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Geomorphological Characteristics of a Hydrographic Basin using RS and GIS on the Example of the Venna River (Maharashtra, India)

Kotramma Sharanappa Gali [a++*], S. S. Shinde [a#], V. N. Barai [a†], B. K. Gavit [a‡], P. G. Popale [b#] and S. B. Nandgude [a^]

[a] Department of Soil and Water Conservation Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, India.
[b] AICRP on Irrigation Water Management, MPKV, Rahuri, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *M. Tech Student;*
[#] *Assistant Professor;*
[†] *Professor;*
[‡] *Associate Professor, Deputy Director of Research;*
[^] *Head;*
**Corresponding author: E-mail: kotrammagali15@outlook.com;*

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ABSTRACT

Assessing the impact of geomorphological processes on a catchment's hydrology necessitates a quantitative analysis of its geometry. This can be effectively achieved using remote sensing (RS) and geographic information systems (GIS), which have become increasingly popular for supporting strategists and decision-makers in making precise and efficient plans and decisions. A morphometric analysis of the Venna River basin was conducted using RS and geographic information systems GIS. This study aims to assist local communities in effectively utilizing land and water resources for the sustainable development of the basin area. The drainage network was developed by digitizing Survey of India (SOI) toposheets. The Venna River basin, covering an area of 318.96 km², exhibits a dendritic drainage pattern with a 5thorder river system dominated by lower-order streams. A mean bifurcation ratio of 6.02 indicates undulating topography with structural influences on drainage. The basin's elongated shape is reflected in its circulatory ratio (0.3) and elongation ratio (0.38), while a form factor of 0.12 suggests low peak flows over extended durations. Low drainage density value of 0.6, indicates that basin has high permeability, slow surface runoff and value of constant of channel maintenance of 1.66 indicates basin has moderate slopes and effective infiltration. The relief ranges from 619 m to 1380 m, with a relief ratio of 0.015, indicating less resistant rock types. A ruggedness number of 0.46 suggests moderately rough terrain, allowing for some erosion potential while highlighting the basin's capacity for water retention, infiltration and sustainable resource management. The areal parameters, such as the form factor, circulatory ratio, elongation ratio and drainage density, suggest elongated basin geometry with high drainage intensity, implying slower runoff and moderate potential for groundwater recharge. The results of this study are valuable for effective watershed management, erosion control, and informed decision-making in land use planning and engineering projects.

Keywords: Venna river; Geographic Information Systems (GIS); infiltration; drainage density; circulatory ratio; elongation ratio.

1. INTRODUCTION

“Morphometry refers to the scientific process of measuring and analyzing landforms to understand their structure, including their size and shape” (Krupavathi et al., 2024). “Morphometric analysis of a river basin is typically conducted to understand its evolutionary history, analyze its hydrological behavior, assess runoff and groundwater potential, identify and evaluate seasonal changes in basin characteristics, and address issues related to soil and water erosion management caused by high flow events” (Jayswal et al., 2021; Chorley, 1985). “Morphometry involves the measurement and mathematical analysis of the earth's surface configuration, including the shape and dimensions of its landforms” (Clarke 1996; Agarwal 1998; Obi Reddy et al., 2002). “Successful morphometric analysis is achieved through the measurement of linear, aerial and relief aspects, as well as the gradient of the channel network and the contributing ground slope of the basin” (Nautiyal 1994; Magesh et al., 2012b). “Watershed planning relies on drainage basin analysis using morphometric parameters, as it provides essential insights into drainage characteristics, terrain, slope, soil quality, and runoff generation” (Dhanush et al., 2024; Singh et al., 2023; Paras et al., 2022; Krupavathi et al., 2024). Morphometry entails the quantitative measurement and analysis of various parameters, such as elevation, slope and other characteristics that define the shape and structure of landforms. It offers valuable insights into the physical properties of soil, erosion patterns and land processes. In particular, a thorough understanding of river drainage morphometry is crucial for studying and interpreting these aspects. Muluneh et al. (2014) utilized “remote sensing and GIS techniques to analyze the morphometric attributes of watersheds, highlighting their significant influence on hydrology and morphology. These studies offer essential insights for watershed management, rainwater harvesting, and planning”. “Morphometric analysis enables the prioritization of sub-watersheds by assessing various linear and areal characteristics within the watershed” (Bhat et al., 2023; Gautam et al., 2021).

“Stream network analysis is a crucial component in the study of morphometric parameters, which helps in understanding the hydrological, geological and geomorphological processes occurring within a basin or watershed area. This analysis is particularly useful in regions where features such as mesas, buttes and denudational processes are prominently displayed. Through the study of various morphometric characteristics, one derives insights into the shaping and behaviour of landscapes” (Gautam et al., 2021). Influential works by researchers like Horton (1945), Strahler (1952, 1964) and Hurtrez et al., (1999) have laid the foundation for such analyses.

“The stream network basin serves as a fundamental unit in morphometric analysis, as it encompasses the complete hydrological and geomorphological processes occurring within a watershed. This is where denudational and gradational processes are most prominently displayed, making it an essential focus for understanding the dynamics shaping the landscape. One of the most significant advancements in the study of geomorphological landforms over time has been the development of quantitative methods to analyze physiographic processes. These methods help to describe the evolution and behaviour of surface stream networks”, as emphasized in the influential work by Leopold and Maddock (1953).

“Traditionally, digitizing contours from topographic maps or conducting field surveys to gather data for morphometric analysis required considerable human effort and resources. This process was meticulous and labour-intensive, often relying on manual measurements and calculations. Such limitations reduced the efficiency and cost-effectiveness of the analysis, making it unsuitable for large-scale or extensive studies. In recent years, the focus on watersheds as the primary unit for morphometric analysis has gained traction. Remote sensing (RS) and geographic information systems (GIS) have gained significant popularity in recent years due to their ability to support strategists and decision-makers in making precise and effective plans and decisions” (Krupavathi et al., 2024). “Remote sensing (RS) technologies have emerged as powerful tools for capturing and analysing various aspects of watershed characteristics, including climate, structural features, geomorphology and geology” (Nautiyal, 1994a; Nautiyal, 1994b; Shekar et al., 2023a; Shekar et al., 2023d). “Remote sensing and GIS techniques have proven to be valuable tools for identifying stream characteristics, developing water resources and planning watershed and basin”, as demonstrated by studies such as Hlaing et al., (2008), Javed et al., (2009), Pankaj and Kumar (2009), Pande and Moharir (2015) and Praveen Kumar Rai et al., (2017). Remote sensing is a highly effective method for morphometric analysis, as satellite images offer a comprehensive view of large areas, making it particularly useful for analysing drainage basin morphometry. The rapid advancements in spatial information technologies such as remote sensing, GIS and GPS provide powerful tools for addressing challenges in land and water resource planning and management, surpassing the limitations of conventional data processing methods (Rao et al., 2010).

2. MATERIALS AND METHODS

The Venna River, a tributary of the Krishna River in the Satara district of western Maharashtra, India. It rises near Mahabaleshwar, a popular hill station in the Western Ghats. Veanna River confluences with the Krishna River, near Sangam Mahuli, Satara city. The Venna River has a watershed area of 318.96 km^2 and study area spanning from 17°30’00” N to 17°55’00” N latitude and 73°45’00” E to 74°10’00” E longitude. Location map of Venna River basin depicted in Fig 1.

The drainage basin was digitized for morphometric analysis using ArcGIS 10.8 software. Survey of India toposheets No. 47G13, 47G14, 47K1, 47K2, and 49G9, scaled at 1:50,000, were used for the georeferencing and digitization of the Venna River basin. SOI topographic maps were georeferenced using WGS-1984 datum, Universal Transversal Mercator (UTM) Zone 43N projection in ArcGIS 10.8. The basin boundary and drainage lines were extracted from SRTM-DEM (Shuttle Radar Topography Mission- Digital Elevation Model) and SOI toposheets using the Arc Hydro tool in ArcGIS 10.8. Various morphometric parameters, encompassing linear, relief and areal aspects of the drainage basin, were computed. This digitization effort facilitated a comprehensive analysis of the drainage morphometry.

2.1 Geomorphological Characteristics of Venna River Basin

The geomorphological characteristics of the basin were crucial for understanding its behaviour. Consequently, these characteristics were extracted within a GIS environment. The geomorphological features were categorized into stream properties, shape properties, drainage network characteristics and slope characteristics.

For analysis, three major aspects linear, areal, and relief aspects of watershed are given in and relief were described.

Standard formulae for calculation of linear, areal and relief aspects of watershed are given in Table 1.

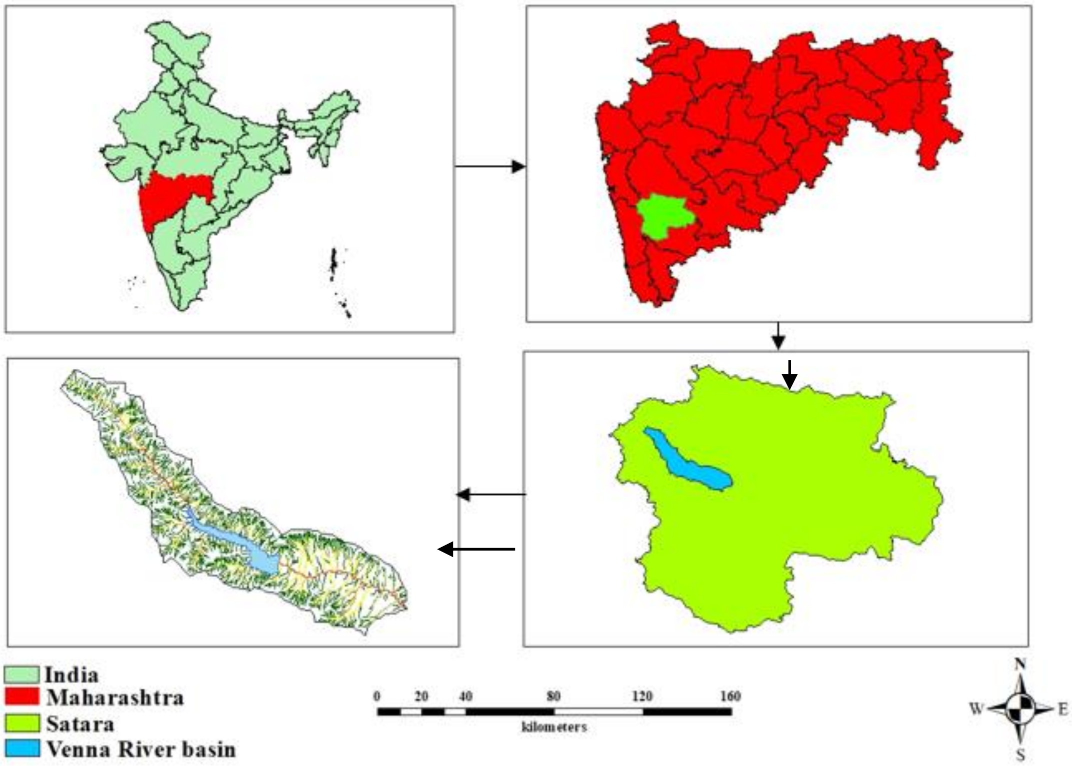

Fig. 1. Location of study area

Table 1. Standard formula for calculating geomorphological parameters

Sr. No	Morphometric Parameter	Formulae	Reference
Linear aspects of drainage network			
1	Stream order(u)	Hierarchial rank	Strahler (1964)
2	Stream length (L_u)	Length of stream (km)	Horton (1945)
3	Mean stream length (L_{sm})	$L_{sm} = L_u / N_u$ Where, L_{sm} = Mean stream length (km) L_u = Total stream length of order “u” N_u = Total no. of stream segments of order “u”	Strahler (1964)
4	Stream length ratio (L_{ur})	$L_{ur} = L_u / L_{u-1}$ Where, L_{ur} = Stream length ratio L_u = Mean of stream length of order “u” L_{u-1} = Mean of stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ Where, R_b = Bifurcation ratio N_u = Total no. of stream segments of order “u”	Horton (1945)

Sr. No	**Morphometric Parameter**	**Formulae**	**Reference**
		N_{u+1} = No. of stream segments of the next higher order	
6	Length of overland flow (L_g)	$L_g = 1/2D_d$ Where, L_g = Length of overland flow(km^2/km) D_d = Drainage density	Schumm (1956)
Areal aspects of drainage network			
7	Basin length (L_b)	The longest dimension of a basin parallel to the main drainage line. (km)	Nookaratnam (2005)
8	Basin perimeter (P)	Outer boundary of drainage basin measured in km.	Schumm (1956)
9	Drainage density (D_d)	$D_d = L_u / A$ Where, D_d = Drainage density(km/km^2) L_u =Total stream length of all orders (km) A = Area of basin (km^2)	Horton (1945)
10	Basin area (A)	Area from which water drains to a common stream. (km^2)	Strahler (1964)
11	Stream frequency (F_s)	$Fs = N_u / A$ Where, F_s = Stream frequency (per km^2) N_u = Total no. of streams of all orders A = Area of basin (km^2)	Horton (1932)
12	Form factor (F_f)	$F_f = A/L_b{}^2$ Where, F_f = Form factor A = Area of basin (km^2) L_b= Basin length (km)	Horton (1932)
13	Circulatory ratio (R_c)	$R_c = 4 \times \pi \times A / P^2$ Where, R_c = Circulatory ratio A = Area of basin (km^2) P = Perimeter of basin (km)	Miller (1953)
14	Elongation ratio (R_e)	$R_e = D_d/L = 1.128\frac{\sqrt{A}}{L}$ Where, R_e = Elongation Ratio A = Area of basin (km^2) L_b = Basin length (km)	Schumm (1956)
15	Drainage texture (D_t)	$D_t = N_u / P$ Where, D_t = Drainage texture (per km) N_u = Stream number P = Perimeter of basin (km)	Horton (1945)
16	Compactness coefficient (C_c)	$C_c = 0.2841 * P / A^{0.5}$ Where, C_c = Compactness coefficient P = Perimeter of basin (km)	Gravelius (1914)
17	Constant channel maintenance(C)	$C = 1 / D_d$ Where, C = Constant channel maintenance (km^2/km) D_d = Drainage density (km/km^2)	Schumm (1956)
Relief aspects of drainage network			
18	Relief (H)	$H = Z - z$	Hadley and

Sr. No	Morphometric Parameter	Formulae	Reference
		Where, H = Relief in (km) Z = Greatest elevation of the catchment area (km) z = Elevation of the catchment outlet (km)	Schumm (1961)
19	Relief ratio (R_r)	$R_r = H/L_b$ Where, R_r =Relief ratio H = Total basin relief (km) L_b = Basin length (km)	Schumm (1963)
20	Relative relief (R_{hp})	$R_{hp} = H \times 100/P$ Where , R_{hp} = Relative relief P = Perimeter of basin (km) H= Total basin relief (km)	Melton (1957)
21	Ruggedness number (R_n)	$R_n = H \times D_d$ Where, R_n = Ruggedness number H = Basin relief (km) D_d = Drainage density (km/km^2)	Strahler (1952)

3. RESULTS AND DISCUSSION

The geomorphological analysis of the Venna River basin was carried out to study the geomorphic parameters. Toposheets and Digital Elevation Model were used in the preparation of the study area's drainage map depicted in Fig 2. The linear, areal and relief aspects of the drainage network of the study area are discussed in the following sections.

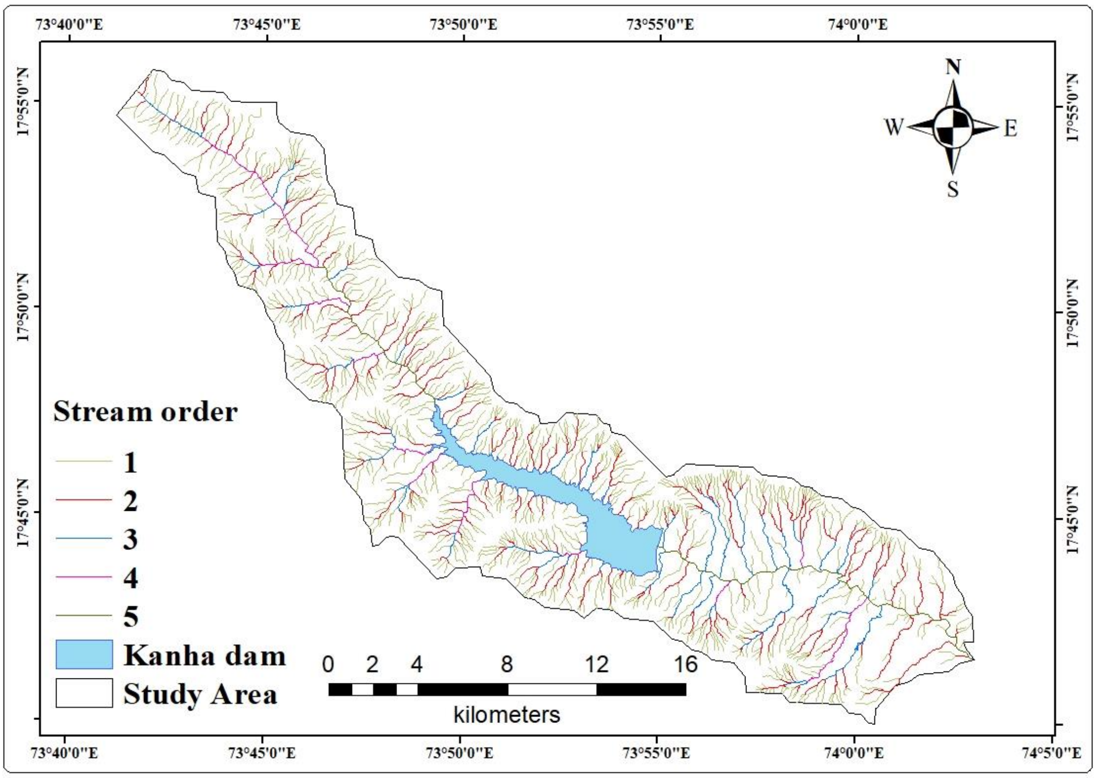

Fig. 2. Drainage map of Venna River basin

3.1 Linear Aspects of Drainage Network

As noted by Radwan et al., (2017), the linear aspects of a catchment, including stream order, stream number, mean stream length, stream length ratio and bifurcation ratio are primarily influenced by the characteristics of the drainage network, which are shaped by the terrain of the area.

3.1.1 Stream order (u)

The stream order indicates the extent of stream branching within a watershed. Strahler's system a slightly modified version of Horton's system has been adopted in this study. It classifies the smallest unbranched fingertip streams as first order, confluences two first order channels to form a second order segment, joins two second order streams to form a third order segment and so on. The higher order is maintained when two channels with different orders join. In the present study, the watershed was of 5th order. It was found that as the stream order increases number of stream decreases.

3.1.2 Stream number (N_u)

The stream number refers to the count of stream channels within a given order. As the stream order increases, the number of drainage fragments decreases and higher stream orders typically correspond to lower permeability and infiltration. There were 1197 streams in all orders, out of which 893 were first order, 237 were second order, 55 were third order,11 were fourth order and one stream was of fifth order.

3.1.3 Stream length (L_u)

Streams with shorter lengths typically indicate region with steeper slopes and finer textures, while longer streams suggest areas with gentle slopes and flatter gradients. Stream length reflects the hydrological properties of the bedrock and drainage area. In regions with permeable bedrock and formations, fewer, longer streams are typically formed in well-drained watersheds. In contrast, in areas with less permeable bedrock and formations, a greater number of shorter streams are developed. The stream length for all the streams of various orders in the Venna River basin were measured on digitized map with the help of GIS. Total length of the first, second, third, fourth and fifth order stream was 615.43 km, 201.87 km, 78.37 km, 34.38 km and 27.36 km respectively. It was observed that the total length of the stream decreases with increase in order of stream. The mean stream length of stream increases with increase in order of stream.

3.1.4 Stream length ratio (L_{ur})

It is defined as the ratio of the mean length of stream segments (Lu) for order 'u' to the mean length of stream segments for the next lower order. The differences in slope and topographic conditions lead to variations in the stream length ratio between successive stream orders. Additionally, this ratio demonstrates a strong correlation between surface flow discharge and the erosional stage of the basin. Stream length ratio of the II/I order was 0.33, III/II order was 0.39, IV/Ⅲ order was 0.44 and Ⅴ/Ⅳ order was 0.80. The stream length ratio is a critical indicator of the surface flow discharge and erosional stage of water body. The variation in the stream length ratio is observed due to differences in slope topographic conditions (Sreedevi et al., 2005). When the ratio of stream length increases from lower order to higher order, the basin is said to be in a mature geographic stage.

3.1.5 Bifurcation ratio (R_b)

The bifurcation ratio is defined as the ratio of the number of stream segments (Nu) at a specific order 'u' to the number of stream segments at the next higher order. Strahler (1964) stated that for drainage basins where geological structures do not disrupt the drainage pattern, the bifurcation ratio typically falls within the range of 3.0 to 5.0. Bifurcation ratio of Venna River basin was ranges from 3.77 to 11. In this study, Venna River basin has mean bifurcation ratio of 6.02 which indicates strong structural control on the drainage pattern and distortion of the drainage pattern. High bifurcation ratio values show that the studied area has an undulating topography and that structural disturbances have a significant influence on the drainage pattern (Vittala et al., 2004).

3.1.6 Length of overland flow (L_g)

It is defined as the distance water travels over the surface before it converges into distinct stream channels (Horton, 1945). It is equal to half the reciprocal of the drainage density (Dd). Horton (1945) noted that overland flow generally has laminar characteristics, with shallow depth and shorter flow length. The duration of overland flow is crucial in influencing the hydrological and physical development of drainage catchments. Length of overland flow of Venna River basin was 0.83 km, which indicates long time of flow in the basin. Higher value of Lg gives gentle slope, more infiltration and reduced runoff. This value represents the average distance that runoff travels over the land surface before entering a defined drainage channel or watercourse.

Linear aspects of Venna River basin were mentioned in Table 2.

3.2 Areal Aspects of Drainage Network

It covers all tributaries of lower order and deals with the entire area projected upon a horizontal plane contributing overland flow to the channel segment of the given order. Areal aspects consist of form factor, circulatory ratio, elongation ratio and drainage density.

3.2.1 Length of basin (L_b)

Length measured in a straight line from a stream's mouth to the drainage divide's farthest point within its basin. The longest dimension of a basin parallel to the main drainage line is its length (Schumm, 1956). Length of basin of Venna River was 52.33 km.

3.2.2 Basin are (A)

Area is just as important as the other metric, a noteworthy relationship between the overall watershed areas and the total stream length which are by the contributing areas was identified by Schumm (1956). The Venna River Basin covers an area of 318.96 km^2.

3.2.3 Basin perimeter (P)

The outer border of the watershed enclosing the basin is known as the basin perimeter. It can be used as a gauge for the size and shape of watersheds since it is measured along the divisions between them. The length of the map line enclosing the drainage basin's catchment region. The Venna River Basin covers an area of 318.96 km^2.

3.2.4 Drainage density (D_d)

Horton (1932) introduced drainage density as a key indicator of the linear scale of landform features in stream-eroded landscapes. It is defined as the ratio of the total length of all channel segments in a basin to the basin's area, typically expressed in km/km^2. Higher drainage density is typically found in basins with weak, impermeable subsurface materials, sparse vegetation and steep relief. Low drainage density results in a coarse drainage texture, while high drainage density produces a fine drainage texture, along with increased runoff and greater erosion potential in the basin area (Strahler, 1964). Venna River basin well-drained, as indicated by its relatively low drainage density of value,0.6 very coarse (<2). The low value of drainage density influences greater infiltration and hence the wells in this region have good water potential leading to higher specific capacity of wells.

3.2.5 Form factor (F_f)

According to Horton (1945) and Sreedevi et al. (2005)., the form factor, defined as the ratio of

Table 2. Linear aspects of drainage network basin

Stream order(u)	No of streams(N_u)	Length(km)(L_u)	Mean stream length(L_{sm})
1	893	615.43	0.69
2	237	201.87	0.85
3	55	78.37	1.42
4	11	34.38	3.13
5	1	27.36	27.36
Total	1197		33.45
Bifurcation ratio, R_b		**Stream length ratio (L_{ur})**	
Ⅰ/Ⅱ	3.77	Ⅱ/Ⅰ	0.33
Ⅱ/Ⅲ	4.31	Ⅲ/Ⅱ	0.39
Ⅲ/Ⅳ	5.00	Ⅳ/Ⅲ	0.44
Ⅳ/Ⅴ	11.00	Ⅴ/Ⅳ	0.80

basin area to the square of basin length, is used to predict the intensity of a basin within a given range. Due to its dimensionless nature and its ability to represent different basin shapes, it is often referred to as an index (Horton, 1932). Typically, the form factor (Ff) ranges from 0.1 to 0.8. A higher form factor indicates a more circular basin, while a lower value suggests an elongated basin. Form factor values should always be less than 0.78. Basins with low form factors tend to have longer-duration, lower peak flows, whereas those with high form factors experience higher peak flows (Patil and Vanjari, 2022). Form factor values should always be smaller than 0.12. Longitudinal watersheds with low form factors have shorter peak flows with longer durations, while basins with high form factors have bigger peak flows. In this present study, form factor of Venna River basin was 0.12, denotes an elongated basin and low peak flows for longer duration.

3.2.6 Elongation ratio (R_e)

Schumm (1956) defined the elongation ratio as the ratio of the maximum length of a drainage basin to the diameter of a circle with the same area. It is a dimensionless measure. Elongation ratio (Re) values generally range from 0.6 to 1.0, across various geological and climatic conditions. Watersheds can be classified based on these values as elongated (0.5–0.7), less elongated (0.7–0.8), oval (0.8–0.9) and circular (0.9–1.0) (Singh and Singh, 1997). Elongation ratio of Venna basin was 0.38 categorized watershed shape was elongated.

3.2.7 Circulatory ratio (R_c)

The circulatory ratio, as defined by Miller (1953), is the ratio of a basin's area to the area of a circle with the same perimeter as the basin. This ratio is influenced by factors such as basin slope, geological formations, land use and cover, stream length and frequency, and climate. A high circulatory ratio indicates the late developmental stage of the topography. According to Miller (1953), circulatory ratio values range from 0.4 to 0.6, with low, medium and high values corresponding to youthful, mature, and old stages in the tributary watershed development cycle. For the present study area, circulatory ratio was 0.3 indicates the drainage network is elongated.

3.2.8 Drainage texture (D_t)

Drainage texture is a key geomorphological concept that refers to the relative spacing of drainage lines. It is influenced by the underlying lithology, infiltration capacity and the relief of the terrain. Drainage texture (Dt) is calculated as the total number of stream segments of all orders divided by the perimeter of the area (Horton, 1945). Smith (1950) classified drainage texture into five categories: very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). One of the most significant concepts in geomorphology is drainage texture, or the relative spacing of drainage lines. In the present study the drainage texture of the Venna River basin was 2.11 per km^2 which indicates coarse texture.

3.2.9 Stream frequency (F_s)

Stream frequency (Fs) refers to the number of stream segments per unit area (Horton, 1932, 1945) and is also known as channel frequency. It shows a positive correlation with drainage density in a watershed, meaning that as drainage density increases, the number of streams also increases. Stream frequency of Venna River basin was 0.75, suggesting fewer channels for water flow and more time for infiltration, which is favourable for groundwater recharge. Lower stream frequencies often correlate with higher infiltration and lower surface runoff.

3.2.10 Compactness coefficient (C_c)

The compactness coefficient is calculated by dividing the perimeter of a watershed by the circumference of a circle with the same area as the watershed (Gravelius, 1914). It depends on the slope of the watershed but is independent of its size. Compactness coefficient of Venna basin was 0.20. A value of compactness coefficient suggests a more elongated basin shape with lower runoff potential, implying better retention and infiltration of water, which benefits groundwater recharge and reduces flood risks.

3.2.11 Constant of channel maintenance (C)

Schumm (1956) introduced the inverse of drainage density, known as the constant of channel maintenance, as a characteristic of landforms. This constant represents the area (in km^2) of the basin surface required to sustain a 1 km long channel. It reflects the relative size of landform units in a drainage basin and carries specific genetic implications (Strahler, 1957). The constant is influenced by factors such as rock type, permeability, climate, vegetation, relief, erosion duration and climatic history. In regions with intense dissection, the constant of channel maintenance is notably low. Constant of channel maintenance of the Venna River basin was 1.66 km^2/km. It not only depends on rock type permeability, climatic regime, vegetation, relief but also as the duration of erosion and climatic history.

Areal aspects of Venna River basin were given in Table 3.

3.3 RELIEF ASPECTS OF DRAINAGE NETWORK

Relief refers to the variation in height of points and lines on the surface relative to a horizontal reference base. It represents the vertical dimension of landforms. The relief aspect includes metrics such as the relief ratio, relative relief, ruggedness number, average slope of the basin and channel gradient. These linear and areal features represent the one- and two-dimensional aspects of a river basin, primarily dealing with length and width. In addition to these dimensions, the third important aspect is related to the elevation or height of the basin, known as relief. Relief plays a crucial role in determining the effectiveness of a basin's drainage system, influencing erosion, transportation, deposition and the overall energy of a river.

3.3.1 Relief (H)

The elevation difference between the catchment's highest point and its outlet is known as maximum basin relief (H). The formula H=Z-z, where Z is the greatest elevation of the catchment area and z is the elevation at the catchment outlet, is used to compute the basin relief. The highest relief was observed at the northwestern tip of watershed where an elevation of 1380 m above mean sea level. The lowest relief was observed at an elevation of 619 m above mean sea level. The overall relief calculated for the Venna River basin was 0.761 km it reveals that basin has undulating terrain.

3.3.2 Relief ratio (R_r)

According to Schumm (1956), the relief ratio (Rr) is the ratio of the maximum relief to the horizontal distance along the basin's longest dimension, running parallel to the main drainage line. Gottschalk (1964) noted that the Rr typically increases as the drainage area and watershed size of a given basin decrease. “The relief ratio reflects the overall steepness of the drainage basin, serving as an indicator of the intensity of erosion occurring along the basin's slope” (Schumm, 1956). It is directly related to erosion intensity and surface runoff. High Rr values indicate steep slopes and high relief, while low Rr values correspond to gentler slopes. Relief influences how quickly potential energy is converted into kinetic energy as water flows out of the basin. In steeper basins, runoff occurs more rapidly, resulting in higher peak flows and increased erosive power. The relief ratio value of Venna River basin was 0.015. It suggests that for each unit of distance along the basin's length or width, there is a substantial increase in elevation. This indicates that while the basin has moderate relief, the overall gradient is gentle. A lower relief ratio implies slower surface runoff, which enhances the potential for water to percolate into the ground, supporting groundwater recharge. Additionally, the risk of flash floods or rapid runoff events is lower.

Table 3. Areal aspects of drainage network

Sr. No.	Parameters	Symbol	Values
1	Area(km^2)	A	318.96
2	Perimeter(km)	P	113.32
3	Maximum basin length(km)	L_{bm}	52.33
4	Form factor	R_f	0.12
5	Circulatory ratio	R_c	0.3
6	Elongation ratio	R_e	0.38
7	Drainage density(km/km^2)	D_d	0.60
8	Drainage texture	T	2.11
9	Constant of channel maintenance(km^2/km)	C	1.66
10	Compactness Coefficient	C_c	0.20
11	Stream frequency (per km^2)	F_s	0.75

Table 4. Relief aspects of drainage network

Sr. No.	Parameter	Symbol	Values
1	Relief (km)	H	0.761
2	Relief ratio	R_r	0.015
3	Relative relief	R_R	0.67
4	Ruggedness number	R_n	0.46

3.3.3 Relative relief (R_{hp})

The maximum basin relief is calculated from the highest point on the basin perimeter to the mouth of stream. Using the basin relief, a 'R_{hp}' was computed as proposed by Schumm (1956). The relative relief of Venna River basin was 0.67 emphasizes that the basin experiences a high percentage increase in elevation from its lowest to highest points relative to its size. This suggests that while there may be significant elevation differences within the basin, it is not excessively rugged or steep compared to nearby areas. This level of relative relief can still allow for moderate water infiltration, but local areas with steeper slopes may experience faster runoff.

3.3.4 Ruggedness number (R_n)

Ruggedness number was calculated by the multiplication of basin relief and drainage density (Strahler, 1968). Ruggedness number (Rn) measures the surface unevenness or roughness. Ruggedness number is combination of the slope steepness along with the length. The Venna River basin has a ruggedness number of 0.46, when calculated appropriately basin terrain may be rough in places, it is not excessively rugged. A value of 0.46 indicates a moderate level of ruggedness in the basin. This means the basin has a mix of flat and steep areas. Moderate ruggedness suggests the basin may experience some erosion but not at extreme levels. It also suggests that the terrain is not overly rough, allowing for reasonable water retention and infiltration opportunities.

Relief aspects of Venna River basin mentioned in Table 4.

The geomorphological parameters of Venna River basin were first studied to understand the linear, aerial and relief aspects of the drainage network. From the quantitative study, it is seen that the basin forms the dendritic pattern of drainage. The Venna River basin has principal order of 5th. Lower order streams predominate in Venna River basin. The linear, areal and relief features of basin were measured in order to perform the morphometric analysis. The mean stream length indicates an average stream length of 6.69 km. The stream length ratio suggests a relatively balanced river network with a ratio close to 1. Venna River basin has mean bifurcation ratio of 6.02 which indicates area has an undulating topography and that structural disturbances have a significant influence on the drainage pattern.

The aerial aspects of the study area indicate that the Venna River basin was elongated in shape, high relief and high infiltration. The basin has a elongated shape (Circulatory ratio = 0.3, elongation ratio = 0.38). Venna River basin has form factor 0.12, denotes an elongated basin and low peak flows for longer duration. The basin was well-drained, as indicated by its relatively low drainage density of value 0.6 very coarse (<2). Constant of channel maintenance was 1.66 indicating that the area high permeability, moderate slope and slow surface runoff.

The basin exhibits a considerable relief of 619 m to 1380 m, indicating significant difference in elevation within the basin area. The relief ratio value of Venna River basin was 0.015 indicates presence of less resistant rocks. The Venna River basin has a ruggedness number of 0.46 when calculated appropriately basin terrain may be rough in places, it is not excessively rugged. Moderate ruggedness suggests the basin may experience some erosion but not at extreme levels. It also suggests that the terrain is not overly rough, allowing for reasonable water retention and infiltration opportunities.

4. CONCLUSION

It is clear from the study that the linear parameters of Venna River basin is dominated by first-order streams, with a moderate bifurcation ratio indicating natural drainage patterns. The areal parameters, such as the form factor, circulatory ratio, elongation ratio and drainage density, suggest elongated basin geometry with high drainage intensity, implying slower runoff and moderate potential for groundwater recharge. The relief parameters indicate moderate elevation with gentle slopes and moderate ruggedness, balancing surface runoff and infiltration.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT
2.Google gemini

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agrawal, C. S. (1998). Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. *Tour Indian Society of Remote Sensing, 26*, 169–175.

Bhat, A. G., Paradkar, V., S., M. S., Balley, P., & K. P. Rema. (2023). Geospatial analysis of Kurumanpuzha Sub Watershed in the Chaliyar River Basin: A remote sensing and GIS approach for geomorphological assessment. *Journal of Experimental Agriculture International, 45*(11), 9–21. https://doi.org/10.9734/jeai/2023/v45i112230

Chorley, R. J., Schumm, S. A., & Sugden, D. E. (1985). *Geomorphology*. Methuen and Co., Ltd.

Clarke, J. I. (1996). Morphometry from maps. In *Essays in geomorphology* (pp. 235–274). Elsevier Publication Co.

Dhanush, S. K., Murthy, M. M., & 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 Resources Management, 1-20*. https://doi.org/10.1007/s11269-024-03815-0

Gautam, V. K., Kothari, M., Singh, P. K., Bhakar, S. R., & Yadav, K. K. (2021). Determination of geomorphological characteristics of Jakham River basin using GIS techniques. *Indian Journal of Ecology, 48*(6), 1627–1634.

Gottschalk, L. C. (1964). Reservoir sedimentation. In *Handbook of applied hydrology* (Section 7-1). McGraw Hill Book Company.

Gravelius, H. (1914). *Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde*. Compendium of Hydrology I. Rivers.

Hadley, R. F., & Schumm, S. A. (1961). Sediment sources and drainage basin characteristics in the upper Cheyenne River basin. *US Geological Survey, USGS Water Supply Paper, 1531-B*.

Hirapara, P., Parmar, S., & Vaibhav, R. (2022). The significance impact assessment of morphological parameters on watershed: A review. *Agricultural Review, 43*(1), 110–115.

Hlaing, T. K., Haruyama, S., & Aye, M. M. (2008). Using GIS-based distributed soil loss modeling and morphometric analysis to prioritize watershed for soil conservation in Bago River basin of lower Myanmar. *Frontiers in Earth Science, 2*, 465–478.

Horton, R. E. (1932). Drainage basin characteristics. *Transactions of the American Geophysical Union, 13*, 350–361.

Horton, R. E. (1945). Erosional development of streams and their drainage basins; hydro-physical approach to quantitative morphology. *Geological Society of America Bulletin, 56*(3), 275–370.

Hurtrez, J. E., Sol, C., & Lucazeau, F. (1999). Effect of drainage area on hypsometry from analysis of small-scale drainage basins in the Siwalik Hills (Central Nepal). *Earth Surface Processes and Landforms, 24*(9), 799–808.

Javed, A., Khanday, M. Y., & Ahmed, R. (2009). Prioritization of sub-watershed based on morphometric and land use analysis using remote sensing and GIS techniques. *Journal of Indian Society & Remote Sensing, 37*, 261–274.

Jayswal, P., Gontia, N. K., & Sondarva, K. (2021). Morphometric study of Dhatarwadi River Basin using RS and GIS techniques. *Current Journal of Applied Science and Technology*, 1–11. https://doi.org/10.9734/cjast/2021/v40i1031354

Krupavathi, C., Srinivasa Gowd, S., Rajasekhar, M., & Ravikumar, P. (2024). Morphometric analysis of Mogamureru river basin at the YSR Kadapa District, Andhra Pradesh, India using GIS and remote sensing. *Geomatica, 76*(1), 100005. https://doi.org/10.1016/j.geomat.2024.100005

Leopold, L. B., & Maddock, T. (1953). The hydraulic geometry of stream channels and some physiographic implications. *Geological Survey Professional Paper, 252*, 1–57.

Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N., & Jini, K. V. (2012). GIS-based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. *Earth Science Informatics, 5*(2), 111–121.

Melton, M. A. (1957). An analysis of the relations among elements of climate, surface properties, and geomorphology. *Project NR 389-042, Technical Report 11*, Columbia University.

Miller, V. C. (1953). A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Columbia University, New York.

Muluneh, T., & Mamo, W. (2014). Morphometric analysis of Didessa River catchment in Blue Nile Basin, Western Ethiopia. *Scientific and Technological Arts Research Journal, 3*(3), 191–197.

Nautiyal, M. D. (1994). Morphometric analysis of a drainage basin using aerial photographs: A case study of Khairkuli basin, District Dehradun. *Journal of Indian Society of Remote Sensing, 22*(4), 251–262.

Nautiyal, M. D. (1994b). Morphometric analysis of a drainage basin, Dist. Dehradun, Uttar Pradesh. *Journal of Indian Society of Remote Sensing, 22*(4), 251–261.

Nookaratnam, K., Srivastava, Y. K., Venkateswarao, V., Amminedu, E., & Murthy, K. S. R. (2005). Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis: Remote sensing and GIS perspective. *Journal of the Indian Society of Remote Sensing, 33*(1), 25–38.

Obi Reddy, G. E., Maji, A. K., & Gajbhiye, K. S. (2002). GIS for morphometric analysis of drainage basins. *GIS India, 4*(11), 9–14.

Pande, C. B., & Moharir, K. (2015). GIS-based quantitative morphometric analysis and its consequences: A case study from Shanur River Basin, Maharashtra, India. *Applied Water Science*. https://doi.org/10.1007/s13201-015-0298-7

Pankaj, A., & Kumar, P. (2009). GIS-based morphometric analysis of five major sub-watersheds of Song River, Dehradun district, Uttarakhand with special reference to landslide incidences. *Journal of Indian Society & Remote Sensing, 37*, 157–166.

Patil, R. S., & Vanjari, O. M. (2022). Morphometric analysis of Warana Basin using GIS and remote sensing techniques. *International Research Journal of Engineering and Technology (IRJET), 9*.

Radwan, F., Alazba, A. A., & Mossad, A. (2017). Watershed morphometric analysis of Wadi Basin Dam catchment area using integrated GIS-based approach. *Arabian Journal of Geosciences, 10*, 256. https://doi.org/10.1007/s12517-017-3046-5

Rao, N. K., Swarna, L. P., Kumar, A. P., & Krishn, H. M. (2010). Morphometric analysis of Gostani River Basin in Andhra Pradesh State, India using spatial information technology. *International Journal of Geomatics and Geosciences, 1*(2), 179–187.

Schumm, S. A. (1956). Evaluation of drainage system and slopes in Badlands at Perth Amboy, New Jersey. *National Geological Society of America Bulletin, 67*, 597–646.

Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Bulletin of the Geological Society of America, 67*, 597–646.

Schumm, S. A. (1963). Sinuosity of alluvial rivers on the Great Plains. *GSA Bulletin, 74*(9), 1089–1100.

Shekar, P. R., & Mathew, A. (2022a). Morphometric analysis for prioritizing sub-watersheds of Murredu River basin, Telangana State, India, using a geographical information system. *Journal of Engineering and Applied Sciences, 69*, 44. https://doi.org/10.1186/s44147-022-00094-4

Shekar, P. R., & Mathew, A. (2023d). Detection of land use/land cover changes in a watershed: A case study of the Murredu watershed in Telangana State, India. *Watershed Ecology and Environment, 5*, 46–55. https://doi.org/10.1016/j.wsee.2022.12.003

Singh, A. P., Ammani, A., Vashisth, S., et al. (2023). Rainfall-induced seismicity beneath the Dharwar Craton of the Indian Shield. *Environmental Earth Sciences, 82*, 410. https://doi.org/10.1007/s12665-023-11092-x

Singh, S., & Singh, M. (1997). Morphometric analysis of Kanhar River Basin. *National Geographer*.

Smith, K. G. (1950). Standard for grading textures of erosional topography. *American Journal of Science, 248*(9), 655–668.

Sreedevi, P. D., Subrahmanyam, K., & Ahmed, S. (2005). The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. *Environmental Geology, 47*, 412–420. https://doi.org/10.1007/s00254-004-1226-4

Strahler, A. (1957). Quantitative analysis of watershed geomorphology. *Transactions, American Geophysical Union, 38*, 913–920.

Strahler, A. N. (1952). Hypsometric (area-altitude) analysis of erosional topography. *GSA Bulletin, 63*(11), 1117–1142. https://doi.org/10.1130/0016-7606(1952)63[1117:HAAOET]2.0.CO;2

Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel networks. In V. T. Chow (Ed.), *Handbook of applied hydrogeology* (pp. 4–76). McGraw Hill.

Strahler, A. N. (1968). Quotative analysis of erosional landform. *Physical Geography, 3rd Edition*, Chapter 29.

Vittala, S., Govindaiah, S., & Gowda, H. (2004). Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques. *Journal of Indian Society of Remote Sensing, 32*, 351. https://doi.org/10.1007/BF03030860

Wilson John, J. S., Chandrasekar, N., & Magesh, N. S. (2012). Morphometric analysis of major sub-watersheds in Aiyar and Karai Pottanar Basin, Central Tamil Nadu, India using remote sensing and GIS techniques. *International Journal of Industrial Engineering and Management Science, 2*(1), 8–15.

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