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Defining the specific weights of morphometric indicators of relief for the evaluation of the ecological-geomorphological condition: A case study of the Eastern part of the Kura depression

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Abstract

Morphometric indicators of the relief (horizontal and vertical fragmentation, hypsometry, slope), which are an integral part of the environment, play a major role in assessing the ecological-geomorphological condition in the territory, and quantitatively assessing its morphology. For this reason, the morphometric quantitative indicators of the relief of the territory were divided into gradations expressing the degree of ecological-geomorphological condition and evaluated on an 8-point scale, and the correlation coefficients were calculated, expressing the relations between them. The binary comparison matrix was constructed using the analytical hierarchical process method. Using mathematical formulas, weights, that reflect the influence of morphometric indicators in the formation of ecological-geomorphological condition in the territory, were calculated: average slope – 47.9%, horizontal fragmentation – 23.9%, vertical fragmentation – 18.8%, and hypsometry – 9.4%. At the final stage, an integrated map of geomorphological risks of the territory was compiled using GIS technology, taking into account the specific weights of morphometric indicators, expressed as a percentage. On the map of ecological-geomorphological condition of the assessed territory on an 8-point scale, four regions were identified: low (1-2 points), moderate (3-4 points), medium (5-6), and high (7-8 points) risk zone.

1. Introduction

The relief of the earth's surface, which plays an important role in the creation of the environment (Khalilov 2010, Khalilov and Abushova 2014), is one of the leading natural components of the geographic stratum (Kurlovich 2012) and the basic element of the human ecosystem (Veselova 2008). The dynamics of the development of endogenous and exogenous processes of relief formation and their interaction (Timofeev 1972) which create a ecological-geomorphological condition, is reflected in the quantitative morphometric indicators of the relief, establishing the presence or absence of links between the factors and conditions of formation and its morphological appearance, commensurability and spatial coincidence of structural and orographic elements (Alizade and Tarikhazer 2015a,b, Kharchenko 2020) In general, morphological, genetic, age,

morphodynamic, morphometric and other quantitative and qualitative characteristics of the terrain determine the ecological condition of the territory under study. When ecological-geomorphological mapping and assessment of the ecological state, it is more expedient to take the morphometric indicators of the relief, since they reflect the statistical and quantitative characteristics of the relief (Tanriverdiyev and Gasimov 2017, Gasimov 2019).

According to the scheme of geomorphological zoning of the territory of the Republic of Azerbaijan, the object of study consists of Shirvan, Southeast Shirvan, Kurboyu, Mugan, Salyan geomorphological zones of Kur-Araz lowland sub-region, Langabiz-Alat, Harami zones of Ajinohur-Jeyranchol foothills sub-region and Mil, Garabagh zones of Lesser Caucasus sloping plains sub-region (Shirinov 1973, Alizade et al. 2014, Gasimov 2021).

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2. Method

When assessing the ecological and geomorphological conditions, the following morphometric indicators were taken in the East Kura depression: horizontal fragmentation as a result of long-term work of linear erosion, vertical fragmentation showing the degree of vertical tectonic uplift and arid-denudation processes, hypsometry, which is the statistical distribution of absolute height in general and its spatial distribution over the territory, the average slope, which plays an important role in the development of exodynamic and gravitational processes.

To calculate and map the horizontal fragmentation of the relief in the ArcGIS 10.2 program, a geospatial database of linear erosional landforms (modern and ancient river valley, ditches, ravine-gully network) was created based on the interpretation of satellite images (Landsat-8 OLI, Google Sattelite, Bing Image, ESRI Basemap and topographic maps at a scale of 1:100,000). When determining the average slope, vertical fragmentation and hypsometric levels in the Eastern Kura depression, a digital elevation model (SRTM - Shuttle Radar Topographic Mission) was used, which is the processed results of a radar topographic survey and has a resolution of 28 m.

When assessing the ecological-geomorphological condition in the study area, correlation coefficients between morphometric factors (average slope, horizontal and vertical dissection, and hypsometry) the specific weights of these individual indicators (Gasimov 2022, Gasimov 2023), were calculated for the first time using the method of analytical hierarchical process (Saaty 1987).

At the final stage, using ArcGIS 10.2 (ArcMap - Spatial Analyst - Weighted Overlay), an integrated map of the ecological and geomorphological assessment of the territory was prepared, taking into account the specific weight of morphometric indicators.

3. Results and Discussion

The slope of the relief is an important morphometric indicator that affects the intensity of slope processes, the energy of the relief, the development of slopes, solar radiation, the circulation of substances, and ecogeomorphological conditions in general (Kuliyev 2010). The slope of the surface also determines the degree of dissection of the relief - an indicator of vertical and horizontal fragmentation. The intensity of denudation directly depends on the slope of the surface. That is, the rate of erosion on slopes and the movement of erosive materials depends on a number of factors (lithological composition, climate, impact, etc.), including slope slope (Simonov et. al. 1988).

The territory of the eastern part of the Kura Depression is less horizontally dissected. First of all, this is due to the poor development of the hydrographic network of the region, which is characterized by arid climatic conditions. The surface of the terrain is mainly divided by the Kura and Araz rivers and their ancient and modern tributaries, oxbow lakes, and a network of ravines. There is also an increase in the natural

horizontal fragmentation in the foothills and lowlands behind a well-developed network of ravines and gorges.

Judging by the values of the vertical fragmentation, one can put forward a certain opinion about the intensity of endogenous and exogenous processes in a given territory. For this reason, the values of vertical fragmentation, expressed as relative (difference in extreme heights) or average heights, depend on the amplitude of vertical (rising and descending) tectonic movements and the intensity of erosion-denudation processes (Piriyev 1986). As we approach the foothills of the Greater and Lesser Caucasus, a gradual increase in vertical fragmentation is observed due to an increase in absolute heights.

The East Kura depression is inclined towards the course of the Kura River. Due to this, its height decreases from west to east to 200 m, 100 m, 20-35 m, 0 m and -25-27 m. Relief hypsometry determines the morphology of lowlands, the degree of dissection, the course of exogenous processes, microclimate conditions, the formation of soil and vegetation, and affects the location and productivity of agricultural lands.

The determination of the degrees of relevance according to the mentioned scale in the method of analytical hierarchical process is based on the personal choice of the expert (researcher). In our opinion, such an approach is subjective and may lead to certain errors in the calculation of the specific weights of individual factors. Based on these considerations, we put forward and applied the initiative to take into account the correlation coefficients between these factors when determining the degree of correlation of individual factors on the indicated scale. In fact, for each of the 4 parameters, the weight coefficient is proportional to the average value of the coefficient of linear correlation of the values of one parameter to all the others. As a result, the higher the average value of the correlation coefficient, the more the parameter has weight and the more it affects the final tension value. Thus, our approach, in our opinion, makes it possible to obtain more accurate results when calculating the specific weights of individual factors by applying the method of multi-criteria analysis.

In morphometric risk assessment, the calculated correlation coefficient between horizontal fragmentation and hypsometry was 0.58, between horizontal and vertical fragmentation, 0.63, between horizontal fragmentation and mean slope, 0.65, and a moderate relationship was found. Accordingly, among the morphometric indicators mentioned above in the binary comparison matrix constructed using the method of analytical hierarchical process, the significance value was estimated as 2 - "slightly more important than the same degree". The correlation coefficient between mean slope and hypsometry is estimated to be high and equal to 0.71, between vertical fragmentation and hypsometry is 0.74, mean slope and vertical fragmentation is 0.81. Mutual significance between them was rated as "slightly more important than important" with an absolute value of 4.

In our study, the consistency coefficient (CI) is 0.086 with four morphometric parameters ($n = 4$), the random instability coefficient (RI) is 0.9, and the consistency ratio

(CR) is 0.096, which satisfies the condition ($CR < 0.1$) on the accuracy of the binary significance matrix between morphometric parameters (Table 1).

Table 1. Binary matrix based on morphometric indicators

M*	A*	B*	C*	D*	W*	W, %
A*	1	2	2	2	0.54	54.0
B*	0.5	1	4	4	0.28	28.0
C*	0.25	0.25	1	4	0.13	13.0
D*	0.5	0.25	0.25	1	0.05	5.0
Σ^*	2.25	3.5	7	11	1	100
Λ^*				4.257		
CI*				0.086		
RI				0.9		
CR*				0.096		

*M – morphometric indicators, A – horizontal fragmentation, B – vertical fragmentation, C – hypsometry, D – mean slope, W – special weights, Σ – sum of values, Λ – constant, CI – consistency coefficient, RI – random instability coefficient, CR – consistency ratio.

Based on the assessment of ecological-geomorphological condition on an 8-point scale (Figure 1), four zones were identified according to the morphometric indicators of the relief in the Eastern Kura depression: weak (1-2 points), moderate (3-4 points), medium (5-6 points) and high (7-8 points) tension zones.

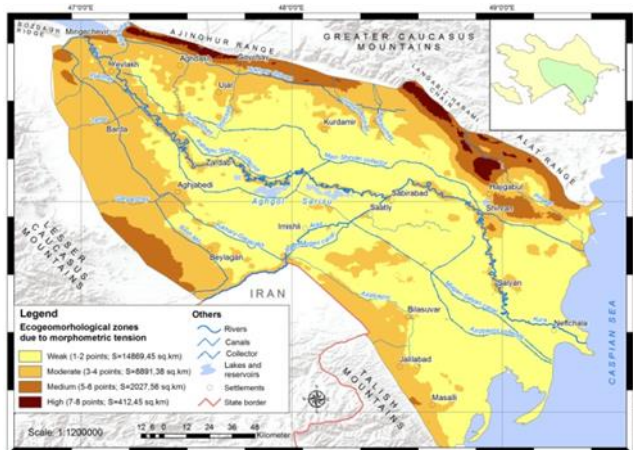


Figure 1. Ecogeomorphological zoning map of eastern Kura depression due to morphometric tension

Territories with weak tension zones (14866.87 sq.km; 56.75%) cover plains (0–1°) with weak erosion and intensive development of accumulative processes, except for the inner heights of the Eastern Kura depression. Against the background of general accumulation, eolian processes, salinization, swamping and flooding developed in the region. Zones of moderate tension (8889.843 sq.km; 33.94%) cover alluvial, alluvial-proluvial and foothill deluvial, proluvial-deluvial plains along the Kura and Araz rivers. The dissection of the relief within the area was caused by gully erosion and moderate tectonic uplift. The medium (2027.213 sq.km; 7.74%) and high (412.379 sq.km; 1.58%) tension zones are located mainly in the northern and northeastern parts of the structural-denudation ranges and ridges of depressions, in the sloping foothills of the Mil Plain in the southwest. Intense tectonic movements and intense arid-

denudation processes in these areas led to a high degree of dissection of the relief, as a result, unsuitable territories for agricultural activity appeared that would cause greater damage to the crop, the so-called "badlands" (Figure 1).

4. Conclusion

An average correlation was found between horizontal and vertical fragmentation, horizontal fragmentation and hypsometry, horizontal fragmentation and average slope, as well as a high correlation between vertical fragmentation and hypsometry, average slope and vertical fragmentation, average slope and hypsometry. Significance between horizontal and vertical fragmentation, horizontal fragmentation and hypsometry, horizontal fragmentation and mean slope, taking into account the correlation coefficients, was assessed as "slightly more important than the same degree", between vertical fragmentation and hypsometry, mean slope and hypsometry, mean slope and vertical fragmentation was rated as "slightly more important than more important." During the ecological-geomorphological assessment, special weights (weight coefficients) were calculated expressing the influence of the listed morphometric indicators in the occurrence of geomorphological risk in the territory: horizontal fragmentation - 54.0%, vertical fragmentation - 28.0%, hypsometry - 13.0%, and mean slope - 5.0%.

In general, an increase in ecological-geomorphological tension is observed due to the increase of morphometric quantitative indicators in the study area, going to the foothills of the Greater and Lesser Caucasus, to the heights within the depression.

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