strip of the Caucasus (Figure 1). At the same time, altitudes 1800–2300 m - 165711 km^2 (49.9%), and 2301–3200 m - 139096 km^2 (41,9%), and above 3201 m - 26679 km^2 (8,2%). That is, in geomorphological terms, high mountains are more widely represented on the territory of the Greater Caucasus, while the middle mountains occupy a slightly smaller area.

The largest area in the low mountains is occupied by elevations of 200–400 and 400–600 m, which include the front ranges. As for the middle mountains, here the distribution of the territory is quite uniform. In the highlands (up to 3000 m), an increase in the proportion of territories with altitudes above 2500 m is noticeable, which can be explained by the presence of significant leveling surfaces both on the Skalisty Ridge and in Intramountainous Dagestan. The highest parts of the mountain structure do not occupy such a significant area. The landscapes of the foothills, low mountains, and low mountains, which rise to 1000–1200 m, are noticeable, up to 600 m, almost completely occupied by them. Territories with 600–800 m elevations gravitate towards the foothills, and with a further increase in the absolute height of the low mountains and foothills, they gradually turn into the actual mountain structure. The distribution of the territory depending on the steepness of the slopes is illustrated.

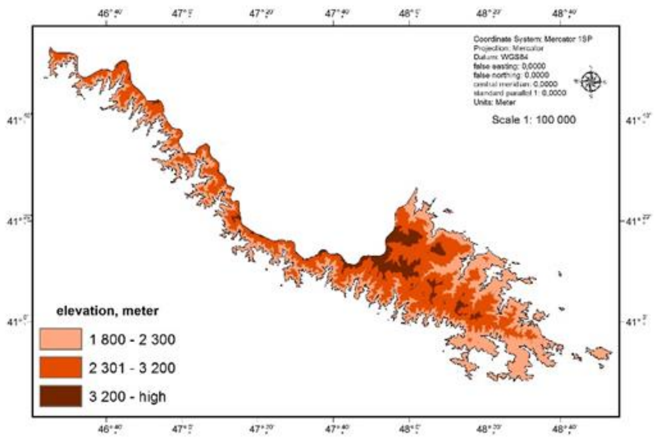

Figure 1. Hypsometric height map of the highland part of the Greater Caucasus

On the territory of the high-mountainous Greater Caucasus, there are slopes with a steepness of up to 45 °. Surfaces with a steepness of up to 10° occupy 41601 km^2 (12.5%). Geomorphologically, they correspond to the plains. In the mountainous part of the territory with such steep slopes, it is most often observed either in basins or these are leveling surfaces in rather elevated parts (mountain plateaus). Slopes with different degrees of slope (from 11^0 to 15°) occupy the largest, in comparison with other slopes - up to 48606 km^2 (14.6%). The next group of slopes is slopes of medium steepness (16–25°), occupying 120144 km^2 (36.6%). Steep slopes (26-30°) occupy 102428 km^2 (30.9%). Steep slopes (36–41°) occupy 17169 km^2 (5.2%). And, finally, sheer cliffs occupy a negligible area. As for the foothill, low-mountain, and low-mountain landscapes, here slopes with a steepness of up to 10° account for more than 50% of similar slopes that have become widespread throughout the North-Eastern Caucasus (Figure 2).

As the steepness of the slopes increases, the proportion of the territory that is located within the mountainous structure of the Greater Caucasus increases. On the whole, within foothill landscapes, a fairly significant proportion of slopes with a steepness of up to 25° is still preserved, and steeper slopes are not typical for the category of foothill, low-mountain, and low-mountain landscapes. Another important morphometric characteristic is sloping exposure (Nikolaev, 2003, Geography, 2015).

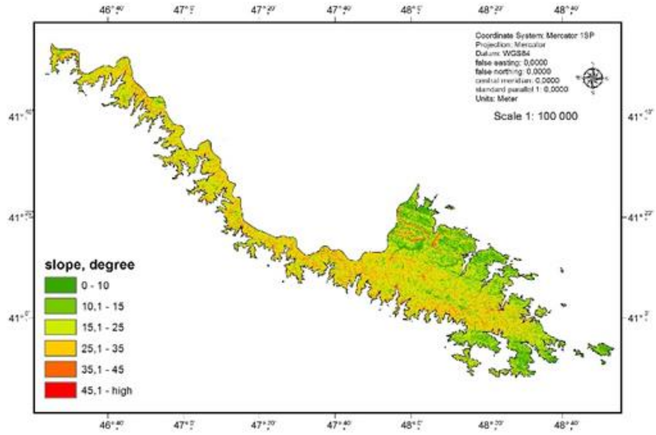

Figure 2. Slope map of the highland part of the Greater Caucasus

As can be seen from the above data, for the high-mountainous Greater Caucasus, the most characteristic are the slopes of the northern points, the total share of which is 42.9%, which is easily explained by the position of the territory on the northern macroscope of the Greater Caucasus. The slopes of the southern points account for 31.3%. From the position of atmospheric circulation, the slopes of the western points, which receive the maximum amount of precipitation in temperate latitudes, occupy more than 30% (33.2%), and the eastern ones - about 40% (39.9%). That is, the combination of these factors leads to the fact that there are more widely represented locations in which there is some lack of heat and moisture. As for foothills, low-mountain, and low-mountain landscapes, flat surfaces are absolutely typical only for foothill landscapes, since they account for 173 out of 174 km^2 (99.4%). The slopes of other exposures here occupy, on the whole, an area proportional to the total area (Figure 3).

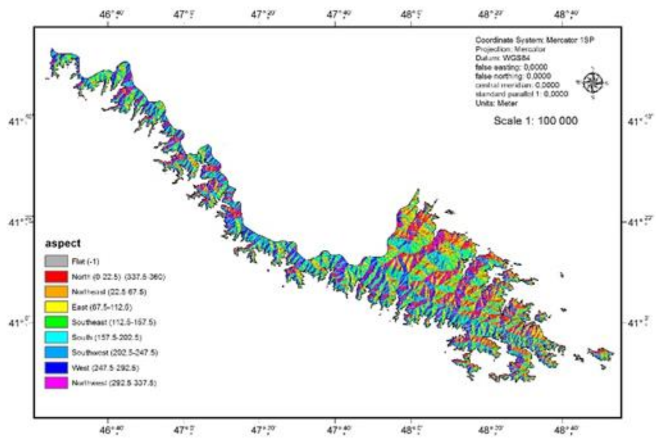

Figure 3. Aspect map of the highland part of the Greater Caucasus

5. Conclusion

Based on the research carried out, the following conclusions can be drawn. The most pronounced factor in assessing the aesthetic properties of the territory is the relief, and the assessment of landscapes should begin with it. An analysis of the relief of the territory, performed on an appropriate scale, allows you to accurately and quickly assess the aesthetic attractiveness of the routes in order to develop tourist and educational routes. Obviously, the dissected relief and the complex structure of the topological level create the most attractive view.

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