

## **Sub-Watershed Analysis using Geospatial Approach: A Case Study of Son Basin, Sihawal Area, Sidhi District of Central India**

Krishna Nand Chaudhari<sup>1\*</sup>, Rabindra Nath Tiwari<sup>2</sup> and Arun kumar Tripathi<sup>3</sup>

<sup>1\*</sup>Research Scholar, Department of Geology, Govt. Model Science College Rewa-486001, MP, India

<sup>2</sup>Professor, Department of Geology, Govt. Model Science College Rewa-486001, Madhya Pradesh, India

<sup>3</sup>Principal, Shiyut College, Gangeo, Rewa, Madhya Pradesh, India

Corresponding Author: Krishna Nand Chaudhari<sup>1</sup>

---

### **Abstract**

The present study examines the morphometric characteristics of the Sihawal watershed, situated within the Son Basin of Central India, and comprising seven distinct sub-watersheds (SW). Traditional watershed analysis methods often inadequately represent the spatial and numerical variability inherent in morphometric parameters. To overcome these limitations, the study adopts a geospatially integrated approach to improve the identification of critical sub-watersheds within the study area. Morphometric analysis is a key tool for recognizing areas prone to soil erosion, as it evaluates the geometric and topographic attributes of watersheds that directly influence erosion processes. The integration of morphometric parameters with Geographic Information System (GIS) techniques enables a more accurate and systematic delineation of watershed priority zones, thereby supporting the formulation of targeted soil and water conservation measures and land management strategies. Sustainable watershed functioning depends on efficient water resource management, which is increasingly supported by geospatial technologies due to their capacity to provide precise, data-driven insights for planning and decision-making. These approaches are particularly effective in monitoring and detecting spatial and temporal changes within watersheds arising from both natural dynamics and anthropogenic interventions. Morphometric analysis further facilitates the evaluation of interrelationships among watershed characteristics, offering a comprehensive framework for hydrological assessment. The drainage network of the Sihawal watershed is organized into stream orders ranging from first to seventh order and is distributed across seven sub-watersheds, designated SW-I to SW-VII. The outcomes of this study provide meaningful guidance for planners, policymakers, and resource managers engaged in watershed development, sustainable resource utilization, and the mitigation of environmental degradation within the study area.

**Keywords:** Morphometric Analysis, Drainage network analysis; Sustainable watershed management; Son Basin; Central India.

---

Date of Submission: 07-06-2026

Date of Acceptance: 17-06-2026

---

### **I. INTRODUCTION**

Water resources play a fundamental role in supporting ecological stability and socio-economic development; consequently, their assessment and management have received increasing attention in response to intensifying climate change impacts and expanding human activities across multiple spatial scales. In this context, watershed management particularly through morphometric analysis plays a pivotal role in mitigating critical issues such as soil erosion, water scarcity, and land degradation [4, 27]. Watersheds function as complex, hierarchical spatial units comprising interconnected sub-watersheds that jointly influence runoff generation, infiltration, and sediment transport [21, 40]. Comprehensive characterization of a watershed requires the systematic assessment of morphometric parameters, which are broadly classified into linear, areal, and relief aspects, as these parameters collectively govern hydrological response, runoff behavior, and landscape evolution [12, 22, 35]. Morphometric indicators have proven to be effective tools for soil and water conservation planning and groundwater resource development [20, 22, 38, 39]. Consequently, watershed management has gained prominence as a strategic solution to address escalating water-related challenges and climate-induced hydrological variability [9]. Morphometric analysis provides a robust framework for understanding the interrelationships among watershed attributes and for interpreting landscape evolution [23, 35]. In recent decades, geospatial approaches integrating Remote Sensing (RS) and Geographic Information System (GIS) techniques have been extensively adopted for watershed analysis due to their efficiency in handling spatial data and their ability to generate accurate, quantitative assessments [1, 2, 6, 24, 26, 29, 30, 36, 39]. Morphometric attributes derived through these techniques provide a numerical representation of catchment characteristics and

serve as a valuable foundation for applications such as watershed prioritization, hydrological modelling, erosion risk assessment, and natural resource conservation planning [40]. Geospatial techniques represent a robust and efficient means of extracting critical quantitative information necessary for watershed-level investigations, enabling objective comparison among sub-watersheds under diverse terrain conditions [23, 39]. The dynamics of surface water flow and the hydrological behaviour of a watershed can be effectively interpreted through detailed analysis of morphometric parameters, as these variables control drainage density, runoff potential, infiltration capacity, and sediment transport processes. The present study evaluates multiple sub-watersheds that occur under varying geomorphological and topographic settings.

Accordingly, the specific objectives of the present study are to:

- (a) Conduct a detailed morphometric evaluation of the Sihawal watershed using RS and GIS techniques;
- (b) Morphometric indicators to identify critical areas requiring management intervention.

## II. STUDY AREA

The study area is located within the boundaries of Survey of India Toposheet No. 63/L7, 63/H15, 63/H14, 63/L3, 63/L2 and 63/L10 positioned between latitudes 24°18'13.359"N to 24°36'57.41"N and longitudes 81°57'4.395"E to 82°22'44.594"E (Figure 1). Sihawal is a town and tehsil situated in the Sidhi District of Madhya Pradesh, India. Sihawal is one of the seven tehsils in the Sidhi district. The district is located in the north eastern part of Madhya Pradesh and forms the state's north-eastern boundary. The area is accessible by bus, taxi, and train, with the Rewa-Sidhi main road running through the central part of the area. The nearest railway station is Rewa. Sihawal Block in Sidhi District, Madhya Pradesh, exhibits a typical subtropical climate characterized by distinct seasonal variations. Summers (March–June) are extremely hot, with temperatures reaching 44–48 °C. The monsoon season (June–September) brings heavy rainfall, moderate temperatures ranging from 22–30 °C, and high humidity. Winters (November–February) are comparatively mild, with pleasant daytime conditions and cooler nights, and temperatures generally varying between 10–25 °C. Overall, the climatic pattern of the area is representative of much of central Madhya Pradesh.

The study area depicts a diverse lithological assemblage reflecting complex stratigraphic and structural conditions. The area is predominantly occupied by sedimentary formations, including Rohtas Limestone, Kaimur Sandstone, Bhagwar Shale, Jhiri Shale, Koldaha Shale, Arangi/Kanwari Shale, and Sandy Shale, indicating deposition under varying paleo-environmental settings. Cherty Quartzite, Deoland Sandstone, and Chorhat Sandstone–Limestone units are also widely distributed, suggesting alternating siliciclastic and carbonate sedimentation phases. Patches of Deonar Porcellanite and BHQ/BHJ represent siliceous lithologies associated with Precambrian depositional environments. Limited exposures of crystalline basement rocks, such as Granite Gneisses/Schists and Dolomite Marble, occur in the southern and southwestern parts, marking older metamorphic terrains. Phyllite exposures further indicate low-grade metamorphism within the region. Overall, the spatial distribution of these lithological units highlights the geological heterogeneity of the study area, which plays a significant role in controlling drainage characteristics, groundwater potential, and geomorphological evolution.

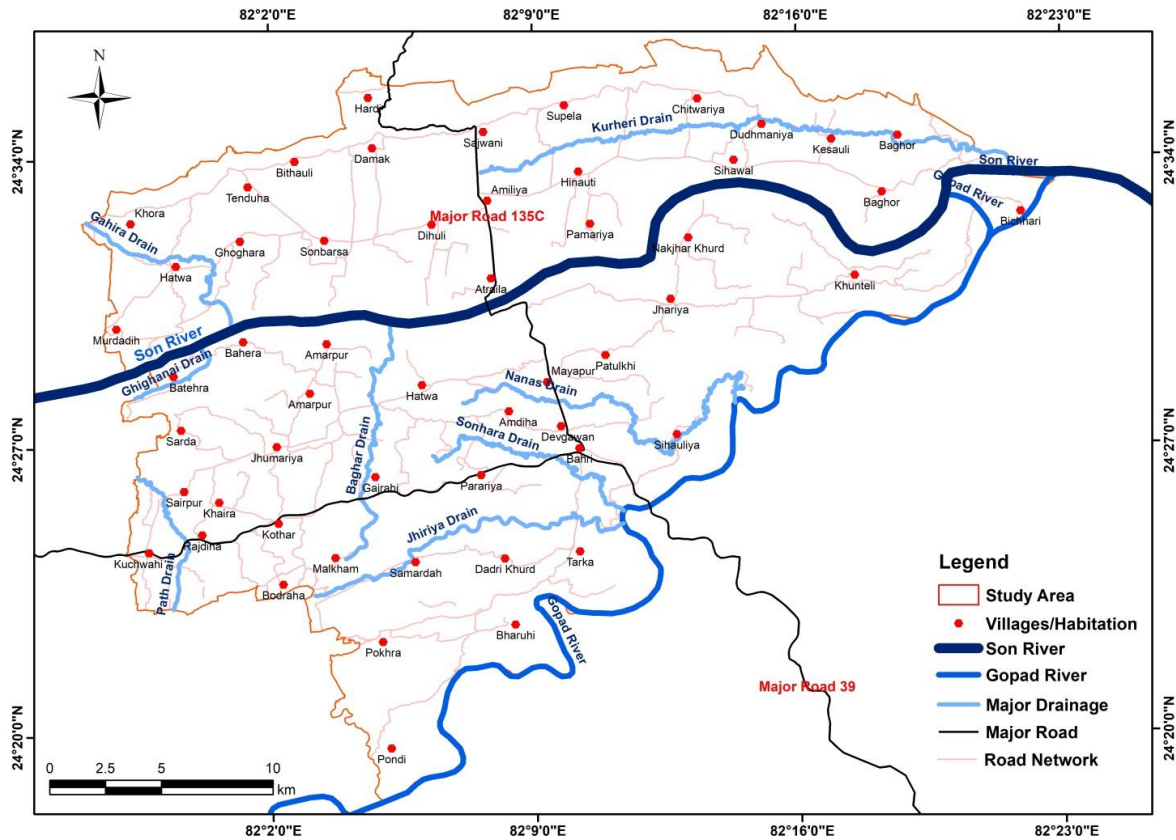


Figure 1: Location of the Study Area

### III. METHODOLOGY

The present study adopts a geospatially integrated approach to investigate the morphometric characteristics of the Sihawal study area. Data required for morphometric evaluation were derived from Survey of India topographic sheets, SRTM DEM and subsequently processed using Geographic Information System (GIS) techniques. Georeferenced toposheets were mosaicked and clipped using the ArcGIS mosaic tool to generate a seamless base map covering the entire study area. This composite map served as the foundation for the extraction and digitization of the watershed drainage network.

The morphometric assessment of the digitized drainage system involved meticulous processing, as stream ordering, nomenclature, and the accurate merging or segmentation of stream segments require careful interpretation and are inherently time-intensive, even when supported by advanced GIS platforms. A broad range of morphometric parameters was analyzed in the present study, encompassing areal, linear, and relief aspects. These parameters include basin area and perimeter, stream order, stream number, stream length, bifurcation ratio, drainage density, stream frequency, drainage texture, basin length, form factor, elongation ratio, and texture ratio.

The computation and interpretation of these morphometric indices were carried out in accordance with well-established methodologies proposed in earlier studies [7, 8, 10, 11, 18, 25, 33, 34, 39]. The mathematical expressions and formulae used for the calculation of the selected morphometric parameters are presented in Table 1. The detailed workflow illustrating data preparation, watershed delineation, morphometric parameter extraction, and sub-watershed prioritization is shown in Figure 2. The spatial distribution and arrangement of the delineated sub-watersheds within the study area are illustrated in Figure 3. All analyses were performed within the ArcGIS environment, thereby ensuring methodological consistency, spatial accuracy, and the reliability of the generated results.

Table 1. Formula for computation of morphometric parameters

Aspect	Parameter	Symbol	Formula/Description	Reference
Linear Aspects	Stream Order	U	Hierarchical ranking of streams according to Strahler's method	Strahler (1964)
	Number of Streams	Nu	Total number of stream segments of a given order	Horton (1945)
	Stream Length (km)	Lu	Total length of streams of a given order	Horton (1945)
	Mean Stream Length	Lsm	$Lsm = Lu / Nu$	Strahler (1964)
	Bifurcation Ratio	Rb	$Rb = Nu / Nu+1$	Schumm (1956)

	Stream Length Ratio	RL	$RL = Lu / Lu-1$	Horton (1945)
	Mean Bifurcation Ratio	Rbm	Average of bifurcation ratios of all stream orders	Strahler (1964)
Areal Aspects	Basin Area (km <sup>2</sup> )	A	Area enclosed by the watershed boundary	Horton (1945)
	Basin Length (km)	Lb	$Lb = 1.312 \times A^{0.568}$	Nookaratnam et al. (2005)
	Circularity Ratio	Rc	$Rc = 4\pi A / P^2$	Miller (1953)
	Compactness Coefficient	Cc	$Cc = 0.2821 \times P / \sqrt{A}$	Horton (1945)
	Drainage Density (km/km <sup>2</sup> )	Dd	$Dd = Lu / A$	Horton (1932)
	Drainage Intensity	Di	$Di = Fs / Dd$	Faniran (1968)
	Drainage Texture	T	$T = Nu / P$	Horton (1945)
	Elongation Ratio	Re	$Re = (2/Lb) \times \sqrt{(A/\pi)}$	Schumm (1956)
	Form Factor	Rf	$Rf = A / Lb^2$	Horton (1945)
	Infiltration Number	If	$If = Fs \times Dd$	Faniran (1968)
	Length of Overland Flow (km)	Lo	$Lo = 1/(2Dd)$	Horton (1945)
Stream Frequency	Fs	$Fs = Nu / A$	Horton (1932)	
Relief Aspects	Basin Relief (m)	H	$H = Z - z$ , where Z and z are maximum and minimum elevations, respectively	Strahler (1957)
	Relief Ratio	Rh	$Rh = H / Lb$	Schumm (1956)
	Ruggedness Number	Rn	$Rn = Dd \times (H/1000)$	Melton (1957); Strahler (1964)

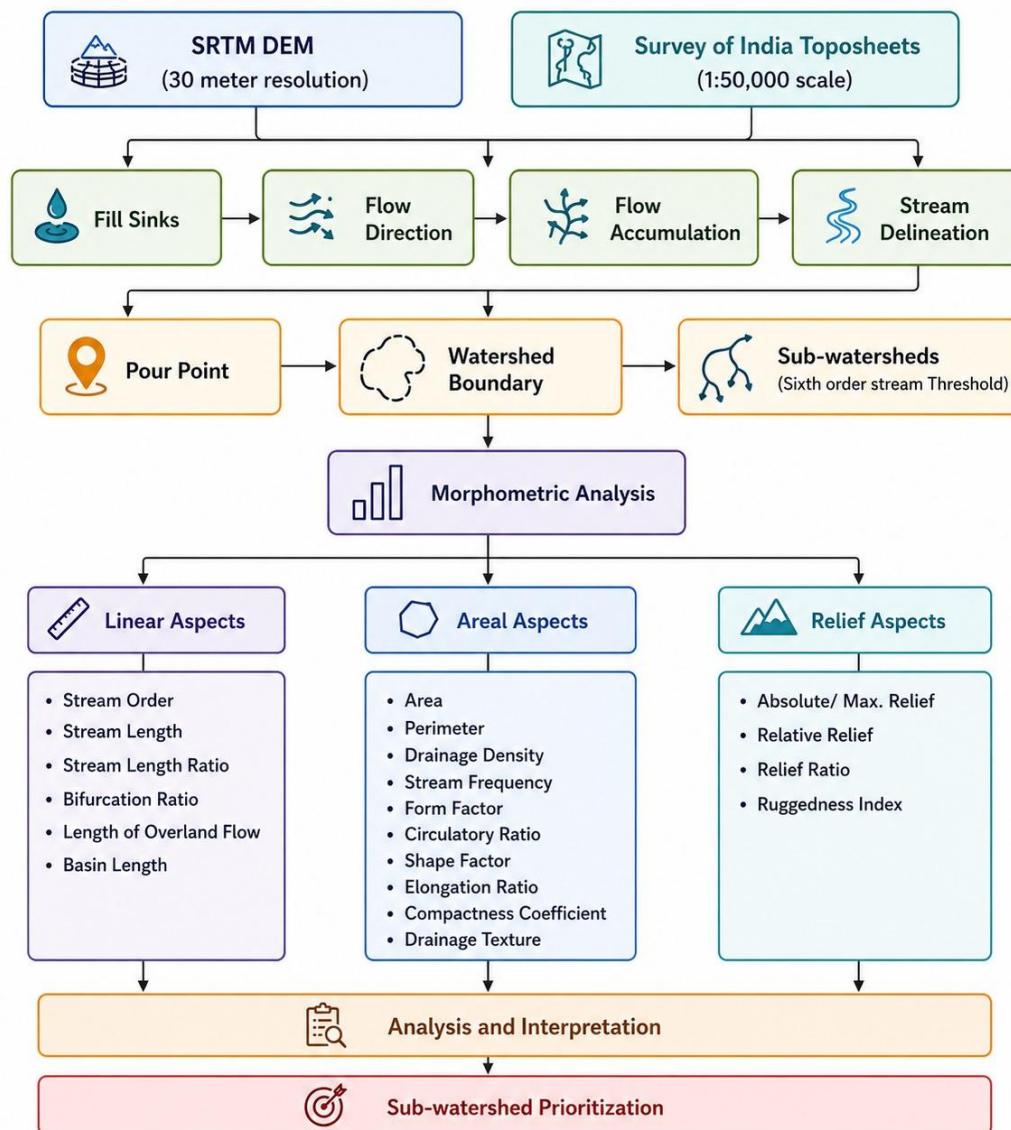


Figure 2: Methodological framework for watershed delineation and sub-watershed prioritization.

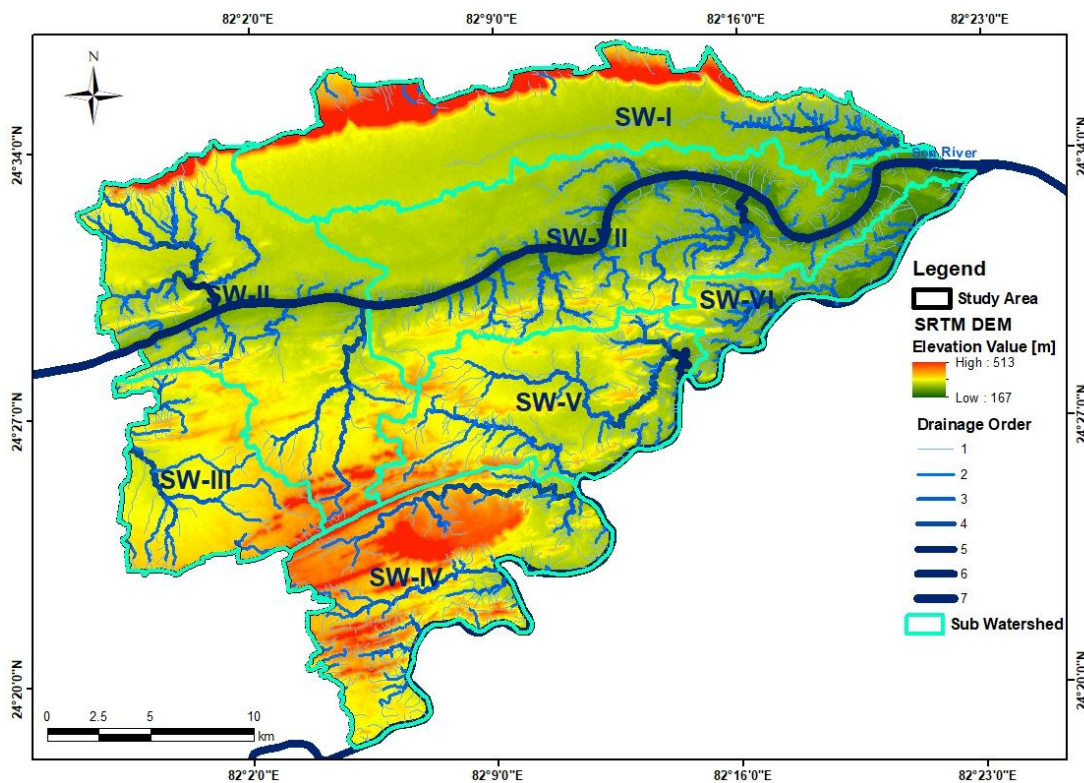


Figure 3: Sub Watershed map of Sihawal Watershed area

#### IV. RESULTS AND DISCUSSION

Morphometric analysis involves the quantitative evaluation of the geometric characteristics of a drainage basin and its drainage network. These parameters are conventionally grouped into linear, areal, and relief aspects, each representing distinct hydrological and geomorphological controls within a watershed [3, 10, 33]. The statistical details and graphical representation illustrated in Table-2, 3, 4 and Figure 4.

##### LINEAR ASPECTS

Linear morphometric parameters describe the drainage network properties and provide insight into stream hierarchy, structural influence, and runoff behaviour.

**Stream Order (U)** is a hierarchical ranking of streams based on their branching complexity, initially proposed by Horton (1945) and later modified by Strahler (1957). Higher stream order indicates a more mature and integrated drainage system. The stream order across the study area ranges from first to seventh order, indicating a well-developed and hierarchically organized drainage system. Sub-watershed SW-VII exhibits the highest stream order, reflecting a mature drainage network, whereas sub-watersheds such as SW-I, SW-III, and SW-IV show comparatively lower maximum stream orders, suggesting less evolved drainage development.

**Stream Number (Nu)** refers to the total count of stream segments within each order and generally decreases with increasing stream order, following Horton's law of stream numbers. The number of streams (Nu) consistently decreases with increasing stream order across all sub-watersheds, conforming to Horton's law of stream numbers. SW-VII records the highest total number of streams, followed by SW-II and SW-IV, indicating greater drainage dissection and higher surface runoff potential. In contrast, SW-VI and SW-III exhibit relatively fewer streams, which may be attributed to lower basin area and subdued topographic conditions.

**Stream Length (Lu)** represents the cumulative length of streams of a given order, while Mean Stream Length (Lsm) is the average length of streams in that order and reflects channel development and slope conditions. Total stream length (Lu) shows significant spatial variation, with SW-VII and SW-II exhibiting the highest cumulative stream lengths, suggesting extensive drainage networks and higher runoff conveyance capacity. Mean stream length (Lsm) generally increases with stream order, reflecting progressive channel development and downstream flow accumulation. Variations in stream length ratio (RL) among sub-watersheds indicate differences in slope, lithology, and geomorphic controls influencing channel elongation.

**Bifurcation Ratio (Rb)** is defined as the ratio of the number of streams of a given order to those of the next higher order. It is a key indicator of structural control on drainage development, with higher values suggesting tectonic or lithological influence, whereas lower values indicate natural drainage evolution [25, 34]. The bifurcation ratio (Rb) values across the sub-watersheds range from low to moderately high. Mean bifurcation

ratio values indicate that SW-I and SW-IV exhibit relatively higher structural influence on drainage development, whereas SW-VII and SW-V show lower values, suggesting minimal structural disturbances and comparatively natural drainage evolution. Overall, the linear morphometric parameters suggest that drainage patterns within the study area are primarily governed by topography and lithological conditions, with limited tectonic control.

**Areal ASPECTS**

Areal morphometric parameters describe the spatial characteristics and shape of the watershed, which strongly influence runoff generation, infiltration, and flood response.

**Drainage Density (Dd)** is defined as the total length of streams per unit basin area and reflects the degree of landscape dissection, surface permeability, and infiltration capacity [10]. Drainage density (Dd) varies considerably among the sub-watersheds, with SW-VI exhibiting the highest value, indicating closely spaced channels, steep slopes, and relatively impermeable surface conditions. In contrast, SW-I and SW-III show lower drainage density values, suggesting gentler slopes, higher infiltration potential, and permeable subsurface materials.

**Stream Frequency (Fs)** refers to the number of stream segments per unit area and is closely related to drainage density, indicating runoff potential [11]. Stream frequency (Fs) follows a pattern similar to drainage density, further confirming the strong influence of surface runoff and terrain characteristics. Sub-watersheds SW-VI and SW-IV exhibit higher stream frequency, reflecting greater susceptibility to surface erosion and quicker hydrological response to rainfall events.

**Drainage Texture (T)** expresses the relative spacing of drainage lines and is influenced by lithology, soil type, and relief [32]. Drainage texture ratio (T) values classify the study area predominantly under moderate to fine drainage texture. SW-IV and SW-II exhibit relatively higher texture ratios, indicating well-developed drainage networks and higher dissection intensity. Basin length (Lb) varies notably, with SW-VII having the longest basin length, reflecting elongated basin geometry and delayed peak runoff conditions.

**Form Factor (Rf)**, which indicates basin shape and flood potential; **Elongation Ratio (Re)**, expressing the degree of elongation of a basin; and **Circulatory Ratio (Rc)**, which compares the basin area to that of a circle with the same perimeter [16]. Shape parameters such as form factor (Rf), elongation ratio (Re), and circulatory ratio (Rc) indicate that all sub-watersheds are predominantly elongated in shape. Schumm (1956) introduced the concept of the elongation ratio to characterize basin shape, defining it as the ratio of the maximum basin length to the diameter of a circle with an equivalent area to that of the study basin. Low form factor and elongation ratio values suggest reduced flood peaks and longer runoff durations, which are favorable for groundwater recharge. Lower values of Rf and Re in the study area indicate elongated basin shapes, suggesting lower peak discharge and longer runoff duration.

The **compactness coefficient (Cc)** is a ratio that relates the perimeter of a watershed to the circumference of a circle having the same surface area as the watershed [11]. Compactness constant (Cc) values further support the elongated nature of the basins, with SW-IV and SW-III being relatively more compact compared to others.

**Length of Overland Flow (Lo)** represents the average distance water travels over the surface before entering a channel and is inversely related to drainage density. Length of overland flow (Lo) values are lowest in SW-VI and SW-IV, indicating shorter travel distance for surface runoff and higher erosion susceptibility.

**Infiltration Number (If)** is the product of drainage density and stream frequency and serves as an indicator of infiltration capacity, with higher values representing greater runoff dominance [7]. Infiltration number (If) is highest in SW-VI and SW-IV, reflecting high runoff potential and limited infiltration capacity, whereas lower values in SW-I and SW-III indicate relatively better infiltration conditions.

**Table 2. Sub-watershed wise input morphometric parameters**

Sr. No.	Details of Sub Watershed	Basin Area (A) (km <sup>2</sup> )	Perimeter (P) (km)	Elevation (m)			
				Std. Deviation	Max	Min	Mean
1.	SW-I	136.65	116.34	62.27	491	183	280.00
2.	SW-II	155.43	90.4	38.96	513	209	270.89
3.	SW-III	64.79	52.1	26.80	501	246	292.28
4.	SW-IV	106.01	64.57	47.02	513	216	308.35
5.	SW-V	91.16	61.57	29.43	474	194	271.58
6.	SW-VI	35.53	52.8	22.16	305	167	227.06
7.	SW-VII	180.15	119.7	23.19	350	173	237.92

**Table 3. Linear Aspect of morphometric parameters**

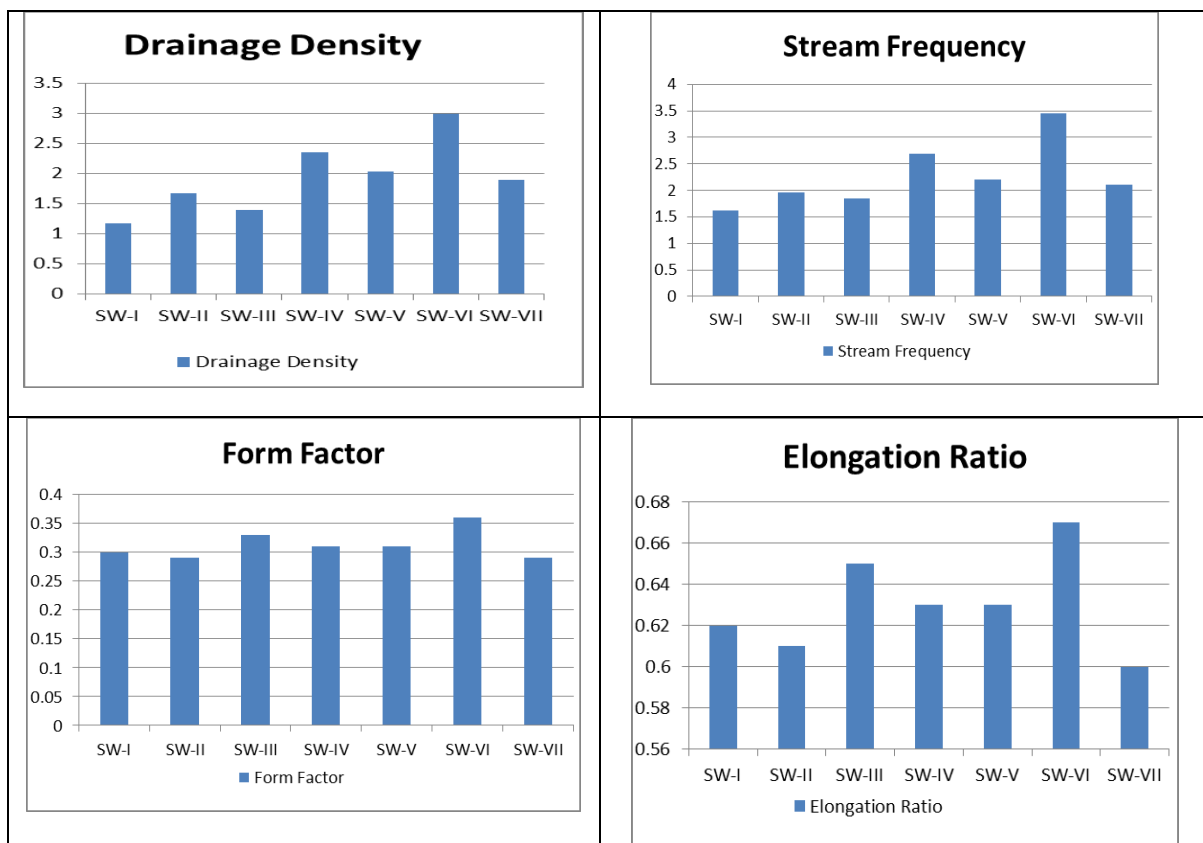
Sub Watershed (SW)	Stream Order							Mean Bifurcation ratio
	I	II	III	IV	V	VI	VII	
SW I								

No. of stream (Nu)	175	38	7	1	-	-	-	5.68
Stream length (Lu)(km)	115.64	24.21	10.43	9.65	-	-	-	
Mean stream length (km) (Lsm)	0.66	0.64	1.49	9.65	-	-	-	
Stream length ratio(km) (RL)	0.21	0.43	0.93	-	-	-	-	
Bifurcation Ratio (Rb)	4.61	5.43	7.00	-	-	-	-	
<b>SW II</b>								
No. of stream (Nu)	227	60	13	3	1	-	-	3.93
Stream length Lu (km)	137.32	51.83	44.84	11.34	2.47	-	-	
Mean stream length (km) (Lsm)	0.60	0.86	3.45	3.78	2.47	-	-	
Stream length ratio(km) (RL)	0.38	0.87	0.25	0.22	-	-	-	
Bifurcation Ratio (Rb)	3.78	4.62	4.33	3.00	-	-	-	
<b>SW III</b>								
No. of stream (Nu)	90	24	5	1	-	-	-	3.39
Stream length Lu (km)	46.30	33.40	6.37	3.93	-	-	-	
Mean stream length (km) (Lsm)	0.51	1.39	1.27	3.93	-	-	-	
Stream length ratio(km) (RL)	0.72	0.19	0.62	-	-	-	-	
Bifurcation Ratio (Rb)	3.75	4.80	5.00	-	-	-	-	
<b>SW IV</b>								
No. of stream (Nu)	220	54	9	1	-	-	-	4.77
Stream length Lu (km)	136.98	41.55	33.02	10.12	-	-	-	
Mean stream length (km) (Lsm)	0.62	0.77	3.67	10.12	-	-	-	
Stream length ratio(km) (RL)	0.30	0.79	0.31	-	-	-	-	
Bifurcation Ratio (Rb)	4.07	6.00	9.00	-	-	-	-	
<b>SW V</b>								
No. of stream (Nu)	153	38	6	2	1	1	-	3.27
Stream length Lu (km)	108.34	31.34	24.79	8.93	3.24	8.94	-	
Mean stream length (km) (Lsm)	0.71	0.82	4.13	4.47	3.24	8.94	-	
Stream length ratio(km) (RL)	0.29	0.79	0.36	0.36	2.76	-	-	
Bifurcation Ratio (Rb)	4.03	6.33	3	2	1	-	-	
<b>SW VI</b>								
No. of stream (Nu)	87	28	6	1	-	1	-	3.44
Stream length Lu (km)	55.58	20.93	7.53	3	-	19.72	-	
Mean stream length (km) (Lsm)	0.64	0.75	1.26	3.00	-	19.72	-	
Stream length ratio(km) (RL)	0.38	0.36	0.40	-	-	-	-	
Bifurcation Ratio (Rb)	3.11	4.67	6.00	-	-	-	-	
<b>SW VII</b>								
No. of stream (Nu)	304	67	13	3	1	1	1	3.17
Stream length Lu (km)	205.26	60.65	34.26	3.90	2.47	0.25	34.13	
Mean stream length (km) (Lsm)	0.68	0.91	2.64	1.30	2.47	0.25	34.13	
Stream length ratio(km) (RL)	0.30	0.56	0.11	0.63	0.10	-	-	
Bifurcation Ratio (Rb)	4.54	5.15	4.33	3.00	1.00	1.00	-	

**Table 4. Areal and Relief Aspect of morphometric parameters**

Parameters	SW I	SW II	SW III	SW IV	SW V	SW VI	SW VII
<b>Aerial Aspects (Aa)</b>							
Drainage Density (Dd)	1.17	1.68	1.39	2.36	2.04	3.00	1.89
Basin Length (Lb)	21.42	23.05	14.01	18.54	17.02	9.96	25.06
Stream Frequency (Fs)	1.62	1.96	1.85	2.69	2.20	3.46	2.10

<b>Drainage Texture ratio (T)</b>	1.90	3.37	2.30	4.41	3.26	2.33	3.26
<b>Form Factor (Rf)</b>	0.30	0.29	0.33	0.31	0.31	0.36	0.29
<b>Circulatory Ratio (Rc)</b>	0.13	0.24	0.30	0.32	0.30	0.16	0.16
<b>Elongation Ratio (Re)</b>	0.62	0.61	0.65	0.63	0.63	0.67	0.60
<b>Compactness Constant (Cc)</b>	2.81	2.05	1.83	1.77	1.82	2.50	2.52
<b>Drainage Intensity (Id)</b>	1.38	1.17	1.33	1.14	1.08	1.15	1.14
<b>Length of overland flow (Lo)</b>	0.43	0.30	0.36	0.21	0.25	0.17	0.26
<b>Infiltration Number (If)</b>	1.89	3.29	2.57	6.33	4.49	10.40	4.10
<b>Relief Aspects (Ra)</b>							
<b>Basin Relief (R)</b>	308.00	304.00	255.00	297.00	280.00	138.00	177.00
<b>Relief ratio (Rr)</b>	14.38	13.19	18.20	16.02	16.45	13.86	7.06
<b>Ruggedness Number (Rn)</b>	0.36	0.51	0.35	0.70	0.57	0.41	0.33
<b>Hypsometric Integral (HI)</b>	0.32	0.20	0.18	0.31	0.28	0.44	0.37



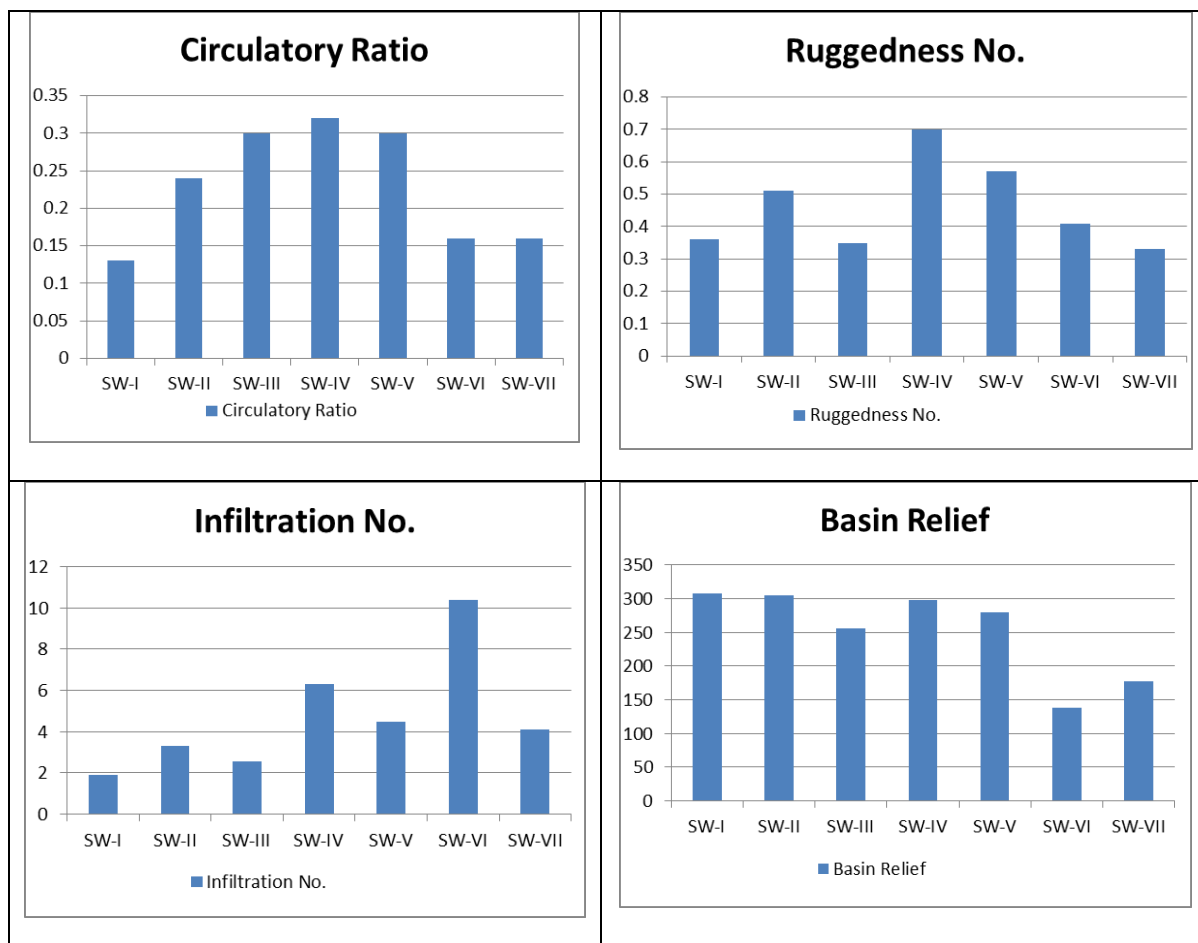


Figure 4: Graphical representation of major morphometric aspects

### HYSOMETRIC CURVE

A hypsometric curve represents the relationship between relative elevation and relative area of a watershed. It is widely used to assess the geomorphic and erosional stage of a basin [21, 31, 33]. The curve provides insight into the erosional status and geomorphic evolution of the watershed. The corresponding hypsometric integral values indicate varying stages of landscape development among the sub-watersheds, ranging from youthful to mature stages [15, 17]. The hypsometric curves for the sub-watersheds were generated using minimum, maximum, and mean elevation values derived from Table 2, following the hypsometric integral approximation method. Relative elevation was plotted against relative area to obtain normalized hypsometric curves. The resulting curves exhibit concave to S-shaped profiles for most sub-watersheds, indicating mature to old geomorphic stages characterized by reduced relief and dominant erosional processes. Sub-watershed SW-VI displays a relatively higher hypsometric integral, suggesting a youthful to early mature stage with active denudation. Overall, the hypsometric analysis reveals varying stages of landscape evolution across the study area, reflecting differences in topography, erosion intensity, and drainage development.

The curves variations in geomorphic evolution, ranging from youthful to mature and old stages across the study area illustrated in Table 5 and Figure 5. SW-VI and SW-VII show relatively higher, less concave curves, indicating youthful to early mature stages with comparatively active denudation. SW-II and SW-III exhibit strongly concave curves, characteristic of mature to old geomorphic stages with reduced relief. SW-I, SW-IV, and SW-V display intermediate, concave to S-shaped profiles, representing mature landscape conditions.

Table 5. Statistical parameter for Hypsometric curve

Sr. No.	Sub Watershed	Hypsometric integral (HI) values	Hypsometric Curve Type	Geomorphic Stage
1.	SW-I	0.32	Slightly concave	Mature
2.	SW-II	0.20	Strongly concave	Old / Peneplain
3.	SW-III	0.18	Strongly concave	Old stage
4.	SW-IV	0.31	Concave-S shaped	Mature
5.	SW-V	0.28	Concave	Mature
6.	SW-VI	0.44	Slightly convex	Youthful-early mature

7.	SW-VII	0.37	S-shaped	Mature
----	--------	------	----------	--------

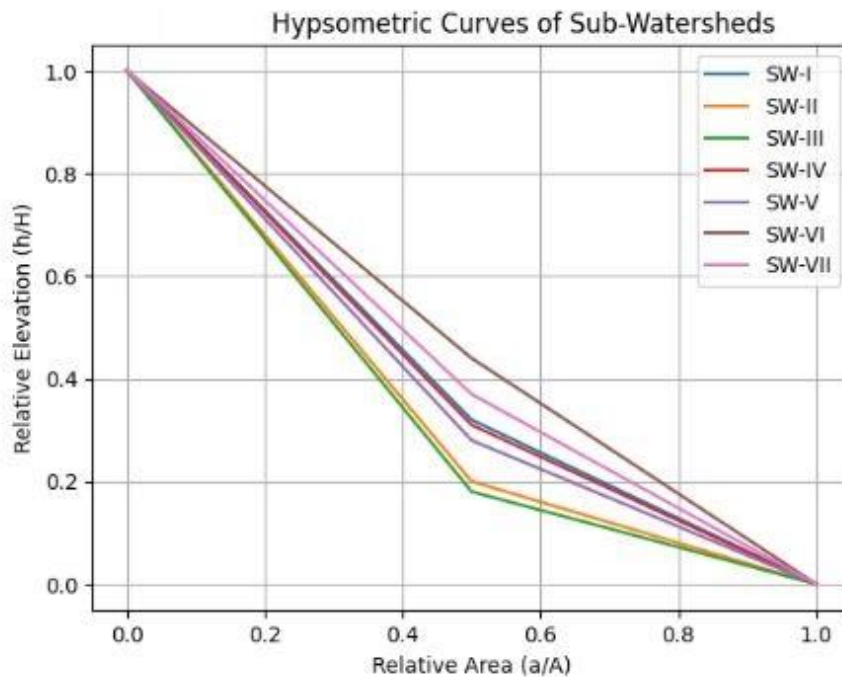


Figure 5: Spatial distribution of Hypsometric curve of Sub Watersheds

#### Sub Watershed Priority

The priority ranking chart indicates that SW-VI and SW-IV are most vulnerable to erosion and require immediate soil and water conservation interventions. Sub-watersheds with moderate scores, such as SW-V and SW-VII, require medium-level management, whereas SW-I, SW-II, and SW-III exhibit lower erosion risk and can be prioritized later. This ranking aligns with the morphometric analysis of drainage density, bifurcation ratio, hypsometric integral, and ruggedness number, etc. as illustrated in table 6 and Figure 6.

Table 6. Standardize Parameters for sub watershed priority

Sr. No.	Sub Watershed	Linear Aspects			Aerial Aspects				Relief Aspects
		(Rbm)	(Fs)	(Dd)	(HI)	(Rn)	(Lo)	(If)	(R)
1	SW-I	5.68	1.62	1.17	0.32	0.36	0.43	1.89	308
2	SW-II	3.93	1.96	1.68	0.20	0.51	0.30	3.29	304
3	SW-III	3.39	1.85	1.39	0.18	0.35	0.36	2.57	255
4	SW-IV	4.77	2.69	2.36	0.31	0.70	0.21	6.33	297
5	SW-V	3.27	2.20	2.04	0.28	0.57	0.25	4.49	280
6	SW-VI	3.44	3.46	3.00	0.44	0.41	0.17	10.40	138
7	SW-VII	3.17	2.10	1.89	0.37	0.33	0.26	4.10	177

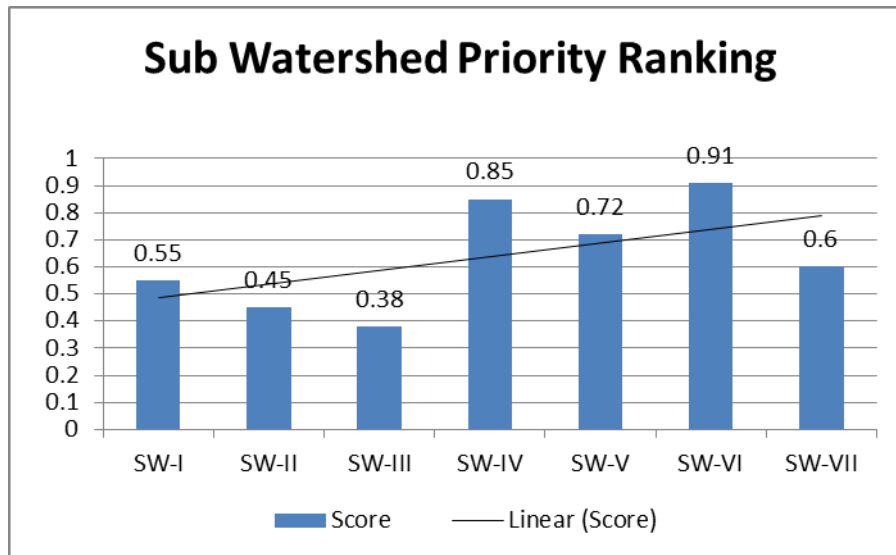


Figure 6: sub watershed priority for Sihawal Watershed Area

## V. CONCLUSION

This study applied an integrated geospatial and GIS-based framework to evaluate the morphometric characteristics of the Sihawal watershed and its seven constituent sub-watersheds. The analysis of linear, areal, and relief parameters demonstrates pronounced spatial variability in drainage configuration, watershed morphology, and topographic conditions across the study area. Linear morphometric attributes, including stream order, stream number, stream length, and bifurcation ratio, reflect a structurally controlled yet well-developed drainage system. Sub-watersheds SW-VII and SW-II exhibit relatively extensive and hierarchically organized drainage networks, whereas SW-VI shows compact watershed geometry with a high degree of dissection, indicating enhanced surface runoff response.

Areal morphometric parameters, such as drainage density, stream frequency, elongation ratio, basin length, and hypsometric integral, further emphasize contrasts in hydrological behaviour and erosional susceptibility. Sub-watersheds SW-VI and SW-IV are characterized by higher drainage density and stream frequency, suggesting greater runoff generation and a higher likelihood of soil erosion. In contrast, SW-II and SW-III display elongated basin forms and lower erosional indices, corresponding to mature to old geomorphic stages with comparatively stable landscape conditions. Relief-related parameters, including basin relief, relief ratio, ruggedness number, and infiltration number, reveal substantial variations in slope steepness and terrain ruggedness, underscoring differential erosion potential among the sub-watersheds.

The hypsometric analysis supports the morphometric interpretations, with SW-VI and SW-VII exhibiting higher hypsometric integral values and less concave hypsometric curves, indicative of youthful to early mature stages of landscape evolution and on-going denudational processes. Conversely, the concave hypsometric curves and lower integral values observed in SW-II and SW-III reflect advanced geomorphic maturity and relative terrain stability. Based on the integrated morphometric evaluation, SW-VI and SW-IV emerge as high-priority sub-watersheds for soil and water conservation interventions due to their elevated runoff potential and erosion susceptibility. Overall, the findings highlight the effectiveness of GIS-based morphometric analysis as a decision-support tool for watershed prioritization, erosion risk assessment, and sustainable watershed management planning.

The findings from the morphometric analysis of the Sihawal watershed are instrumental in guiding groundwater resource management initiatives. The inclusion of socio-economic considerations in future research is recommended to support comprehensive and sustainable watershed planning.

## REFERENCE

- [1]. Abdo, H.G., Almohamad, H., Al Dughairi, A.A., Karuppanan, S. (2023) "Sub-basins prioritization based on morphometric analysis and geographic information systems: a case study of the Barada river basin, Damascus countryside governorate, Syria". *Proc. Indian Natl. Sci. Acad.* Vol.89, pp.376–385. <https://doi.org/10.1007/s43538-023-00168-8>.
- [2]. Bogale, A. (2021) "Morphometric analysis of a drainage basin using geographical information system in GilgelAbay watershed, Lake Tana Basin, upper Blue Nile Basin, Ethiopia". *Appl Water Sci.* Vol.11(122). <https://doi.org/10.1007/s13201-021-01447-9>.
- [3]. Chorley, R. J. and Morgan, M.A. (1962) "Comparison of Morphometric Features, Unaka Mountains, Tennessee and North Carolina, and Dartmoor, England." *Geol. Soc. America Bull.* Vol. 73, pp. 17-34.
- [4]. Denekewu, G. A., Meshesha, D. T., and Tsegaye, E. A. (2026) "Morphometric analysis and weighted sum priority based prioritization of micro-watershed, Kiltie Watershed, Upper Blue Nile Basin, Ethiopia". *Scientific Reports*, Vol.16 (2870).

- [5]. Dhanush, S. K., Murthy, M.M. and Sathish, A. (2024) "Quantitative Morphometric Analysis and Prioritization of Sub-Watersheds for Soil Erosion Susceptibility: A Comparison between Fuzzy Analytical Hierarchy Process and Compound Parameter Analysis Method". *Water Resour. Manage.*, Vol.38, pp.1587–1606. <https://doi.org/10.1007/s11269-024-03741-y>.
- [6]. El Mhamdi, A., Habib, A., Tajdi, A., and Aarab, M. (2026) "GIS-based morphometric terrain analysis for watershed characterization: Case study of Ain Leuh Watershed, Morocco". *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-4/W18-2025, 119–126.
- [7]. Feniran, A. (1968) "The Index of Drainage Intensity - A Provisional New Drainage Factor". *Australian Jour. Sci.*, Vol. 31, pp. 328-330.
- [8]. Frisell, C.A., Liss, W.J., Warren, C.E. and Hurley, M.D. (1986) "A hierarchical framework for stream habitat classification: viewing streams in a watershed context". *Environ. Manag.*, Vol.10, pp. 199-214.
- [9]. Gautam, V. K., Pande, C.B., Kothari, M., Singh, P.K. and Agrawal, A. (2023) "Exploration of groundwater potential zones mapping for hard rock region in the Jakham river basin using geospatial techniques and aquifer parameters". *Adv Space Res.*, Vol.71(6), pp.2892–2908. <https://doi.org/10.1016/j.asr.2022.11.022>.
- [10]. Horton, R. E. (1932), "Drainage basin characteristics. Trans". *Am. Geophys. Union*, v.13, pp.350 - 361. <https://doi.org/10.1029/TR013i001p00350>.
- [11]. Horton, R. E. (1945) "Erosional development of streams and their drainage basins : Hydrophysical approach to quantitative morphology". *Geol. Soc. Amer. Bull.*, Vol.56, pp. 275-370. <https://doi.org/10.1177/030913339501900406>.
- [12]. Kulimushi, L.C., Choudhari, P., Maniragaba, A., Elbeltagi, A., Mugabowindekwe, M., Rwanyiziri, G. and Singh, S.K. (2021), "Erosion risk assessment through prioritization of sub-watersheds in Nyabarongo River catchment, Rwanda". *Environ. Challenges*, v.5(100260).
- [13]. Mehta D., Hadvani J., Kanthariya D. & Sonawala P. (2023) "Effect of land use land cover change on runoff characteristics using curve number: A GIS and remote sensing approach". *Int. J. Hydrol. Sci. Technol.*, Vol.16(1), pp.1–16.
- [14]. Melton, M. A. (1957) "An Analysis of the Relations among Element of climate, Surface Properties, and Geomorphology". Technical Report 11, Department of Geology, Columbia University.
- [15]. Mehta, A., Sharma, R., and Patel, P. (2023), "Geospatial assessment of watershed geomorphic evolution using hypsometric analysis and morphometric parameters". *Sustainable Water Resou. Manag.*, Vol.9 (128). <https://doi.org/10.1007/s40899-023-00845-2>.
- [16]. Miller, V. C. (1953) "A Quantitative Geomorphic Study of Drainage Basin Characteristics in Clinch Mountain Area, Virginia and Tennessee". Technical Report, 3, Office of Naval Research, Department of Geology, Columbia University, New York.
- [17]. Nehra, S., Singh, V. and Kumar, R. (2022) "Hypsometric integral and morphometric evaluation of watershed dynamics using remote sensing and GIS". *Arabian Jour. Geosci.*, Vol.15(1894). <https://doi.org/10.1007/s12517-022-09134-6>.
- [18]. Nukaratnam, K., Srivastava, Y.K., Venkateswara Rao, V., Amminedu, E. and Murthy, K.S.R. (2005) "Check dam Positioning by Prioritization of Microwatershed Using SYI Model and Morphometric analysis. Remote Sensing and GIS Perspectives". *J. Indian Soc. Rem. Sensing*. Vol.33(1), pp. 25-28.
- [19]. Pande, C.B., Kushwaha, N.L., Orimoloye, I.R., Kumar, R., Abdo, H.G., Tolche, A.D., Elbeltagi, A. (2023) "Comparative assessment of improved SVM method under different Kernel Functions for predicting multi-scale drought index". *Water Resour. Manag.*, v.37, pp.1367–1399. <https://doi.org/10.1007/s11269-023-03440-0>.
- [20]. Pandey, R. K., Anshumali, & Singh, A. K. (2026) "Disappearing streams and morphometric degradation in small watersheds of the Ganga River Basin". *Discover Water*, Vol.6(16).
- [21]. Pastor, I., Tanislav, D., Nedelea, A., Dunea, D., Serban, G., Haghghi, A.T., Sabau, D., Bretcan, P. (2024) "Morphometric Analysis and Prioritization of Sub-Watersheds Located in Heterogeneous Geographical Units—Case Study: The Buzău River Basin". *Sustainability*, Vol.16(7567). <https://doi.org/10.3390/su16177567>.
- [22]. Patel, A., Singh, M.M., Singh, S.K., Kushwaha, K., Singh, R. (2022) "AHP and TOPSIS based sub-watershed prioritization and tectonic analysis of Ami River Basin, Uttar Pradesh". *J. Geol. Soc. India*, Vol.98(3), pp.423–430.
- [23]. Rao, K. N. (2010) "Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, India Using Spatial Information Technology". *Intern. Jour. of Geomatics and Geosci.*, Vol. 1(2), pp. 179-187.
- [24]. Redvan, G., and Mustafa, U. (2021) "Flood prioritization of basin based on geomorphometric properties using principal component analysis, morphometric analysis and Redvan's priority methods: a case study of Harshit river basin". *J. Hydrol.*, Vol.603. <https://doi.org/10.1016/j.jhydrol.2021.127061>.
- [25]. Schumann, S.A. (1956) "Development of drainage systems and slopes in the bodlands in Perth Amboy, New Jersey". *Geol. Society. AM. Bull.* pp.597-646.
- [26]. Sharma, S., Mahajan, A.K. (2020) "GIS-based sub-watershed prioritization through morphometric analysis in the outer Himalayan region of India". *Appl. Water Sci.*, Vol.10(163). <https://doi.org/10.1007/s13201-020-01243-x>.
- [27]. Shekar P. R., Mathew A., Ben Hasher F. F., Mehmood K. and Zhran M. (2025) "Areas Using Morphometric Analysis and Multi-Criteria Decision-Making Techniques". *Sustainability*, Vol.17(5), 2124. <https://doi.org/10.3390/su17052124>.
- [28]. Shekar P. R., Mathew A., Hasher F. F. B., Mehmood K. and Zhran M. (2025) "Towards Sustainable Development: Ranking of Soil Erosion-Prone Areas Using Morphometric Analysis and Multi-Criteria Decision-Making Techniques", *Sustainability*, Vol.17(5), pp.2124; <https://doi.org/10.3390/su17052124>.
- [29]. Shelar, R.S., Shinde, S.P., Pande, C.B., Moharir, K.N., Orimoloye, I.R., Mishra, A.P. and Varade, A.M. (2022), "Sub-watershed prioritization of Koyna river basin in India using multi criteria analytical hierarchical process, remote sensing and GIS techniques". *Phys. Chemi. Earth Parts a/b/c*, Vol.128. <https://doi.org/10.1016/j.pce.2022.103219>.
- [30]. Singh, W. R., Barman, S. and Trikey, G. (2021), "Morphometric analysis and watershed prioritization in relation to soil erosion in Dudhnaï Watershed". *Appl Water Sci.*, <https://doi.org/10.1007/s13201-021-01483-5>.
- [31]. Singh, P., Thakur, J.K., and Singh, U.C. (2021) "Morphometric and hypsometric analysis for prioritization of sub-watersheds using geospatial techniques". *Environ. Earth Sci.*, Vol.80, 456. <https://doi.org/10.1007/s12665-021-09754-3>.
- [32]. Smith, K.G. (1950) "Standard for Grading Texture of Erosional Topography". *Amer. Jour. Sci.*, Vol. 248, pp. 655-668.
- [33]. Strahler, A. N.(1957) "Quantitative Analysis of Watershed Geomorphology". *Trans. Am. Geophys. Union.*, Vol. 38, pp. 913-920.
- [34]. Strahler, A. N.(1964) "Quantitative Geomorphology of Drainage Basins and Channel Networks In". *Handbook of Applied Hydrology*, McGraw Hill Book Company, New York, Section 4 ll.
- [35]. Subramanian, A. (2026) "Morphometric analysis and tectonic implications of the Chinnar River Basin using remote sensing and GIS, Southern India". *Discover Civil Engineering*, Vol.3(20). <https://doi.org/10.1007/s44290-026-00415-z>.
- [36]. Tiwari, R.N., Sharma, B. and Mishra, A. K. (2026), "Integrated AHP and GIS-Based Delineation of Groundwater Potential Zones in the Tipan River Basin, India: A Multi-Criteria Decision and Sensitivity Analysis Approach." *Jour. Geosci. Research*, Vol. 11(1), pp.85-94.

- [37]. Tiwari, R.N., Singh, S., Sharma B. and Dwivedi, R. (2014) "Morphometric Study of Govindgarh Area With Reference to Water Management, Rewa District, MP". *Watershed Management for Sustainable Development*. Excellent Publishers, New Delhi. pp. 135-144.
- [38]. Tiwari, R. N. (2016) "Hydrogeology and Watershed (Ed.)", Excellent Publisher, New Delhi, 169p.
- [39]. Tiwari, R. N., Kushwaha, V. K. (2021) "Watershed Prioritization Based on Morphometric Parameters and PCA Technique: A Case Study of Deonar River Sub Basin, Sidhi Area, Madhya Pradesh, India". *J Geol Soc India*, Vol.97, pp.396-404. <https://doi.org/10.1007/s12594-021-1697-z>.
- [40]. Thambidurai, P., Mookiah, M., Dikshit, A. K., et al. (2026) "Sub-watershed prioritization in Greater Andaman through morphometric insights". *Water Science*, Vol.40(15).