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Modern methods of studying inaccessible mountain relief with GIS technology

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Abstract

The application of these methods, in addition to remote means of studying the Earth's surface, makes it possible to carry out complex studies of the modern condition of mountain ranges and mountain villages. The development of such a system is complicated by different levels of accessibility information for each key site, so creating a project GIS that concentrates data on a single cartographic basis with an appropriate database for subsequent automated analysis of this information is the most effective way to address assigned tasks. On-based SRTM DEM using GIS technology performed morphometric analysis of relief Shinchay-Damiraparanchay mudflow basins. With these purpose-built maps of hypsometry, slopes, aspect, range relief and drainage density, indexes, dissection and ruggedness, and surface curvature. Also analyzed the areal distribution of these parameters by grade. Now, in connection with the development of digital technologies and the broad availability of data of remote sensing, detailed assessment of relief became possible. Application of the digital models of a relief (DMR) considerably simplified the morphometric analysis of a relief.

1. Introduction

Modeling of the mountain terrain was carried out with the help of GIS ArcGIS, which provides the ability to create and analyze maps. ArcGIS interacts with web mapping services that allow users to display any structure and any location on the map via web-platform, which also helps in the transmission of data or information through various web platforms from anywhere in the world.

Two terrain models can be used for web mapping GRID and TIN, which are widely used in GIS. GRID and TIN models are well enough to display geographical objects or phenomena that fluctuate in space, as they are different methods of construction and visualization of relief, which allows them to be used for different purposes depending on the tasks. The advantages of such a model include simplicity and speed of computer processing, it is connected with the very essence of the raster model. Output devices, such as monitors, printers, and plotters to show images use point sets (pixels), t. e. also have raster format, resulting in the GRID image being quickly visualized on the screen.

The drainage basin is the fundamental unit in fluvial geomorphology within which the relationships between landforms and the processes that modify them have been studied. The study of the geometry of the basin and the way in which it changes in response to processes has become a major part of modern geomorphology. Morphometric analysis of a drainage basin is a quantitative description of a basin and an important aspect to know the character of the basin (Ivanov, 2018).

In foreign literature, this direction gained development under the name "geomorphometry" (Piriev, 1986).

There are also synonyms for this term such as "quantitative morphology" (the quantitative morphology) and "quotative terrain analysis" (the quantitative analysis of a relief).

The area of the explored region is 3220 sq.km (Figure 1).

Figure 1. A geographical location of the explored region

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2. Method

The ILRIS Optech laser scanning system is the most modern tool for geodetic surveying of inaccessible surfaces. It allows you to get thousands of X, Y, Z points per second, from which can then be built accurate 3D models. To shoot a single point from which the entire surface of the relief is seen (Piriev, 1986). As input data for the GIS analysis of morphometric indexes of relief materials of satellite photos of SRTM are used (Figure 2).

Data of SRTM (Shuttle Radar Topographic Mission) represent the processed results of a radar survey of the surface of the globe made from the board of the American Shuttle spaceship by the method of radar interferometry, in February of the 2018 th year. This survey was conducted almost in all territories of the water area of Earth between 60 ° north lat., 54 ° south lat. by means of the radar SIR-C and X-SAR (Alizade, 2004).

The main operations were carried out in the ArcGIS - Spatial Analyst applications, 3D analyst, and geostatistical Analyst. The Hydro Tools tool model operations of watersheds, reservoirs, and drainage networks perform functions of processing and preparation of the digital models of a relief (DMR).

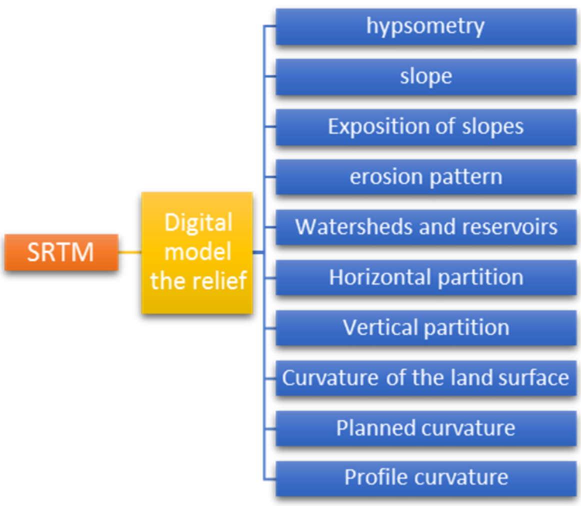


Figure 2. Scheme of creation of morphometric maps

The DEM Tools applications which contain a number of functions, for the calculation of some morphometric indexes, was useful for realization in some of the operations (Piriev, 1986). The scheme of creation of the morphometric maps on the basis of digital models of relief on ArcGIS (Figure 3).

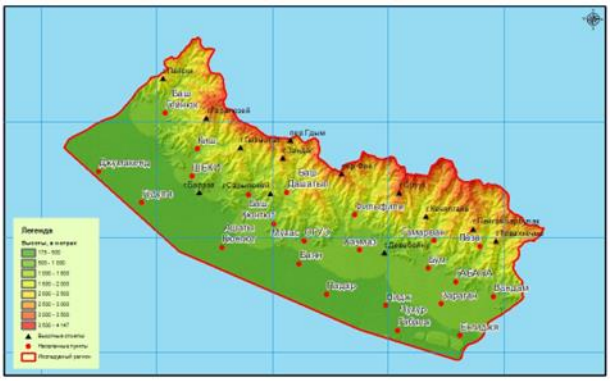


Figure 3. The hypsometric map of the explored region

2.1. Hypsometry

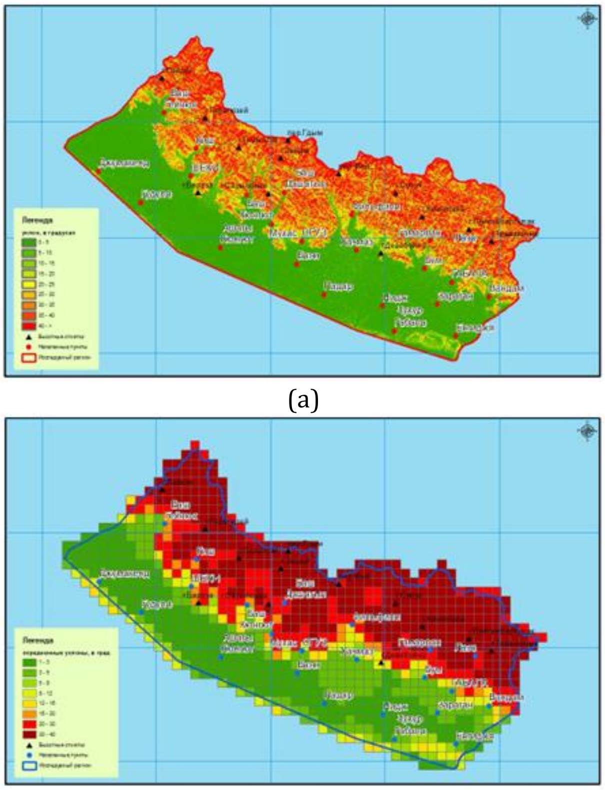
The analysis of the Digital model of relief (DMR) shows that absolute heights fluctuate here from 175 m to 4147 m. The analysis of the hypsometric map (Figure 3) shows that the largest space (54% in the explored region) is occupied by the range of height 175-1000 m (Table 1).

Table 1. Distribution of the total areas on a hypsometry

Hypsometry, m	175 - 500	500 - 1000	1000 - 1500	1500 - 2000
Area, км²	1003	760,8	407	391,5
Area, %	31,1	23,6	12,6	12,1

2.2. Biases of a surface (steepness) and exposition of slopes

Calculations of the biases of a surface it is necessary for the assessment of slope processes, soil erosion calculations, assessment of lands, etc. According to the calculations received from the map (Figure 4) slopes with the 10° occupy 49.5% of the total area (Table 2).



(a)

(b)

Figure 4: The map of slope angles of the explored region received by reference by method (a) and the card of average slope angles received by the method of Zone statistics (b)

Table 2. Distribution of the total areas on slope angles

Angles	5-10°	10-15°	15-20°	20-25°	25-30°
Area, км²	233	104	115	161	234
Area, %	7,23	3,22	3,57	5,01	7,27

Slopes of more than 10° where slope processes proceed more intensively, is occupied 50.5% of the territory, at the same time the large territory is covered with the slopes by the steepness more than 40° [3].

The exposition of a slope characterizes the slope relation to the multi-scale processes (insolation, gravitation, circulation etc.).

The exposition can be considered as the direction of a bias (Alekperova et al. 2017; Ivanov, 2018).

The exposition of a slope is one of the morphometric characteristics of relief, characterizing the dimensional orientation of the elementary slope (Figure 5, Table 3).

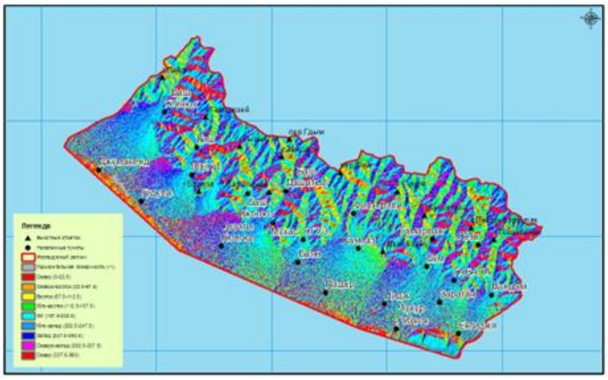


Figure 5. The map of an exposition of slopes of the explored region

Table 3. Distribution of the total areas on an exposition of slopes

Exposition	Flatness	North	East	South	west
Area, км^2	47,29	231,07	200,83	762,79	419,73
Area, %	1,47	7,18	6,24	23,69	13,03

As seen from the table, the southern exposition slopes (southern, southern, western, southern, and eastern) are composed of half a total of 56.5%. The slopes with anti-polar orientation (northern, southern-western and northern-western) have more than twenty-eight percent of the total area.

2.3. Vertical and horizontal partition

Calculates vertical scattering by using a cartogram, which is a tool used by ArcGIS (Spatial Analyst Tools → Zonal Statistics), which calculates the amplitude (in meters) of the DMR values in the calculable cells (Figure 6). The vertical clearance, more than 350 m, was discovered in the main section of the Caucasus Quarter and in the high-altitude zone (Piriev, 1986.

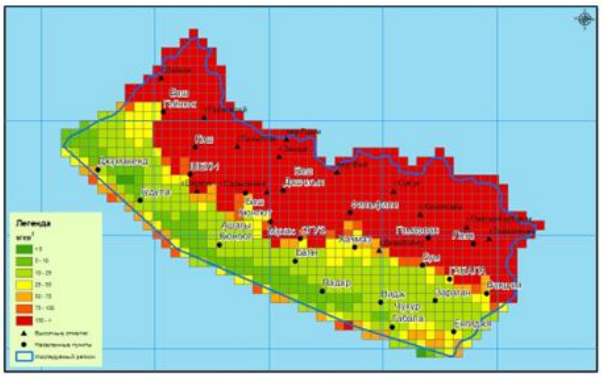
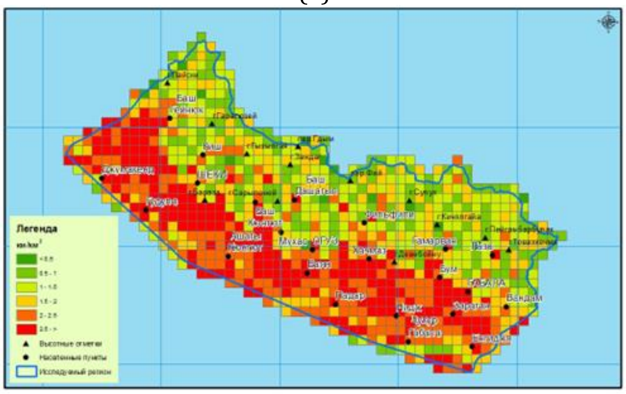


Figure 6. Map of vertical spreading relief of the region

For horizontal computing, has been used the Hydrology Tool (Spatial Analyst) to create all erosion network (Figure7).

(a)



(b)

Figure 7. Resistance to CMS Erosion network (a) and map horizontally-distal relief region of the method zonal statistics (b)

The erosion network was the base for the calculation of horizontal partition. The analysis of the map (figure 7 b) shows that the maximum marks* of horizontal partition are found for the Qanix-Ayrichay plain, the least – for water separate zones.

2.4. DI, dissection index

This index expresses a ratio of the relative relief (in this case vertical partition) to an absolute relief (i.e., to the maximum indicators of a relief, so-called topmost surfaces).

$$DI = (Zmax - Zmin)/Zmax$$

It is an important index of the partition of a surface and indicates a vertical partition. The high value of the index indicates orogeny, low value corresponds to stable areas. The analysis of literary data and morphometric features of the explored territory allows us to choose on the basis of this index five class scale system - such as very low DI (<0,1), low DI (0,1-0,2), temperate DI (0,2-0,3), high DI (0,3-0,4) and very high DI (>0,4) (Figure 8). More detailed characteristics of this index are given in Table 4.

Figure 8. Distribution of the index of a partition

Table 4. Distribution of the total areas by the index of a partition (DI)

Class	DI	Area, km^2	Area, %
very low	<0,1	1067,6	33,17
very low	0,1-0,2	594,94	18,49
T, °C	0,2-0,3	1225,4	38,08
High	0,3-0,4	312,82	9,72
Very high	>0,4	17,44	0,54

2.5. Ruggedness index

This index describes complexity and roughness of a land relief. The ruggedness defines extent of crossing of area where the drainage (erosive) network acts as key parameter. Chorley (1972) developed a formula for this index [4-6]:

$$(Deep\ partition\ (m/〖km〗^2) * horizontal\ partition\ (km/〖km〗^2))/1000$$

This index is widely used by scientists in morphological research for the best comprehension of the formation of elements of a relief in the difficult geomorphological conditions [5-8]. Results of the analysis show that the maximum values are partition are observed in mountain and mid-mountain zones of the territory (Figure 9).

Figure 9. Distribution of the index of ruggedness

3. Conclusion

GIS technologies for remote data and map analysis significantly simplify and expedites the collection and analysis of materials, and provide an opportunity to obtain intermediate and preliminary results, to better identify and follow the main objectives of the study, as well as operationalize results in the form of appropriate maps or spatial data infrastructures.

1. So, for the first time for the explored territory is carried out the complex morphometric analysis according to the radar interferometric topographic trajectory SRTM, with the software of ArcGIS.
2. On the basis of the created DMR and the modern GIS technologies are calculated morphometric parameters of a relief. This way allows one to carry out the assessment of the modern erosive processes on a quantitative basis and to create a set of geomorphological maps.
3. By means of our research materials is possible to study characteristic of processes of an erosion and accumulation and also assessment of potential stability or tendency to an erosion of various sites of the explored territory.

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