Morphometric Analysis of the Sangzor River and Its Basin

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Abstract: This study investigates the morphometric characteristics of the Sangzor River and its basin located in the Jizzakh region of Uzbekistan. Key parameters such as river length, sinuosity and density coefficients, slope, and other morphometric indicators have been determined. Additionally, the geographical location, boundaries, extremities, basin width and length, stream order, stream hierarchy, stream length, maximum and average elevation, symmetry, slope, and exposure of the Sangzor River basin have been analyzed using both traditional and modern methods. Studying these parameters of the river and its basin and drawing conclusions from them is of great importance for addressing future issues related to the sustainable use of the region's natural resources.

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1. Introduction

Rivers on the Earth's surface differ from each other in terms of length, number of tributaries, their spatial arrangement, and other characteristics. Similarly, their basins also vary in shape and size, and one basin does not replicate another. These differences can be studied through the morphometry of river systems and their basins, which involves determining the shape by comparing the sizes of its components.

Morphometric analysis of river basins is the quantitative measurement of basin geometry (shape) and drainage network structure to draw conclusions regarding water flow, erosion, water resources, and potential demands. This analysis includes planimetric (horizontal measurements) and relief (elevation) aspects and calculates morphometric parameters of the drainage network.

Morphometric analysis of a river basin is an essential part of basin study and plays a significant role in the efficient future use of the river basin and its components.

The morphometric parameters of rivers and their basins include:

- Planimetric morphometry (2D parameters);
- Basin area (A), perimeter (P);
- Basin length (Lb) — the longest flow path;
- Stream orders according to Strahler, and the number of streams in each order;
- Conventional indices;
- Relief morphometry;
- Relief (H) — difference between the highest and lowest points;
- Relief ratio (H / Lb) or other measurements;
- Slope;
- Aspect (exposure);
- Drainage density (Dd);
- Number and distribution of stream orders;
- Bifurcation ratio (Rb);
- Length ratio (RL).

Hydrological processes occurring in a river basin are related to its characteristics — size, structure, location, and drainage density. Moreover, they significantly influence many geomorphological processes within the basin. Specifically, morphometric parameters of a river basin are crucial in many geomorphological changes such as flooding, formation of muddy flows, erosion, and sediment formation processes.

2. Materials and Methods

Two main approaches are used to analyze the morphometric parameters of river basins, which can be referred to as traditional and modern methods.

Traditionally, morphometric parameters of river basins are determined based on topographic maps and field surveys. However, using topographic maps to delineate basin boundaries and identify stream networks is time-consuming and labor-intensive. Moreover, this traditional approach is performed in a non-digital format. Many researchers have applied this method to study various characteristics of river basins.

Traditional methods also encompass cartographic, mathematical and statistical, field observation and geodetic techniques, modeling, and historical analysis. Collectively, these approaches can be classified under the umbrella term "traditional methods."

In the cartographic method, orographic maps are used to determine basin boundaries, length, area, elevation, slope, and other parameters.

The mathematical and statistical method involves calculating parameters such as river length, basin area, average slope, drainage density, stream orders, and sinuosity coefficient.

The field observation and geodetic measurement method employs surveying instruments to determine current relief conditions, channel changes, slopes, and related parameters. This method is particularly effective for studying small river basins.

The modeling method is used to develop hydromorphological models of basins, facilitating flow analysis and identifying areas at risk of erosion.

The historical analysis method involves comparing maps from different periods to study the evolution of river channels or basins. This approach is useful for identifying morphological changes over time.

With advances in science and technology, modern research methods have emerged. Contemporary analysis of river basin morphometric parameters increasingly relies on remote sensing and Geographic Information Systems (GIS).

Compared to traditional data processing methods, remote sensing and GIS technologies, as rapidly developing spatial data technologies, offer significant advantages in planning and managing water and land resources. Satellite-based remote sensing provides the capability to assess basin morphometry over large areas.

One key advantage of this modern approach is that, based on Digital Elevation Models (DEM), basin boundaries and hydrographic networks can be automatically delineated. Additionally, satellite images from platforms such as Landsat and Sentinel allow for accurate identification of land surfaces and water bodies. Using these technologies, all tasks performed by traditional methods can be executed more efficiently and with higher accuracy.

3. Results and Discussion

One of the morphometric parameters of a river is its length. The Sangzor River is the largest river in the study area, with a total length of 123 km, making it the longest river in the region.

The sinuosity coefficient is also an important morphometric parameter and is calculated using the following formula:

$$K\varepsilon = \frac{l\,AB}{L} \qquad K\varepsilon = \frac{76}{123} = 0{,}61$$

Where K_ε is the sinuosity coefficient, l_{AB} is the straight-line distance from the most distant point along the flow to the nearest point on the bank, and L is the actual length of the river. The sinuosity coefficient is always expected to be less than 1. Based on this formula, the sinuosity coefficient of the Sangzor River was determined to be 0.6.

Typically, the density of river networks is expressed using the drainage density coefficient. The drainage density coefficient for the tributaries of the Sangzor River was calculated using the following formula:

$$\alpha = \frac{(L + \Sigma\, l_i)}{F},$$

Where α-is the drainage density coefficient, L-is the length of the main river, l_i are the lengths of tributaries, and F-is the total area of the basin. Using this formula, the drainage density coefficient was found to be 0.41 km. It is important to note that this value includes both perennial streams and those with intermittent flow within the basin.

River slope varies across different sections. The upper reaches of the Sangzor River have a steep slope, which decreases upon reaching flatter terrain. The slope of the river and its tributaries can be determined for the entire river or for specific segments. The source of the Sangzor River, called Guralash, originates at an elevation of 3300 m, while the lower part, known as Qli, is situated at 328 m. The slope is calculated as follows:

$$\mathfrak{I} = \frac{(3300 - 328)}{123} = \frac{2972}{123} = 24{,}1$$

Apart from the morphometric parameters of the river, the basin itself has important characteristics. The morphometric features of the Sangzor River basin quantitatively describe the geometric properties of the basin. This aids in understanding the geomorphological characteristics, geological structure, and the basin's appearance formed over various hydrological cycles.

The structure and hydrographic patterns of each basin follow the objective hierarchical classification of rivers and river basins proposed by R. Horton and A. Strahler. In this system, the initial elementary streams are classified as first order; second order streams are formed by the confluence of two first order streams. As the network becomes more complex, the order increases discretely by whole numbers.

The Sangzor River was classified according to Horton's method, which divides river basins into nine stream orders. These include very small (orders 1–3), small (4–5), medium (up to 6), large (up to 7), and the largest rivers (8–9).

The morphometric parameters of the Sangzor River and its basin were analyzed stepwise (Figure 2.3).

The number of streams in a river system depends on the basin area, geomorphological structure of the terrain, and geographic location. Based on the basin area, the Sangzor River belongs to the group of small basins. Consequently, according to Horton's classification, it was assigned a small order, i.e., five stream orders (Figure 2.4).

Using GIS software, the number of streams of various orders was recorded, and the lengths from the source to the drainage divides were measured. The total lengths of streams for the first through fifth orders were found to be 627 km, 265 km, 58 km, 79 km, and 32 km, respectively (Table 2.7).

Stream order numbers are assigned based on the characteristics of the streams. According to Horton, the number of streams of each order forms an inverse geometric progression. Initial elementary streams are assigned first order, while the highest order streams are designated with numbers increasing according to the river system's characteristics.

The morphometric parameters of the Sangzor River and its basin were analyzed stepwise (Figure 1).

This figure illustrates the sequential procedure for analyzing the morphometric parameters of the river and its basin. This sequence is applied in remote sensing and GIS methodologies

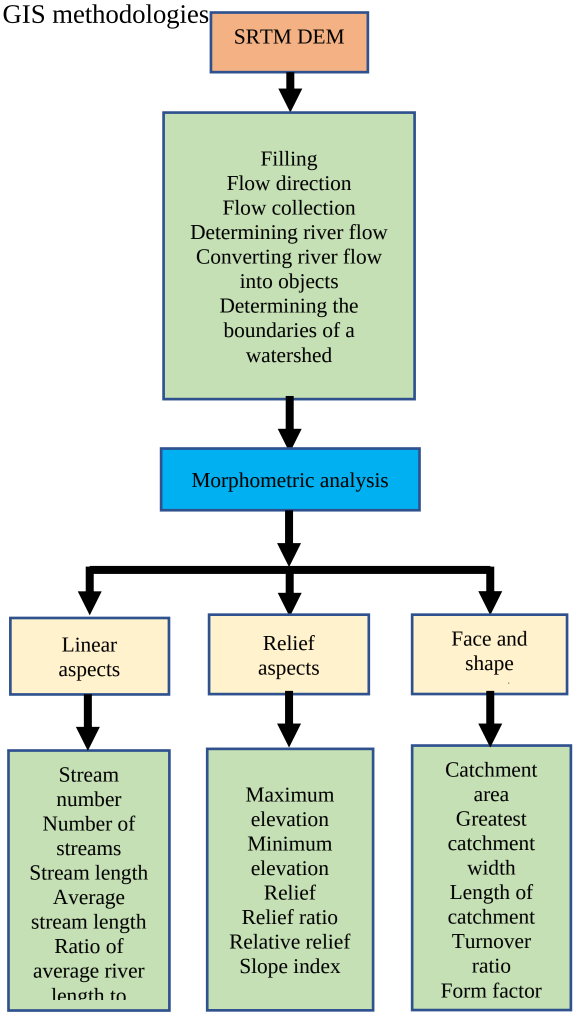

Figure 1. Scheme of Morphometric Analysis

The stream number is determined based on the characteristics of the streams and is assigned according to numerical values. According to Horton, the number of stream segments of each order forms an inverse geometric series. In this system, the initial elementary streams are designated as first-order, while the highest-order streams are assigned increasing numbers depending on the characteristics of the river network (Figure 2).

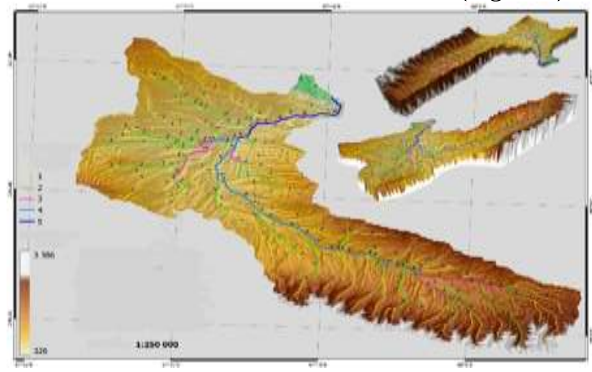

Figure 2. Stream Orders of the Sangzor River

Number of Streams. It was determined that the Sangzor River has 5 stream orders, with a total of 140 streams identified. Among these, 103 are first-order streams, 27 are second-order, 7 are third-order, 2 are fourth-order, and 1 is fifth-order (Table 1).

The stream order is assigned based on the characteristics of the streams. According to Horton, the number of stream segments at each order forms an inverse geometric series. The initial elementary streams are designated as first order, while the highest-order streams are assigned increasing numbers based on the properties of the river system.

Table 1

Linear Characteristics of Streams in the Sangzor River Basin

Stream Order	Number of Streams	Stream Length, km	Average Stream Length, km
1	103	627	6,08
2	27	265	9,8
3	7	58	8,2
4	2	79	39,5
5	1	32	32
140 ta		1062	

Stream length refers to the total length of streams of a certain order formed within the basin area. The total length of all streams in the Sangzor river basin is 1062 km.

Average stream length is a characteristic feature of the stream network and the corresponding surface area within the basin. It is calculated by dividing the total length of streams of each order by the number of streams of that order.

Maximum elevation indicates the altitude above sea level from which each stream originates. In the Sangzor basin, the highest maximum elevations of streams are observed in the tributaries formed on the slopes of the Chumqor and Morguzar mountains. For example, the upper reaches of the Guralash stream, which is a first-order stream, originate at an absolute elevation of 3300 meters.

Slope is one of the important morphometric parameters of the basin, representing the topographic steepness relative to the plain. In the Sangzor river basin, slope values were determined using GIS software. According to the results, slopes vary between 0° and 50°. Variations in slope gradients influence flow directions and contribute to geomorphological processes within the basin, such as flow velocity, erosion, and landslide occurrence (see Table 2 and Figure 3).

Table 2

The slope characteristics of the Sangzor river basin

No	**Degree of slope of the hillside**	**Area (thousand km²)**	**Percentage of the area within the basin (%)**
1	0-1	218,3	8
2	1,1-3	778,7	30
3	3,1-5	437,5	17
4	5,1-8	307,1	12
5	8,1-12	255,1	10
6	12,1-15	143,6	6
7	15,1-20	212,4	8
8	20,1-30	205,1	8
9	31,1-45	22	1
10	45,1-50	0,2	00,1
		2580	**100**

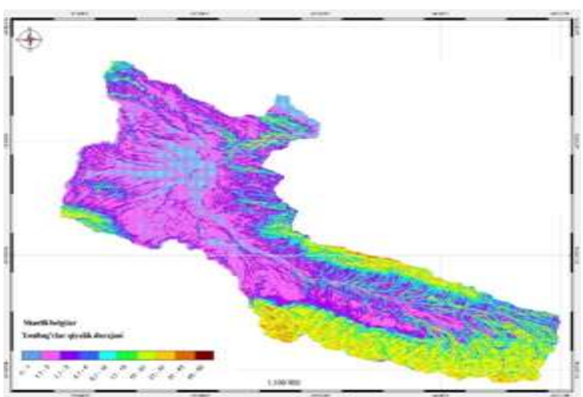

Figure 3. Slope Map of the Sangzor River Basin

Table 2

Slope Characteristics of the Sangzor River Basin

No	**Slope degree of the hillside**	**Area (thousand km²)**	**Share in the basin (%)**
1	0-1	218,3	8
2	1,1-3	778,7	30
3	3,1-5	437,5	17
4	5,1-8	307,1	12
5	8,1-12	255,1	10
6	12,1-15	143,6	6
7	15,1-20	212,4	8
8	20,1-30	205,1	8
9	31,1-45	22	1
10	45,1-50	0,2	00,1
		2580	**100**

Slope aspect refers to the orientation of a land surface relative to the cardinal directions and the Sun. Variations in slope aspect contribute to differences in topographic characteristics, influencing the diversity of mountain landscapes. Depending on the direction a slope faces, its climate, vegetation, soil, and fauna can vary significantly.

A slope aspect map is a crucial tool for determining solar radiation exposure. According to Kang (2005), differences in slope aspect can lead to temperature variations within a catchment area. For instance, the amount of solar radiation received by a surface changes throughout the day, affecting the surface temperature accordingly.

For the Sangzor River Basin, slope aspect data were derived using Geographic Information System (GIS) software. The raster map created indicates orientation in degrees from 0° to 360° (Figure 4).

The maximum basin width is defined as the perpendicular distance from the widest part of the basin to a line representing the basin's length. In the Sangzor River Basin, the widest section is located in the northwestern region, approximately 40 km wide, narrowing towards the east (Figure 5).

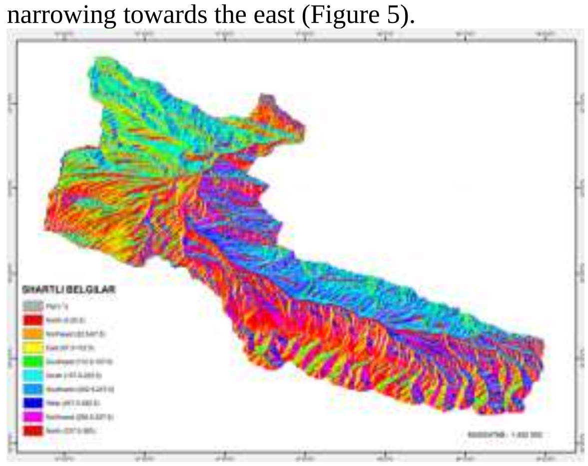

Figure 4. Exposure map of the slopes of the Sangzor River Basin

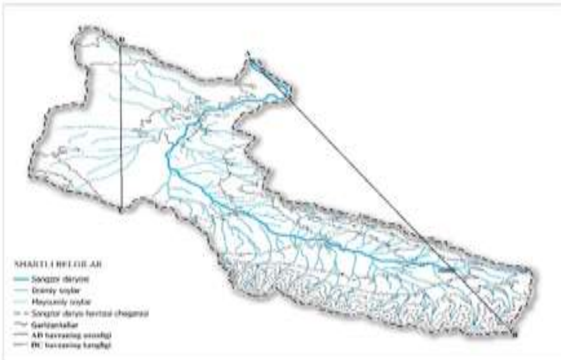

Figure 5. Width and symmetry of the basin

The degree of symmetry of the Sangzor River basin was determined relative to the main river. This parameter was estimated using the asymmetry coefficient.

$$K_a = \frac{F_{ч} - F_{у}}{F} \qquad K_a = \frac{1909 - 671}{2580} = 0{,}47$$

The average elevation of the basin area was determined using a method that involves delineating contour lines at 500-meter intervals and calculating the areas between these contours. This approach allows for a detailed representation of the elevation distribution across the landscape. Figures 6 and 7 illustrate the contour lines and the corresponding areas within the Sangzor River Basin.

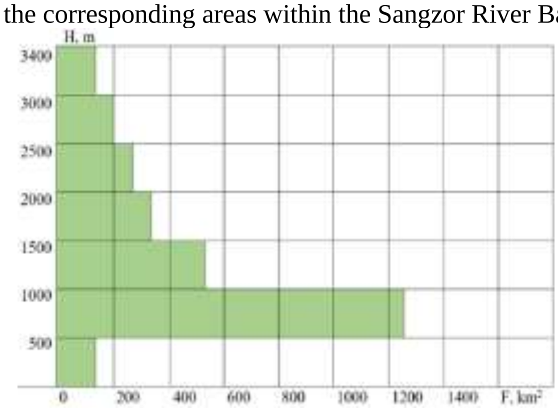

Figure 6. Hypsometric Indicator of the Sangzor River Basin.

An integrated basin-based approach to the use of the Sangzor River Basin encompasses the management of water, soil, vegetation, animal life and other resources within the basin's geographical boundaries, as well as land use and ecosystem management. At the same time, this basin-based approach recognizes the interconnections among water, land and ecosystems and serves to facilitate their sustainable use, development, and resource management.

Some potential utilization opportunities in the Sangzor River Basin based on a basin approach include:

a) Identifying water resources in the basin and establishing mechanisms for their equitable allocation among different basin users. This can encompass agriculture, industry, domestic use and ecosystem needs;

b) Implementing practices for the protection and enhancement of small water basins within the Sangzor River Basin, supporting improvements in water quality, reduction of erosion, and preservation of biodiversity;

c) Understanding how changes in land use affect flood events in the basin, and taking measures to reduce flood risk through infrastructure development or restoration of natural floodplains;

d) Protecting important natural habitats and biodiversity in the Sangzor Basin, maintaining ecological balance and supporting sustainable development practices;

e) Ensuring stakeholder participation in decision-making processes during basin planning and management.

Overall, the management of the Sangzor River Basin's natural resources in collaboration with stakeholder organizations aims to achieve sustainable development objectives.

Although the Sangzor River and its basin are relatively small, they possess a complex geomorphological structure and a variety of hydrological characteristics. A thorough analysis of the morphometric, relief and ecological indicators of the Sangzor River Basin is essential as a basis for the sustainable management of water resources and conservation of nature.

4. Conclusion

1. The Sangzor River is one of the largest rivers in Jizzakh Province, with a total length of 123 km, highlighting its central role and significance within the region's hydrological system.

2. The river's meandering coefficient is 0.61, indicating a sinuous channel that conforms to the relief.

3. In the Sangzor River Basin, five stream orders were identified, with a total of 140 streams, indicating a high degree of network branching in the basin.

4. The basin's overall slope is 24.1 percent, which is an important factor influencing flow velocity, erosion processes and sediment transport.

5. Using a Digital Elevation Model (DEM) and GIS technologies, the basin morphometry was analyzed, identifying the basin's elevation, slope, aspect, and drainage networks.

6. Slopes range from 0° to 50°, with more than 30 % of the basin area located in the 1.1–3° range, indicating relatively favorable lands for agricultural use.

7. The Sangzor Basin exhibits a large disparity between mean elevation and maximum elevation (3300 m – 328 m), indicating significant relief variation within the basin.

8. Differences in hillside exposure (aspect) significantly influence the basin's microclimate and erosion processes.

9. A basin-based approach to resource use (water, land,

ecosystems) is an important strategic framework for ensuring sustainable development and ecological security.

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