Morphometric Characteristics Analysis of the Sazan Valley Basin in Sulaymaniyah Governorate

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Abstract. Geographic Information Systems (GIS) and mathematical modelling are used to evaluate the hydrological dynamics of the Sazan River Basin in northern Iraq via the analysis of its morphometric attributes. The basin has a drainage density and form ratio that are markedly uneven, indicating a moderate response to precipitation. Additional significant indicators are stream length, gradient, and morphology. These findings support improved land-use planning, flood risk mitigation, and water resource management. This work uses GIS and mathematical modelling to analyse the morphometric characteristics of the Sazan River Basin in northern Iraq to evaluate its hydrological behaviour. Key indications of the basin's irregular structure and drainage density include the slope, stream length, and shape ratios. The results indicate a limited reaction to precipitation, potentially impacting water resource management, flood risk mitigation, and sustainable land use planning. The research underscores the need of corroborating the morphometric analysis using empirical meteorological and hydrological data. This will enhance the results and make them relevant to practical scenarios such as flood forecasting and ecosystem management.

Keywords. Morphometric characteristics, Erosion-prone zones, Valley basin, GIS Northern Iraq.

1 Introduction

According to this study, geomorphological analysis is very beneficial in many modern geological domains, including resource management, agriculture, land-use planning, and environmental engineering [2, 4, 5]. The comprehension of terrestrial landscapes is facilitated by the amalgamation of climatic, hydrological, and tectonic elements within geomorphology, a multidisciplinary field. This research demonstrates that morphometric analysis is essential for comprehending the hydrology of river basins. The Sazan River Basin in northern Iraq will be meticulously analysed using GIS-based methodologies. The study will concentrate on the basin's reaction to precipitation, its capacity for water resource management, flood risk mitigation, and the advancement of sustainable land use. This work recognises the need of integrating morphometric findings with empirical hydrological and

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meteorological data for more dependable and pragmatic results, particularly in resource management and flood prediction.

How much do morphometric features affect the hydro-geomorphic dynamics of the Sazan Valley Basin? That is the overarching study topic.

In order to: Track geomorphic developmental phases, the approach relies on quantitative morphometric study of the drainage network of the basin. Put landscapes affected by rivers and earthquakes into categories.

Identify erosion-prone and sediment-sensitive zones [10].

The research indicates that slope gradient, lithological diversity, climatic factors (such as precipitation, temperature, and evapotranspiration), and soil characteristics together influence geomorphic processes, especially erosion, deposition, and drainage morphology [12].

Geologically, the Sazan Basin lies along the convergent boundary of the Arabian and Iranian tectonic plates, a setting characterized by intense structural deformation—notably folding and faulting—which plays a central role in shaping surface morphology [1].

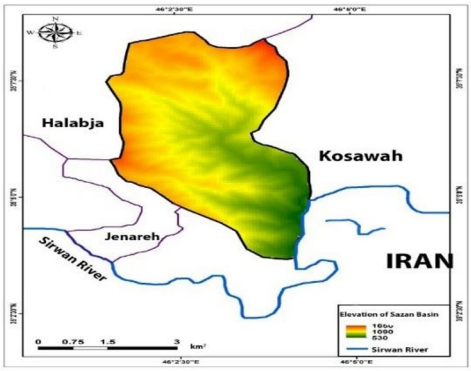
The structural framework includes The Middle Regional Fold–Thrust Zone, encompassing the Kani Rash subrange and the Main Unstable Shelf Zone, extending through the Sulaymaniyah–Zakho sector (Buday's classification of Iraq [10, 11, 12].

These units reflect a long history of tectonic uplift, marine transgressions, and sedimentary basin shifts, leading to lithological heterogeneity and complex surface structures that directly affect geomorphic systems and hydrological behavior [10, 13].

A- Height categories for the study area: The categories of the study area vary as shown in Table 1 and Map 1.

Table 1. Heights of study area.

Terrain units	Categories
Floodplains	600 - 500
Mountainous plains	800 - 601
Low hills	1000 - 801
High hills	1200 - 1001
Highlands	1400 - 1201
Low mountains	1650 - 1401



Map No. 1. Lines of Equal Elevations of the Sazan Valley Basin.

Source: The Researcher's Work Based on The Source of The Ministry of Water Resources, Soil Conservation Center, Bahr Joe, Archive Department and Relying on The Topographic Painting of Halabja District, Scale 1:250000, 2005.

1.1Topographic classification and slope dynamics in the sazan valley basin

1.1.1 Hypsometric zonation

Based on the analysis of Map (1) and Table (1), the Sazan Valley Basin is categorized into six discrete elevation tiers, each reflecting specific morphogenetic characteristics:

Elevation Category	**Altitude Range (m a.s.l.)**	**Topographic Zone**	**Morphological Traits**
I	500–600	Peripheral alluvial plains (north/south)	Uniform flatlands with negligible fluvial incision
II	601–800	Mountainous plains (central sectors)	Mild to moderate relief, increased surface runoff and erosion
III	801–1000	Low hills (southeast and central basin)	Sharper slopes with limited water incision
IV	1001–1200	Elevated highlands (central-southeast)	Moderate slopes, limited drainage articulation
V	1201–1400	Plateau margins (south/southwest)	Erosively active, broader surface exposure
VI	1401–1650	Southern mountainous rim	Rugged morphology with high-energy fluvial activity

This hypsometric variation results in a complex relief pattern where highland terrains dominate the basin's spatial extent. These elevational shifts critically influence regional microclimates, especially in regulating orographic precipitation and thermal regimes, both of which are key drivers in geomorphic system evolution [13].

1.2.1 Slope morphometry and geomorphic function

Slope, conceptualized as the angle of inclination between two elevation points, represents a fundamental variable in morphometric analysis. It plays a crucial role in defining erosional intensity, hydrological behavior, and sediment transport potential.

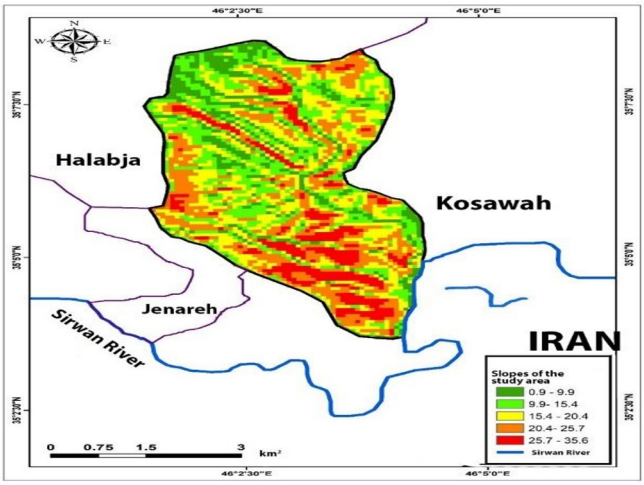
As revealed in Map (2), slope conditions in the basin vary widely and demonstrate the following geomorphic implications:

- **Hydrodynamic Efficiency**: Steeper gradients enhance runoff velocity, magnifying erosion and sediment discharge.
- **Slope Instability**: Inclined surfaces are prone to gravitational mass movements and localized structural failure.
- **Water Infiltration and Runoff**: Slope angle governs infiltration rates, runoff concentration, and surface storage capacity.
- **Sediment Flux**: Slope steepness directly affects the detachment, entrainment, and deposition of surficial materials.

The slope variable, second only to elevation in geomorphic significance, articulates the heterogeneity of landscape evolution across the basin. It underscores the spatial differentiation of landform processes and reveals how litho-structural context and surface inclination interact to determine erosional vulnerability [1].

Table 2. Study area slopes.

Regression varieties	Categories
insignificant	10 - 1
Very little	15 - 10
A little	20 - 15
medium	25 - 20
Relatively steep slope	35 - 25



Map No. 2. Slopes of the Sazan Valley Basin.

Certainly, Ebraheem. Here's an academically structured summary that synthesizes the slope classification and hillshade characteristics of the Sazan Valley Basin, while preserving the analytical depth and source attribution to [1]:

1.2 Slope gradient classification and hillshade analysis of the sazan valley basin

1.2.1 Slope gradient distribution

Based on Map (2) and Table (2), the basin exhibits five distinct slope categories, each representing a different degree of topographic inclination and spatial concentration:

Slope Category	**Degree Range**	**Spatial Location**	**Terrain Character**
I	1°–10°	Northern portions	Gentle slopes, minimal geomorphic activity
II	10°–15°	Northern and northeastern sectors	Very mild inclination
III	15°–20°	Northern and n orthwestern sectors	Low slope, minor erosional processes
IV	20°–25°	Central portions of the basin	Moderately inclined terrain
V	25°–35°	Central and southern regions	Relatively steep, erosion-prone surfaces

This topographic heterogeneity plays a pivotal role in controlling runoff velocity, infiltration rates, and sediment transport intensity across the basin. Steeper gradients,

especially in Categories IV and V, are more susceptible to fluvial incision, slope instability, and accelerated geomorphic change [13].

2 Hillshade characteristics and geomorphic implications

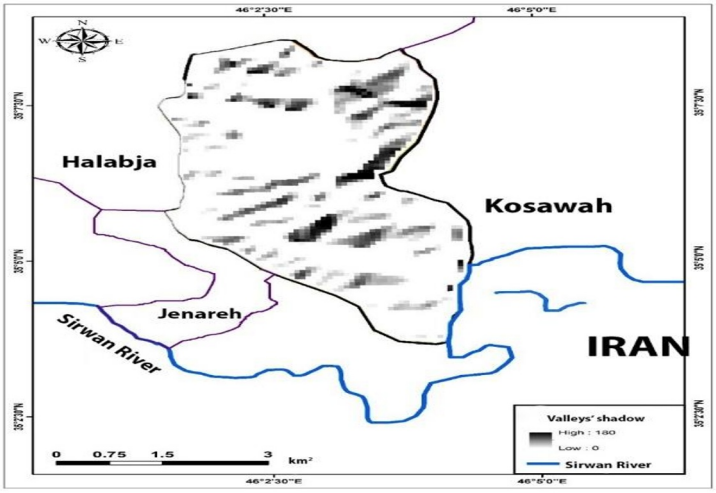
Hillshade analysis—derived from solar angle calculations based on terrain orientation—identifies zones of reduced solar exposure that significantly influence microclimatic and hydrological processes. According to [1], shaded terrain zones exhibit the following environmental and geomorphic functions:

- Reduced solar radiation decreases surface temperatures, promoting accumulation and persistence of snow and water, especially in calcareous terrains.
- Chemical weathering processes are intensified in these zones due to prolonged moisture retention and subsurface percolation, fostering dissolution features in carbonate lithologies.
- Water harvesting potential is elevated, making these areas optimal for runoff collection and groundwater recharge.
- Solar energy site selection benefits from hillshade mapping by identifying low-shade zones suitable for photovoltaic installations.
- Additionally, ecological and tourism planning can utilize hillshade data to determine sites conducive to orchards, shaded vegetation, and potential eco-tourism development.

This dual analysis of slope and solar exposure underscores the geomorphological complexity of the Sazan Valley Basin and provides a basis for sustainable land use, conservation, and development planning [1, 6, 7].

Table 3. Classification of hill shade for study area.

characteristics	Categories
Weak	120 - 72
medium	160 - 121
High	244 - 161



Map No. 3. Hill Shadow of the Sazan Valley Basin.

Through map No. (3) and Table No. (3), the shadow areas of the study basin can be classified as follows:

2.1 Hillshade classification and climatic influence in the sazan valley basin

The study categorizes the terrain of the Sazan Valley Basin into three hillshade classes based on solar exposure, which significantly affects geomorphic activity and energy utilization:

1. High Solar Exposure (72–120°) Found in the southern and southwestern parts, this category receives intense solar radiation, resulting in high temperatures and active physical weathering processes. It is also favorable for solar energy generation due to the consistent intensity of sunlight.
2. Moderate Solar Exposure (121–160°) Encompassing central and eastern sectors, this class experiences medium irradiance, coupled with relatively high temperatures and moderate humidity, fostering mixed geomorphic responses.
3. Low Solar Exposure (161–244°) Concentrated in the northern, northeastern, and western parts, this zone receives limited sunlight, leading to lower temperatures and higher humidity. Such conditions enhance chemical weathering, soil weakening, and rock disintegration, especially through moisture-assisted dissolution. These areas exhibit significant slope failure and soil creep due to saturation and mineral leaching.

2.2 Climatic context

Climate is a key driver of geomorphic processes such as weathering, erosion, and sedimentation. Based on observations from the Sazan meteorological station, the drought index was recorded at 22.27, placing the basin within the humid climatic zone [11] (Enitdhar Mahdi & Abdul Rahman, 2018).

Understanding these climatic components—in tandem with topographic orientation—provides essential insights into the spatial variability of landform development across the basin.

2.3 Environmental and climatic profile of the sazan valley basin

2.3.1Temperature regime

Thermal characteristics of the basin exhibit notable annual and seasonal variation. According to meteorological data from the Sazan station:

- Annual average maximum temperatures range between *20.18°C* and *25.2°C*, while minimum averages fluctuate between *7.68°C* and *13.7°C*.
- Peak summer temperatures occur in July and August, reaching up to *40.1°C*, whereas January records the lowest temperatures, down to *1.5°C*.
- The region is characterized by a significant diurnal and seasonal thermal amplitude, with monthly thermal ranges reaching *12.5°C* in summer and declining to *8.2°C* in winter [13].

2.3.2 Wind dynamics

Wind speed plays a subordinate but geomorphologically relevant role:

- The mean annual wind speed at Sazan station is *1.7 m/s*, with a maximum of 2.7 m/s during summer months.
- Winter months experience lower wind activity (*~1.2 m/s*) due to soil saturation and high atmospheric pressure, reducing wind-driven geomorphic processes.
- In contrast, summer winds facilitate aeolian transport due to dry surface conditions and increased solar heating, enhancing surface erosion [13].

2.3.3 Rainfall characteristics

Precipitation in the basin aligns with the Mediterranean winter rainfall regime:

- Annual precipitation totals range from *535 mm* to *989.1 mm* across the observation period.
- Rainfall peaks in January, corresponding to mid-latitude cyclone activity, while dry conditions prevail in summer.
- Orographic uplift enhances precipitation on windward slopes, whereas leeward zones remain in rain shadow, receiving limited rainfall. The earliest rains are detected in September, with gradual increases toward winter maxima [8, 9], awaiting confirmation from Mahdi Omran).

2.3.4 Relative humidity

Humidity levels demonstrate a direct correlation with seasonal temperature:

- The average annual relative humidity at the Sazan station is *43.9%*.
- Winter months, especially January, record elevated humidity levels (*up to 72.6%*), enhancing soil moisture retention and chemical weathering potential.
- Humidity declines sharply during summer months, notably August, driven by high evapotranspiration [1].

2.3.5 Soil classification and distribution

The region's pedological composition reflects climatic, topographic, and lithological controls [13]:

- **Red Chestnut Soil:** Found in northern, northeastern, and western sectors, these are clay-rich, organic matter–enhanced soils with depths ranging from *35–65 cm*. Fertile and well-drained, they are agriculturally productive
- **Deep Chestnut Soil:** Occurs centrally and eastward, similar in origin but sandier and deeper (*85–100 cm*), ideal for fruit orchards and diversified cropping.
- **Rugged Rocky Soils:** Predominate in southern, southeastern, and western margins. Shallow (*20–35 cm*), gravelly, and calcareous, these soils exhibit low fertility except within valley bottoms, where increased depth and gentler slopes support vegetation.
- Vegetation and Altitudinal Zonation Floral assemblages are governed by elevation, lithology, and climatic moisture availability:
- **Mountain plants and mixed forests**: Oak woodlands (Quercus spp.) dominate elevations of *600–800 m a.s.l.*, particularly in limestone-dominated zones. These ecosystems benefit from ample rainfall, solar radiation, and high humidity, rendering them critical for biodiversity conservation and sustainable land use [3].

2.3.6 Water resources and geomorphic influence

Water plays a pivotal role in shaping geomorphological processes within the Sazan Basin. These resources are classified into surface and subsurface forms:

- **Surface Water:** Derived primarily from rainfall and snow, especially in elevated regions reaching up to 1600 m a.s.l., contributing to runoff generation and valley incision [1].
- **Groundwater:** Formed by infiltration through porous and fractured rock layers, influenced by structural features, lithology, and climate. Groundwater contributes to terrain formation through dissolution, weathering, and karstification processes.

- **Natural springs and eyes:** Include 7 recorded springs, 4 of which are perennial and 3 seasonal, exhibiting karstic, faulted, or torsional origins.
- **Al-Kahriz systems:** Traditional subsurface water channels with gradual inclines, spaced between 15–25 m. These serve as a major water extraction method in the basin.
- **Wells:** Varying in depth from 35 m (shallow) to 185–240 m (deep), providing water for agricultural and domestic use [11].

2.3.7 Natural vegetation and environmental roles

Natural vegetation in the basin is shaped by climatic, edaphic, and topographic factors, and it performs essential ecological and geomorphological functions:

- Soil stabilization, erosion reduction, and enhancement of water infiltration are key benefits of vegetation cover [1].
- Vegetation types include:
- **Riparian vegetation**: Forest patches along valleys, sustained by year-round groundwater presence and fertile, organic-rich soils. These areas support grazing and the use of native medicinal herbs.
- **Seasonal weeds and grasses:** Dominant on slopes and plains distant from water sources, these herbaceous plants rely on seasonal rainfall and serve as grazing pastures. Their cycle is closely tied to snowmelt and spring precipitation [11].
- **Montane and mixed forests:** Predominantly oak species (Quercus spp.) between 600–800 m a.s.l., thriving in zones rich in limestone, humidity, and insolation [3].

3 Morphometric analysis

Using geographic information system (GIS) methods, the Sazan River Basin's morphometric study extracted important data like the basin's shape, drainage density, slope, and stream length. The hydrological behavior of the basin was evaluated by analyzing these factors. Improve the accuracy and robustness of the suggestions offered for water resource management and flood risk reduction by confirming these results in future research by comparing the morphometric findings with observable hydrological data, such as rainfall and streamflow measurements. The morphometric attributes of the drainage basin—such as area, perimeter, length, and width—are essential for understanding its hydrological behavior and fluvial morphology. These parameters were extracted using ArcGIS software, providing quantitative insights into basin form, runoff potential, and erosion patterns. As shown in Table (4,5)

Table 4. Cadastral characteristics of the river basin of the sazan valley basin.

Length/Sleeve	Ocean/km	Average width/km	How many square areas
9,2	24,16	4,12	25,92

Table 5. Morphological characteristics of the sazan valley basin.

Aquarium shape	Rotation coefficient	Elongation coefficient	Morphometric coefficient
0,12	0,55	0,62	Halabja Basin

3.1 Elongation ratio

The elongation rate in the Sazan Valley basin reached (0.62) and this indicates that the shape of the basin approaches the elongation shape as a result of increasing the area to the length and this is a result of changing the width of the water conditions from the source to the mouth, which indicates the irregularity of the water flow and the zigzag of the water dividing line of the basin as well as the short lengths of the waterways, especially in the upper ranks of the basin

The coefficient of the basin shape of the basin of the Sazan Valley was recorded (0.12), which is a low value far from the correct one, which indicates the inconsistency and regularity of the shape of the basin, as well as its approach to the triangular shape, as the head of the triangle is at the mouth and its base at the source, and this indicates the danger of the basin's exposure to flooding within a short time.

3.2 Characteristics of the water network

The water network of the aquarium consists of the main tributaries and secondary tributaries as well as the main stream in the aquarium and the study of these characteristics is important in geomorphological and hydrological studies and these characteristics include the following as shown in Table (6)

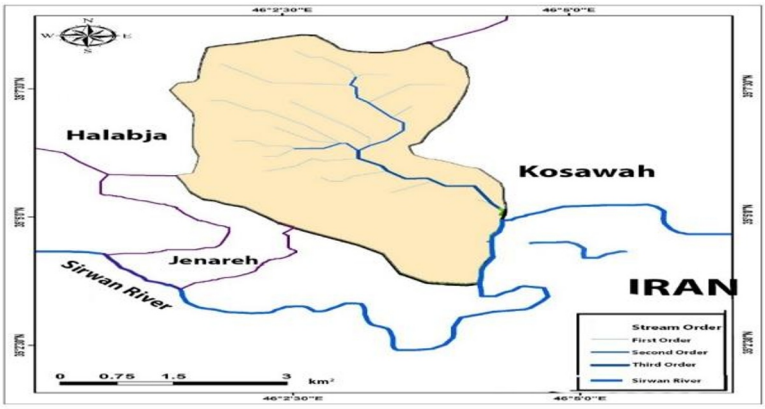
Table 6. Characteristics of the water network.

Third	The second	The first	Mattresses
1	2	15	Number of sewers

3.3 River mattresses

The concept of stream ordering, referred to as "river mattresses" in this study, represents a key morphometric indicator for assessing fluvial hierarchy and hydrological response. Utilizing the Strahler method—a widely adopted hierarchical classification system—the Sazan Valley Basin was delineated into three stream orders, comprising a total of 18 stream segments: 1st order streams: 15, 2nd order streams: 2 and 3rd order stream: [7]

This hierarchical arrangement is vital for evaluating surface runoff potential, estimating discharge capacity, and planning appropriate flood mitigation and water harvesting infrastructure. Stream order analysis enables the identification of valley systems with higher hydrological significance, guiding decision-making for sustainable watershed development.



Map No. 5. Halabja Basin Water Network**.**

Employing Artificial Intelligence Algorithms in Analyzing the Morphometric Properties of the Sazan Valley Basin especially the Support Vector Machine (SVM) algorithm, were employed to analyze the morphometric characteristics of the Wadi Sazan basin located in Sulaymaniyah Governorate, with the aim of classifying the basin areas according to the degree of exposure to flood risks.

Raw data were collected from the Digital Elevation Model (DEM), and a set of basic morphometric indicators were derived that play an important role in determining runoff behavior and the severity of different areas within the basin. These indicators included: degree of slope, elevation, elongation ratio, and shape coefficient, as well as distance to the nearest watercourse. To analyze these characteristics, a comprehensive spatial database was prepared, and then the SVM algorithm model was trained using a portion of field-disaggregated data, with the aim of enabling the model to distinguish between high, medium and low-risk areas Table (7).

Table 7: Model of morphometric properties used in the morphologyof the (svm) algorithm.

Form coefficient	Rotate ratio	Elongation ratio	Height	Degree of regression
0,12	0,55	0,62	(600 – 400) – (1800 – 1601)	(2-0) – (35-26)

The results showed that the SVM algorithm is able to classify the pelvic areas with high accuracy, as the results mostly matched the traditional field analysis.

The findings point to a drainage density and shape of the Sazan River Basin that are somewhat irregular, which in turn indicates a reaction to rainfall that is medium-level. Consequently, the basin may be susceptible to flooding during instances of intense precipitation. Nevertheless, researchers must corroborate the morphometric results using empirical meteorological or hydrological data, including temperature, streamflow, and precipitation, to enhance the validity of these conclusions. This study might provide more precise suggestions for water resource planning and enhanced tactics to mitigate flood risk. This work underscores the need of integrating AI methodologies into modern geomorphological research, as it enhances efficiency and objectivity in the results.

4 Conclusion

This study elucidates the hydrological behavior of the Sazan River Basin using morphometric analysis. The findings have tangible implications for water resource management, flood risk mitigation, and sustainable land use planning. Future study must authenticate the morphometric conclusions by using actual hydrological and climatic data. This validation will enable the refinement of ideas and, more broadly, enhance the hydrological system of the basin's resilience to climatic fluctuations. The adoption of artificial intelligence methods, notably the Support Vector Machine (SVM) approach, has significantly enhanced the analysis of the morphometric aspects of the Sazan Valley Basin and the objective categorization of hazardous locations. The need of integrating artificial intelligence techniques into modern geographical and hydrological research is paramount, since this technology has improved analytical quality while reducing reliance on human evaluation. As a result, the findings of these investigations are more precise and effective.

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