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QUANTİTATİVE MORPHOMETRİC ANALYSİS OF AGSUCHAY WATERSHEDS: BASED ON THE USE OF SPACE PHOTOGRAPHS AND GIS TECHNOLOGY

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Abstract

Morphometric analysis involves the quantitative measurement and mathematical evaluation of landforms, serving as a critical tool for understanding the spatial characteristics of drainage basins and the dynamics of flow. This study aims to quantitatively assess the morphometric characteristics of river basins, using the Agsuchay basin as a case study, to facilitate effective soil and water conservation practices.

Keywords: Morphometric analysis, Drainage density, Agsuchay watershed, Hypsometric curve, GIS

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1. Introduction. Morphometrics is the science of mathematically analyzing elevation, slope, and other quantitative indicators related to the shape and configuration of the terrain. This discipline provides valuable insights into the physical properties of soil, as well as processes such as erosion, denudation, and accumulation. The foundation of morphometric analysis for river networks and the study of their origins was established by Horton and Strahler.Today, geographic information system (GIS) software facilitates precise morphometric analyses, particularly following the Strahler method. Recent advancements in remote sensing technologies and high-resolution multispectral satellite imagery have significantly simplified the calculation of various relief and hydromorphometric characteristics of river basins. Studies conducted by numerous researchers have demonstrated the efficacy of geospatial methods in systematically generating detailed and updated information about drainage basins. These findings highlight the role of morphometric studies in providing comprehensive insights into basin characteristics, including hydrogeological features, erosion-prone areas, and groundwater potential. Moreover, integrating morphometric findings into effective watershed management strategies is essential for addressing critical natural challenges such as drought, water and nutrient shortages, low agricultural productivity, soil degradation, and inadequate water infiltration.

2. Object and methodology of research. The study was conducted in the Agsu region, situated within the basin of the Agsuchay River in the Greater Caucasus. This region is bordered by Shamakhi to the east and northeast, Hajigabul and Kurdamir to the south, and Ismayilli to the west and northwest. Considering the region's physical characteristics, the Agsuchay basin was selected as the focus of the study. The Agsuchay River, a left-bank tributary of the Kura River, traverses the Shamakhi, Agsu, and Kurdamir regions before joining the Kura River via an artificial channel [6].

To achieve the study's objectives, topographic maps at a scale of 1:25000, geological maps at a scale of 1:500000, and a Digital Elevation Model (DEM) were utilized as primary data sources. The DEM, in FGDBR format, features a 20x20-meter resolution, a linear unit of 1 meter, and is projected in the WGS-84 coordinate system within the UTM Zone 39 N (Figure 1.a). Digital Elevation Models are essential for describing and analyzing river networks; however, they require preprocessing to ensure compatibility with hydrological analyses. Using GIS tools, including the "Fill," "Flow Direction," and "Flow Accumulation" functions from ArcMap's Hydrology toolbox, gaps in the DEM were eliminated to prepare the data for hydrological analysis. Two methodologies were employed in this study. The first is the D8 method, also referred to as the 8-direction flow model. This method determines flow direction by analyzing which of the eight neighboring cells adjacent to a pixel in the DEM directs the flow. Before calculating morphometric indicators, an elevation map of the study area (Figure 2.a) was generated using the D8 model. The morphometric analyses were selected to ensure a comprehensive assessment of the basin's morphological characteristics, taking into account anonymous, absolute, and relative morphometric indicators. Key linear (one-dimensional) indicators, including flow order (by Strahler's method), hypsometric curve (Ho), hypsometric integral (Hi), relative elevation (h), total elevation (H), relative area (a), and total area (A), were determined for the basin (Strahler, 1952).The second method applied was the Strahler method, which organizes river networks into hierarchical orders. First-order tributaries combine to form second-order tributaries, continuing until the main river branch is defined (Figure 1.c)

3. Research results, analysis, and discussion. To efficiently analyze digital morphometric data for the study area, all analyses were conducted in ArcMap 10.4.1. This platform was selected for its ability to provide accurate and streamlined data analysis while also enabling the systematic storage and sharing of results through a database.

Method of calculating the Hypsometric curve and Hypsometric integral

A hypsometric curve, also known as a cumulative elevation curve, represents the distribution of land area at different elevations. This graphical representation plots relative area against relative elevation, offering insights into the morphological characteristics of a given surface or region. One of the most commonly utilized parameters in geomorphology to evaluate terrain relief is the hypsometric integral (HI).The hypsometric integral is typically calculated by plotting the cumulative elevation against the cumulative area for individual river basins and summing the area under the resulting curve to determine its value. In GIS environments, the hypsometric integral is derived by dividing river basins into elevation bands and plotting the cumulative area associated with each band.Despite its utility, the hypsometric integral is distinguished by its computational complexity, requiring iterative and intricate calculations. Automating the determination of this parameter within GIS frameworks is therefore of significant importance, as it streamlines the process and reduces computational challenges.

The hypsometric curve is calculated by the following formula:

$$y = \frac{h}{H}\ ;\ x = \frac{a}{A} \qquad (1)$$

here: y - hypsometric curve,

h - relative altitude, m;

H – total altitude, m;

a– relative area, hec;

A – total area, hec;

The hypsometric integral is calculated by the following formula:

$$H_i = \frac{\bar{H} - H_{min}}{H_{max} - H_{min}} \qquad (2)$$

here: Hi - hypsometric integral,

Hmax – maximum altitude, m;

Hmin– minimum altitute, m;

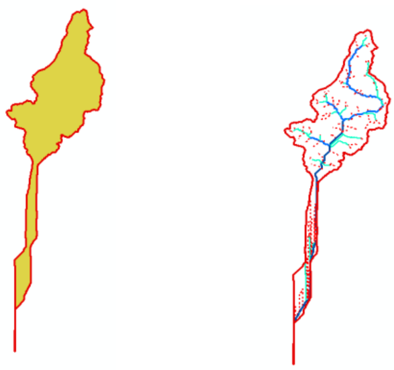
H – mean altitute, m;

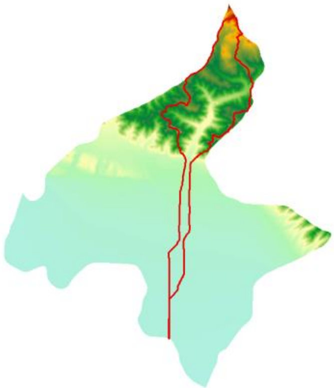
One of the methods employed in this study involves extracting elevation and area data from a Digital Elevation Model (DEM) using the ArcGIS raster data model. In a GIS environment, a DEM is represented as a regular raster surface or grid, which consists of a rectangular array of cells containing elevation values, each spaced at equal intervals [7]. Depending on the type of data represented by a cell, the grid can be classified as either "integer" (if the cell stores whole numbers) or "float" (if the cell stores decimal values). In ArcGIS, each layer is associated with an attribute table, transforming the raster cells into numeric data that directly influence the analysis. The attribute table of a DEM typically includes two key fields:

Value: Stores the unique value of each cell, often representing elevation.

Count: Represents the number of cells corresponding to each unique value.

For instance, when the attribute table represents a DEM, it contains elevation values, and the number of pixels (regular square cells) provides a direct measure of the area they cover [3]. This data structure facilitates the computation of essential morphometric parameters. By applying a simple algorithm, the DEM attribute table (when in integer format) can be utilized to calculate ratios such as the relative height to total height ratio (h/H) and the relative area to total area ratio (a/A). These calculations are





performed based on the parameters outlined in Table 1.

a) b) c)

Figure 1. Digital elevation model for the Agsuchay basin (source: USGS, Alos Palasar satellite, 2023); b) Basin definition and separation from the DEM; c) River tributaries determination in the Agsuchay basin using the Strahler method;

3.1. Relief morphometric parameters of Agsuchay watersheds

Regions characterized by high relief values exhibit steeper and elevated slopes, resulting in shorter runoff accumulation times and an increased likelihood of flooding during precipitation events. Basin relief also plays a critical role in the development of drainage networks, influencing the dynamics of surface and groundwater flow, soil permeability, soil surface evolution, and the intensity of erosion processes. In this study, the Agsuchay basin was classified into 10 elevation bands. Utilizing 20-meter resolution DEM data, the Agsuchay drainage basin spans a length of 83 km, covers an area of 571 km², and has an average elevation of 568.19 meters. The elevation parameters of the basin are as follows: maximum elevation (Hmax) at 1466 meters, minimum elevation (Hmin) at 13 meters, and mean elevation (Hmean) at 568.19 meters.

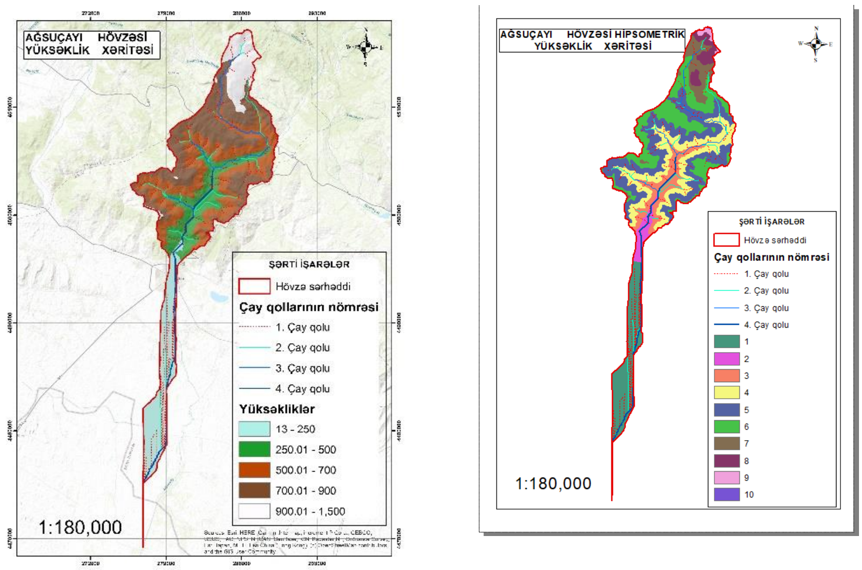
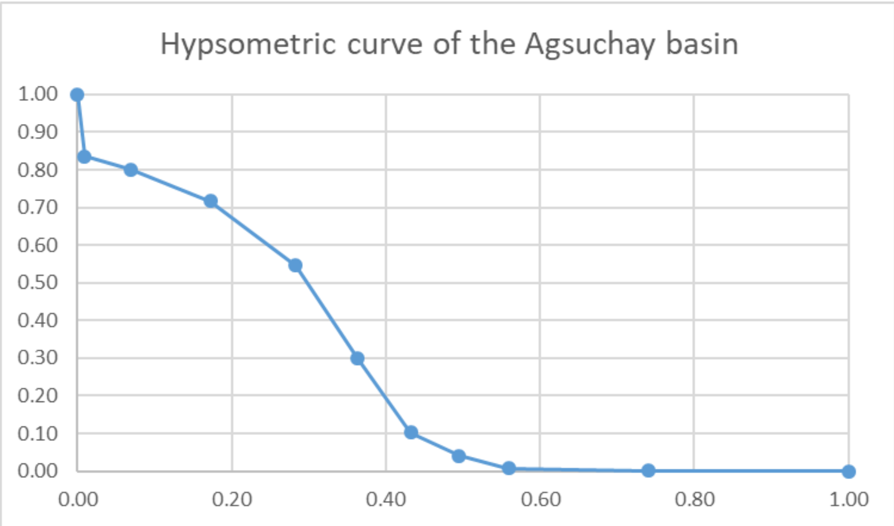


Figure 2. a) Agsuchay basin elevation map; b) Agsuchay basin hipsometric elevation map

Table 1. Elevation data obtained from DEM for the Agsuchay basin

Relia-tive alti-tute (h)	Total altitute (H)	Relia-tive area (a)	Total area (A)	h/H	a/A
0	1,466	16,423	16,423	0.00	1.00
13	1,466	13,717	16,423	0.01	0.84
101	1,466	13,164	16,423	0.07	0.80
252	1,466	11,777	16,423	0.17	0.72
415	1,466	8,963	16,423	0.28	0.55
533	1,466	4,904	16,423	0.36	0.30
634	1,466	1,673	16,423	0.43	0.10
726	1,466	661	16,423	0.50	0.04
820	1,466	124	16,423	0.56	0.01
1,086	1,466	10	16,423	0.74	0.00
1,466	1,466	0	16,423	1.00	0.00

Based on the elevation values listed in the table, the following hypsometric curve can be



constructed:

Figure 3. Hypsometric curve of the Agsuchay basin

The hypsometric curve (or hypsographic curve), which illustrates the distribution of elevation within a basin, serves as a critical tool for understanding erosion processes and basin evolution. This curve provides valuable insights into the physiographic age of a basin. A concave-shaped hypsometric curve indicates that the basin has undergone extensive erosion, is in an advanced aging stage, and exhibits reduced river flow and diminished erosion power. Conversely, a convex-shaped curve suggests that the basin is in the early stages of erosion, characterized by strong and vigorous erosional activity. The hypsometric curve for the Agsuchay basin (Figure 3) reveals that the basin is of intermediate age and is transitioning toward the aging stage. This suggests that the erosion processes within the area and along the riverbed began long ago. Furthermore, the river currently displays significant discharge, highlighting its active hydrological and geomorphological dynamics. Additionally, the hypsometric integral value of the area is 0.38.

4. Result

This study focused on the Agsuchay basin in the Agsu district, applying five morphometric analyses to the river network using GIS methodologies. The digital data generated through these analyses provided a detailed understanding of the morphometric characteristics of the basin. The main findings are as follows:

River Network Structure:

In the Agsuchay basin, rivers flow from high mountainous regions toward plains. Tributaries in the mountainous areas exhibit a more branched structure, whereas those in the plains tend to follow a more rectilinear path. Additionally, first-order tributaries in the plains are longer compared to the shorter first-order tributaries originating from the mountainous areas.

Geometric Variability of Basins:

The basins within the study area exhibit diverse geometric forms. Basins containing short and high-altitude rivers typically display a branched structure, significantly fragmenting the landscape. This characteristic underscores the flood-prone nature of these basins. In contrast, elongated basins are more prominent in the central and southern portions of the Agsuchay basin.

Importance of Digital Elevation Models (DEMs):

In medium-scale analyses over extensive areas, meticulous attention is required when constructing a Digital Elevation Database. Higher-resolution DEMs yield more precise results, underscoring the necessity of clearly defining the survey scope in such studies.

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