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Watershed Prioritization of Sub-watersheds of the Wainganga River Basin, Central India using geospatial tools

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Abstract: Watershed prioritization is crucial for efficient conservation and management of water and soil resources. The present study area is part of the Wainganga River basin in Maharashtra's Gadchiroli district. It extends between $20^0$15'00"to $20^0$45'00"N latitude and $79^0$30'00"E to $80^0$30'0"E longitude. Geologically, the study area is mainly constituted by the rocks of Paleoproterozoic age with some patches of Late Permian-Early Triassic age in the central area and the northern and southern area is covered by Archean age while Paleoproterozoic-Mesoproterozoic and Quaternary age covered only northern area. Geomorphologically, the study area is covered majorly by alluvial and pediplain while pediments, plateau and denudational hills covered the western area. This study presents a comprehensive approach to prioritize sub-watersheds in regarding topographical characteristics such as slope, basin shape, relief, and other relevant parameters using remote sensing and GIS datasets. The whole catchment is divided into four smaller units, sub-watersheds SW-1, SW-2, SW-3 and SW-4 for the detailed study of the area and ranking purpose. Based on the average value of morphometric parameters, the lowest value of morphometric parameters was assigned a rank of 1, the next highest value was given 2, and so on. Further, based on the rankings given to sub-watersheds, the lowest ranker was given the highest priority, and so on. The results indicate that all the four sub-watersheds are in high priority zone indicating that the study area require critical conservation actions. Therefore, this study suggests a relatively unstable watershed scenario, allowing for focused conservation and management strategies.

Keywords: Wainganga River, Watershed prioritization, Morphometry, GIS

1. Introduction

In developing nations like India, managing water supplies remains a difficulty. Drainage basins, catchments, and sub-catchments are the fundamental units for managing land and water resources (Moore et al., 1991). According to (Kumar and Kumar, 2011) and (Manjare 2017), watersheds are naturally occurring hydrologic bodies that span a certain land area and from which precipitation flows to a designated gully, river, or stream at any given location. The technique of identifying ecologically stressed sub-watersheds or pockets in order to prioritize soil conservation measures is known as watershed prioritization. In the past, a number of scientific criteria based on topography, morphological, sediment yield, or soil loss have been used separately to define ecologically challenged sub-watersheds or places (Shrimali et al., 2001, Panda et al., 2005).

In addition to meeting the needs of speed and dependability, remote sensing technology is a perfect tool for producing spatial data, which is necessary for balanced and planned development at the watershed level (Ravindran et al., 1992). For the effective administration of sizable databases, the geographical information system (GIS) technology offers appropriate substitutes. Watershed characterization and prioritization, as well as projects involving the development and management of water resources, have found success with the integration of remote sensing data and GIS technologies (Chalam et al., 1996; Chaudhary and Sharma, 1998; Kumar et al., 2001; Ali and Singh, 2002; Singh et al., 2004; Pandey et al., 2009, 2010, Manjare et al., 2020, Manjare et al., 2021). Technologies for developing water resources are not dependent on yearly rainfall; rather, their spatial and temporal variability is a key factor in identifying the best locations for water conservation. Therefore, it is widely acknowledged that the use of cutting-edge technology (such as remote sensing and GIS) and watersheds as the fundamental management unit are necessary for sustainable land and water management. GIS has become a dominant tool for understanding basin structure (Thomas et al., 2011, Bali et al., 2012, Yadav et al., 2014, Das et al., 2016, Choudhari et al., 2018, Kumar et al., 2018, Yadav et al., 2020, Manjare et al., 2020, Meshram, 2021a, b) due to digital elevation model-based terrain imaging and processing of topographic aspects in morphometric studies (Patel et al., 2016; Manjare et al., 2022).

A thorough assessment of the hydrologic response, including surface runoff generation, infiltration capacity, and even groundwater potential, is provided by morphometric analysis. Morphometric analysis can be used to predict other basin characteristics, such as travel time, time to peak, and intensity of erosional processes, with greater insight and accuracy (Altaf et al., 2013). It may also be a good alternative in ungauged watersheds where there is a lack of information on hydrology, geology, geomorphology, and soil (Lindsay and Evans, 2008, Rudraiah et. al., 2008, Sreedevi et. al., 2009, Romshoo et. al., 2012; Magesh et. al., 2013, Manjare et al., 2014, Senthamizhan et al., 2016, Reddy, 2018, Puno and Puno 2019, Jena and Dandabat, 2019, Manjare et al., 2019, Manjare et al., 2020, Tukura et. al., 2021, Shrivatra et. al., 2021a, b). Thus, the primary dataset for many applications in hydrology, morphometry, etc. is the digital elevation model (DEM) (Kumar et al., 2017, Kumar et al., 2018, Manjare, 2020).

No comprehensive research has been conducted in the Wainganga sub-watershed to analyse and prioritize its watersheds. Given that watershed prioritization is a crucial tool for soil and watershed management, particularly in addressing land erosion concerns, this study aims to fill the knowledge gap. This research prioritizes the watersheds within the Wainganga sub-watershed using morphometric parameters. The findings of this study offer a critical foundation for developing effective soil and water conservation strategies, ultimately contributing to the sustainable management of the Wainganga sub-watershed's natural resources.

2. Study area

The study area is a small portion of the Wainganga River basin which is bounded by latitude and longitude 20^{0}15'00" to 20^{0}45'00"N and 79°30'00"E to 80^{0}30'0"E with an altitude of 714 to 164 m which falls in Gadchiroli district, Maharashtra (Figure 1). The area of the sub-watershed is 6169.18 km^2. The Wainganga River rises in the Mahadeo Hills in Mundara, Seoni district, Madhya Pradesh, and flows 580 kilometers south before joining the Wardha River in Maharashtra state, northeast of Kagaznagar. The study location has a tropical environment. While May is the warmest month with an average temperature of 36°C and January is the coldest month with an average temperature of 21°C, the majority of precipitation occurs in July, with an average rainfall of 700 to 800 mm in the study region.

Geology

Paleoproterozoic rocks make up the majority of the study area, especially in the center region. It includes the villages of Dhanora, Malewada, and Kurkheda. With a few areas of Late Permian-Early Triassic and Quaternary age, the northern portion is occupied by Archean, Paleoproterozoic-Mesoproterozoic, and Paleoproterozoic rocks. Chichgad, Arjuni, Palandur, Lakhandur, Wadsa, and Armori are all included. Archean age covers the southern portion. It also encompasses the regions of Vairagad and Gadchiroli (Figure 2).

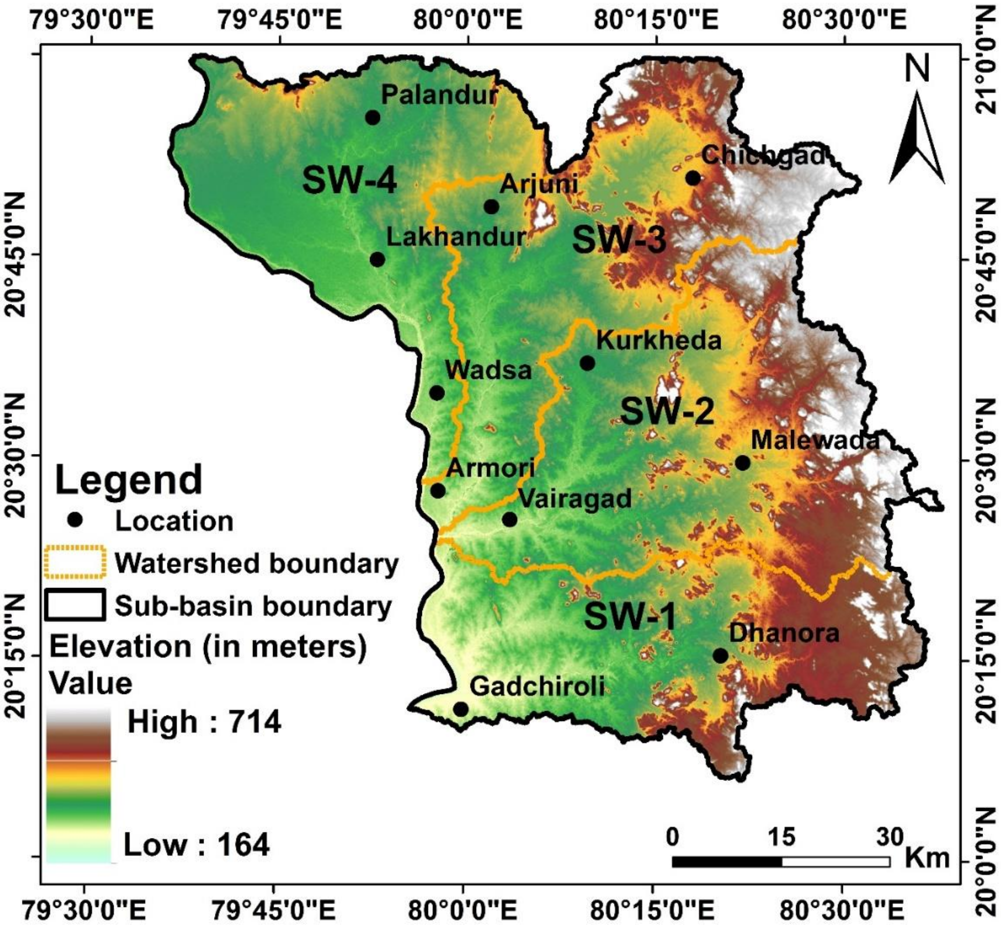

Figure 1. SRTM DEM (30 m) of Wainganga River sub-basin, Central India

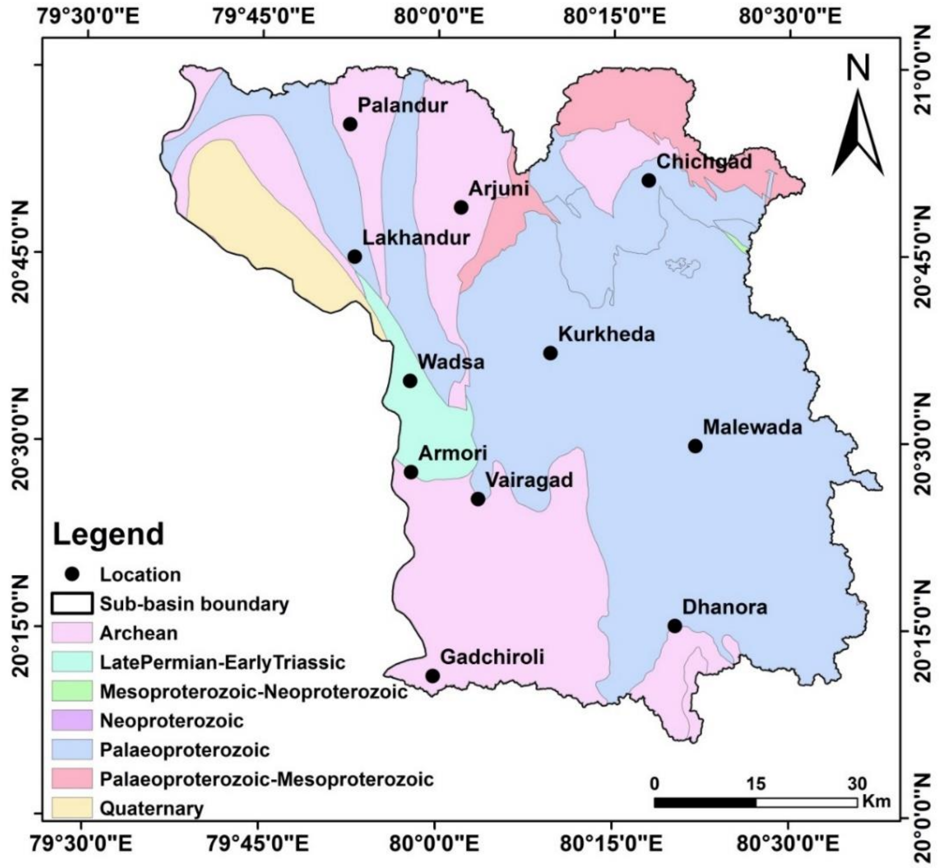

Figure 2. Geology of the study area

Geomorphology

Five main geomorphic units—denudational hills, plateau, pediments, pediplain, and alluvial plain—are found in the study area (Figure 3). The active processes of weathering, mass wasting, and erosion brought on by exogenic agents acting on exposed rocks result in denudational landforms. In the study region, patches of this cover the northern and eastern parts of the watershed. This process wears away the rock on the land surface, reducing the land surface generally. It encompasses the region around Malewada village and Chichgad. A plateau is a level, raised landform with one side that rises significantly above the surrounding terrain. Every continent has plateaus, which make up one-third of the planet's land area. Together with hills, plains, and mountains, they make up the four main landforms. The plateau in the study region primarily includes NE and a little portion of SW which is situated close to Dhanora village, Malewada, and Chichgad. A pediment is a low-relief plain or gently sloping erosion surface created by flowing water in an arid or semiarid area at the foot of a retreating mountain front. The bedrock beneath a pediment is usually covered by a thin, irregular veneer of alluvium and soil from upland regions. It is located between plain and hilly terrain/plateau in the study area. It is situated close to Dhanora village, Malewada, and Chichgad. The broad, comparatively flat rock surface created by the junction of many pediments is known as a pediplain. A thin layer of sediments may cover pediplains, which are often developed in arid or semi-arid climates. The pediplain is thought to be the ultimate outcome of erosion processes and the last stage of landform evolution. It is situated close to Palandur, Arjuni, Kurkheda, Malewada, and Dhanora village, and it encompasses the middle portion of the watershed. A mostly level landform known as an alluvial plain is produced when one or more rivers from highland areas dump sediment over an extended period of time, forming alluvial soil. The silt from the highlands is carried to the lower plain as a result of weathering and water flow. It encompasses the western portion of the watershed in the study area such as Palandur, Lakhandur, Wadsa, Armori, Vairagad, and Gadchiroli village are all close by.

3. Methodology

The present study utilizes a diverse range of data sources, including multidate IRS 1D/P6 LISS III data (March 2007) in digital format geocoded at a scale of 1:50,000, Survey of India toposheets at a scale of 1:50,000, District Resource Map, and SRTM DEM 30m data (USGS/NASA), which were integrated to generate and interpret various thematic layers and information. The distinct geological and geomorphological data were taken from the Bhukosh platform of Geological Survey of India (GSI) (Figure 2 and 3). The thematic map depicting the various classes was prepared using digitally enhanced satellite data. The ArcMap software package was utilized for data integration, analysis, and digital database building.

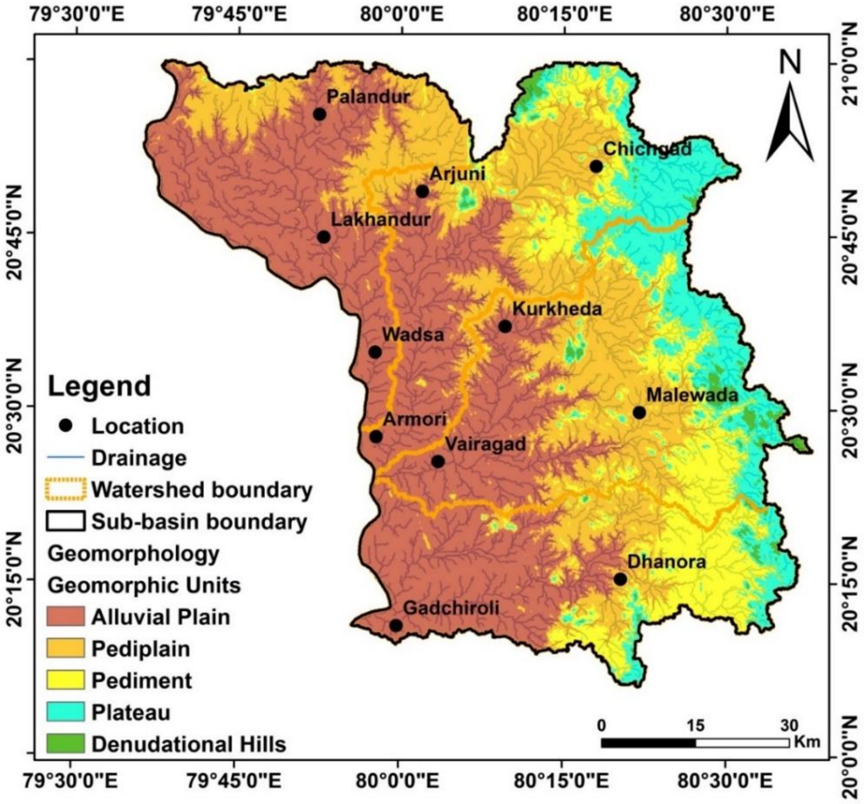

Figure 3. Geomorphology of the study area

The Wainganga River underwent morphometric investigation utilizing the United States Geological Survey's (USGS) Digital Elevation Model (DEM), which was used to create a database and extract a variety of drainage characteristics. Stream order, length, length ratio, elongation ratio, circulation ratio, drainage density, drainage texture, bifurcation ratio, and so on are all included in the analysis.

The methodology involved a particular sequence and permits a rapid characterization of large areas on a regional scale. The drainage pattern and sub-watershed was delineated from the DEM image by processing hydrology tool in ArcGIS software for morphometric analysis (Figure 4), also the slope map has been prepared with the help of DEM image. Next, using the stream order function found in the ArcGIS software's hydrology tool, the extracted drainage network was arranged according to Strahler's categorization. After that, the morphometric parameters of the sub-watersheds have been calculated using the formulae present in (Table 1). Further the ArcGIS software has been used for digitization, editing and topology creation. At last, various thematic maps at a scale of 1:50,000 were prepared for the study area with the help of SOI toposheet, satellite data and other ancillary data.

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Morphometric analysis

The measurement of features found on the earth's surface that are the result of both endogenetic and exogenetic processes, as well as their mathematical analysis, is known as morphometry. The linear, areal, and relief features of the basin are measured in order to perform the morphometric analysis (Nag and Chakraborty, 2003). Morphometric analysis of a watershed can be used to study its features, regional topography, drainage pattern, basin geometry, bedrock type, and groundwater potential zones. At the watershed level, morphometric analysis is employed for natural resource conservation and watershed priority. Drainage morphometry can be used to investigate the physical qualities of soil, erosional features, and landform processes (Horton, 1945, Strahler, 1957). The spatial information required to calculate the morphometric parameters of drainage basins is largely provided by remote sensing and GIS techniques. Morphometric parameters reveal details on the nature of bedrock, denudation features, and other aspects of the landscape. Three aspects—linear, aerial, and relief—are used to do the morphometric study (Table 1)

Table 1. The formulas used to calculate morphometric parameters

S. No	Parameters/References	Formula
1	Stream Order (S_u) Strahler (1952)	Hierarchical rank

2	Stream number (N_u) Horton (1945)	N_u=S1+S2+S3…Ln
3	Stream Length (L_u) Strahler (1964)	Length of the stream (kilometres)
4	Mean stream length (L_{sm}) Strahler (1964)	L_{sm}= L_u/N_u where, L_u= Total stream length of order 'u' N_u= Total no. of stream segments of order 'u'
5	Stream length Ratio (R_L) Strahler (1964)	R_L= Lsm/L_{sm}-1 L_{sm}= Mean stream length of a given order and L_{sm}- 1 = Mean stream length of next lower order
6	Bifurcation Ratio (R_b) Schumm (1956)	R_b=N_u/N_u+1 where, N_u=Total no. of stream segments of order 'u' N_u+1=Number of stream segments of the next higher order
7	Mean bifurcation ratio (R_{bm}) Strahler (1964)	R_{bm}= Average of bifurcation ratio of all orders
8	Basin perimeter (P) (km) Schumm (1956)	P= Outer boundary of drainage basin measured in kilometres
9	Basin length (L_b) (km) Schumm (1956)	$L_b = 1.312 \times A^{0.568}$ where, A = Area of the basin
10	Basin area (A) (km^2) Schumm (1956)	Area from which water drains to a common stream and boundary is determined by opposite ridges
11	Form factor (R_f) (R_f< 1) Horton (1932)	R_f =A/L_b^2 where, A= area of the basin (km^2) and L_b= basin length, km
12	Drainage density (D_d) Horton (1932)	D_d= L_u/A measured in (km/ km2) where, L_u = Total length of the stream (km) and A = Area of the basin in (km^2)
13	Stream frequency (F_s) Horton (1945)	F_s = N_u/A where, N_u = Total no. of stream segments of all orders and A = area of the basin (km^2)
14	Drainage texture (R_t) Horton (1945)	R_t= N_u/P where, N_u= Total no. of stream of all orders and P= basin perimeter measured in km
15	Circulatory ratio (R_c) ($R_c \leq 1$) Miller (1953)	R_C= $4\pi A/P^2$ where, A = area of the basin (km^2) and P= basin perimeter measured in km
16	Elongation ratio (R_e) Bull & Mc Fadden (1977)	$R_e=2\sqrt{(A/\pi)}/Lb$, Where, A= Basin area, L= Basin length
17	Constant of channel maintenance (CCM) (km^2/km) Schumm (1956)	CCM=1/D_d Where, D_d= drainage density

4. Result and Discussion

Linear aspect

Stream order (N_u)

The initial stage in morphometric analysis of a drainage basin is to designate the stream order based on the hierarchic structure of streams (Strahler, 1957). The Wainganga River has been designated as a sixth-order stream. (Table 2) contains the stream number and stream order. SW-2 and SW-4 have sixth-order streams, whereas SW-1 and SW-3 have fifth-order streams (Figure 4).

Table 2. Computation of various linear morphometric parameters for each of the four sub-watersheds within the study region

S. No.	Sub Watershed Code	Basin Area (km^2)	Stream Order (S_u)	Stream Number (N_u)	Stream Length (L_u) (km)	Log N_u	Log L_u
1.	SW1	1414.31	I	409	504.93	2.61	2.70
			II	194	277.40	2.28	2.44
			III	24	158.02	1.38	2.19
			IV	5	43.81	0.69	1.64
			V	1	63.61	-	1.80
			VI	-	-	-	-
2.	SW2	1832.81	I	566	688.92	2.75	2.83
			II	279	396.85	2.44	2.59
			III	27	154.11	1.43	2.18
			IV	8	100.81	0.90	2.00
			V	2	84.02	0.30	1.92
			VI	1	15.55	-	1.19
3.	SW3	1556.00	I	481	650.86	2.68	2.81
			II	223	334.75	2.34	2.52
			III	23	165.55	1.36	2.21
			IV	5	72.16	0.69	1.85
			V	1	77.44	-	1.88
			VI	-	-	-	-
4.	SW4	1366.06	I	393	509.30	2.59	2.70
			II	188	244.79	2.27	2.38
			III	17	151.52	1.23	2.18
			IV	3	21.03	0.47	1.32
			V	2	93.42	0.30	1.97
			VI	1	28.93	-	1.46

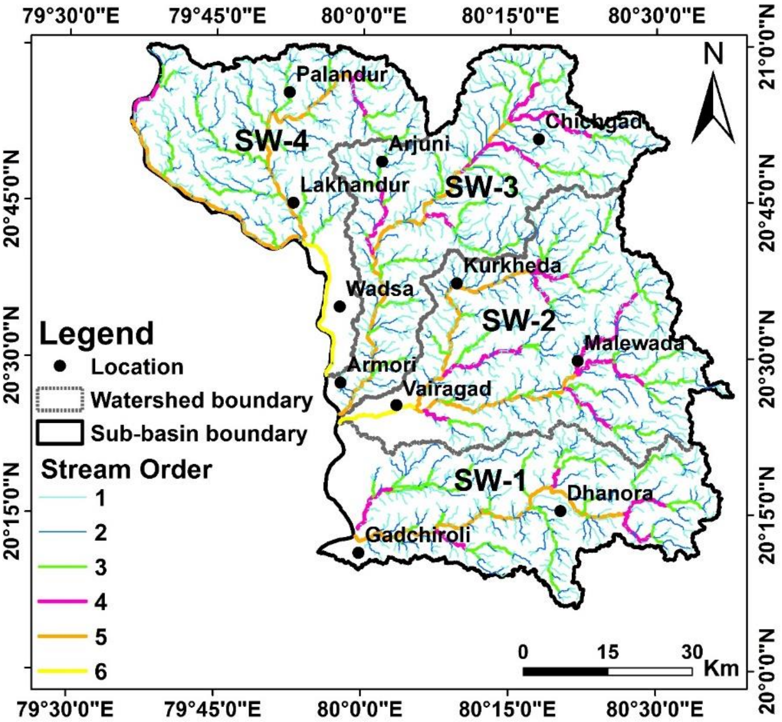

Figure 4. Stream order of the study area

Stream length (L_u) and mean stream length (L_{sm})

The stream length (L_u) of each order is the sum of the lengths of its distinct stream segments. In order to get the average (or mean) length of a stream in a certain order, the length of all streams in that order is divided by the number of streams in that order. As stream order increases, the length of the stream in each order grows exponentially. Stream segments are typically long overall in first order streams and get shorter as stream order rises. The stream segments of different orders in SW-1, SW-3, and SW-4 deviate from widespread observations. In SW-1, SW-3, and SW-4, the length of the fifth order is longer than the fourth. This shift can once more reveal the terrain's form and the correctness of the slope determined by the satellite data (Table 2).

According to (Strahler, 1964), the mean stream length of a stream channel segment of order "u" is a dimensional attribute that shows the typical size of drainage network components and the basin surface that contributes to them. Young morphological development and strong erosion potentiality are indicated by lower values in the sub-watershed's upper reaches. All of the other sub-watersheds, with the exception of SW-4, have low values in the upper reach. The reason for SW-4's low L_{sm} value may be the streams in this order has stopped their channel lengthening much earlier than the lower order streams, measuring 7.01 km for the fourth order and 28.93 km for the sixth (Table 3).

Stream length ratio (R_L)

The stream length ratio is the ratio of mean stream lengths from one order to the next lower order of the stream (Horton, 1945). Compared to regular plateau fringe river basins, areas with mountain-plain front river basins tend to have an uneven stream-length ratio (Magesh and Chandrasekhar, 2014). All four sub-watersheds had their R_L values determined. In the study area, the R_L for SW-1 begins at 1.13 for first to second order, 4.63 for second to third order, etc.; for SW-2, it begins at 1.17 for first to second order, 4.01 for second to third order, etc.; for SW-3, it begins at 1.11 for first to second order, 4.79 for second to third order, etc.; and for SW-4, it begins at 1.0 for first to second order, 6.85 for second to third order, etc. (Table 3). The variations in slope and topographic circumstances cause variations in the R_L between the basin's consecutive stream orders (Adhikari S, 2020).

Table 3. Stream length ratio (R_L) and mean stream length (L_{sm}) calculations for each of the four sub-watersheds in the study region

	Sub-watershed codes			
	SW1	SW2	SW3	SW4
Mean stream length (L_{sm}) (km)				
I	1.23	1.21	1.35	1.29
II	1.42	1.42	1.50	1.30
III	6.58	5.70	7.19	8.91
IV	8.76	12.60	14.43	7.01
V	63.61	42.01	77.44	46.71
VI	-	15.55	-	28.93
Stream length ratio (R_L)				
II/I	1.13	1.17	1.11	1.00
III/II	4.63	4.01	4.79	6.85
IV/III	1.33	2.21	2.00	0.78
V/IV	7.26	3.33	5.36	6.94
VI/V	-	0.37	-	0.61

Table 4. Computations of the mean bifurcation ratio (R_{bm}) and bifurcation ratio (R_b) for each of the four sub-watersheds in the study region

	Sub-watershed codes			
	SW1	SW2	SW3	SW4
Bifurcation ratio (R_b)				
I/II	2.10	2.05	2.15	2.09
II/III	8.08	10.33	9.69	11.05
III/IV	4.8	3.37	4.6	5.66
IV/V	0.2	4.0	5.0	3.0
V/VI	-	2.0	-	-
Mean bifurcation ratio (R_{bm})	3.03	4.35	4.26	21.8

Bifurcation ratio (R_b)

The ratio of the total number of streams in a particular order (N_u) to the number of streams in the next higher order (N_u+1) is known as the bifurcation ratio (Horton, 1945). A lower R_b value suggests structurally less affected watersheds with no drainage pattern distortion, whereas a larger R_b value indicates drainage pattern distortion with severe floods (Suji et al., 2015, Bogale, 2021). For each of the four sub-watersheds, the bifurcation ratio is computed (Table 4). SW-1 has a R_b value of 2.10 for first to second order, 8.08 for second to third order, etc. SW-2 has a R_b value of 2.05 for first to second order, 10.33 for second to third order, etc. SW-3 has a R_b value of 2.15 for first to second order, 9.69 for second to third order, etc. SW-4 has a R_b value of 2.09 for first to second order, 11.05 for second to third order, etc. For SW-1, SW-2, and SW-3, the mean bifurcation value (R_{bm}) is 3.03, 4.35, 4.26, and 21.8, respectively. The remaining SW-1 and SW-3 have lower R_{bm} values, whereas SW-2 and SW-4 have greater values. SW-2 and SW-4 indicate comparatively more disturbed sub-watersheds than SW-1 and SW-3, respectively, based on the R_b value.

Areal aspect

The two-dimensional characteristics of a basin are known as the areal aspect. From the location of the stream's confluence with the higher order stream, the watershed can be traced along hillcrests, passing upslope of the source and returning to the junction. Slopes that feed water into streams and those that drain into other streams are separated by this line. The link between stream discharge and watershed area yields hydrologically significant information about fluvial morphometry. Drainage density, texture ratio, stream frequency, form factor, circulatory ratio, and elongation ratio are among the various morphometric parameters that are included.

Drainage density (D_d)

Drainage density (D_d) is defined as the ratio of total stream length in a basin to its entire area. Over a broad spectrum of geology and climatic characteristics, areas with low relief and highly permeable subsurface material under thick vegetative cover are more likely to have low drainage densities. High D_d, on the other hand, is preferred in areas with limited vegetation, mountainous topography, and weak or impermeable subsurface materials (Iqbal and Sajjad, 2014). The D_d ranges from 0.74 km/km^2 to 0.83 km/km^2 and is computed for each of the four sub-watersheds (Table 5). A D_d of 0.74 km/km^2 is found for SW-1, 0.78 km/km^2 for SW-2, 0.83 km/km^2 for SW-3, and 0.76 km/km^2 for SW-4. According to the D_d values, the study region is primarily located in the low drainage density zone (<2 km/km^2), which denotes low water regimes, low relief, low slope, and high infiltration capacity across the basin.

Stream frequency (F_s)

Drainage frequency is directly proportional to lithological features. Stream frequency, also known as drainage frequency, is the number of stream segments per unit area (Horton, 1945). The F_s value, which varies from 0.44 to 0.48, is determined for each of the four sub-watersheds (Table 5). The F_s value for SW-1 is 0.44, the F_s values for SW-2, SW-3, and SW-4 are 0.48, 0.47, and 0.44, respectively. In terms of F_s value, SW-1 and SW-4 have low values, indicating little relief in the basin, whereas SW-2 and SW-3 display high values, indicating considerable relief in the basin.

Drainage texture (R_t)

The total number of stream segments of all orders inside a basin per basin perimeter is known as the drainage texture (Horton, 1945). Drainage texture was divided into five categories by (Smith, 1950): extremely coarse (<2), coarse (2–4), moderate (4–6), fine (6–8), and very fine (>8). According to (Table 5), the Rt value for each of the four sub-watersheds ranges from 2.16 to 2.80, indicating that they all have coarse drainage textures.

Circulatory ratio (R_c)

The circulatory ratio is comparable to the elongation ratio, which was first described as the ratio of the basin's area to a circle with the same circumference as the basin perimeter (Miller, 1953). Between 0 (inline) and 1 (in a circle), the circulatory ratio's value fluctuated. The length and frequency of streams, geological features, land use/cover, climate, relief, and slope of the watershed are the primary factors that affect the circulatory ratio. The R_c values in the study area range from 0.18 to 0.23 (Table 5). All four of the sub-watersheds are determined to be elongated to subcircular in form based on R_c values.

Elongation ratio (R_e)

The diameter of a circle with the same area as the basin divided by the greatest length of the basin is known as the elongation ratio (R_e) (Schumm, 1956). Higher elongation ratio readings indicate low runoff and a high capacity for infiltration. In terms of discharge to runoff, a circular basin outperforms an elongated basin. In a severely elongated shape, the value of R_e is zero; in a circular shape, it is one, or 1.0. All four of the sub-watersheds had R_e values between 0.59 and 0.76 (Table 5), indicating that they are all elongated in nature.

Constant of channel maintenance (CCM)

The reciprocal of drainage density is used to compute the constant of channel maintenance (Schumm, 1956). According to (Reddy et al. 2004), a low CCM value suggests that the area is experiencing high levels of structural disturbance, low permeability, steep to extremely steep slopes, and high surface runoff, while a high CCM value indicates that the area is experiencing very few structural disturbances and low runoff conditions. The CCM value, which varies from 1.20 to 1.35, is determined for each of the four sub-watersheds (Table 5). The CCM values for SW-1, SW-2, SW-3, and SW-4 are 1.35, 1.28, 1.20, and 1.31, respectively. While SW-2 and SW-3 have lower CCM values, which indicate high structural disturbances and high runoff in these sub-watersheds, SW-1 and SW-4 have higher values, indicating less structural disturbances and less runoff.

Slope analysis

Slope elements vary in resistance depending on the kind of rock in the basin and are closely linked to water runoff, which influences the amount of time needed for precipitation water to enter the river beds that comprise the river basin network (Magesh et al., 2011). The basin's slope ranges from almost level (0–1%) to steeply sloped (>30%) (Figure 5). The areas with gentle (3-5%) to moderate (5–10%) slopes are affected by erosion and differential weathering. Mainly found on subdued plateaus, the moderately steep slopes (10–15%) are associated with pediments. The steep slopes (15–25%) are typically found on isolated mounds and degraded hills. In all four sub-watersheds, the slope ranges from level to nearly level (0–1%) to steeply sloping (>25%) (Figure 5).

Table 5. Areal aspect calculations for each of the four sub-watersheds in the study region

S. No.	Areal aspect parameters	Sub-watershed codes			
		SW1	SW2	SW3	SW4
1	A (sq.km)	1414.31	1832.81	1556.00	1366.06
2	P (km)	289.15	314.40	324.95	279.16
3	L_b (km)	68.30	63.39	75.11	59.18
4	D_d	0.74	0.78	0.83	0.76
5	F_s	0.44	0.48	0.47	0.44
6	R_t	2.18	2.80	2.25	2.16
7	R_f	0.30	0.45	0.27	0.39
8	R_c	0.21	0.23	0.18	0.22
9	R_e	0.62	0.76	0.59	0.70
10	CCM	1.35	1.28	1.20	1.31

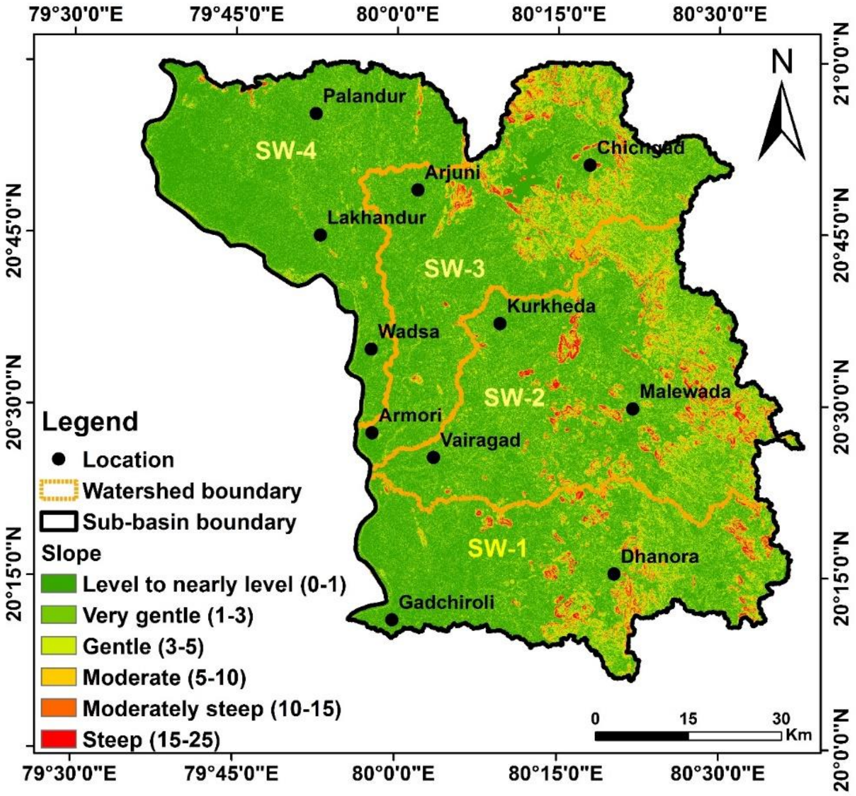

Figure 5. Slope of the study area

Watershed prioritization

The watershed manager can use the prioritization method as a tool to determine the basin's targeted areas, priority contaminants, and possible priority sources. Finding the most important issues with water quality is the first step in the prioritization process. According to (Manjare et al., 2018), basin prioritizing is the process of ranking various sub-watersheds in order of importance for treatment and conservation efforts. For flood management and water resource modelling, morphometric analysis and watershed prioritization are crucial (Youssef et al., 2011, Bali et al., 2012). Prioritization is crucial for effective planning and management of natural resources for sustainable development since resource development plans are typically implemented on a watershed basis (Vittala et al., 2004). Whereas shape parameters have an inverse relationship with erodibility—the lower the value of these parameters, the more erodible the soil—linear parameters have a direct relationship with soil erodibility—the higher the value, the more erodible the soil in a watershed (Nookaratnam et al., 2005; Sujatha et al., 2015, Manjare et al., 2016). These morphometric parameters, which have been used to prioritize watersheds, are also known as erosion risk assessment parameters. They include bifurcation ratio (R_b), constant of channel maintenance (CCM), drainage density (D_d), stream frequency (F_s), drainage texture (D_t), form factor (R_f), circularity ratio (R_c), and elongation ratio (R_e) (Biswas et al., 1999). Therefore, the highest linear parameter value was assigned a rank of 1, the second-highest rank was assigned a rank of 2, and so on, with the lowest value being assigned a final rank in the sub-watershed prioritization process. The lowest value in the shape parameters was assigned a rank of 1, followed by a rank of 2, and so on. The mean values of the four sub-watersheds were calculated to arrive at a compound value (C_p) following the rating process based on each and every parameter. Individual indicators were ranked in order to carry out the prioritization process, and a compound value (C_p) was computed (Table 6). Based on their compound value (Cp), sub-watersheds have been roughly categorized into three priority zones: Low (10 and above), Medium (8.0-10) and High (<8.0). Priority and ranking according to compound value (Cp) are displayed in (Figure. 6 and 7)

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Table 6. Calculated parameters for sub-watershed prioritization and ranking

S. No.	**Parameters**	**Computed Parametric Values and Ranks**			
		SW-1	**SW-2**	**SW-3**	**SW-4**
1	R_{bm}	3.03	4.35	4.26	21.8
2	D_d	0.74	0.78	0.83	0.76
3	F_s	0.44	0.48	0.47	0.44
4	R_t	2.18	2.80	2.25	2.16
5	R_f	0.30	0.45	0.27	0.39
6	R_c	0.21	0.23	0.18	0.22
7	R_e	0.62	0.76	0.59	0.70
8	CCM	1.35	1.28	1.20	1.31
Cumulative Value		8.87	11.13	10.05	27.78
Compound Value (C_p)		1.10	1.39	1.25	3.47
Rank		1	3	2	4
Final Priority		High	High	High	High

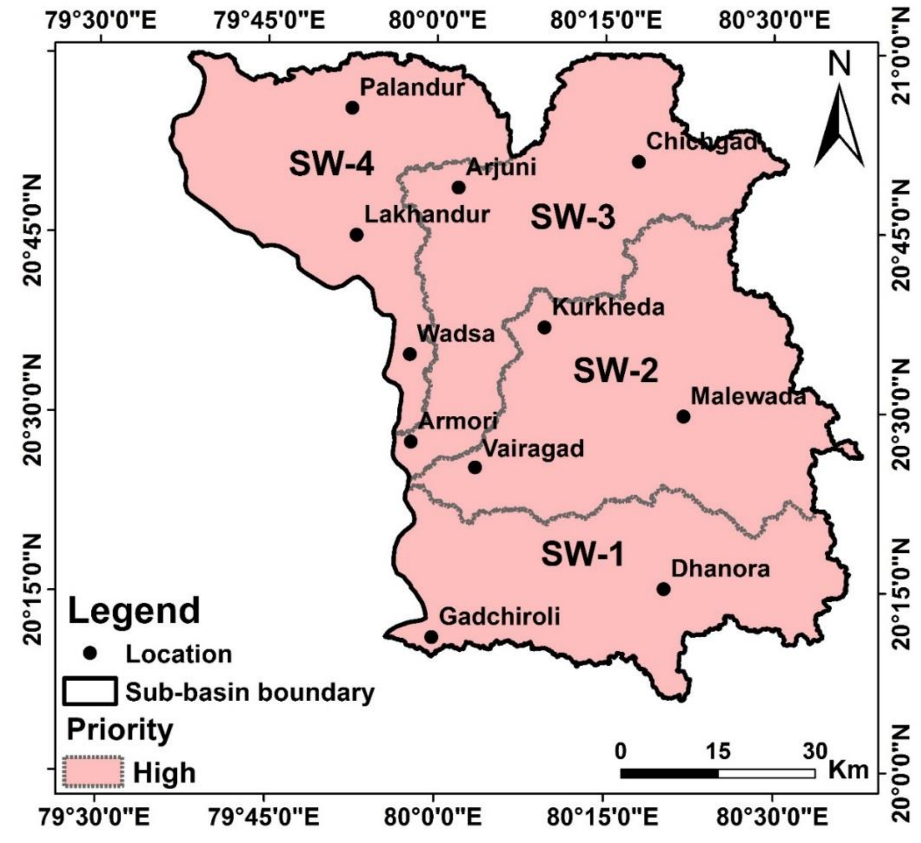

Figure 6. Map of the study area's sub-watersheds prioritized by morphometric parameters

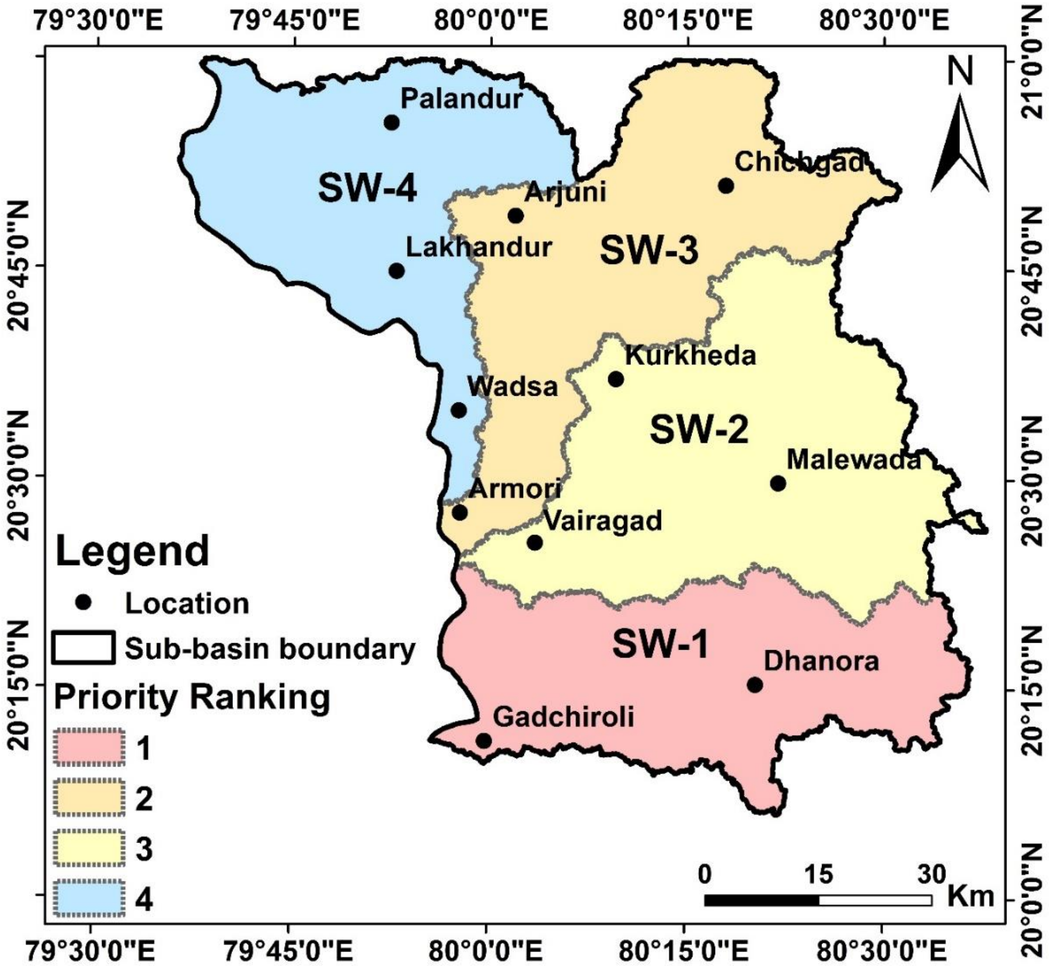

Figure 7. Ranking of the study area's sub-watersheds

5. Conclusion

The analysis of morphometric parameters, derived from remote sensing and GIS techniques, revealed that all four sub-watersheds in the study area fall under high priority for water conservation. This suggests that the entire region requires immediate attention for conservation measures to ensure sustainable management of water resources. The integration of remote sensing and morphometric parameters proved to be an effective approach in identifying areas prone to water scarcity and erosion risk, providing valuable insights into the spatial distribution of water conservation needs. The morphometric parameters, such as drainage density, stream frequency, and ruggedness number, provided a quantitative assessment of the watershed characteristics. The findings of this study can serve as a valuable tool for developing effective water conservation strategies, prioritizing areas that are most susceptible to water scarcity and erosion. Implementation of conservation measures, such as water harvesting, watershed management, and efficient irrigation practices, can help mitigate water scarcity and ensure sustainable management of the watersheds. Furthermore, the approach used in this study can be replicated in other regions to identify areas vulnerable to water scarcity and erosion, facilitating targeted conservation efforts and promoting sustainable water management practices

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