

Morphometric Analysis-based Prioritization of Sub-watersheds for Conservation Planning in Purna River Basin, Maharashtra

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Handling Editor:

Dr Mukesh Kumar Tiwari

Key words:

Morphometric parameter
Prioritization
Stream power index
Sediment transport index
Topography
Watershed management

ABSTRACT

Watershed studies provide a critical framework for understanding hydrological responses to environmental and developmental activities, enabling effective planning for resource optimization. This study focuses on prioritizing sub-watersheds according to their vulnerability to soil erosion, based on morphometric, topographic-hydrological parameters, land use, and land cover in the Purna River basin of the Marathwada region, Maharashtra, India. The Purna basin is of 7th order and contains 22 sub-watersheds (SW). The slope in the study area ranges from 0 to 117%. The mean bifurcation ratio values for various sub-watersheds in the river basin range from 1.96 (SW-22) to 5.98 (SW-13). The drainage density values of sub-watersheds in the Purna river basin vary from 0.78 (SW-13) to 0.92 km/km² (SW-22), reflecting the presence of poor and coarse drainage texture. The channel maintenance constant shows that, on average, 1.20 km² of basin area is required to develop and maintain a 1 km long stream channel. The prioritization indicates that SW-13 (C_p=3.91), SW-5 (C_p=4.10), and SW-16 (C_p=4.79) are high-priority sub-watersheds needing structural interventions (check dams, contour bunding) and vegetative measures based on their elevated bifurcation ratios (>4.17), low drainage density (<0.81 km/km²), and intensive agricultural land use (>85%). Since the prioritization relies solely on GIS-based DEM-derived empirical models and land use and land cover analysis, it can serve as an initial framework for resource allocation. These rankings should be viewed as indicative rather than definitive. Consequently, the operational implementation of this prioritization should involve a comprehensive validation process to align model predictions with field conditions and long-term watershed management goals.

1 | INTRODUCTION

The expansion in urbanization, industrial, and agricultural sectors, driven by a high population, along with climate change, has created tremendous pressure on land and water resources, leading to land degradation. Soil erosion is one of the most prominent forms of land degradation. In India, soil erosion due to water and wind affects approximately 71% of the total geographic area of the country. Being an agrarian country, India needs sustainable land and water management for its food and nutritional security. Sustainable use of land and water is even more important in semi-arid regions, as this ecology faces constraints due to water availability and high evaporative demand. Hence, in a semi-arid environment, watershed management has been proven to be one of the best approaches for natural resource management. Numerous researchers have emphasized the importance of prioritizing sub-watersheds for effective planning and

implementation of appropriate conservation measures, as it aids in identifying vulnerable areas and enhancing the overall impact of watershed management efforts (Ahirwar *et al.*, 2019; Dahipale *et al.*, 2022; Fenta *et al.*, 2024; Sekhar and Mathew, 2022).

The weighted sum analysis (WSA) method is one of the most efficient for prioritizing sub-watersheds in ungauged or data-scarce regions (Adam *et al.*, 2024). It uses only the digital elevation model (DEM) to compute various morphometric parameters of sub-watersheds for their prioritization. Morphometric parameters describe the shape, configuration, and dimensions of a watershed (Strahler, 1964), and their measurement and characterization are carried out through morphometric analysis (Adhikary and Dash, 2018). The integration of topo-hydrological indices such as the Sediment Transport Index (STI), Stream Power Index (SPI), and Topographic Wetness Index (TWI) helped

to clarify the watershed hydrological behavior (Singh and Singh, 2022). Both topo-hydrological and morphometric features are generated using Geographic Information Systems (GIS) platforms to analyse terrain features, which in turn help in understanding erosion patterns, predicting flood-prone areas, and assessing the overall hydrological response of a landscape (Sanchez and Alvarez, 2024).

While morphometric analysis has been applied globally, the Purna River basin, Maharashtra, characterized by erratic monsoon rainfall (750-900 mm), frequent droughts, black cotton soils with poor drainage, and intensive cotton-sorghum agriculture, presents a unique hydrogeological setting. Previous studies on Purna tributaries (Ingle, 2022; Chaudhari *et al.*, 2023) conducted only basic morphometric analysis without integrating topo-hydrological indices or LULC dynamics. The present study aims to integrate morphometric parameters with topo-hydrological indices (TWI, SPI, and STI) and high-resolution (10 m) land use and land cover (LULC) data for comprehensive sub-watershed prioritization across the entire Purna River basin. The integration of these datasets will enable assessment of erosion susceptibility, hydrological response, and sediment transport potential, providing a replicable framework for watershed management and conservation planning in data-scarce semi-arid regions.

2 | MATERIALS AND METHODS

2.1 | Study Area

The Purna river basin is a major tributary of the Godavari river and flows from north to southeast, covering an area of 15,864.2 km². The basin lies between latitudes 19° 11' 08.43" to 20° 24' 51.41" N and longitudes 75° 13' 33.41" to 77° 00' 2.61" E in Maharashtra, India (Fig. 1). The river originates in the Ajanta hill range. The basin outlet is located just before the Purna river merges with the Godavari near Purna village. The elevation of the study area ranges between 361 to 933 m. The region experiences a tropical climate with three distinct seasons: winter (November to February), summer (March to May), and southwest monsoon season (June to September). The annual rainfall ranges between 750 and 900 mm, and is predominantly received during the south-west monsoon. The average rainy days are of 65 days. The mean minimum temperature is 13 °C, whereas the mean maximum temperature is 39.8 °C. The study area is characterized by diverse soil types and geomorphological features shaped by its semi-arid climate and Deccan plateau geology. The predominant soil type is black cotton soil, derived from basaltic parent material, which is highly fertile but has poor drainage and shrink-swell properties. Other soil types, such as red soils and laterites, are found on elevated terrains, often associated with weathered and eroded landforms. Geomorphologically, the region features undulating plains, isolated hills, and river valleys, with the Purna river and its tributaries playing a crucial role in shaping the landscape. The cropping pattern in the area is influenced mainly by its

HIGHLIGHTS

- Integration of morphometric parameters with topo hydrological and land use land cover analysis allowed for a comprehensive assessment of watershed condition.
- Novel integration of topo-hydrological indices (TWI, SPI, STI) with high-resolution LULC data provides a replicable framework for data-scarce semi-arid regions.
- Positive Stream Power Index values (4.85-5.49) coupled with 86 % agricultural dominance indicate high basin-wide erosion susceptibility in Marathwada's drought-prone landscape.

semi-arid climatic conditions, soil types, and irrigation availability. Major crops include cotton (*Gossypium hirsutum*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), pigeon pea (*Cajanus cajan*), and chick pea (*Cicer arietinum*). Additionally, a few horticultural crops, such as pomegranate and mango, are extensively cultivated. In irrigated areas, sugarcane (*Saccharum officinarum*) and wheat (*Triticum aestivum*) are also cultivated. The cropping pattern exhibits seasonal variability, with rainy season crops dominating due to reliance on rainfall, and limited winter season crops grown in regions with assured irrigation facilities. Overall, it's cropping pattern highlights the interplay of agro-climatic factors and the resourcefulness of farmers adapting to challenging environmental conditions.

2.2 | Data Source and Pre-Processing of Data

In this study, the Shuttle Radar Topography Mission (SRTM) DEM from the United States Geological Survey (USGS) Earth Explorer, with a resolution of 30 m, was used to delineate the Purna river basin and its sub-watersheds. The SRTM DEM (30 m resolution) was selected because: (i) it provides consistent global coverage essential for large basin analysis (15,864 km²), (ii) it's 30 m resolution adequately captures terrain variability in gently undulating Deccan plateau topography (slope ranges 0 to 117%, with a mean value of 5%), and (iii) previous validation studies for basaltic terrain of Central India show SRTM vertical accuracy of less than 10 m, suitable for drainage network delineation (Zade *et al.*, 2022). The processing of DEM was done with a sequence of operations such as fill, flow direction, flow accumulation, stream definition, stream to feature, along with stream outlet point and sub-watersheds delineation. Google Earth Pro based satellite data was utilized to support watershed delineation, locating outlet, verify stream networks and other terrain features. ArcGIS software (version 10.7.1), along with the ArcSWAT extension, was employed to delineate the watershed and extract relevant parameters for geospatial analysis. Further, the WSA was conducted to assess and prioritize the sub-watersheds.

To ensure reliability of morphometric parameters, SRTM DEM elevation values were validated against: (i) Survey of India topographic sheets (1:50,000 scale) at 50

reference points distributed across elevation gradients, and (ii) 25 ground control points collected using Differential GPS (DGPS) with vertical accuracy of ± 0.5 m. The root mean square error (RMSE) was calculated as:

$$RMSE = \sqrt{[\sum(ZDEM - ZGPS)^2/n]}$$

Where ZDEM is DEM elevation, ZGPS is reference elevation, and n is number of points.

2.3| Morphometric and Topo-hydrological parameters

The two sets of factors, including morphometric and topographic-hydrological factors, were computed for all sub-watersheds using an integrated approach involving Remote Sensing (RS) and Geographic Information Systems (GIS). High-resolution satellite imagery and SRTM DEM datasets were used to delineate sub-watershed boundaries and extract the drainage network. Sub-watershed delineation followed a systematic workflow: (1) DEM conditioning through sink filling (depth threshold: 5 m), (2) flow direction computation using D8 algorithm, (3) flow accumulation with minimum threshold of 500 cells (45 ha) to define channel initiation, (4) stream network extraction

and ordering following Strahler's method, (5) outlet point placement at coordinates (77° 01' 34.07" E and 19° 6' 55.49" N) before Purna-Godavari confluence, and (6) automated watershed segmentation using ArcSWAT's watershed delineator tool. The 45 ha threshold was selected based on Google Earth validation to match observable drainage channels in the field. Morphometric factors include a) linear parameters [stream order (So), bifurcation ratio (Rb)], b) areal parameters [stream frequency (Fs), drainage density (Dd), drainage texture (Dt), constant channel maintenance (Cm), compactness coefficient (Cc)] and c) relief parameters [form factor (Rf), circularity ratio (Rc), elongation ratio (Re)], whereas TWI, STI and SPI were estimated as topo-hydrological parameters. The formula or equations used for the calculation of these parameters are presented in Table 1. The present approach to prioritizing the sub-watersheds allows for a detailed characterization of the watershed's topography and hydrological behavior, facilitating improved understanding of runoff processes, erosion potential, and watershed management strategies (Fig.2).

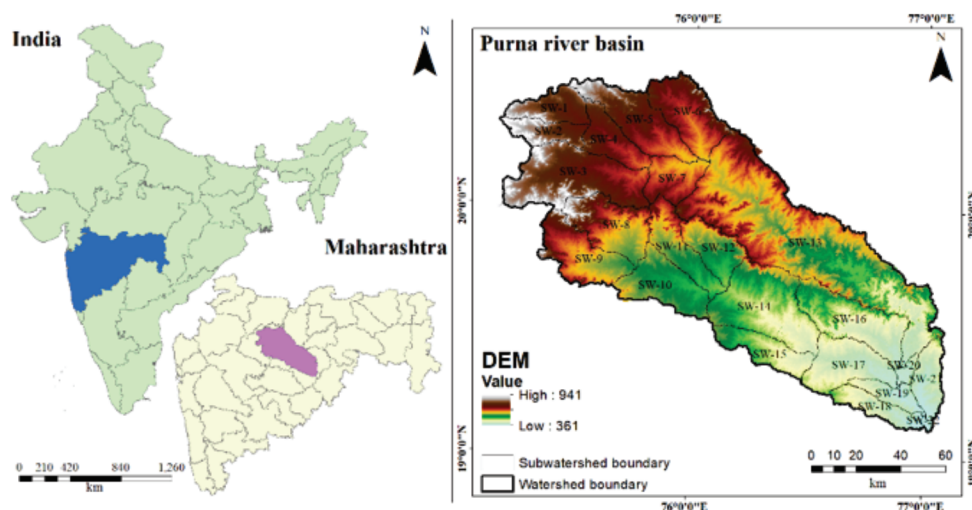


FIGURE 1 Map showing the study area with its elevation and sub-watersheds

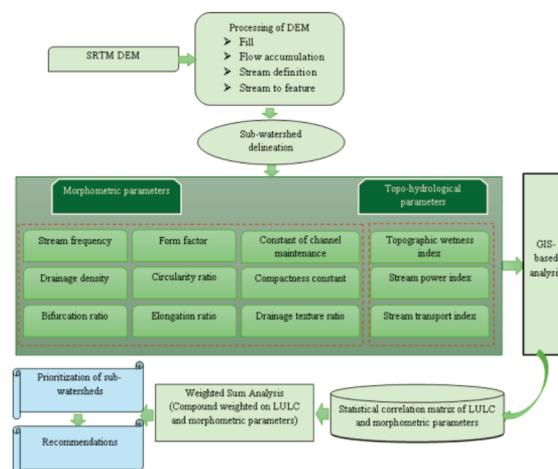


FIGURE 2 Flow chart showing process followed for prioritizing sub-watersheds

TABLE 1 Equation/formula used morphometric and topo-hydrological parameters computation

Sl. No	Parameters	Defination/formula	Reference
1	Dt, per km	$Dt = Nu/P$; Ratio of total stream number of all orders and basin perimeter (P)	Horton, 1945
2	Rc	$Rc = 4\pi A/P^2$; Ratio of basin area to the area of a circle having the same perimeter as that of basin	Miller, 1953
3	Re	$Re = 2(A/\pi)^{0.5}/Lb$; Ratio between the diameter of a circle having same area as that of basin and the maximum basin length	Schumm, 1956
4	Cc	$Cc = P/2 \times (\pi A)^{0.5}$; Ratio of perimeter of the watershed to the circumference of circle having same area as that of the watershed	Gravelius, 1914
5	Cm, km ² /km	$Cm = 1/Dd$; Reciprocal of drainage density	Schumm, 1956
6	TWI	$TWI = \ln(As/\tan\beta)$; As is the local upslope area draining through a certain point per unit contour length and $\tan\beta$ is the local slope	Beven, 1986
7	SPI	$SPI = As \times \tan\beta$	Rahmati et al., 2019
8	STI	$STI = (m+1) \times (As/22.13m) \times (\sin\beta/0.0896^n)$; where b is the local slope gradient in degrees, m is the contributing area exponent, and n is the slope exponent	Ahmad et al., 2019

*Other parameters include Rb, Dd, Fs, and Rf as per their standard definition (Horton, 1932; Strahler 1964)

2.4| Land Use & Land Cover (LULC)

The LULC analysis for each sub-watershed of the study area was carried out using ESRI open-source data with a resolution of 10 m for the year 2024. Each sub-watershed was classified into six LULC categories, namely forest, open scrub, agriculture, water bodies, habitation, and wasteland. LULC classification accuracy was assessed using 150 randomly distributed validation points (25 points per class) generated through stratified random sampling. Reference data were collected from: (i) Google Earth Pro high-resolution imagery (2024), (ii) field photographs from 35 accessible locations, and (iii) the BHUVAN portal imagery. A confusion matrix was constructed, and overall accuracy, producer's accuracy, user's accuracy, and Kappa coefficient were calculated. The overall accuracy of 87.3% and the Kappa coefficient of 0.83 indicated substantial agreement, meeting USGS Level II classification standards.

2.5| Correlation Analysis

Inter-parameter correlation analysis was conducted to identify redundant variables and understand parameter interactions. The weighting scheme was based on (i) established erosion-parameter relationships from literature (Rahmati et al., 2019; Sekhar and Mathew, 2022), (ii) correlation strength among parameters (Fig. 5), and (iii) physical significance of each parameter in the semi-arid black cotton soil environment. Parameters with direct erosion linkages (Rb, Dd, STI, SPI) received higher weights.

2.6| Weighted sun analysis (WSA) & Prioritization of sub-watersheds

The WSA method is one of the effective techniques for prioritizing sub-watersheds. It is a multi-criteria decision-making technique used to combine several input layers by assigning relative importance or weights to them (Aher et

al., 2014; Rahmati et al., 2019). The relative importance or weights of each parameter was estimated through the statistical correlation (Rahmati et al., 2019). This allows prioritization of sub-watersheds based on their overall suitability for a specific purpose, in this case, mitigation of soil erosion. In this study, each of these factors was considered based on its contribution to surface runoff, infiltration, erosion susceptibility, and overall watershed sensitivity.

Some morphometric factors have a linear or direct association with soil erosion, while others have an indirect relationship. Linear parameters such as Rb, Fs, Dd, and Dt have a direct relationship with soil erodibility, whereas areal parameters (Rf, Rc, Re, Cc) have an inverse relationship with soil erodibility (Sujatha et al., 2015). Even though constant of channel maintenance is an areal parameter, it exhibits a direct relationship with soil erodibility. Similarly, all three topo-hydrological parameters (TWI, SPI, and STI) have a direct relationship with soil erodibility. Hence, the sub-watershed with the highest value in these linear parameters was rated as 1st rank, the second-highest value was rated as second rank, and so on. On the contrary, a sub-watershed showing the lowest value in areal parameters was rated as 1st rank, the next lower value rated as 2nd rank, and so on.

Similarly, forests and open scrub have an inverse relationship with soil erosion, while wasteland, habitation, and agricultural land have a direct relationship with erosion. Hence, the sub-watershed with the maximum area under waste land, agriculture, and habitation was rated as 1st rank, the second-highest value was rated as 2nd rank, and so on. In the contrary, a sub-watershed having minimum area under forest and open scrub was rated as 1st rank, the next lower value rated as 2nd rank and so on.

The compound value was calculated by summing the ranking values of all parameters for each sub-watershed and dividing by the number of parameters considered. The equation used to calculate the compound parameter (C_p) for prioritizing sub-watersheds is mentioned below (Rahmati *et al.*, 2019).

$$C_p = \sum_{i=1}^n r_i / n$$

Where r_i is the rank or weight of each morphometric/topo-hydrological/LULC parameter, and n is the no. of parameters. Further, the final cumulative compound values for sub-watershed prioritization were calculated by integrating topohydro-morphometric parameters with LULC data. In the prioritization, 75% and 25% weightage were given to topo-hydro-morphometric parameters and LULC, respectively, as morphometric parameters represent the permanent physiographic controls on runoff and erosion, which remain stable over time and are essential for long-term watershed behaviour, while LULC, being transient and variable, is assigned lower weight as it fine-tunes rather than defines the fundamental hydrological response. Nevertheless, incorporating sensitivity analysis in future research could help refine and validate the relative weights of these parameters. The sub-watershed with the least value of the compound parameter was considered the most susceptible sub-watershed and ranked as 1, the next higher value was ranked as 2, and so on. Ultimately, the sub-watershed with the highest C_p value was assigned the lowest priority. This implies that the highest priority indicates the risk of runoff occurrence, with subsequent soil erosion being maximum in that sub-watershed.

2.7 | Assumptions of the Study

The present study primarily relies on secondary geospatial data and has certain assumptions; hence may affect the precision and reliability of the findings. Those are presented below:

- SRTM DEM (30m) may not capture micro-relief features affecting localized erosion.
 - LULC data (2024) represents a single temporal snapshot and does not account for seasonal variability or recent land use changes.
 - Morphometric parameters are static and do not reflect dynamic processes such as rainfall intensity variations, soil moisture dynamics, or anthropogenic interventions (roads, check dams, mining).
 - Prioritization rankings are DEM-based empirical model-derived and require field validation through erosion measurements, sediment yield monitoring, and ground reconnaissance before operational use.
 - Weightage assignments (75:25 for morphometric-LULC integration) are based on expert judgment and may be refined through sensitivity analysis or stakeholder consultation.
- Despite these limitations, the framework provides a cost-effective first-order assessment for prioritizing sub-

watersheds for planning and execution of suitable conservation measures in data-scarce semi-arid basins.

3 | RESULTS AND DISCUSSION

3.1 | Basin Characteristics

The entire Purna river basin has been divided into 22 sub-watersheds as depicted in *Fig. 1*. The smallest sub-watershed is SW-22, having an area of 37.38 km², followed by SW-20 (80.52 km²) and SW-19 (240.00 km²) while the largest sub-watershed is SW-13 (3668.34 km²), followed by SW-3 (1316.19 km²) and SW-14 (1229.11 km²) (Table 2). The elevation of the river basin ranges between 361 and 941 m (*Fig. 1*). The significant variation in sub-watershed size (37.38 to 3668.34 km²) presents challenges for comparative analysis, as size influences several morphometric parameters. SW-13 accounts for 23.1% of the total basin area, while the smallest five sub-watersheds (SW-22, SW-20, SW-19, SW-21, SW-18) collectively represent only 6.5%. This size asymmetry necessitates the use of normalized parameters (Dd, Fs, Rb) rather than absolute values for prioritization. The elevation gradient of 580 m (361-941 m) across relatively short horizontal distances indicates moderate to steep terrain conducive to rapid runoff generation, consistent with the region's flash flood history during monsoon events.

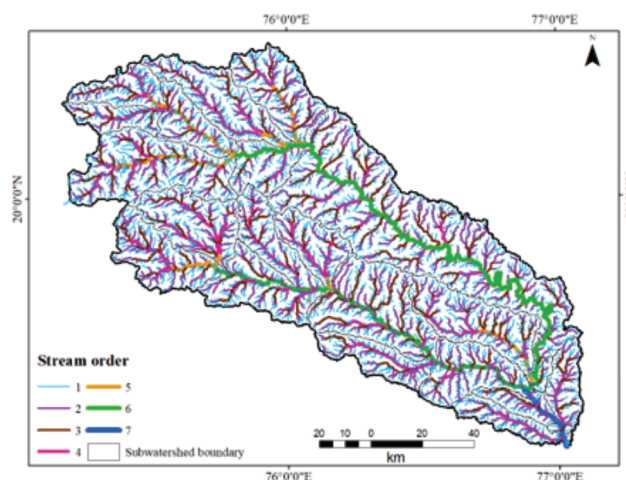


FIGURE 3 Stream order map of the river basin

3.2 | Slope Analysis

Slope analysis was performed by reclassifying DEM-derived slope maps into five categories following NBSS&LUP classification: nearly level (0-1%), very gently sloping (1-3%), gently sloping (3-5%), moderately sloping (5-10%), and steep (>10%). Results show that 68.3% of the Purna basin falls under gently to moderately sloping terrain (3-10%). In comparison, 12.7% exhibits steep slopes (>10%) primarily in the upper catchment areas of SW-1, SW-2, and SW-3 near the Ajanta hill range. Sub-watersheds SW-13, SW-16, and SW-17 contain significant areas (15-22%) with slopes exceeding 10%, where conventional agriculture without conservation measures accelerates soil erosion. The mean slope of the basin is 5.2%, with a standard deviation of 4.8%, indicating

moderate topographic heterogeneity. These slope characteristics directly influence the SPI and STI values discussed in Section 3.4.

3.3 | Morphometric Parameters

3.3.1 | Linear Aspects

Stream order (So): It quantifies a stream's position within the hierarchical structure of its network, reflecting the connectivity between stream segments and the discharge contributions from upstream catchments (Strahler, 1964). The higher the stream order, the higher the basin area. The main and highest order (7th order) is shown at SW-22 (Fig.

3), whereas the maximum sub-watersheds are of 4th order. Stream order distribution across the basin follows Horton's law of stream numbers, with 1st order streams constituting 62.4% (3857 streams), 2nd order 23.1% (1429 streams), 3rd order 9.8%, and higher orders forming progressively smaller proportions. This hierarchical pattern indicates a well-developed, mature drainage network. However, sub-watersheds SW-5 and SW-13 deviate from this pattern with higher proportions of 1st order streams (68.2% and 71.3% respectively), suggesting active headward erosion and ongoing channel network expansion—both indicators of erosion vulnerability.

TABLE 2 Perimeter, basin length, area, no. of streams, stream length, and elevation of sub-watersheds

Sub-Watershed	Parameters						
	Perimeter (P), km	Basin length (Lb), km	Area (A), km ²	Minimum elevation (h), m	Maximum elevation (H), m	No. of streams (Nu)	Stream length, km
SW-1	170.59	42.31	417.81	599	907	172	359.24
SW-2	162.37	40.97	336.07	599	911	145	281.42
SW-3	317.71	69.22	1316.19	545	933	497	1088.41
SW-4	181.64	43.99	462.50	545	778	212	385.10
SW-5	264.59	68.10	811.72	528	898	598	635.11
SW-6	212.34	46.80	753.43	523	760	269	615.90
SW-7	161.88	35.36	437.83	523	667	168	368.99
SW-8	223.89	48.53	774.72	480	922	284	654.89
SW-9	231.86	53.42	745.88	480	930	298	673.63
SW-10	222.59	44.83	712.36	450	637	275	588.07
SW-11	229.57	56.90	561.09	438	669	221	454.49
SW-12	168.18	36.27	482.72	438	675	183	393.11
SW-13	689.82	156.13	3668.34	377	706	1374	2843.49
SW-14	268.73	51.93	1229.11	392	667	451	984.73
SW-15	202.58	49.74	481.09	392	524	184	399.60
SW-16	260.08	64.16	915.85	377	596	354	737.57
SW-17	219.38	49.14	698.46	369	476	272	584.33
SW-18	184.11	46.56	331.28	361	519	141	280.44
SW-19	160.15	36.20	240.00	365	450	101	204.49
SW-20	84.74	17.26	80.52	369	436	32	67.04
SW-21	157.37	38.40	369.82	365	544	166	318.51
SW-22	57.19	11.96	37.38	361	414	18	34.44

Bifurcation ratio (Rb): In this study, the mean bifurcation ratio of sub-watersheds varied between 1.96 in SW-22 to 5.98 in SW-13 (Table 3). Ingle (2022) reported a mean Rb of 4.62 for the Morna river, whereas Chaudhari *et al.* (2023) found 5.09 for the Kasura river, both tributaries of the Purna river basin. Typically, Rb values within a range of 3.0 to 5.0 are common in river basins, which reflects the independence of the drainage pattern of the basin on its geological structure (Strahler, 1964). Low Rb values (< 4) indicate elongated drainage basins having high overland flow, increased infiltration rate, extended peak discharge durations, and reduced risks of flooding and soil erosion. In contrast, high Rb (> 5) values imply a circular drainage system with a low infiltration rate, sharp peak flow, limited groundwater recharge, and enhanced susceptibility to soil erosion and flooding (Adhikary and Dash, 2018). The sub-

watersheds SW-4, SW-5, SW-13, SW-15, and SW-21, exhibiting high bifurcation ratio values (Rb > 5), are likely to experience concentrated runoff, resulting in increased soil erosion and sediment transport potential

3.3.2 | Areal Aspects

Stream frequency (Fs): Stream frequency (Fs) depends on lithology, drainage texture, climate, soils, vegetation, relief, infiltration, permeability, and runoff. Low Fs (< 3) indicates flat terrain with high infiltration and low erosion risk, while high Fs (> 6) suggests faster runoff and greater erosion potential. In the Purna river basin, Fs ranges from 0.36 to 0.78/km² (Table 3), indicating a poorly developed drainage network, low permeability, low relief, and reduced surface flow (Singh and Singh, 2022). Ingle (2022) reported a low Fs value of 2.11 km⁻² for the Morna river.

TABLE 3 Morphometric and topohydrological parameters of the sub-watersheds

Sub-Watershed	Morphometric							Topo-hydrological				
	Rb	Fs	Dd	Dt	Cc	Cm	Rf	Re	Rc	TWI	SPI	STI
SW-1	4.15	0.41	0.86	1.01	2.37	1.16	0.23	0.55	0.18	11.16	5.21	16.86
SW-2	4.96	0.43	0.84	0.89	2.52	1.19	0.20	0.51	0.16	10.93	5.49	17.39
SW-3	4.49	0.38	0.83	1.56	2.49	1.21	0.27	0.59	0.16	11.17	5.21	17.49
SW-4	5.73	0.46	0.83	1.17	2.40	1.20	0.24	0.55	0.18	11.29	5.03	16.36
SW-5	5.26	0.74	0.78	1.04	2.64	1.28	0.18	0.47	0.15	11.27	5.07	17.24
SW-6	4.05	0.36	0.82	1.27	2.20	1.22	0.34	0.66	0.21	11.21	5.13	16.95
SW-7	3.73	0.38	0.84	1.04	2.20	1.19	0.35	0.67	0.21	11.38	4.94	15.96
SW-8	3.88	0.37	0.85	1.27	2.29	1.18	0.33	0.65	0.19	11.26	5.13	17.44
SW-9	3.54	0.40	0.90	1.29	2.41	1.11	0.26	0.58	0.17	11.45	4.89	16.50
SW-10	3.95	0.39	0.83	1.24	2.37	1.21	0.35	0.67	0.18	11.33	4.98	16.64
SW-11	3.73	0.39	0.81	0.96	2.75	1.23	0.17	0.47	0.13	11.28	5.03	16.84
SW-12	3.26	0.38	0.81	1.09	2.17	1.23	0.37	0.68	0.21	11.21	5.27	18.80
SW-13	5.98	0.37	0.78	1.99	3.24	1.29	0.15	0.44	0.10	11.41	4.96	16.92
SW-14	3.35	0.37	0.80	1.68	2.18	1.25	0.46	0.76	0.21	11.11	5.25	17.43
SW-15	5.29	0.38	0.83	0.91	2.62	1.20	0.19	0.50	0.15	11.41	4.94	16.62
SW-16	4.17	0.39	0.81	1.36	2.44	1.24	0.22	0.53	0.17	11.22	5.20	17.20
SW-17	3.84	0.39	0.84	1.24	2.36	1.20	0.29	0.61	0.18	11.42	5.01	16.78
SW-18	4.89	0.43	0.85	0.77	2.87	1.18	0.15	0.44	0.12	11.34	5.07	16.48
SW-19	3.58	0.42	0.85	0.63	2.94	1.17	0.18	0.48	0.12	11.34	5.07	15.57
SW-20	2.95	0.40	0.83	0.38	2.68	1.20	0.27	0.59	0.14	11.37	5.00	14.69
SW-21	5.11	0.45	0.86	1.05	2.32	1.16	0.25	0.57	0.19	11.40	4.98	16.20
SW-22	1.96	0.48	0.92	0.31	2.66	1.09	0.26	0.58	0.14	11.52	4.85	13.53

Drainage density (Dd): It reflects the extent of channel development and stream distribution within a basin, and also indicates a watershed's vulnerability to hydrological hazards, especially where hydro-meteorological data are scarce. Dd is classified into five categories: very fine (>4.97 km/km²), fine (3.73-4.97), moderate (2.49-3.73), coarse (1.24-2.49), and very coarse (<1.24 km/km²) (Sekhar and Mathew, 2022). High Dd suggests dense stream networks, typical of steep areas with rapid runoff. Low Dd indicates coarse drainage texture, low relief, permeable soil, dense vegetation, high infiltration, and greater groundwater recharge. In the Purna River basin, Dd ranges from 0.78 (SW-13) to 0.92 (SW-22) km/km² (Table 3), reflecting poor and very coarse drainage texture.

Drainage texture (Dt): Drainage texture depends on climate, soil, infiltration, elevation, and vegetation. Fine texture occurs in soft rocks with sparse vegetation, while resistant rocks lead to coarse texture. Dt is classified as: very coarse (<2 /km), coarse (2-4), moderate (4-6), fine (6-8), and very fine (>8 /km). Finer textures indicate higher erosion risk. In this study, the mean Dt is 1.15, indicating a very coarse drainage texture.

Compactness coefficient (Cc): It is slope-dependent but not related to watershed size. A Cc value of 1 indicates a circular shape, while values >1 show increasing elongation. In this study, the lowest Cc values are in SW-12 (2.17), SW-14 (2.18), and SW-6 (2.20), while SW-13 (3.24), SW-19 (2.94), and SW-18 (2.87) show the highest (Table 3). Thus, all sub-watersheds in the Purna river basin are elongated in shape.

Constant of channel maintenance (Cm): Constant of channel maintenance, the reciprocal of drainage density, indicates the drainage area required to develop and maintain one unit length of stream channel, reflecting basin infiltration and runoff characteristics (Singh and Singh, 2022). Classified into five erodibility categories (Sekhar and Mathew, 2022), the Cm values for the Purna river basin's sub-watersheds range from 1.09 to 1.29 km²/km, averaging 1.20 km²/km (Table 3). This suggests low erodibility and moderate surface runoff within the basin.

3.3.3 | Relief Aspects

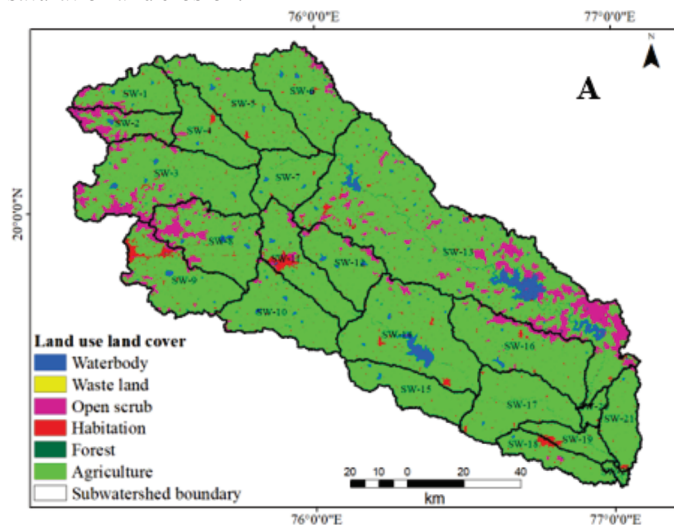
Form factor (Rf): It indicates flow intensity and runoff characteristics within a basin. Lower Rf values suggest elongated watersheds with lower runoff and longer time of concentration, while higher values indicate more circular basins with higher runoff and shorter concentration times (Adhikary and Dash, 2018). In this study, Rf values ranged from 0.15 to 0.46 across sub-watersheds, with SW-13, SW-18, and SW-11 exhibiting lower values and SW-14, SW-12, and SW-10 showing higher values (Table 3). Ingle (2022) and Chaudhari *et al.* (2023) reported Rf values of 0.32 and 0.21 for the Morna river and Kasura river, respectively.

Elongation ratio (Re): It ranges theoretically from 0 to 1, but typically varies between 0.5 and 1.0. Watersheds are classified as circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5). Circular basins tend to have higher peak discharge and are more prone to erosion. In this study, Re values ranged from 0.44 to 0.76, indicating predominantly elongated sub-

Circulatory ratio (Rc): Influenced by geology, relief, climate, and land use, Rc ranges from 0 to 1 and reflects basin maturity: high values correspond to older basins, while low values indicate younger basins. In the Purna basin, Rc values ranged from 0.10 (SW-13) to 0.21 (SW-12), suggesting watersheds at an early stage of development with low runoff potential (Table 3).

3.4 | Topo-hydrological parameters

Topographic wetness index (TWI): It quantifies the influence of topography on hydrological processes and soil moisture distribution. It is determined by the slope and the contributing upstream area per unit width orthogonal to the flow direction. TWI correlates with soil properties such as organic matter, silt content, and soil depth (Singh and Singh, 2022). Higher TWI values (>10) reflect areas with greater potential for surface runoff and an elevated risk of soil erosion due to accumulation of water. Within the Purna river basin, TWI values vary from 10.93 (SW-2) to 11.52 (SW-22), indicating that the entire river basin is susceptible to saturation and erosion.



Stream Power Index (SPI): It indicates the potential erosive power of overland flow (Singh and Singh, 2022), influenced by slope, basin size, soil, vegetation, and climate. Positive SPI values highlight erosion-prone areas, while negative values indicate depositional zones. In the Purna river basin, SPI values range from 4.85 to 5.49, suggesting moderate erosive potential across the sub-watersheds.

Sediment Transport Index (STI): It quantifies the spatial dynamics of erosion and deposition within a watershed by representing the convergence and divergence of sediment fluxes along topographic gradients. It is strongly correlated with soil detachment and transport capacity, thereby serving as a proxy for erosion susceptibility and zones of potential sediment accumulation. In the Purna river basin, STI values range from 13.53 in SW-22 to 18.80 in SW-12 (Table 3). Elevated STI values correspond to steeply sloping terrain, deeply incised ravines, and dense drainage networks, collectively indicative of intensified erosion and sediment yield potential.

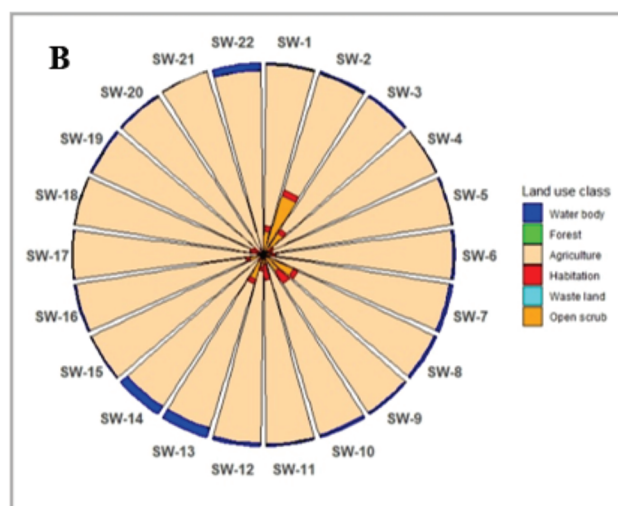


FIGURE 4 Land use and land cover map (A) and its percentage distribution (B) in study area

3.5 | Land use and Land cover of Purna river basin

The land use and land cover analysis is also a critical factor in prioritizing sub-watersheds. LULC categorization includes six classes, such as water bodies, forest, agriculture, habitation, waste lands, and open scrubs (Fig. 4A). The analysis highlights agriculture as the primary activity, spanning over 13733.17 km² (86.57% of total area), underscoring the region's agricultural reliance (Fig. 4B). Open scrub follows with an area of 1265.46 km². Water bodies constitute a tiny proportion of the area, covering 373.44 km² (2.35% of the area), highlighting limited aquatic resources and the probability of development of irrigation. The area under habitation accounts for 488.16 km², representing the space allocated for residential, industrial, and urban activities within the Purna river basin.

3.6 | Correlation Analysis

The correlation matrix for topo-hydro-morphometric

parameters and LULC of sub-watersheds is presented in Fig. 5. The positive moderate association between Rb and Rf ($r = 0.56$) indicates that sub-watersheds with higher Rb tend to be more compact, favouring rapid runoff concentration and increased erosion susceptibility (Fig. 5A). In contrast, Rb has a negative correlation with the Dd ($r = -0.24$) and Dt ($r = -0.32$). Aside from its correlation with STI ($r = 0.52$), Fs shows no significant correlation with the other parameters. The strong positive correlation of Rf with Re ($r = 0.84$) and Rc ($r = 0.63$) indicates that more circular basins are hydrologically more responsive, exhibiting higher peak discharge and thus higher soil-erosion risk. Further, the strong TWI-SPI correlation ($r = 0.72$) emphasizes that zones with high water accumulation also exhibit greater erosive power of overland flow, making them hotspots of soil loss. LULC interactions reveal that declining forest cover ($r = -0.48$ with habitation) and agricultural expansion ($r = 0.71$ with habitation) increase

runoff potential by reducing infiltration and protective vegetative cover (Fig. 5B).

Overall, sub-watersheds with high Rb, compact shapes (high Rf/Re/Rc), elevated TWI-SPI values, and reduced forest cover are more prone to intense runoff and soil

erosion. Based on correlation coefficient weights given to different parameters for prioritization of sub-watersheds, it can give insights for prioritization of erosion-prone sub-watersheds for targeted soil- and water-conservation interventions.

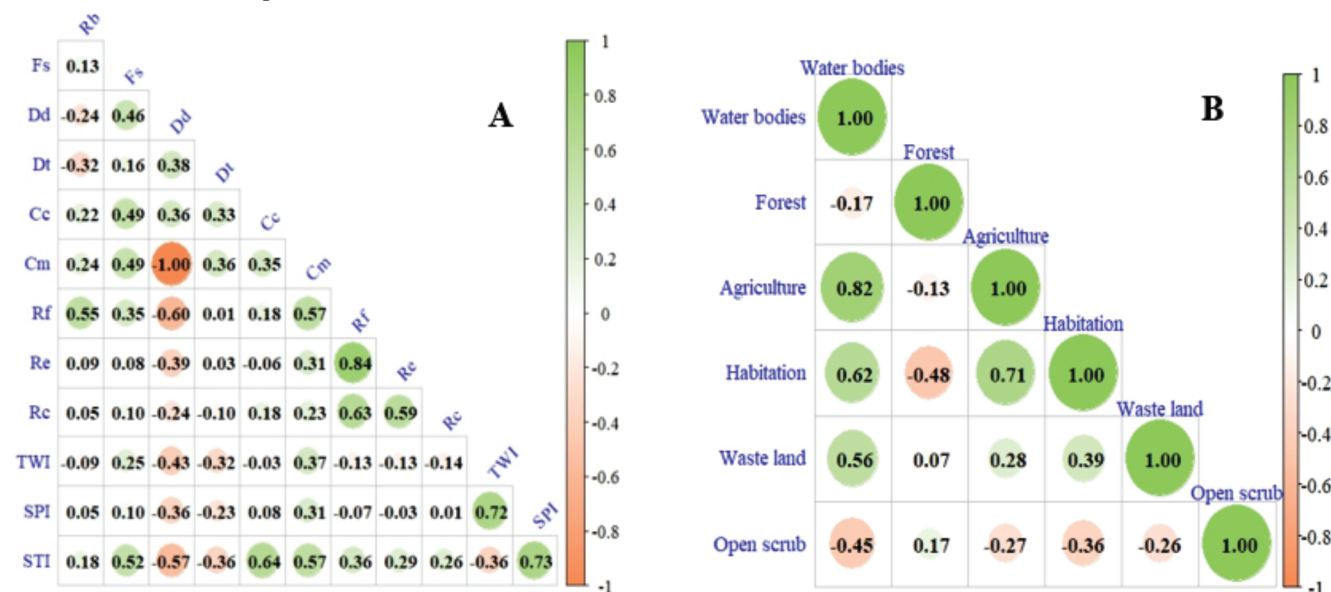


FIGURE 5 Correlation matrix of A) Topohydro-morphometric parameters B) LULC

3.7 | Prioritization of sub-watershed based on topohydro-morphometric parameters

Prioritizing sub-watersheds for conservation ensures efficient resource allocation and targeted interventions. Each morphometric and topohydrological parameter was weighted based on its influence on soil erosion. Linear parameters (Rb, Fs, Dd, Dt) show a direct relationship with erosion; hence, sub-watersheds with higher values were given higher priority (rank 1 being most erosion-prone). In contrast, areal/shape parameters (Rf, Rc, Re, Cc) exhibit an inverse relationship, so higher values received lower weights. Cm, along with TWI, SPI, and STI, shows a direct link to erosion risk and was accordingly assigned higher

priority. The compound parameter value (Cpm) for each sub-watershed was calculated as the mean of all weights, reflecting cumulative susceptibility to erosion.

Based on Cpm, sub-watersheds were ranked (Table 4), in which SW-5 (Cpm = 7.50) and SW-13 (Cpm = 8.42) ranked 1st and 2nd while SW-7 ranked lowest. These were classified into four priority groups: high (1-5), medium to high (6-10), medium (11-16), and low (17-22) (Fig. 6A). High-priority sub-watersheds indicate greater erosion risk and require urgent soil and water conservation measures.

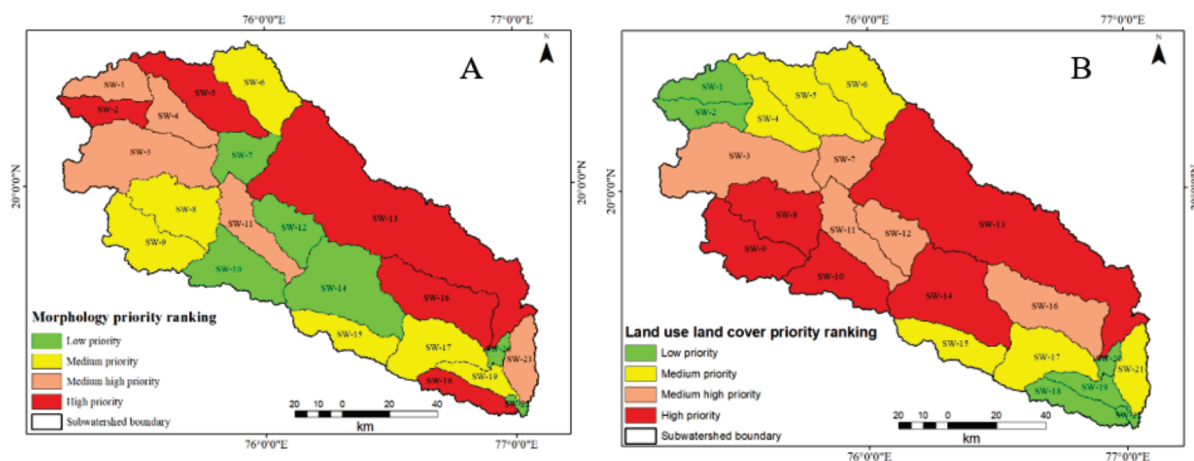


FIGURE 6 Priority ranking of sub-watersheds based on (A) topo-hydro-morphometric parameters and (B) LULC

TABLE 4 Weightage, compound parameter and rank of sub-watersheds based on topo-hydro-morphometric parameters

Sub-Watershed	Rb	Fs	Dd	Dt	Cc	Cm	Rf	Re	Rc	TWI	SPI	STI	Compound parameter (Cpm)	Rank
Weightage assigned													Compound parameter (Cpm)	Rank
SW-1	10	8	4	15	9	19	9	9	14	20	4	10		
SW-2	6	5	9	18	14	14	7	7	9	22	1	5	9.75	3
SW-3	8	18	14	4	13	9	15	15	10	19	5	2	11.00	10
SW-4	2	3	11	11	10	12	10	10	13	12	12	17	10.25	6
SW-5	4	1	21	1	16	2	4	4	7	14	10	6	7.50	1
SW-6	11	22	16	8	3	7	18	18	20	18	7	8	13.00	16
SW-7	16	15	8	14	4	15	19	19	19	7	20	19	14.58	22
SW-8	13	21	7	7	5	16	17	17	18	15	8	3	12.25	15
SW-9	18	9	2	6	11	21	13	13	12	2	21	15	11.92	14
SW-10	12	14	15	10	8	8	20	20	15	11	16	13	13.50	20
SW-11	15	11	18	16	19	5	3	3	4	13	13	11	10.92	8
SW-12	20	17	17	12	1	6	21	21	22	17	2	1	13.08	17
SW-13	1	19	22	2	22	1	1	1	1	4	18	9	8.42	2
SW-14	19	20	20	3	2	3	22	22	21	21	3	4	13.33	18
SW-15	3	16	13	17	15	10	6	6	8	5	19	14	11.00	11
SW-16	9	13	19	5	12	4	8	8	11	16	6	7	9.83	4
SW-17	14	12	10	9	7	13	16	16	16	3	14	12	11.83	13
SW-18	7	6	6	19	20	17	2	2	3	9	11	16	9.83	5
SW-19	17	7	5	20	21	18	5	5	2	10	9	20	11.58	12
SW-20	21	10	12	21	18	11	14	14	5	8	15	21	14.17	21
SW-21	5	4	3	13	6	20	11	11	17	6	17	18	10.92	9
SW-22	22	2	1	22	17	22	12	12	6	1	22	22	13.42	19

TABLE 5 Weightage, compound parameter and rank of sub-watersheds based on LULC

Sub-Watershed	Water bodies	Forest	Agriculture	Habitation	Waste lands	Open scrub	Compound parameter (Cpl)	Rank
SW-1	15	16	17	16	7	22	15.50	21
SW-2	13	21	20	18	10	21	17.17	22
SW-3	3	19	3	4	10	20	9.83	8
SW-4	18	1	14	10	10	19	12.00	16
SW-5	11	12	5	6	10	18	10.33	11
SW-6	6	17	6	7	10	17	10.50	12
SW-7	10	1	15	15	8	16	10.83	13
SW-8	4	7	9	9	2	15	7.67	4
SW-9	9	13	10	2	3	14	8.50	5
SW-10	5	1	8	13	5	13	7.50	3
SW-11	12	18	11	3	4	12	10.00	9
SW-12	8	1	13	17	6	11	9.33	7
SW-13	1	22	1	1	1	10	6.00	2
SW-14	2	8	2	5	9	9	5.83	1
SW-15	16	1	12	20	10	8	11.17	14
SW-16	7	14	4	11	10	7	8.83	6
SW-17	14	11	7	14	10	6	10.33	10
SW-18	20	20	18	8	10	5	13.50	18
SW-19	17	15	19	12	10	4	12.83	17
SW-20	21	10	21	21	10	1	14.00	20
SW-21	22	1	16	19	10	1	11.50	15
SW-22	19	9	22	22	10	1	13.83	19

3.8 | Prioritization of sub-watersheds based on land use land cover

The LULC-based prioritization of sub-watersheds is shown in Fig. 6B. The SW-14 (Cpl- 5.83) and SW-13 (Cpl- 6.00) ranked 1st and 2nd, while SW-2 ranked lowest (22nd) (Table 5).

Sub-watersheds were grouped into four categories: high priority (1-5), medium-high (6-10), medium (11-16), and low (17-22) (Table 5). High-priority sub-watersheds reflect greater erosion and runoff risk and are key targets for soil and water conservation measures.

3.9 | Prioritization of sub-watersheds based on both LULC and topographic-hydro-morphometric parameters

The final prioritization of sub-watersheds for soil conservation was derived by integrating topo-hydro-morphometric (75% weight) and LULC (25% weight) parameters. A cumulative score was calculated for each sub-watershed, and the mean score determined their final ranking (Table 6). Sub-watersheds with lower scores (3.91), such as SW-13, indicate higher erosion susceptibility and thus require greater conservation attention, whereas SW-20, with the highest score (7.06), ranks lowest in priority (Fig. 7). High-priority sub-watersheds should be targeted for erosion control; reforestation, wetland restoration, and groundwater recharge initiatives. Collaborative efforts with local communities, NGOs, and government agencies can further strengthen sustainable watershed management.

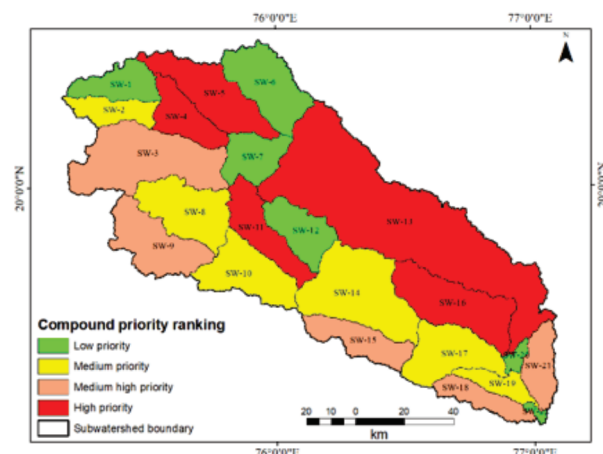


FIGURE 7 Priority ranking of sub-watersheds for SWC measures

TABLE 6 Cumulative weightages and rank of sub-watersheds based of Purna river basin

Sub-Watershed	Morphometric and topo-hydrologic parameter		LULC		Mean	Rank	Priority
	Cpm	On base 75%	Cpl	On base 25%			
SW-1	10.92	8.19	15.50	3.88	6.03	17	Low [#]
SW-2	9.75	7.31	17.17	4.29	5.80	14	Medium [@]
SW-3	11.00	8.25	9.83	2.46	5.35	6	Medium high ^s
SW-4	10.25	7.69	12.00	3.00	5.34	4	High
SW-5	7.50	5.63	10.33	2.58	4.10	2	High
SW-6	13.00	9.75	10.50	2.63	6.19	19	Low
SW-7	14.58	10.94	10.83	2.71	6.82	21	Low
SW-8	12.25	9.19	7.67	1.92	5.55	11	Medium
SW-9	11.92	8.94	8.50	2.13	5.53	9	Medium high
SW-10	13.50	10.13	7.50	1.88	6.00	16	Medium
SW-11	10.92	8.19	10.00	2.50	5.34	5	High
SW-12	13.08	9.81	9.33	2.33	6.07	18	Low
SW-13	8.42	6.31	6.00	1.50	3.91	1	High*
SW-14	13.33	10.00	5.83	1.46	5.73	12	Medium
SW-15	11.00	8.25	11.17	2.79	5.52	8	Medium high
SW-16	9.83	7.38	8.83	2.21	4.79	3	High
SW-17	11.83	8.88	10.33	2.58	5.73	13	Medium
SW-18	9.83	7.38	13.50	3.38	5.38	7	Medium high
SW-19	11.58	8.69	12.83	3.21	5.95	15	Medium
SW-20	14.17	10.63	14.00	3.50	7.06	22	Low
SW-21	10.92	8.19	11.50	2.88	5.53	10	Medium high
SW-22	13.42	10.06	13.83	3.46	6.76	20	Low

[#]High priority sub-watersheds considered combined effect of steeper slopes, higher Rb, finer Dt, higher STI, with more than 85% agriculture and minimal forest/scrub buffer, chance of active sheet-rill erosion, frequent gully formation, high sediment delivery, immediate action need for execution of conservation measures.

^sModerately high slope, with moderate SPI/STI, moderate-fine drainage texture with 70-85% agriculture and scattered scrub, pronounced sheet and rill erosion, localized gully along drainage lines.

[@]Gentler slopes, coarse drainage texture and agriculture still dominant land use, chance of sheet erosion during heavy rains, and minor rills

^{*}Low slope, coarse Dt, lower Rb and SPI/STI, higher TWI in valley floors acting as depositional zones, agriculture present on flatter terrain, low-intensity sheet erosion only, limited sediment export.

3.10 | Possible soil and water conservation measures

In the Purna basin, effective soil and water conservation should target erosion mitigation, runoff regulation, and groundwater recharge through an integrated strategy combining (a) structural interventions-such as contour bunds, check dams, gabions, and terracing; (b) vegetative

measures-including afforestation, vegetative barriers, and cover crops; and (c) water-harvesting structures-such as farm ponds, percolation tanks, and recharge pits (Fig. 8). Complementary practices, including mulching with locally available biomass, strip cropping, conservation tillage, and micro-irrigation, enhance soil moisture retention and

reduce surface runoff. Detailed specifications for these measures within the Purna basin are summarized in Table 7.

The watershed-based approach, which integrates conservation engineering, reforestation, and community participation, is most effective when supported by policy convergence across agencies and technologies such as Remote Sensing and GIS for site-specific planning and implementation. For instance, the SW-13, identified as potentially the most vulnerable sub-watershed with elevated SPI (4.96) and elongated morphology ($Re = 0.44$), exhibits concentrated flow erosion. This warrants the installation of check dams and gabions in 3rd and 4th order streams to dissipate energy and reduce sediment transport. Similarly, in SW-5, high stream frequency (0.74 km^{-2}) indicates susceptibility to sheet and rill erosion, making contour bunding and vegetative barriers the preferred interventions. The 3rd most vulnerable sub-watershed, SW-16, characterized by moderate STI (17.20) and intensive agricultural land use, requires farm ponds for runoff harvesting coupled with conservation tillage to minimize soil loss and enhance infiltration.

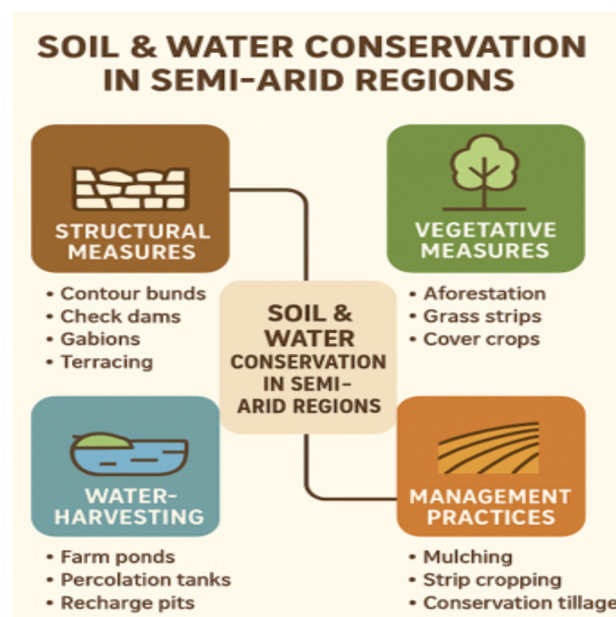


FIGURE 8 Conservation measures for semi-arid region

TABLE 7 Land use-wise possible measures and their specification for Purna river basin

Land use	Treatment	Cross section (m^2)	Unit ha^{-1}
Agriculture	Contour/farm bund, vegetative bund	0.45 -1.0	250 – 400 rm
	Stone outlets, earthen gully plugs	1.5 -.5	Site-specific
	Plantation on bund	Mango, guava, teak (variety: Brahma)	-
Forest/Open scrub	Water absorption trench (WAT)	1.0	300 rm
	Continuous contour trench (CCT)	0.18	1200 rm
	Refilling of CCT (RCT)	0.24	600 rm
	Stone bund	0.45-0.60	300 rm
	Gully plug	1.0	Site-specific
Waste land		1.0, 0.18, 0.24	Same as above
	WAT, CCT, RCT		
	Plantation (horticultural plant)	Pomegranate, grape, ber, custard apple	600 nos.
Gully control and water harvesting	Grass seeding	Buffel, Marvel, Vetiver	-
	Line cement gully plug	-	66 units ha^{-1}
	nala bund, farm pond, check dam	-	Site-specific

3.11 | Limitations of present study

The present study is focused chiefly on prioritizing sub-watersheds of the Purna river basin through a GIS-based framework, using only DEM and LULC. The topo-hydro-morphometric analysis is a useful, cost-effective and potential approach for sub-watershed prioritization, however, the method has its own limitations (Fig. 9). It primarily relies on the geometric and topographic characteristics derived from DEMs or maps and does not account for dynamic factors such as rainfall variability, soil properties, and human interventions (construction of road, deforestation, mining etc.) that strongly influence erosion

processes. The accuracy of prioritization is also constrained by the resolution and quality of input datasets (DEM), especially in areas with complex terrain. Furthermore, morphometric parameters alone cannot capture seasonal variations in runoff, sediment yield, or the effects of ongoing conservation measures. Similarly, sub-watershed rankings are governed exclusively by the output generated from the DEM-derived equations or empirical models. Therefore, the prioritization of watersheds in this study provides an initial framework for resource allocation. However, these rankings should be interpreted as indicative rather than definitive. To ensure reliability and practical

relevance, they require rigorous field validation through soil-loss measurements, sediment-yield monitoring, gully-density surveys, and consultations with local farmers. Such ground-truthing not only strengthens the accuracy of the top-hydro-morphometric outcomes but also enhances stakeholder acceptance and facilitates context-specific interventions. Consequently, operational implementation of these rankings should follow a comprehensive validation process to align model predictions with field realities and long-term watershed management objectives.

3.12 | Synthesis and Erosion Mechanism

The Purna basin's dominantly elongated, low-relief, coarse-textured sub-watersheds are better suited for infiltration-based water conservation, while localized high TWI, SPI, and STI zones require targeted structural and vegetative erosion-control measures. With respect to the high-priority sub-watersheds (SW-13, SW-5, SW-16), they have common characteristics that explain their erosion susceptibility. The SW-13 (rank 1, $C_p=3.91$), the largest sub-watershed (3668 km²), exhibits the highest bifurcation ratio (5.98), indicating structural control and rapid runoff concentration. Lowest drainage density (0.78 km/km²), suggesting coarse texture with inadequate channel network to distribute flows. Maximum agricultural land (86%), leaving soils exposed during monsoon onset. Form factor (0.15) indicates an elongated shape, yet high STI (16.92) and moderate SPI (4.96) suggest concentrated flow paths prone to incision. This combination creates a "flashy" hydrological response: sparse drainage channels concentrate runoff during intense monsoon events (typical 24-hr rainfall >100 mm), causing gully formation and bank erosion in agricultural lands with minimal vegetative cover. Similarly, the SW-5 exhibits high soil-erosion risk due to its almost complete agricultural land cover (94.5 %), negligible forest (<0.01%), and high topo-hydro-morphometric indices (Rb - 5.26, Dt - 2.26, STI - 17.2), which indicate concentrated runoff, fine drainage texture, and strong slope-driven erosive forces. Further, a lack of vegetative buffer can make it prone to intense sheet and rill erosion with significant sediment yield. The SW-16 (89.7 % agriculture, 7.3% scrub, Rb-4.67, Dt -1.9, STI-16.2) also exhibits high erosion susceptibility, due to extensive cropland.

4 | CONCLUSIONS

Optimum utilization and proper management of natural resources, particularly land and water, is utmost important for agricultural sustainability in the Marthawada region of Maharashtra, India, and agricultural sustainability depends on watershed-based management of natural resources. This present study developed and demonstrated a GIS-based framework integrating morphometric parameters, topo-hydrological indices (TWI, SPI, STI), and LULC data to prioritize 22 sub-watersheds in the Purna river basin (15,864 km²) for soil and water conservation. Based on weighted integration (75% morphometric-hydrological, 25% LULC), SW-13 ($C_p=3.91$) emerged as the highest priority sub-watershed, followed by SW-5 ($C_p=4.10$) and SW-16 ($C_p=4.79$). These sub-watersheds exhibit combined

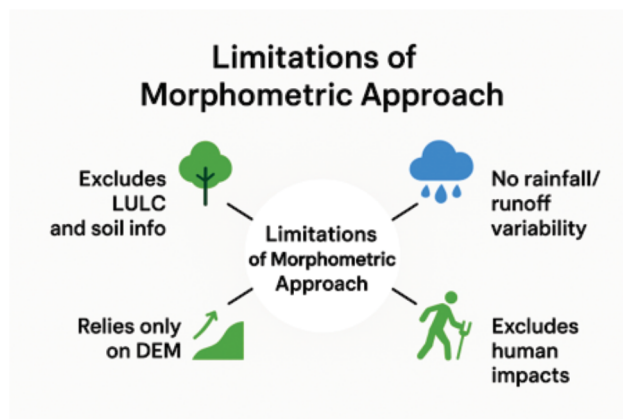


FIGURE 9 Limitation of morphometric approach

characteristics of high bifurcation ratios (4.17-5.98), low drainage density (0.78-0.81 km/km²), elevated stream power indices (4.96-5.20), and intensive agricultural land use (>85%), indicating heightened vulnerability to runoff concentration and soil erosion. The 7th order Purna basin displays coarse drainage texture (mean $D_d=0.83$ km/km², $D_t=1.15$ /km), elongated sub-watershed morphology (mean $R_e=0.58$), and positive SPI values (4.85-5.49), collectively indicating moderate-to-high erosion susceptibility across the basin.

Prioritization is based entirely on geospatial modeling without field validation. Rankings must be verified through ground-truth assessments, including: (i) erosion plot measurements in representative sub-watersheds, (ii) sediment yield monitoring at outlet points, (iii) participatory rural appraisal with farmers to confirm problem areas, and (iv) temporal LULC change analysis (2010-2024) to assess land degradation trends. This framework provides a replicable, cost-effective approach for preliminary sub-watershed prioritization in data-scarce semi-arid regions, but field validation remains essential before operational implementation. The methodology advances existing knowledge by integrating multiple parameters and can inform evidence-based watershed planning across Marathwada and similar geomorphological settings.

ACKNOWLEDGEMENTS

The authors acknowledge with gratitude Dr. N.G. Patil, Director, ICAR-NBSS&LUP, Nagpur, Maharashtra, for facilitating the four-month In-Plant training, from which this manuscript has emerged.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

This work was not supported by any funding.

DATA AVAILABILITY STATEMENT

The data presented in this study are available upon request

from the corresponding author.

DECLARATION

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

AUTHOR'S CONTRIBUTION

GW, PM & SAC: Formal analysis and writing – original draft; CJD: Conceptualization and writing – review & editing; SAC, CJD, SA & MRM: Writing – review & editing; PP: Visualization (land use map preparation); HB: Supervision.

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How to cite this article: Wani, G., Mahiske, P., Chaware, S.A., Dash, Ch. J., Adamala, S., More, M.R., Pakhare, P., & Biswas, H., 2025. Morphometric Analysis-based Prioritization of sub-watersheds for Conservation Planning in Purna River Basin, Maharashtra. *Indian J. Soil Cons.*, **53(2): 89-102**