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Morphometric Analysis Of Amarpatan Block, Madhya Pradesh India, Using GIS And Remote Sensing Techniques

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Abstract
Remote sensing and GIS techniques are used as effective tools for morphometric analysis. Morphometric analysis classification is the most commonly adopted method for waterhed analysis. This method is helpful in conserving water resources by analyzing the drainage aspects of the catchment area. This study was conducted in Amarpatan block of Satna district, Madhya Pradesh. Morphometric features were analyzed using Digital Elevation Model (DEM) and ArcGIS software. The area was divided into 6 sub-watersheds. Stream order was determined from first to sixth order, which shows the dendritic drainage pattern. The parameters of morphometric analysis are measured as linear, aerial, and relief aspects (e.g., stream order, drainage density, stream frequency, bifurcation ratio, elongation ratio, etc.). The analysis contributes to understanding watershed management sites for the conservation of soil and water. This study provides information to policy makers for sustainable water resources development and management.
Keywords: *Amarpatan Block, Digital Elevation Model (DEM), Geographical Information System (GIS), Morphometric analysis, Remote Sensing.*

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I. Introduction

Groundwater, a crucial natural resource, is vital for economic development, particularly in irrigation, yet is increasingly threatened by overuse due to population growth, urbanization, and industrialization. Despite efforts to boost water supply, effective management of water resources remains lacking. Improved water-use efficiency across domestic, agricultural, and industrial sectors can be achieved through better management, economic tools, technological adoption, and a nationwide conservation mindset. Morphometric analysis of river basins, a key area within geomorphology, has gained prominence for its role in hydrology and environmental management. Using geospatial techniques and GIS tools, researchers can analyze watershed characteristics, prioritize sub-watersheds, and address issues like soil erosion and flood risks. Studies across India and globally demonstrate how morphometric analysis contributes to sustainable water management, emphasizing its importance for mitigating environmental challenges and supporting resource conservation efforts.

The integration of geospatial techniques and remote sensing in watershed management and morphometric analysis has gained prominence in recent years. Mohaimen et al. (2024) conducted tectono-morphometric analyses of drainage systems in the Chengi and Myinee river basins, focusing on the Chittagong Hill Tracts to understand tectonic influences on river morphology. Joy et al. (2023) applied GIS and remote sensing to analyze the morphometry of the river basin in the southwestern part of the Great Ganges Delta, demonstrating how such techniques support sustainable management. Work by Luo et al. (2023) highlighted morphometric analysis in fault and river systems in China, showcasing the global relevance of such studies in understanding active deformation patterns and basin dynamics. Dutal (2023) extended this by applying morphometric analysis to assess flash flood susceptibility in Turkey's Mediterranean region, highlighting the global relevance of such studies in disaster risk reduction. Shekar and Mathew (2023) provided a comprehensive review of data sources, quality, and geospatial techniques used in watershed morphometric analysis, emphasizing the importance of accurate data for sustainable water management. Dutal (2023) extended this by applying morphometric analysis to assess flash flood susceptibility in Turkey's Mediterranean region, highlighting the global relevance of such studies in disaster risk reduction. Ganie et al. (2022) analyzed the Saryu River basin in the Himalayas, using remote sensing and GIS to gain insights into its morphometric characteristics, further illustrating the utility of these tools in mountainous regions.

Geospatial techniques and morphometric analysis continue to play a critical role in understanding watershed dynamics and supporting water resource management globally. Mani et al. (2022) utilized geospatial techniques for the morphometric analysis of the Suswa River Basin, highlighting the importance of such methods in understanding basin characteristics. Shekar and Mathew (2022) extended this work by prioritizing sub-watersheds in the Murredu River basin using GIS tools, underlining the role of technology in hydrological assessments. Suresh and Krishnan (2022) utilized geospatial techniques to study the Vanniyar Basin in southern India, showing how morphometric analysis can inform basin management. Kant et al. (2022) applied modeling techniques to assess geomorphological parameters of a mountainous river basin, further contributing to water resource management using remote sensing and GIS. Similarly, Hasanuzzaman et al. (2022) used GIS and morphometric parameters to map flood susceptibility, underlining the role of these techniques in flood risk management. Hasanuzzaman et al. (2022) used GIS and morphometric parameters to map flood susceptibility, underlining the role of these techniques in flood risk management. Shekar and Mathew (2022) and Singh et al. (2021) focused on prioritizing sub-watersheds using morphometric analysis in river basins, employing principal component analysis and geospatial techniques to support water conservation strategies.

The application of geospatial techniques and GIS for morphometric analysis is instrumental in understanding river basins and managing water resources effectively. Tiwari and Kushwaha (2021) have contributed to watershed prioritization, particularly in the Deonar River sub-basin, utilizing PCA techniques to assess morphometric parameters. Kumar et al. (2021) demonstrated how remote sensing and GIS can aid in watershed prioritization, offering sustainable management insights for large-scale water resource management. Similarly, Singh et al. (2021) focused on the Dudhnai Watershed, emphasizing watershed prioritization in relation to soil erosion, a critical aspect of sustainable water management. Das et al. (2021) prioritized sub-basins of the Gomti River for soil and water conservation through morphometric and LULC (Land Use Land Cover) analysis, showcasing the potential of geospatial techniques in improving conservation efforts. Rajasekhar et al. (2020) provided a comprehensive morphometric analysis of the Jilledubanderu River Basin in Andhra Pradesh, employing geospatial technologies to inform groundwater management strategies. Hamad (2020) conducted a multiple morphometric characterization of the Malakan Valley drainage basin, using GIS and remote sensing to assess its hydrological potential and sustainability in Iraq. Abdeta et al. (2020) conducted morphometric analysis in Ethiopia's Gidabo Basin to prioritize sub-watersheds for better management planning. Mahala (2019) explored how morphometric analysis can help understand hydrological and morphological characteristics in different morpho-climatic settings, offering insights into water management strategies across varied environments. Parupalli et al. (2019) integrated remote sensing, the SWAT model, and morphometric analysis in the Kaddam River basin for integrated river basin management, highlighting the potential of these technologies in planning sustainable water resource management. Jahan et al. (2018) explored the hydrological implications of morphometric analysis in the Atrai-Sib River basin, applying GIS and remote sensing to guide water resource management strategies in Bangladesh. Tiwari and Bharti (2011) and Tiwari et al. (2011) provided important insights on morphometric studies and groundwater dynamics focused on different areas of Madhya Pradesh. These studies emphasize the growing importance of morphometric analysis in hydrological assessments across diverse geographic regions.

The aim of this study is to conduct a detailed morphometric analysis of the Amarpatan Block, Madhya Pradesh, using GIS and remote sensing techniques. By quantifying and evaluating various morphometric parameters, the study seeks to understand the region's physiographic and hydrological characteristics. This analysis will support effective watershed management, enabling better resource utilization, water conservation, and flood mitigation. The study also aims to identify suitable water harvesting structures, such as check dams, recharge shafts, and storage tanks, for sustainable water management in the region, while providing valuable insights and guidelines for future research and development initiatives.

II. Materials And Methods

Study area

Amarpatan is a block in Satna district of Madhya Pradesh. Satna district is located in the Vindhyachal plateau of the state of Madhya Pradesh. Amarpatan block is bordered by Rampur Baghelan to the north, Rewa district to the east, Maihar district to the west, and Ramnagar block to the south. It lies between north latitude 24°12'44.261"N to 24°31'20.03"N and east longitude 80°54'21.627"E to 81°17'32.433"E. It falls under Survey of India toposheet numbers 63H/2, H/3, H/4, H/7, H/15, and H/16. The study area is characterized by undulating terrain with a maximum elevation of 433 m in the Rewa sandstone hills to the south. The land slopes towards the northeast, with flat limestone areas used for agriculture. A Nala flows north of Ghuinsa, draining into the perennial Bihar River, which flows south of the area in a NE-SW direction. The region has a structurally controlled drainage system, influenced by geological joints. Hillocks of upper Bhander sandstone in the northwest exhibit distinct geomorphic features and weathering patterns.

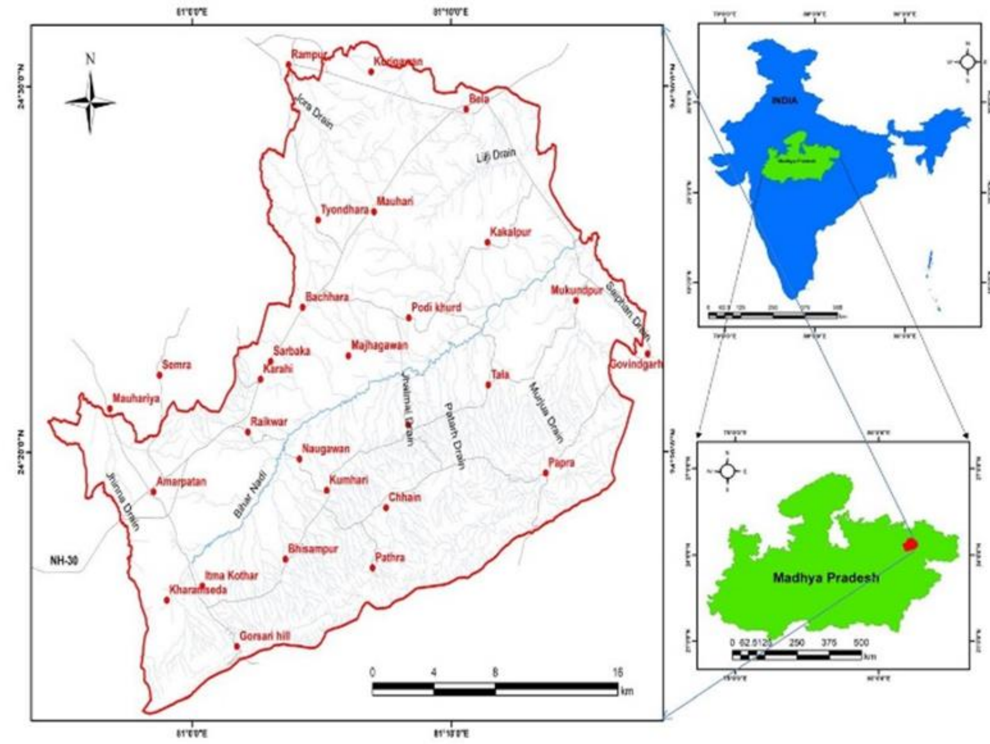

Fig 1: Study Area Map

Climate

The study area, located in the Vindhyan Scarpland and Beghelkhand Plateau, is characterized by a hot dry subhumid climate with deep loamy to clayey red and black soils. The region experiences four distinct seasons: a cold season (December-February), a hot season (March-June), a southwest monsoon season (June-September), and a post-monsoon period (October-November). Meteorological data from IMD, Satna (52 km from the site), indicates a normal maximum temperature of 41.7°C in May and a minimum of 9.1°C in January, with an annual mean of 25.7°C. Extreme temperatures recorded were 0.4°C and 47.8°C. The region receives an average annual rainfall of 1142.0 mm, primarily during the SW monsoon (88.87%). Rainfall is erratic, ranging from about 903 mm in 2022 to about 1351 mm in 2013, with the SW monsoon contributing 87.62% and the NE monsoon 6.14% of the annual rainfall.

Methodology

Morphometric analysis for watershed characterization and their management is a versatile method that provides valuable information about the size and shape of landforms. Using various approaches and statistical techniques, the morphological features of topography, drainage networks, water divides, channel lengths, and the geomorphological and geological setup of an area can be analyzed. (Mani et al. 2022). Quantitative analysis of morphometric parameters offers crucial insights into the hydrological conditions, rock formation stability, permeability, and storage capacity, which collectively determine a basin's yield. This research utilizes integrated secondary data sets from various sectors, with topographical sheets geometrically rectified and geo-referenced using UTM projection and WGS 1984 datum. The drainage network and related parameters were calculated using SRTM DEM and ArcGIS. The methodology involves identifying drainage networks and extracting watersheds through DEM, using ArcGIS. Various morphometric parameters were analyzed, with PCA used to reduce and identify the most sensitive parameters for watershed prioritization. This morphometric study plays a vital role in water resource management for the region.

Table 1: Formula for computation of morphometric parameters

Parameters	Formula's	Reference's
Linear Aspects (La)		
Stream order (U)	Hierarchical rank	Strahler (1964)
Number of Streams (Nu)	$Nu= N_1+N_2…+N_n$	Horton (1945)
Stream length in km (Lu)	$Lu= L_1+L_2….+L_n$	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)	Avg. of Rb ratio of all orders	Strahler (1964)
Aerial Aspects (Aa)		
Basin Length (Lb)	$Lb=1.312*A^{0.568}$	Nookaratnam et al. (2005)
Circulatory Ratio (Rc)	$Rc= 4\pi A/P^2$	Miller (1953)
Compactness Constant (Cc)	$Cc= 0.2821*P/A^{0.5}$	Horton (1945)
Drainage density (Dd)	Dd = Lu /A	Horton (1932)
Drainage Intensity (Di)	Di = Fs / Dd	Faniran (1968)
Drainage Texture Ratio (T)	T= Nu/P	Horton (1945)
Elongation Ratio (Re)	$Re= (2/Lb)*(A/\pi)^{0.5}$	Schumn (1956)
Form Factor (Rf)	$Rf= A/Lb^2$	Horton (1945)
Infiltration Number (If)	If = Fs * Dd	Faniran (1968)
Length of overland flow (Lo)	Lo = 1 / Dd*0.5	Horton (1945)
Stream frequency (Fs)	Fs = Nu/A	Horton (1932)
Relief Aspects (Ra)		
Basin relief in m (H)	H = Z - z	Strahler (1957)
Relief ratio (Rh)	Rh = H / Lb	Schumm (1956)
Ruggedness Number (Rn)	Rn=Dd*(R/1000)	Melton (1957), Strahler (1964)

III. Result And Discussion

Morphometric parameters

Morphometric analysis, a fundamental component of this discipline, has been revolutionized by the integration of remote sensing and Geographic Information Systems, enabling researchers to accurately assess temporal dynamics of watersheds and river basins (Singh et al., 2021). Analysis of various topographic features for modelling purposes using the Digital Elevation Model (DEM) has proved very effective. The definition of various morphometric parameters used in the study is discussed in detail and the mathematical formulas are presented in Table 1.

Stream Orders

Stream ordering involves determining the hierarchical position of streams within a drainage basin (Strahler, 1957). A river basin is composed of various segments, each with distinct morphometric characteristics. Understanding the relative position of these segments is crucial for visualizing the stream network's hierarchical organization. As shown in Figure 2, the watershed contains 1,497 streams, with a predominance of first and second-order streams. These lower-order streams make up about 94% of the total streams in the six sub-watersheds, while higher-order streams are relatively fewer. This distribution highlights the significance of smaller streams in the overall drainage pattern of the watershed.

Streams number (N)

Number of streams describes the total count of stream segments of different orders and is inversely proportional to the stream order. Stream number is denoted by N.

Total stream length (L)

Total stream length is measured as the total length of all ordered perennial streams within the watershed and is denoted by Lu. In general, the total stream length is measured on 1: 50000 topographical maps.

Mean stream length (L)

Mean stream length (L) is an important morphometric parameter, calculated as the ratio of the total stream length of a specific order to the number of streams within that order. It provides information about the hydrologic processes of the basin, and indicates the evolutionary stage of the stream and the underlying geologic controls.

Stream length Ratio (R_L)

Stream length ratio (R_L) is an important morphometric parameter that represents the ratio of the cumulative mean length of streams of a given order to the cumulative mean length of streams in the next lower order. This ratio provides insight into the hydrological and geomorphological characteristics of the drainage basin, helping to understand how stream lengths evolve across different stream orders. A higher R_L indicates an increase in stream length with order, which can reflect factors like basin topography, gradient, and geological control. This parameter is critical for analyzing the efficiency of the drainage network and watershed development.

Bifurcation ratio (R_b) and mean bifurcation ratio (R_{bm})

Strahler (1957) defined the bifurcation ratio (R_b) as the ratio between the number of streams in a given order to those in the next higher order. Horton (1945) and Schumm (1956) recognized Rb as an index of relief and dissection. In watersheds with minimal geological distortion, the mean bifurcation ratio (R_{bm}) reflects the branching pattern of the drainage network. As shown in Table 2, Rbm values for different sub-watersheds range from 3.39 to 4.37, indicating minor variations in structural control over drainage development. These values provide insights into the geomorphological stability and drainage dynamics of the region.

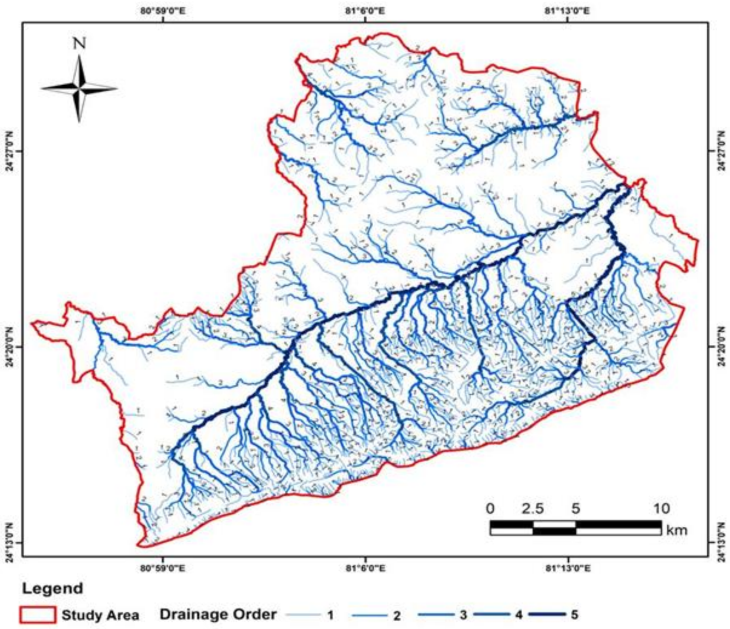

Fig 2: Drainage Map of Study Area

Table 2: Linear Aspect of morphometric parameters

Sub Watershed (SW)	Stream Order					Mean Bifurcation ratio
	I	II	III	IV	V	
SW I						
No. of stream (Nu)	186	46	12	3	1	3.72
Stream length (Lu)(km)	132.16	62.62	36.49	7.87	8.97	
Mean stream length (km) (Lsm)	0.71	1.36	3.04	2.62	8.97	
Stream length ratio(km) (Rl)	0.47	0.58	0.22	0.14	-	
Bifurcation Ratio (Rb)	4.04	3.83	4.00	3.00	-	
SW II						
No. of stream (Nu)	261.00	60.00	15.00	4.00	1.00	4.03
Stream length Lu (km)	153.32	73.05	39.55	20.41	11.97	
Mean stream length (km) (Lsm)	0.59	1.22	2.64	5.10	11.97	
Stream length ratio(km) (Rl)	0.48	0.54	0.52	0.59	-	
Bifurcation Ratio (Rb)	4.35	4.00	3.75	4.00	-	
SW III						
No. of stream (Nu)	252.00	63.00	16.00	3.00	1.00	4.07
Stream length Lu (km)	187.67	77.69	59.81	19.24	13.61	
Mean stream length (km) (Lsm)	0.74	1.23	3.74	6.41	13.61	
Stream length ratio(km) (Rl)	0.41	0.77	0.32	0.71	-	
Bifurcation Ratio (Rb)	4.00	3.94	5.33	3.00	-	
SW IV						
No. of stream (Nu)	258.00	56.00	13.00	2.00	2.00	4.10
Stream length Lu (km)	164.88	56.77	18.58	4.23	28.10	
Mean stream length (km) (Lsm)	0.64	1.01	1.43	2.12	14.05	
Stream length ratio(km) (Rl)	0.34	0.33	0.23	6.64	-	
Bifurcation Ratio (Rb)	4.61	4.31	6.50	1.00	-	
SW V						
No. of stream (Nu)	103.00	22.00	4.00	1.00	0.00	3.39
Stream length Lu (km)	60.37	23.66	8.82	10.32	0.00	
Mean stream length (km) (Lsm)	0.59	1.08	2.21	0.00	-	
Stream length ratio(km) (Rl)	0.39	0.37	1.17	0.00	-	
Bifurcation Ratio (Rb)	4.68	5.50	0.00	-	-	
SW VI						
No. of stream (Nu)	81.00	23.00	5.00	1.00	0.00	4.37
Stream length Lu (km)	66.72	36.36	21.99	4.49	0.00	
Mean stream length (km) (Lsm)	0.82	1.58	4.40	4.49	-	
Stream length ratio(km) (Rl)	0.54	0.60	0.20	0.00	-	
Bifurcation Ratio (Rb)	3.52	4.60	5.00	-	-	

Table 3: Sub-watershed wise input morphometric parameters

S. No.	Details of Sub Watershed	Basin Area (A) (km^2)	Perimeter (P) (km)
1.	SW-I	130.71	68.61
2.	SW-II	121.34	59.31
3.	SW-III	156.79	59.82
4.	SW-IV	121.58	68.93
5.	SW-V	61.60	33.23
6.	SW-VI	81.50	48.91

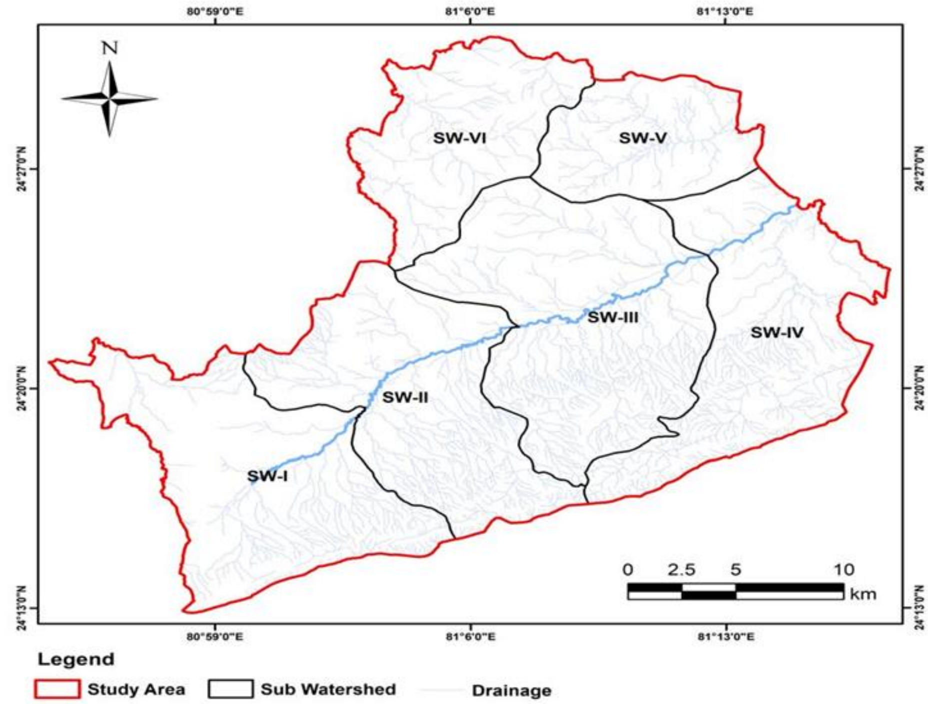

Fig 3: Watershed Map of Study Area

Basin Length (Lb)

Basin length is a key indicator of the geometrical size and shape of a drainage basin. In the study area, sub-watershed lengths (SW-I to SW-VI) range from 13.62 to 23.16 km, reflecting variations in watershed size and flow dynamics. Longer basin lengths suggest more extended flow paths, potentially reducing runoff speed, while shorter lengths indicate more compact basins with quicker runoff responses.

Circulatory Ratio (Rc)

The circularity ratio (Rc), measures basin shape by comparing the basin area to the area of a circle with an equivalent perimeter (Miller, 1953). It reflects stream length, frequency, and basin compactness. In the study area, Rc values range from 0.32 (SW-IV) to 0.70 (SW-V), indicating varied basin shapes. Higher Rc values (0.70) suggest a more circular, compact basin with faster runoff, while lower values (0.32) indicate elongated basins with slower runoff and longer flow paths.

Compactness Constant (Cc)

Compactness coefficient (C), introduced by Horton (1945), is a key morphometric parameter that defines the shape of a watershed. It is calculated as the ratio of the watershed's perimeter (P) to the circumference of a circle with an equivalent area. A more circular basin indicates a shorter time of concentration before peak flow, making it more susceptible to rapid runoff. In the study area, compactness coefficient values range from 1.20 (SW-V) to 1.76 (SW-IV), highlighting varying susceptibility to drainage efficiency. Lower compactness coefficient (1.20), suggests a more circular basin shape, leading to faster runoff and potentially higher flood risks. Higher value (1.76), indicates an elongated shape, allowing for longer flow paths and reduced peak flow rates.

Drainage density (Dd)

Drainage density measures the total length of stream segments across all orders per unit area, reflecting the proximity of channels in a drainage basin. It is a key indicator of surface runoff characteristics and groundwater infiltration. Langbein (1947) highlighted its significance in determining water travel time. In the study area, drainage density values range from 1.59 to 2.46, indicating moderate to high surface runoff. The observed drainage density values suggest that sub-watersheds with values closer to 2.46 have more frequent and closely spaced streams, reflecting faster surface runoff and reduced infiltration. Lower values, like 1.59, indicate more permeable materials and better infiltration capacity.

Drainage Intensity (Di)

Drainage intensity, an important parameter in watershed prioritization. It is the ratio of stream frequency to drainage density. It indicates the combined effect of both factors on runoff efficiency (Shekar and Mathew, 2022). Higher values (2.46 in SW-II) suggest more effective runoff and drainage efficiency, while lower values (1.59 in SW-VI) indicate reduced drainage effectiveness.

Drainage Texture Ratio (T)

Drainage texture, introduced by Horton (1945), represents the relative spacing between streams in a watershed. It is calculated as the ratio of the total number of stream segments of all orders to the watershed perimeter. The texture ratio (T) is a crucial morphometric parameter, influenced by factors such as lithology, infiltration capacity, and terrain characteristics. In the study area, drainage texture ratio values range from 2.25 (SW-VI) to 2.46 (SW-II), reflecting underlying geological and hydrological features of watersheds. Higher drainage texture values indicate a finer drainage network, suggesting less permeable materials and reduced infiltration whereas lower values indicate better infiltration capacity and less structural control on stream formation.

Elongation Ratio (R_e)

The elongation ratio (R_e) is the ratio of the diameter of a circle with the same area as the watershed to the basin's maximum length. For circular, oval, and elongated basins, R_e values are >0.9, 0.9–0.8, and <0.7, respectively. Sub-watersheds I to VI have ER values of 0.62, 0.62, 0.61, 0.62, 0.65, and 0.64, indicating elongated shapes. These values suggest that the sub-watersheds are more prone to elongated drainage patterns, potentially affecting hydrological responses and flood management strategies.

Form Factor (Rf)

The form factor, defined by Horton (1932), is the ratio of basin area (A) to the square of its maximum length (L). A lower form factor indicates a more elongated watershed, while higher values suggest greater peak flows over shorter durations. In the study area, form factor values range from 0.29 to 0.33 across SW-I to SW-VI. Sub-watersheds with higher form factor values (0.33 in SW-V) experience sharper, quicker peak flows, while lower values (0.29 in SW-III) indicate more elongated shapes with prolonged flow durations.

Infiltration Number (If)

The infiltration ratio (If), defined by Faniran (1968) as the product of Stream Frequency and drainage density, inversely correlates with infiltration capacity and positively with surface runoff. Sub-watersheds I to VI exhibit If values of 3.60, 6.91, 4.88, 6.10, 3.56, and 2.15, respectively. Higher If values indicate reduced infiltration capacity and increased surface runoff, suggesting that sub-watersheds II and IV may experience more surface runoff, impacting water management and flood control strategies.

Length of overland flow (Lo)

The length of overland flow, a key hydrological and morphometric factor, represents the mean horizontal flow path from the watershed divide to the stream in a first-order basin. It is a critical measure of stream spacing and watershed dissection, roughly equivalent to half the reciprocal of drainage density (Chorley, 1969). In the study area, values range from 0.20 (SW-II) to 0.36 (SW-VI). Lower values (0.20) suggest shorter flow paths and higher runoff potential, while higher values (0.36) indicate longer flow paths and better infiltration capacity.

Stream frequency (Fs)

Stream frequency, as defined by Horton (1932), represents the total number of stream segments per unit area and reflects the texture of the drainage network. It is primarily influenced by the lithology of watershed. Stream frequency offers insights into the lithological characteristics of the watershed and its drainage texture. In the study area, values range from 1.35 (SW-VI) to 2.81 (SW-II) (Table 4), indicating varying levels of drainage complexity and catchment permeability. Higher stream frequency values (closer to 2.81) indicate denser, finer drainage networks, likely due to less permeable subsurface materials. Lower values (around 1.35) suggest coarser drainage textures and higher permeability, allowing more infiltration.

Basin Relief (R)

Maximum watershed relief, also known as vertical relief, represents the vertical distance between the highest and lowest points within a basin (Strahler, 1957). The relief values for sub-watersheds (SW-I to SW-VI) range from 63 m to 394 m above mean sea level, with an average basin relief of 332 m (Table 4). Higher R (SW-V) indicate steeper slopes and potential for higher surface runoff, while lower relief in SW-I and SW-VI suggests more gradual slopes and slower runoff, impacting erosion and flood management strategies.

Relief ratio (Rr)

The relief ratio, defined by Schumm (1956) as the ratio between total relief and the longest dimension of the basin along the main drainage line, ranges from 3.95 to 28.93 across sub-watersheds (SW-I to SW-VI) (Table 4). This variation reflects the diverse topographical gradients within the basin, with SW-V exhibiting the steepest slopes and SW-VI most gentle. Higher Rr (SW-V) suggest steeper slopes, faster runoff, and potential erosion, while lower values (SW-VI) indicate flatter terrain with slower water movement, favoring infiltration.

Ruggedness Number (Rn)

The ruggedness number, defined as the product of basin relief and drainage density (Strahler, 1957; Melton, 1957), ranges from 0.10 to 0.92 across sub-watersheds (SW-I to SW-VI). Higher values (SW-II, 0.92) indicate more rugged terrain and higher erosion potential, while lower values (SW-VI, 0.10) suggest flatter, more stable areas with reduced erosion risk.

Table 4: Aerial and Relief Aspect of morphometric parameters

Parameters	SW I	SW II	SW III	SW IV	SW V	SW VI
Aerial Aspects (Aa)						
Basin Length (Lb)	20.89	20.02	23.16	20.05	13.62	15.97
Circulatory Ratio (Rc)	0.35	0.43	0.55	0.32	0.70	0.43
Compactness Constant (Cc)	1.69	1.52	1.35	1.76	1.20	1.53
Drainage density (Dd)	1.90	2.46	2.28	2.24	1.68	1.59
Drainage Intensity (Di)	1.00	1.14	0.94	1.21	1.25	0.85
Drainage Texture Ratio (T)	3.61	5.75	5.60	4.80	3.91	2.25
Elongation Ratio (Re)	0.62	0.62	0.61	0.62	0.65	0.64
Form Factor (Rf)	0.30	0.30	0.29	0.30	0.33	0.32
Infiltration Number (If)	3.60	6.91	4.88	6.10	3.56	2.15
Length of overland flow (Lo)	0.26	0.20	0.22	0.22	0.30	0.31
Stream frequency (Fs)	1.90	2.81	2.14	2.72	2.11	1.35
Relief Aspects (Ra)						
Basin Relief (R)	385.00	373.00	388.00	389.00	394.00	63.00
Relief ratio (Rr)	18.43	18.63	16.76	19.40	28.93	3.95
Ruggedness Number (Rn)	0.73	0.92	0.89	0.87	0.66	0.10

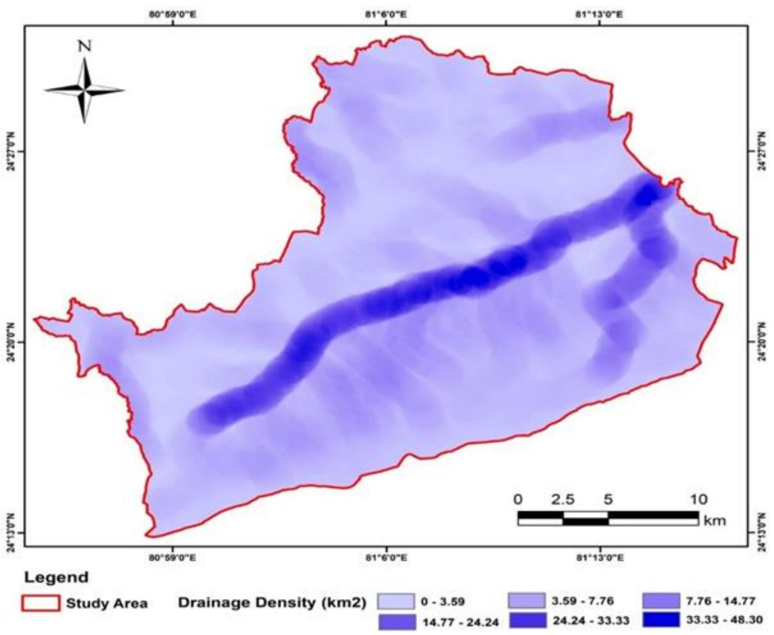

Fig 4: Drainage Density Map of Study Area

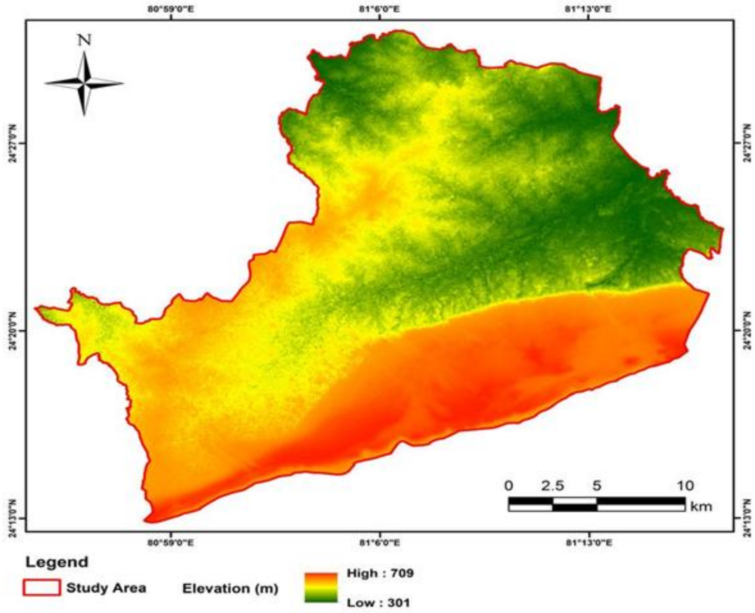

Fig. 5 Elevation Map of Study Area

IV. Conclusion

Morphometric analysis of the Amarpatan block in Madhya Pradesh, India, using GIS and remote sensing techniques, reveals significant insights into the geomorphological and hydrological characteristics of the region. By integrating modern tools such as digital elevation models (DEM) and ArcGIS software, we have calculated various morphometric parameters, including stream order, bifurcation ratio, drainage density, and more. The analysis reveals that the study area comprises six sub-watersheds (SW-I to SW-VI) consisting mainly of first and other sequence streams, accounting for about 94% of the total stream count. This prevalence of low-order streams promotes a finely dissected watershed network that plays a vital role in shaping surface water flow. The calculated bifurcation ratio (Rb) ranges from 3.39 to 4.37, suggesting minimal hydrological control on the watershed network, depicting a stable geomorphological environment in most of the sub-watersheds. Water density (Dd) values, ranging from 1.59 to 2.46, exhibit moderate to high runoff potential. Stream frequency (Fs) values varying from 1.35 to 2.81 demonstrate the diverse drainage patterns within the region, with denser networks in some sub-watersheds suggesting more impervious surfaces. The extension ratio (Re) of all sub-watersheds is below 0.7, indicating that sub-watersheds are predominantly extensional. Form factor values, ranging from 0.29 to 0.33, show a slightly more circular shape with sub-watersheds V, potentially making it more vulnerable to fast runoff events. The compactness coefficient (Cc) and circularity ratio (Rc) reflect the diverse basin shapes in the region. The infiltration number (If) and overland flow length (Lo) demonstrate the complex relationship between surface runoff and groundwater recharge in the study area. Higher infiltration numbers in sub-watersheds II and IV indicate increased runoff and reduced groundwater infiltration, while sub-watersheds with higher Lo values, such as SW-VI, exhibit longer flow paths, which promote better infiltration capacity. Basin relief values range from 63 to 394 meters, with SW-V exhibiting steeper slopes and higher surface runoff potential. Relief ratios, ranging from 3.95 to 28.93, reveal topographical diversity, while ruggedness numbers (0.10–0.92) indicate varying erosion risks.

These parameters are essential for understanding watershed behaviour, surface runoff and groundwater infiltration, which are crucial for effective water resource management and flood control. The findings provide valuable data for enabling more informed decisions for flood mitigation, groundwater recharge strategies, and sustainable land use planning.

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Data Availability:

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary material. Raw data that support the findings of this study are available from the corresponding author, upon reasonable request.

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Statements And Declarations

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Competing Interests

The authors have no competing interests.

Authors Contributions

Gaurav Mishra, Research Scholar, Department of Geology, Govt. Model Science College Rewa, Madhya Pradesh, India, has contributed toward collection of the data and literature review. He has contributed towards creating figures and relevant literatures.
Rabindra Nath Tiwari, Professor and Head, Department of Geology, Govt. Model Science College Rewa, Madhya Pradesh, India has made a significant contribution to the conception/design and interpretation of data, drafting and critically revising the manuscript.
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Covering Letter

20 Sep. 2024

From,

Gaurav Mishra
Research Scholar
Department of Geology, PM College of Excellence Govt. Model Science College Rewa, Madhya Pradesh, India

To
Editor-in-Chief,
IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
Dear Sir,

We wish to submit an original research article entitled "Morphometric Analysis of Amarpatan Block, Madhya Pradesh India, Using GIS and Remote Sensing Techniques" in your most reputed journal.
This research work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.
In this paper, we have discussed Morphometric Analysis of Amarpatan Block, Madhya Pradesh India, Using GIS and Remote Sensing Techniques. The research work is very useful because water conservation is urgently needed due to water scarcity problem in India. The research work carried out by authors may be extremely useful for

academicians and planners in direction of environmental management such as soil erosion, water conservation and groundwater resource development.
We believe that this manuscript is very appropriate for publication in IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) because it provides the scope of the dissemination of current research contributions in the rapidly developing fields of Geosciences.

Thank you for your consideration of this manuscript.
Sincerely,
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