EARTH SCIENCES

DEFINITION AND CLASSIFICATION OF MORPHOMETRIC PARAMETERS FOR AUTOMATIC DETERMINATION

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MORFOMETRİK GÖSTƏRİCİLƏRİN AVTOMATLAŞDIRILMIŞ QAYDADA TƏYİNİ VƏ MORFOMETRİK GÖSTƏRİCİLƏR ÜÇÜN SİNİFLƏNDİRMƏ ANLAYIŞI

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Abstract

In earlier times, the characterization of landforms and their attributes relied heavily on manual delineation within physiographic and morphometric maps. However, advancements in morphometrics, digital elevation models (DEM), image processing, and geographic information systems (GIS) have facilitated the automated extraction of relief features from maps and their storage in diverse software platforms. This technological evolution has significantly enhanced the efficiency of analyses in disciplines such as geomorphology, soil science, and ecology.Integral to this process are GIS-based digital elevation models (DEM), from which parameters such as slope, curvature, elevation, horizontal and vertical profiles, elevation differentials, topographic gaps, and hypsographic curves are derived. These parameters serve as morphometric indices, delineating features such as slopes, plains, valleys, etc., with three-dimensional (3D) attributes on the Earth's surface.The transformation of these relief features' boundaries into two-dimensional (2D) geometric entities through software, coupled with the computation of their parameters and scale, and the establishment of associations with classification methodologies, remain subjects of ongoing inquiry. Furthermore, investigations persist into the topological interrelations among relief features in nature and the uniformity of the relief landscape.This article elucidates various purposeful methodologies employed by researchers for the GIS-based automated determination and pixel-precise classification of Earth's relief.

Xülasə

Keçmişdə relyef formaları və onların xüsusiyyətləri fizioqrafik və morfometrik xəritələrdə əl ilə təsvir edilirdi.Morfometriyanın,rəqəmsal yüksəklik modellərinin (DEM), təsvirin emalı və coğrafi informasiya sistemləri (CİS) sahələrindəki inkişaf relyef formalarının xəritələrdə avtomatik çıxarılmasına və müxtəlif proqram təminatlarında saxlanmasına imkan vermişdir.Bu hal geomorfologiyada,torpaqşünaslıqda,ekologiyada daha səmərəli nəticələrin alınmasına gətirib çıxarmışdır.Belə tədqiqatlarda əsas məlumatlar CİS əsaslı rəqəmsal yüksəklik modelləri (DEM) və ondan hesablanan yamac,əyrilik,baxarlıq,üfüqi və şaquli parçalanma, hündürlük fərqi, topoqrafik boşluq, hipsoqrafik əyri və s. morfometrik parametrlər olmuşdur.Yer üzərindəki komponentləri üçölçülü (3D) olan yamaclar, düzənliklər, dərələr və s. formaların sərhədlərinin proqram təminatı ilə ikiölçülü (2D) həndəsi elementlərə çevrilməsi, onların parametrlərinin hesablanması, miqyası,təsnifat üsulu ilə əlaqəsinin qurulması,təbiətdəki relyef formalarının bir-birinə görə topoloji əlaqələri, relyefin bircinsliliyi hələ də tədqiq olunan məsələlərdəndir.Bu məqalədə müxtəlif tədiqatçılar tərəfindən yer relyefinin CİS əsaslı avtomatlaşdırılmış qaydada təyin olunmasına aid müxtəlif təyinatlı üsullar və piksel dəqiqlikli sinifləndirmə prosesi öz əksini tapmışdır.

Keywords: relief, DEM (Digital Elevation Model), morphometry, GIS (Geographic Information System), morphometric classification.

Açar sözlər: relyef,DEM,morfometriya,CİS,morfometrik sinifləndirmə

Introduction. The surface of the Earth possesses distinctive physical features and shapes such as mountains, valleys, hills, plains, slopes and ravines. Understanding the classification, types, and reasons behind these landforms is crucial for researchers conducting such studies. Since the advent of computer usage in mapping during the 1970s, various studies have been conducted to determine the boundaries of basins using Digital Elevation Models (DEM) and to identify ridges that delineate rivers and streams [3, p.15]. In this context, the determination of morphometric parameters and relief forms, establishing relationships between parameters and forms, determining scale magnitudes, and investigating the impacts of scale magnitude on the identification of relief forms have provided significant contributions to research (Evans, 1980; Mark, 1975; Pike, 1988; Belgran, 1873; R. Kh. Priyev,1986).Furthermore, the development of schemes and algorithms facilitating the transition from two-dimensional geometric elements to three-dimensional landforms, along with their integration into various software platforms, has greatly contributed to the automated identification of landforms. Advances in image processing since the 2000s have notably enhanced classification and accuracy analysis research. Presently, studies utilizing DEM for classification can be categorized into two main domains:

1.Classification of physiographic regions using Lidar data.

2.Classification of physiographic regions using medium or low-resolution DEM's.

Morphometric analysis is a mathematical analytical method that allows for the determination of the dimensions of the earth's surface shape, including relief features, or generally, and the analysis of its characteristic properties. Examining the area enables researchers to compare various relief forms and neotectonics within the basin and assists in calculating geomorphic indicators that may be useful in defining specific features like activity level. Additionally, morphometric analysis of basins aids in the investigation of geomorphic history, evolution, and characteristics of landforms, as well as the development of drainage networks [1,p.528].An example of this is the morphometric analysis of rivers on the northeastern slope of the Greater Caucasus in the territories of Azerbaijan by R. Kh. Piriyev [6,p.12]. While the morphometric analysis of basins began in the mid-20th century based on manual analysis of printed topographic maps, the emergence of Geographic Information Systems (GIS) enabled the digital extraction of morphometric parameters from Digital Elevation Models (DEMs) for quantitative characterization of land forms.Such analyses are conducted using morphometric indices. For instance, the hypsometric curve of different river basins has been analyzed and correlated with lithological resistance and tectonic uplift. Various morphometric parameters can be derived from basins, making it often challenging to determine which is more effective in geomorphological reasoning.

Digital Elevation Model (DEM). A Digital Elevation Model (DEM) or Digital Surface Model (DSM) is a three-dimensional computer graphic representation of elevation data, typically used to differentiate surface areas or overlapping objects. DEM's are commonly utilized in Geographic Information Systems (GIS) and serve as a common foundational source for digitally produced relief maps. A DEM can also be conceived as a matrix of the Earth's surface, where each cell contains metric elevation values calculated from specified vertical reference points. The coordinates of the first cell's location and the designated horizontal data are saved in a computer file. Other recorded elements include the number of rows and columns in the matrix and the size of each cell [6,p.17]. The elevation values to be included in the cells of the DEM are computed by interpolating from sampled point elevations of the surface's existing contour lines on maps. In addition to direct measurements with geodetic instruments, photogrammetry and remote sensing methods, Lidar data, indirect or direct measurements from photographs, as well as modeling using the EGM-96 geoid provided by the international WGS-84 ellipsoid and datum, play a significant role in both marine and terrestrial areas. Hence, the creation of DEMs worldwide from satellite imagery is facilitated. Generally, morphometric studies conducted on continents utilize DEMs referenced at scales ranging from 250 meters to 1 kilometer, while regional studies employ DEMs referenced at scales between 30 meters and 90 meters, and local studies utilize DEMs referenced at scales ranging from 1 meter to 30 meters. The topographic and morphometric parameters acquired from DEMs primarily consist of the elevation change between two points on the surface.

Determination of morphometric parameters and three-dimensional relief forms in two-dimensional form. During the early 1970s, one of the significant topics studied within the morphometric framework was slopes, valleys, and river basins. By determining parameters such as slope, elevation difference, curvature, etc., and establishing relationships between these parameters and landforms through calculations, it is possible to delineate the boundaries of landforms using developed methods. Important studies on this topic in Azerbaijan have been summarized under the work of R. Kh. Piriyev. One of these parameters includes horizontal partition elements. The following indicators can be used for horizontal partition: length of horizontal lines per unit area, number of relief waves per unit area, average area of the fundamental basin, length of erosion network per unit area, etc. According to R.K. Piriyev, the main purpose of these indicators is the average area of the fundamental basin and the length of erosion network per unit area. This is because they are directly related to the length of the erosion network in the territory of Azerbaijan. Many rivers pass through basins of different shapes and sizes in different elevation zones. On one hand, shape, size, and slopes are important indicators characterizing the horizontal partitioning of the region, while on the other hand, they play a significant role in the formation of river flow. For instance, in elongated basins, the duration of snow-rain floods in rivers is longer, resulting in calm floods for such rivers, whereas floods in rounded basins are short-lived but stormy and intense. One of the indicators characterizing the shape of the basin is the filling factor determined by the formula $\gamma = \frac{P}{l^2}$ [5, p.12].

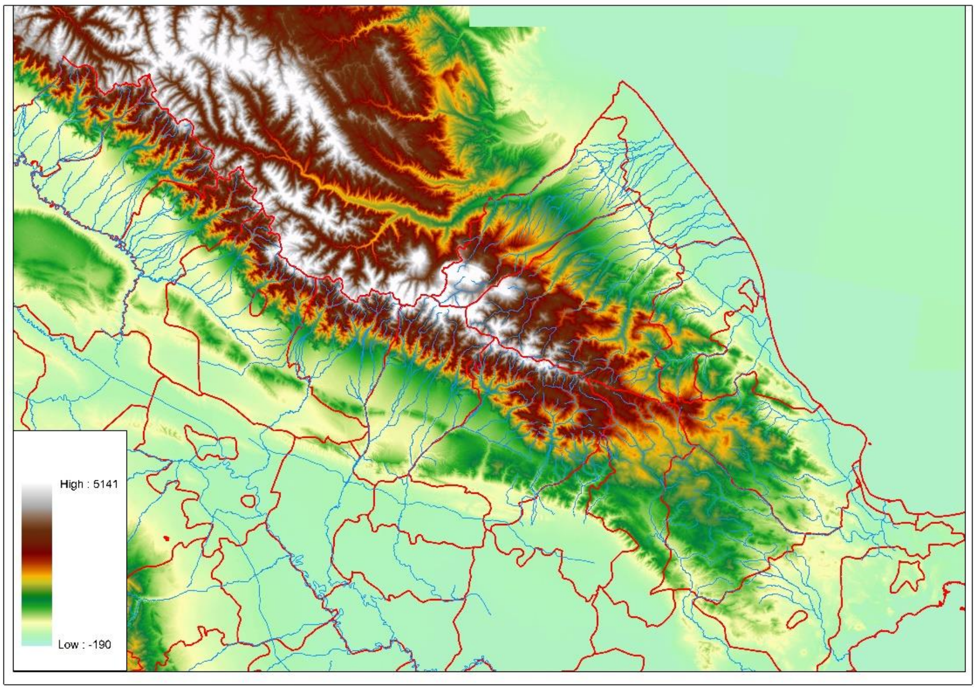

Figure 1. Definition of rivers in the digital elevation model (Case study: Greater Caucasus)

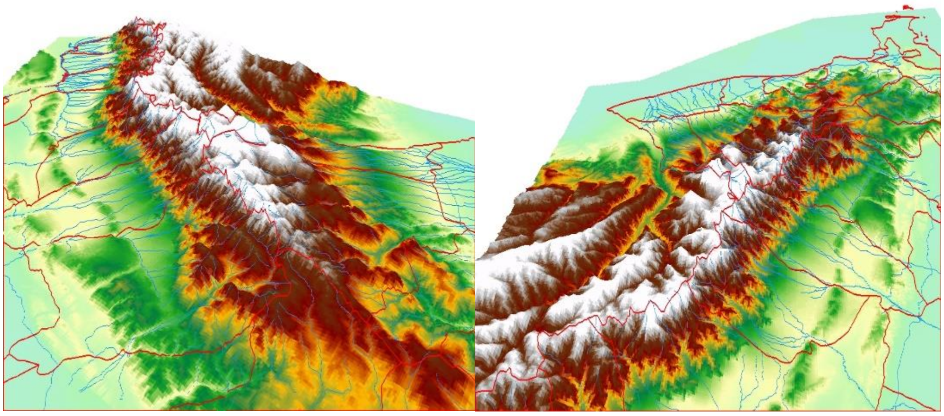

Figure 2. Various perspectives of the digital elevation model of the region (Case study: Greater Caucasus)

Classification. Since the late 1960s, the processing of remote sensing imagery, active utilization of LANDSAT satellite imagery in the 1970s, and subsequent technological advancements have evolved into significant research areas for scientists. The objective of image analysis and processing leading to classification is to separate target object groups from the image at the highest level possible. Consequently, as homogeneity within a class increases, similarity between different classes decreases. There are numerous different approaches to solving the classification problem. Initially, spectral values were the sole basis for classification; however, advancements in image processing technology have led to the development of various methods incorporating texture, image topology, and morphological parameters. Presently, approaches such as artificial intelligence, machine learning, deep learning, etc., contribute to solving the classification problem and enhancing accuracy. When utilizing satellite imagery in remote sensing, morphometric indicators derived from DEM are employed as quantitative indicators. Another approach among these methods can be termed as pixel-based and object-based classification [2,p.2978]. In pixel-based approaches, each pixel in the image is grouped into one or more target classes based on defined criteria. Segments (polygons) are derived from pixel groups, and classification algorithms are applied to segments rather than pixels. The accuracy of the obtained classes through classification is determined by comparison with field measurements, samples from existing images, or maps. The similarity between the two systems is verified through analysis and statistical calculations using modules such as ArcGIS, QGIS, etc., within GIS programs. One of the earliest studies in this field was conducted by Hammond (1954) using classical methods.Hammond conducted the first systematic classification of physiography by calculating elevation differences (relief), slope, and profile values in squares drawn on maps and classifying them. His methodology was aimed at preparing medium and small-scale maps and gained recognition in the literature as an applicable study.

Result. The most critical aspect in delineating relief forms is the identification of algorithms capable of transforming three-dimensional shapes into two-dimensional geometric elements. Factors such as the size of the form to be determined, DEM resolution, calculated slope, curvature, elevation differences, and other morphometric parameters serve as quantitative indicators. Following parameter computation in the determination of landforms, the subsequent stage is classification. The fundamental reason for the lack of development of a classification standard thus far is the complexity of landforms and their inherent lack of conformity to a specific systematic framework.

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