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Morphometric analysis and prioritization of subwatersheds for soil and water conservation planning using remote sensing and GIS: A case study of the Dantiwada watershed, India

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ABSTRACT

Effective soil and water conservation planning in semi-arid watersheds requires spatial identification of subwatersheds that are relatively more vulnerable to erosion and hydrological degradation. The present study develops a GIS-based morphometric prioritization framework for the Dantiwada Watershed, a semi-arid agricultural watershed of the Banas River basin in northern Gujarat, India. A 30-m Shuttle Radar Topography Mission (SRTM) digital elevation model was processed in a GIS environment to delineate the drainage network and divide the 2746.24 km² watershed into 15 subwatersheds. Thirteen morphometric indicators representing basin geometry, drainage characteristics and relief were calculated, including circularity ratio, elongation ratio, form factor, unity shape factor, watershed shape factor, compactness coefficient, total relief, length of overland flow, fitness ratio, relief ratio, relative relief, constant of channel maintenance and drainage density. For erosion-oriented prioritization, seven parameters with direct relevance to basin shape and runoff response were integrated using the compound parameter method. Parameter-specific ranks were assigned according to their relationship with erosion susceptibility, and the mean rank was used to derive the compound parameter and final priority order. The analysis identified SW-6 as the first-priority subwatershed, followed by SW-15, SW-11, SW-3 and SW-12. SW-4 recorded the lowest priority. The particularly low circularity ratio (0.136), elongation ratio (0.349) and form factor (0.095) of SW-6 indicate a strongly elongated basin configuration, while its drainage characteristics further contributed to its high composite priority. The morphometric prioritization was subsequently interpreted together with subwatershed-level land use/land cover, soil and slope characteristics to formulate location-specific soil and water conservation interventions. The resulting framework provides a spatially explicit basis for sequencing conservation investments and can support watershed development planning in semi-arid agricultural landscapes.

Keywords: Morphometry, Subwatershed prioritization, Soil erosion, Remote sensing, GIS, Compound parameter, Watershed management, Gujarat

1. Introduction

Land and water resources in semi-arid agricultural regions are increasingly exposed to degradation resulting from erosion, runoff concentration, land-use pressure and climatic variability. Soil erosion removes the productive upper layer of soil and can reduce agricultural productivity while transporting sediment into downstream drainage systems and reservoirs. Consequently, scientific watershed planning requires identification of spatial units where conservation interventions can be implemented according to their relative vulnerability. The watershed provides an appropriate planning unit because hydrological processes, drainage behaviour, topography and land resources are spatially interconnected within its boundaries. Your source material similarly establishes watershed-based planning as an appropriate framework for sustainable land and water resource management (Donatien *et al.*, 2024; Liu *et al.*, 2023) [1, 2].

Subwatershed prioritization is particularly important where financial, technical and institutional resources are insufficient to implement conservation measures simultaneously throughout an entire watershed. Prioritization allows subwatersheds to be ranked according to their relative susceptibility and consequently facilitates phased implementation of soil and water conservation measures. Earlier studies have demonstrated the use of morphometric characteristics, sediment yield indices and erosion models for this purpose (Liu *et al.*, 2023; Verburg *et al.*, 2010) [2, 3].

Morphometric analysis provides a quantitative description of drainage-basin geometry and drainage-network characteristics. Horton and Strahler established the foundations of quantitative drainage-basin analysis, while subsequent studies demonstrated the usefulness of parameters such as drainage density, circularity ratio, elongation ratio, form factor and relief-related indices for understanding hydrological response and ero

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sion behaviour (Patro *et al.*, 2024) [4]. The morphometric parameters used in the present study and their formulations are based on established relationships reported by Horton, Miller, Schumm, Melton and Strahler (Hemati *et al.*, 2021) [5].

The increasing availability of satellite-derived digital elevation models and GIS has substantially improved the efficiency of morphometric analysis. Remote sensing and GIS enable drainage networks, watershed boundaries, slope, elevation and other spatial variables to be extracted and integrated within a common geographic framework. Earlier research has demonstrated the applicability of GIS-based morphometric analysis for watershed characterization and prioritization. Recent studies continue to use GIS-based morphometric approaches for identifying erosion-sensitive subwatersheds and supporting soil and water conservation planning (Rawat *et al.*, 2024; Talukdar *et al.*, 2020) [6, 7].

However, a limitation of conventional morphometric studies is that calculation of numerous parameters does not necessarily translate into a practical conservation-planning framework. The management relevance of morphometry increases when the quantitative assessment is converted into a spatial priority sequence and subsequently linked with terrain, soil and land-use conditions. In this context, the present study goes beyond simply reporting morphometric characteristics by integrating 13 morphometric indicators across 15 subwatersheds, selecting erosion-relevant parameters for compound ranking, and translating the resulting priority sequence into a conservation-planning framework.

The Dantiwada Watershed provides an important case for such an assessment. It covers approximately 2746 km² in the northern semi-arid region of Gujarat and forms part of the Banas River basin (Vimala, 2020) [8]. The watershed is predominantly agricultural and experiences considerable spatial variation in elevation, slope, soil characteristics and water availability. The watershed is also characterized by seasonal drainage, with the Dantiwada reservoir constructed across the Banas River (Mondal *et al.*, 2014) [9].

Therefore, the objectives of this study were to: (i) delineate and characterize the drainage system of the Dantiwada Watershed using SRTM DEM and GIS; (ii) quantify morphometric indicators for subwatersheds; (iii) prioritize the subwatersheds using an erosion-ori-

ented compound parameter approach; and (iv) develop a spatially differentiated soil and water conservation planning framework by interpreting priority rankings together with land use/land cover, soil and slope conditions.

The central contribution of the study is therefore not the development of new morphometric equations, but the translation of multi-parameter morphometric information into a spatially explicit intervention sequence for watershed conservation planning.

2. Materials and Methods

2.1 Study area

The Dantiwada Watershed, a sub-basin of the Banas River Basin, is located in the northern part of Gujarat, India, and extends into adjoining areas of Rajasthan. The watershed covers approximately 2746.24 km² and lies between 72°20'00"–73°09'30"E longitude and 24°12'00"–24°54'30"N latitude. The watershed exhibits substantial topographic variability, with elevation ranging from 77 to 1665 m above mean sea level.

The region is characterized by a semi-arid, semi-tropical climate with considerable spatial and temporal variability in rainfall and frequent dry periods. Agriculture is the dominant land use and an important livelihood activity. Major Kharif crops include pearl millet, cotton, maize and groundnut, whereas wheat, mustard, cumin and vegetables are commonly cultivated during the Rabi season. Groundwater, accessed primarily through open wells and tube wells, is an important source of irrigation.

The watershed contains predominantly loam and silt-loam soils, while the drainage network is largely seasonal and is primarily active during the monsoon period. The overall terrain exhibits a general northeast-to-southwest slope gradient, influencing surface drainage and runoff movement. The Dantiwada Reservoir, constructed across the Banas River, represents an important water-resource infrastructure within the watershed.

For spatial characterization, the watershed was divided into six slope classes: 0–3%, 3.1–6%, 6.1–9%, 9.1–15%, 15.1–33% and > 33%. These classes represented approximately 21.70%, 21.01%, 9.46%, 10.19%, 20.02% and 17.58% of the watershed area, respectively.

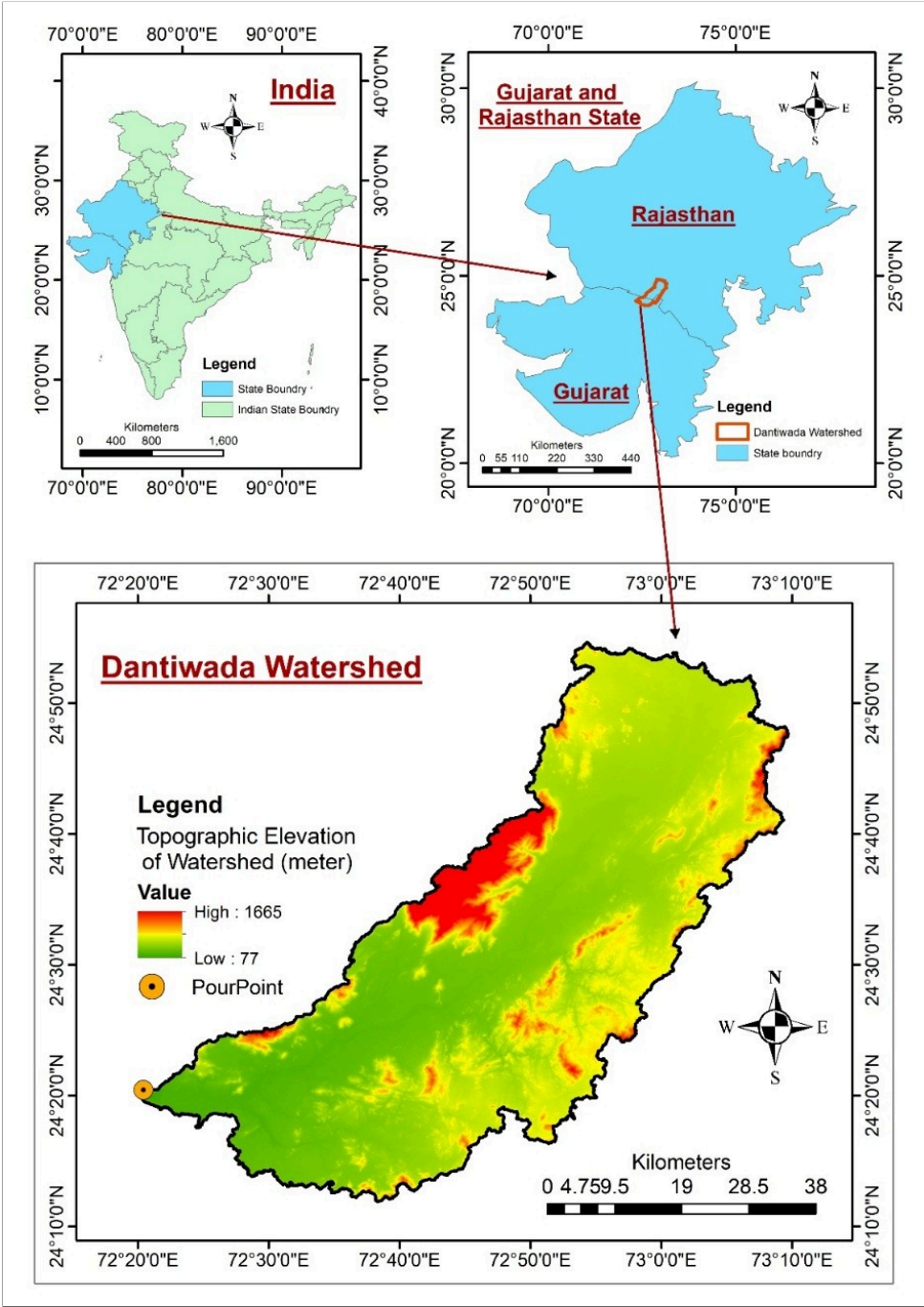


Figure 1. Location map of Dantiwada watershed

2.2 Data acquisition

A 30-m Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) was used as the primary topographic dataset for watershed delineation, drainage-network extraction and morphometric analysis. The DEM was projected to the appropriate Universal Transverse Mercator (UTM) coordinate system before spatial processing.

Landsat imagery was used to derive land use/land cover information, while soil information was obtained from the FAO World Soil Map. Geological information was available from the USGS World Geologic Map. The source study also used IMD gridded rainfall data for 1991–2024; however, rainfall was not incorporated into the core morphometric prioritization procedure (Tou *et al.*, 1974) [10].

Table 1. Spatial datasets used in the study

Dataset	Source	Resolution/period	Application
SRTM DEM	SRTM/USGS	30 m	Watershed and drainage delineation; morphometry
Landsat 7	USGS	2002	LULC
Landsat 8	USGS	2013, 2024	LULC
Soil map	FAO World Soil Map	—	Conservation planning
Geological map	USGS World Geologic Map	—	Watershed characterization
Rainfall	IMD gridded data	1991–2024	Supporting watershed characterization

(continued on next page)

2.3 GIS-based watershed and drainage delineation

The SRTM DEM was subjected to hydrological preprocessing to remove artificial depressions and establish a continuous surface for drainage analysis. The principal processing sequence consisted of Fill → Flow Direction → Flow Accumulation → Stream Definition → Stream Ordering → Pour Point → Watershed Delineation. The Fill operation was used to correct depressions in the DEM, while Flow Direction determined the direction of surface drainage from individual raster cells. Flow Accumulation was subsequently used to identify areas of concentrated flow and potential drainage channels.

The extracted drainage network was subjected to stream ordering following the Horton stream-ordering approach. A pour point was defined at the watershed outlet, and the processed flow-direction raster was used with the outlet location to delineate the watershed boundary. The resulting raster watershed was converted into a polygon for subsequent spatial analysis.

The delineated watershed was subsequently subdivided into 15 sub-watersheds, designated SW-1 to SW-15, based on the drainage network and hydrological organization.

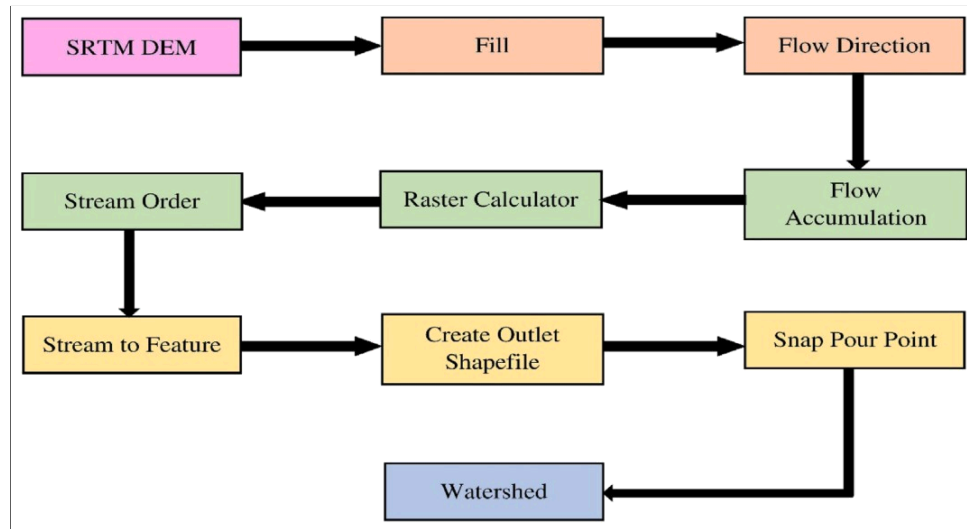


Figure 2. Flowchart for delineation of Dantiwada watershed

2.4 Morphometric analysis

Morphometric analysis was conducted to quantify the geometric, drainage and relief characteristics of the 15 subwatersheds. A total of 13 morphometric indicators were calculated. These indicators were

selected to represent basin size, shape, drainage development, relief and runoff-response characteristics.

Table 2. Morphometric indicators considered in the study

Linear/Shape parameters	Morphometric Parameters	Formula	References
Linear	Area (A)	A	Horton (1932)
Linear	Perimeter (P)	P	Horton (1932)
Linear	Basin length (L_B)	L_B	Horton (1932)
Linear	Drainage density (D_d)	$D_d = L_u/A$	Horton (1932)
Shape	Circularity ratio (R_c)	$R_c = 4 \times \pi \times A/P^2$	Miller (1953)
Shape	Elongation ratio (R_e)	$R_e = (2/L_b) \times (A/\pi)^{0.5}$	Schumn (1956)
Shape	Form factor (R_f)	$R_f = A/L_b^2$	Horton (1932)
Shape	Unity shape factor (R_u)	$R_u = L_b/A^{0.5}$	Horton (1945)
Shape	Watershed shape factor (W_s)	$W_s = L_m/D_c$	Wu <i>et al.</i> (1964)
Shape	Compactness coefficient (C_c)	$C_c = 0.2821 \times P/A^{0.5}$	Strahler (1964)
Linear	Total relief (H)	$H = h_1 - h_2$	Hardley and Schumn (1961)
Linear	Length of overland flow (L_g)	$L_g = 1/D_d \times 2$	Horton (1945)
Linear	Fitness ratio (R_{fn})	$R_{fn} = L_b/p$	Melton (1957)
Linear	Relief ratio (R_h)	$R_h = H/L_b$	Schumn (1956)
Linear	Relative relief (R_p)	$R_p = H/P$	Melton (1957)
Linear	Constant of channel maintenances (C)	$C = 1/D_d$	Horton (1932)

Where, A is area of basin (km^2), N_u is total stream segment of order 'u', L_u is total stream length of all order (km), P and p_i is perimeter of basin (km), L_b is Basin length (km), D_c is Diameter of

circle having same area as that of watershed, L_m is Length of main channel (km), h_1 and h_2 is the highest and the lowest points on the valley floor of a watershed.

2.5 Subwatershed prioritization

2.5.1 Selection of erosion-sensitive parameters

Although 13 morphometric indicators were calculated (Section 2.4), not all indicators were directly included in the compound prioritization. The prioritization procedure used seven parameters representing basin shape and drainage-response characteristics:

1. Circularity ratio (R_c)
2. Elongation ratio (R_e)
3. Form factor (R_f)
4. Unity shape factor (R_u)
5. Compactness coefficient (C_c)
6. Length of overland flow (L_g)
7. Drainage density (D_d)

This is an important methodological distinction and should be explicitly stated in the manuscript rather than saying that all 13 parameters were directly averaged. The source methodology confirms that the compound ranking was based on these seven parameters.

2.5.2 Compound-parameter prioritization

Subwatersheds were prioritized using the compound-parameter ranking approach. For each of the seven selected parameters, the 15 subwatersheds were ranked according to the adopted relationship between parameter magnitude and relative erosion susceptibility.

For parameters treated as positively associated with erosion susceptibility, higher parameter values were assigned higher priority. For the selected shape parameters, the source methodology adopted an inverse ranking, whereby lower values received higher priority.

The rank assigned to each parameter was then combined for each subwatershed. The compound parameter was calculated as:

$$CP_i = \frac{\sum_{j=1}^n R_{ij}}{n}$$

where:

CP_i = compound parameter for subwatershed

R_{ij} = rank assigned to subwatershed i for parameter

n = number of prioritization parameters, here $n = 7$

The subwatershed with the lowest compound parameter value was assigned Priority 1, followed sequentially by increasing compound parameter values

2.6 Integration of LULC, soil and slope for conservation planning

The morphometric priority ranking was subsequently integrated with spatial information on land use/land cover, soil and slope to develop a spatially differentiated conservation-planning framework.

Land use/land cover information was derived from Landsat imagery.

The source study classified the watershed into five principal classes:

- Waterbody
- Barren land
- Built-up land
- Dense vegetation
- Vegetation

The source methodology used Landsat 7 imagery for 2002 and Landsat 8 imagery for 2013 and 2024 and applied unsupervised im-

age classification.

For the present morphometric-prioritization paper, I recommend using 2024 LULC as the principal land-cover layer, rather than making the 2002–2024 change analysis a major component of this manuscript.

The soil layer was derived from the FAO World Soil Map after georeferencing and projection to the study coordinate system.

Slope was derived from the 30-m SRTM DEM using GIS-based terrain analysis. The slope layer was subsequently classified into the pre-defined slope classes for interpretation of conservation requirements.

2.7 Conservation planning framework

The conservation-planning stage was designed to translate morphometric priority into location-specific soil and water conservation recommendations. For the high-priority subwatersheds, the suitability of conservation measures was interpreted according to the spatial combination of:

Morphometric Priority + LULC + Soil + Slope

Land use, soil type and slope were considered when identifying suitable conservation measures, with the selected measures matched to the land-use and terrain conditions of individual subwatersheds (Chavda *et al.*, 2026) [11]

The conservation planning framework considered structural and agroeconomic measures such as:

- contour farming
- contour bunding
- strip cropping
- terracing
- nala bunds
- check dams
- farm ponds
- percolation tanks

The purpose of this stage was not to provide final engineering designs, but to identify appropriate intervention types and spatial priority zones for subsequent field investigation and detailed engineering design.

The proposed conservation measures represent GIS-based planning recommendations and require field verification, detailed topographic surveys, hydrological assessment and site-specific engineering design before implementation

3. Results and discussion

3.1 Topographic characteristics and drainage organization of the Dantiwada watershed

The 30-m SRTM DEM revealed pronounced topographic variability across the Dantiwada Watershed. Elevation ranged from 77 to 1665 m above mean sea level, resulting in a total relief of approximately 1588 m. The watershed has a basin area of 2746.24 km², a perimeter of 499.52 km, and a basin length of approximately 133.30 km. The total extracted stream length was 2384.67 km, indicating a well-developed drainage network across the watershed.

The spatial distribution of elevation indicates a distinct topographic gradient within the watershed, with higher terrain occurring toward the upper parts of the basin and relatively lower elevations toward the outlet. Such topographic variability provides the fundamental control for drainage organization and contributes to differences in runoff concentration, channel development and erosion response among individual subwatersheds.

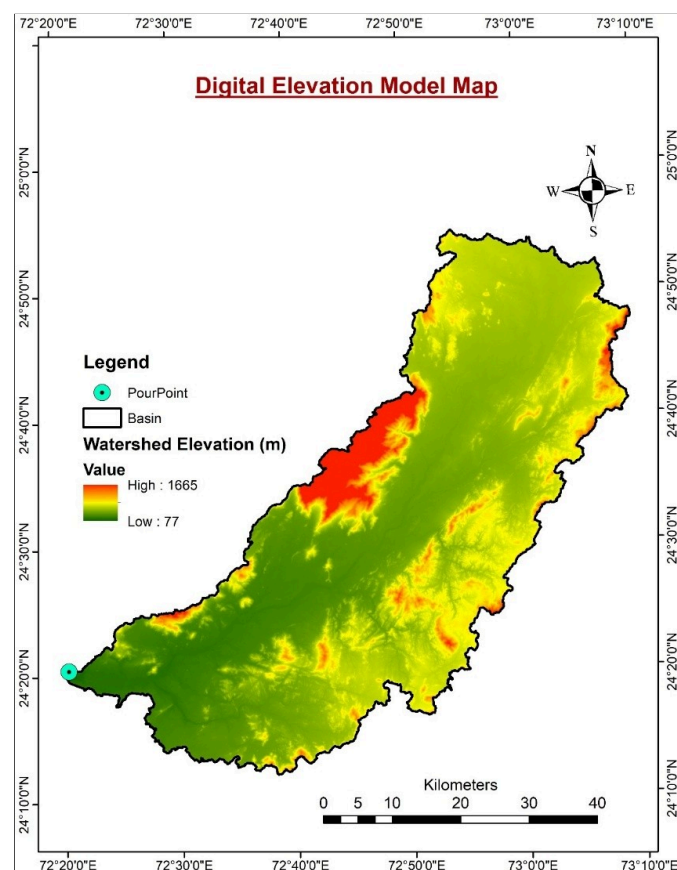


Figure 3. Digital elevation model map of Dantiwada watershed

3.2 Spatial distribution of slope

The slope analysis showed substantial variation in terrain conditions. The watershed slope ranged from nearly level terrain to slopes exceeding 33%. The largest proportion of the watershed occurred in the 0–3% class (21.62%), followed by the 3.1–6% class (21.03%). Approximately 20.04% of the watershed was within the 15.1–33% slope class and a further 17.61% occurred at slopes greater than 33%. Thus, approximately 37.65% of the watershed area occurs at slopes exceeding 15%, demonstrating considerable terrain variability.

Table 3. Slope-class distribution of the Dantiwada Watershed

Slope class (%)	Area (km ²)	Area (%)
0–3.0	593.83	21.62
3.1–6.0	577.40	21.03
6.1–9.0	260.51	9.49
9.1–15.0	280.60	10.22
15.1–33.0	550.40	20.04
> 33.0	483.50	17.61
Total	2746.24	100.00

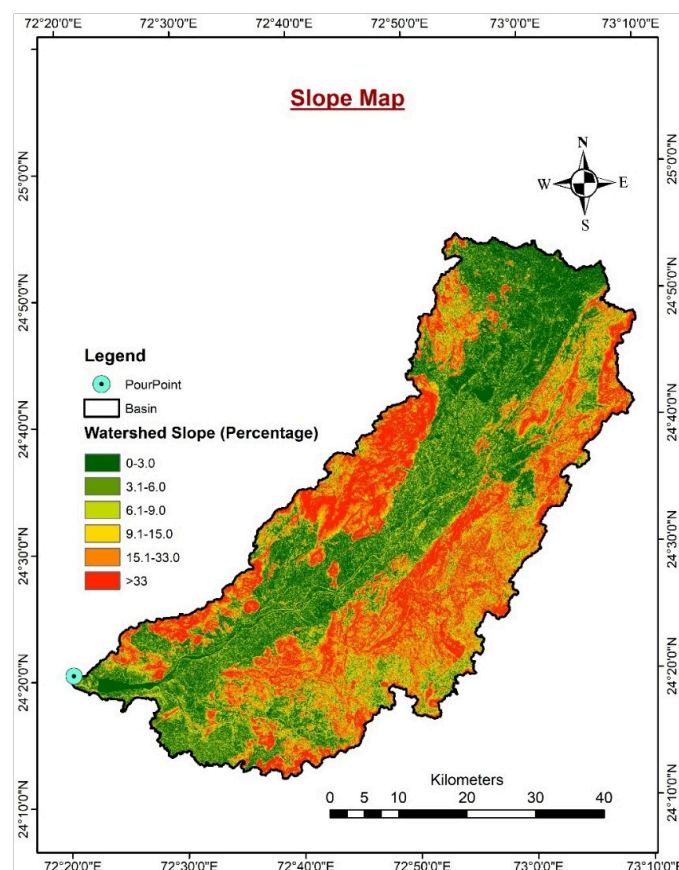


Figure 4. Slope map of Dantiwada watershed

The presence of both gentle and steep terrain indicates that conservation requirements cannot be generalized across the watershed. Gentle slopes provide greater scope for infiltration-oriented and agronomic measures, whereas steeper terrain requires greater emphasis on erosion-control and slope-management interventions. This spatial heterogeneity subsequently becomes important when interpreting the morphometric priority ranking.

3.3 Drainage-network characteristics

The extracted drainage network comprised 3252 stream segments distributed across six stream orders. *First-order streams* were dominant, accounting for 1718 segments (52.83%), followed by second-order streams with 688 segments (21.16%) and third-order streams with 457 segments (14.05%). Fourth-, fifth- and sixth-order streams represented 3.84%, 4.15% and 3.97% of the total stream segments, respectively.

Table 4. Stream-order distribution in the Dantiwada Watershed

Stream order	Number of streams	Percentage (%)
1	1718	52.83
2	688	21.16
3	457	14.05
4	125	3.84
5	135	4.15
6	129	3.97
Total	3252	100.00

The predominance of first-order streams indicates extensive headwater development within the watershed. Such a drainage structure is important for soil and water conservation because small-order channels and their contributing areas provide multiple locations where runoff can be intercepted before it becomes concentrated into higher-order channels.

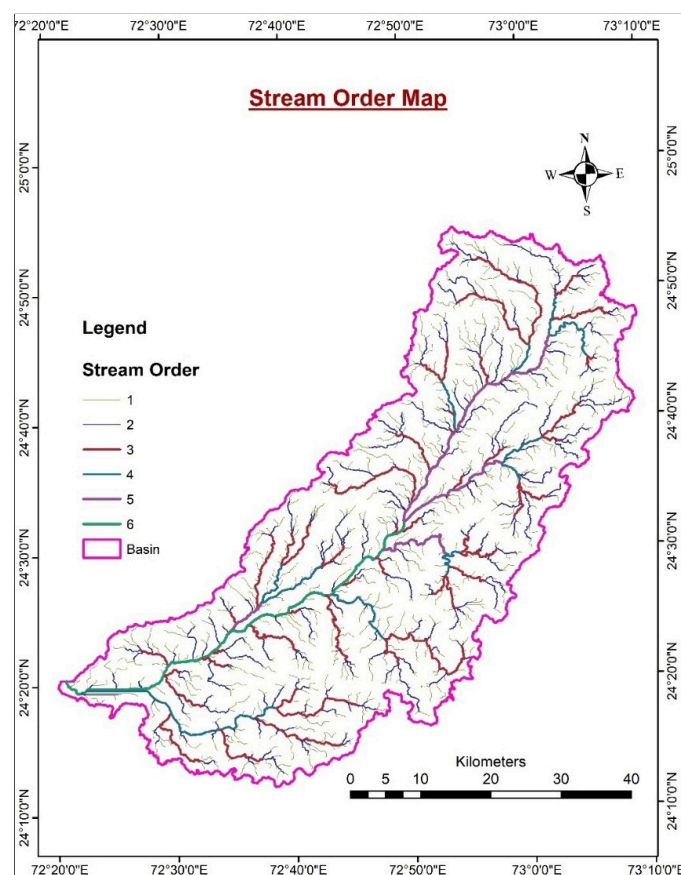


Figure 5. Stream order map of Dantiwada watershed

3.4 Drainage density and length of overland flow

The watershed-scale drainage density was 0.87 km km^{-2} , based on a total drainage length of 2384.67 km and a watershed area of 2746.24 km^2 . The thesis spatial analysis classified drainage density into five classes. The dominant class was $0.83\text{--}1.20 \text{ km km}^{-2}$, covering 1242.26 km^2 (45.23%), followed by $0.44\text{--}0.82 \text{ km km}^{-2}$ covering 1068.51 km^2 (38.91%). Only 0.28% of the watershed occurred in the highest drainage-density class of $1.70\text{--}2.00 \text{ km km}^{-2}$.

Table 5. Drainage-density distribution of the Dantiwada Watershed

Drainage density (km km^{-2})	Area (km^2)	Area (%)
0.036–0.43	192.62	7.01
0.44–0.82	1068.51	38.91
0.83–1.20	1242.26	45.23
1.30–1.60	235.04	8.56
1.70–2.00	7.81	0.28
Total	2746.24	100.00

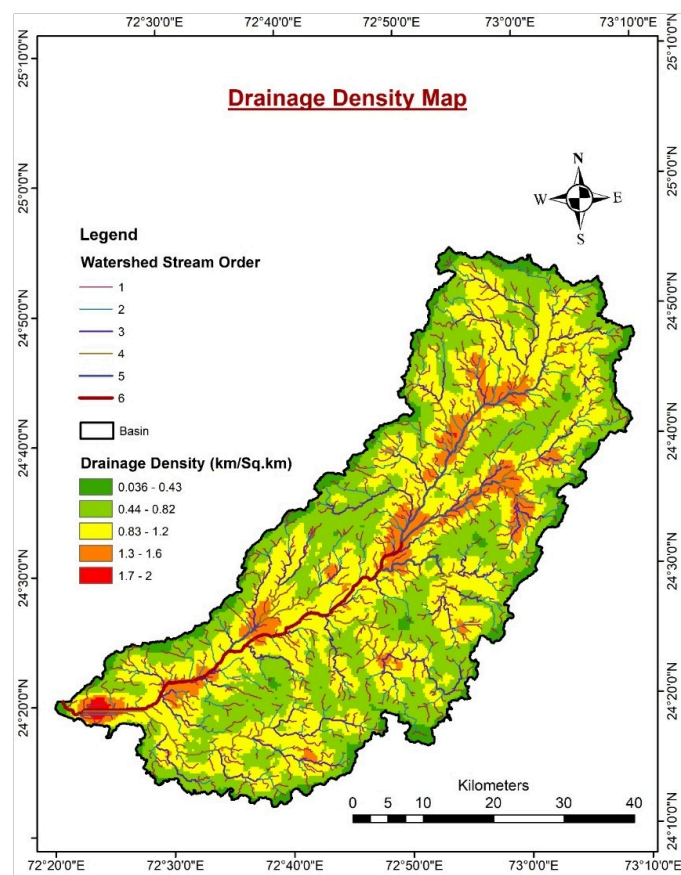


Figure 6. Drainage density map of Dantiwada watershed

The drainage-density pattern demonstrates that drainage development is spatially heterogeneous. The relatively extensive intermediate-density classes indicate considerable channel development across much of the watershed, while localized areas of higher density may represent zones where surface drainage is more concentrated.

3.5 Subwatershed delineation

Hydrological processing of the SRTM DEM resulted in the delineation of 15 subwatersheds, designated SW-1 to SW-15. The delineation followed the extracted drainage network and topographic organization of the basin. The 15 units provide a spatially explicit framework for comparing morphometric characteristics and identifying differences in relative conservation priority.

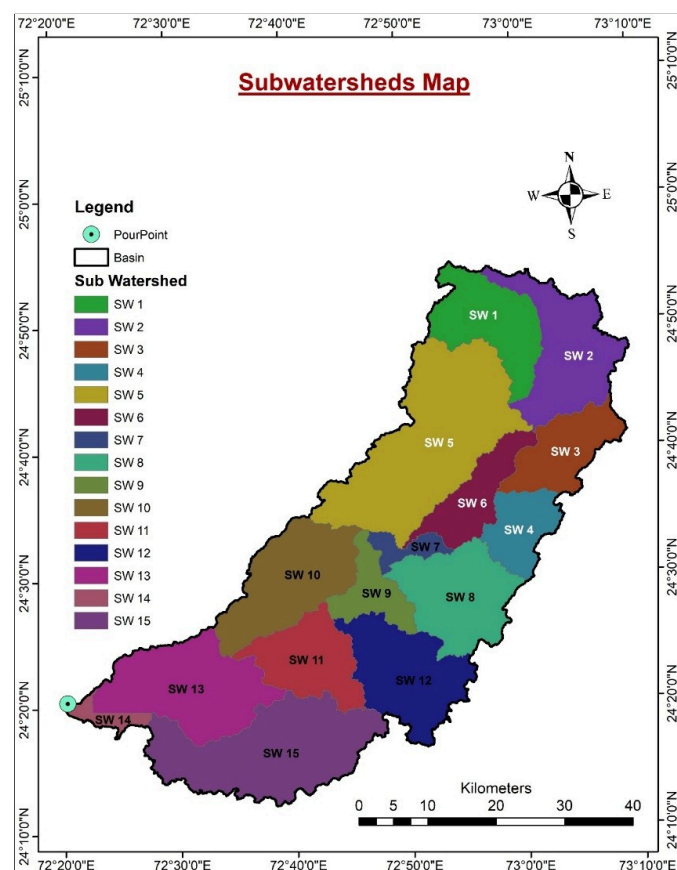


Figure 7. Subwatersheds delineation map of Dantiwada watershed

Table 6. Morphometric parameters of Dantiwada subwatersheds

Subwatershed	Circularity Ratio	Elongation Ratio	Form Factor	Unity Shape Factor	Watershed Shape Factor	Compactness Coefficient	Total Relief (km)	Length of over-land Flow	Fitness Ratio	Relief Ratio	Relative Relief	Constant of channel Maintenance	Drainage Density
1	0.166	0.430	0.145	2.623	2.324	2.457	0.437	0.601	0.301	0.013	0.004	1.202	0.000
2	0.125	0.470	0.173	2.404	2.130	2.825	0.725	0.604	0.240	0.020	0.005	1.208	0.000
3	0.200	0.393	0.121	2.870	2.543	2.238	0.603	0.577	0.362	0.018	0.007	1.154	0.000
4	0.231	0.604	0.287	1.868	1.655	2.081	0.559	0.556	0.253	0.030	0.008	1.113	0.000
5	0.175	0.548	0.236	2.060	1.825	2.389	1.446	0.556	0.243	0.033	0.008	1.111	0.000
6	0.136	0.349	0.095	3.237	2.868	2.709	0.561	0.525	0.337	0.016	0.006	1.050	0.000
7	0.123	0.410	0.132	2.752	2.438	2.847	0.77	0.429	0.273	0.047	0.013	0.859	1.000
8	0.215	0.463	0.168	2.436	2.159	2.156	0.673	0.583	0.319	0.019	0.006	1.165	0.000
9	0.152	0.451	0.159	2.504	2.219	2.567	0.807	0.556	0.275	0.035	0.010	1.111	0.000
10	0.238	0.511	0.205	2.210	1.958	2.049	1.181	0.581	0.304	0.035	0.011	1.161	0.000
11	0.186	0.369	0.107	3.056	2.708	2.318	0.61	0.569	0.372	0.016	0.006	1.138	0.000
12	0.171	0.402	0.127	2.806	2.486	2.420	0.688	0.637	0.327	0.017	0.005	1.273	0.000
13	0.236	0.492	0.190	2.294	2.032	2.061	0.907	0.567	0.314	0.024	0.008	1.134	0.000
14	0.144	0.419	0.138	2.696	2.389	2.638	0.131	0.479	0.288	0.009	0.003	0.958	1.000
15	0.124	0.355	0.099	3.179	2.817	2.843	0.625	0.587	0.316	0.011	0.003	1.175	0.000

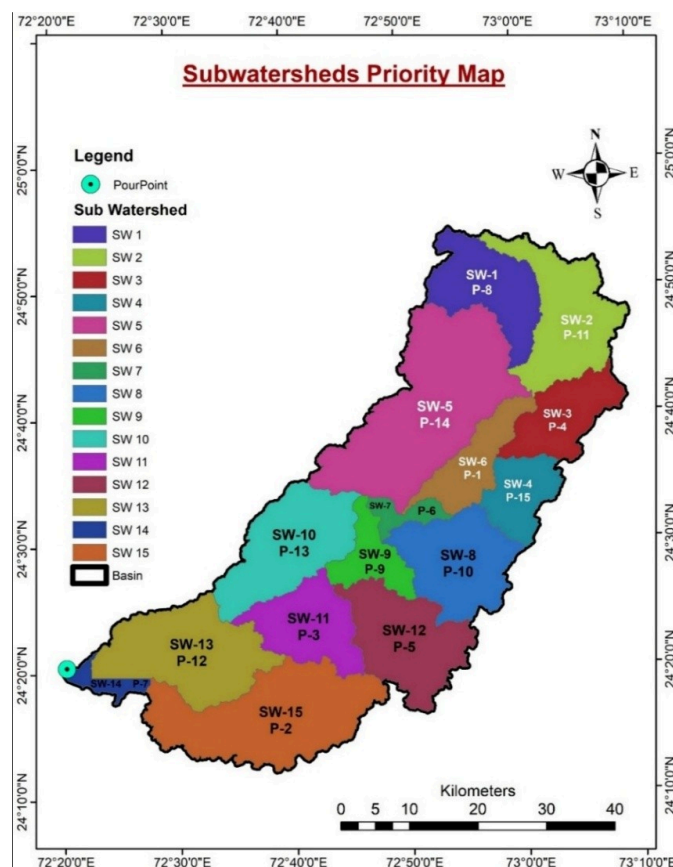
The compound-parameter analysis produced a clear spatial ranking among the 15 subwatersheds. **SW-6 recorded the lowest compound parameter of 7.000 and was assigned Priority 1**, followed by SW-

15 (7.143), SW-11 (7.286), SW-3 (7.429) and SW-12 (7.571). SW-4 recorded the highest compound parameter of 9.000 and was assigned Priority 15.

Table 7. Priority ranking of subwatersheds in Dantiwada subwatersheds

Subwatershed	Circularity ratio	Elongation ratio	Form factor	Unity shape factor	Compactness Coefficient	Length of overland Flow	Drainage Density	Compound Parameter	Final Priority
1	7	8	8	8	9	3	13	8	8
2	3	11	11	5	13	2	14	8.429	11
3	11	4	4	12	5	7	9	7.429	4
4	13	15	15	1	3	10	6	9.000	15
5	9	14	14	2	7	12	4	8.857	14
6	4	1	1	15	12	13	3	7.000	1
7	1	6	6	10	15	15	1	7.714	6
8	12	10	10	6	4	5	11	8.286	10
9	6	9	9	7	10	11	5	8.143	9
10	15	13	13	3	1	6	10	8.714	13
11	10	3	3	13	6	8	8	7.286	3
12	8	5	5	11	8	1	15	7.571	5
13	14	12	12	4	2	9	7	8.571	12
14	5	7	7	9	11	14	2	7.857	7
15	2	2	2	14	14	4	12	7.143	2

The first five positions are occupied by SW-6, SW-15, SW-11, SW-3 and SW-12. Importantly, these rankings should be interpreted as relative morphometric priority within the Dantiwada Watershed, rather than as direct measurements of soil-loss magnitude. Actual erosion is also affected by rainfall erosivity, soil erodibility, land cover, slope, agricultural practices and sediment connectivity.

**Figure 8.** Prioritization map of Dantiwada subwatersheds

The characteristics of the five highest-priority subwatersheds provide insight into the basis of the ranking. SW-6 was characterized by the lowest elongation ratio (0.349) and form factor (0.095) among all 15

subwatersheds, together with a high unity shape factor (3.237). These values indicate a distinctly elongated basin geometry.

SW-15 exhibited a similarly elongated configuration, with $R_e = 0.355$, $R_f = 0.099$ and $R_u = 3.179$. SW-11 also showed low R_e and R_f values of 0.369 and 0.107, respectively. SW-3 and SW-12 had R_e values of 0.393 and 0.402 and R_f values of 0.121 and 0.127, respectively.

The consistency of low elongation and form-factor values among the highest-priority units indicates that basin geometry is an important component of the prioritization. However, the final ranking reflects the combined parameter response rather than any single shape indicator.

SW-6 is particularly notable because it obtained Priority 1 despite not having the highest drainage density. Its drainage density was 0.952 km km^{-2} , while SW-7 recorded the highest value of 1.165 km km^{-2} . This demonstrates that the final ranking cannot be interpreted simply as a drainage-density ranking.

3.6 Land use and land cover characteristics of the subwatersheds

The 2024 LULC analysis classified the Dantiwada Watershed into five classes: waterbody, barren land, built-up land, dense vegetation and vegetation. Across the complete watershed, barren land was the dominant class, occupying 1256.72 km^2 (45.76%), followed by vegetation at 909.61 km^2 (33.13%) and dense vegetation at 438.59 km^2 (15.97%). Waterbodies and built-up land accounted for 1.69% and 3.45%, respectively.

Table 8. Watershed-level 2024 LULC distribution

LULC class	Area (km^2)	Area (%)
Waterbody	46.45	1.69
Barren land	1256.72	45.76
Built-up	94.85	3.45
Dense vegetation	438.59	15.97
Vegetation	909.61	33.13
Total	2746.24	100.00

The integration of LULC, soil and slope provides an important second level of interpretation of the morphometric ranking. The five highest-priority subwatersheds exhibit considerable differences in their physical characteristics.

Table 9. LULC, soil and slope classes wise area in Dantiwada subwatersheds

Sub- wa- ter- shed	LULC Class (km ²)					Soil type (km ²)			Slope Class (km ²)				Sub- water- shed Area (km ²)
	Waterbody	Barren land	Built up	Dense Vegetation	Vegetation	Silt Loam	Loam	0-2.0%	2.1- 10.0%	10.1- 30.0%	> 30%		
1	0.65	115.96	10.04	7.19	40.92	174.76	0.00	52.53	91.63	18.64	11.96	174.76	
2	2.48	123.60	12.36	24.95	54.12	215.59	1.92	62.13	93.54	40.40	21.44	217.51	
3	0.93	48.27	1.15	35.51	47.04	63.49	69.41	7.37	38.23	50.02	37.28	132.90	
4	0.84	39.88	0.41	21.63	36.98	13.45	86.29	7.12	25.54	40.50	26.58	99.74	
5	9.96	205.45	18.74	72.15	143.32	326.63	122.99	76.07	175.26	90.36	107.93	449.62	
6	0.12	54.42	3.97	18.05	35.64	112.20	0.00	18.41	59.43	20.28	14.08	112.20	
7	0.01	14.85	3.96	3.05	13.36	35.23	0.00	7.34	21.14	3.65	3.10	35.23	
8	0.97	90.76	2.35	43.02	68.94	49.22	156.82	5.08	43.40	87.70	69.86	206.04	
9	0.35	25.26	11.15	15.97	30.20	72.03	10.90	11.84	35.33	16.40	19.36	82.93	
10	2.47	104.90	3.00	34.98	84.43	70.86	158.92	31.18	95.04	47.07	56.49	229.78	
11	1.29	61.99	8.34	30.76	54.22	108.22	48.38	20.68	67.40	40.19	28.33	156.60	
12	0.13	83.97	5.89	46.61	77.08	21.16	192.52	4.45	57.06	92.21	59.96	213.68	
13	9.29	128.60	6.62	31.13	89.34	203.24	61.74	38.87	123.07	55.16	47.88	264.98	
14	15.42	9.77	0.90	0.64	1.15	27.88	0.00	9.79	16.61	1.48	0.00	27.88	
15	1.54	149.04	5.97	52.95	132.87	4.59	337.80	28.46	170.26	92.03	51.62	342.37	
Total	46.45	1256.72	94.85	438.59	909.61	1498.56	1247.69	381.32	1112.94	696.09	555.87	2746.24	

3.7 Spatial prioritization and conservation planning for all 15 subwatersheds

The complete ranking provides a basis for sequencing conservation activities throughout the watershed. Rather than treating only SW-6, SW-15, SW-11, SW-3 and SW-12 as relevant, the complete 15-unit ranking can be used as a phased planning framework.

Table 7. Proposed management interpretation based on the complete priority sequence

Priority range	Subwatersheds	Management interpretation
1-3	SW-6, SW-15, SW-11	Immediate detailed conservation assessment
4-6	SW-3, SW-12, SW-7	High-priority conservation planning
7-9	SW-14, SW-1, SW-9	Intermediate conservation planning
10-12	SW-8, SW-2, SW-13	Secondary conservation planning
13-15	SW-10, SW-5, SW-4	Lower relative morphometric priority under the adopted framework

Based on the spatial distribution of land use/land cover, soil type and slope classes, suitable soil and water conservation (SWC) measures were proposed for each subwatershed following the IMSD guidelines. The recommended interventions were differentiated according to land use and terrain conditions. For agricultural land with slopes of 0–2%, contour cropping, strip cropping and mulching were proposed, while bunding was considered for agricultural and forest lands with slopes of 2–10%. Terracing was recommended for agricultural and forest areas having slopes of 10–30%. Among the mechanical measures, nala bunds were considered for suitable areas with slopes of 5–10%, percolation tanks and farm ponds for areas with slopes below 5%, and check dams for suitable locations with slopes below 15%. The applicability of these measures across all 15 subwatersheds is presented in Table 8.

Table 8. Proposal of soil and water conservation structures based on LULC, soil and slope classes in Dantiwada subwatersheds

Subwatershed No.	Proposed Soil and Water Conservation Structures								
	Agronomical Measures			Mechanical Measures					
	Agricultural land			Agricultural and Forest Land		LULC, Soil and Slope Classes as per IMSD Guidelines			
	Land slope 0-2%			Land slope 2-10%	Land slope 10-30%	Land slope 5-10%	Land slope < 5%	Land slope < 15%	Land slope < 5%
	Contour Cropping	Strip Cropping	Mulching	Bunding	Terracing	Nala bund	Percolation Tank	Check dam	Farm pond
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
4	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
7	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
10	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
12	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
14	No	No	No	No	No	No	No	No	No
15	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes

3.8 Limitations of the morphometric prioritization

The compound-parameter ranking should be interpreted as a relative prioritization framework rather than a direct measurement of soil erosion. The analysis is based on morphometric characteristics derived from DEM data and does not directly quantify soil-loss rates, sediment yield or rainfall erosivity.

A further consideration is that drainage density and length of overland flow are mathematically related, because the latter was calculated from the reciprocal of drainage density. Their simultaneous inclusion in the compound parameter can therefore provide drainage development with greater representation than would occur if statistically independent parameters were used.

The ranking also depends on the direction assigned to individual parameters. The methodology states that lower values of the selected shape parameters were given higher priority, while the final compound parameter was obtained by averaging the individual ranks.

These limitations should be explicitly acknowledged so that the study's contribution is framed correctly: the method provides spatial prioritization for conservation planning, not a quantitative erosion model.

4. Conclusion

The present study demonstrated the applicability of an integrated Remote Sensing (RS) and Geographic Information System (GIS) framework for morphometric characterization and prioritization of subwatersheds in the Dantiwada Watershed, Gujarat, India. The watershed was delineated into 15 subwatersheds, and 13 morphometric parameters representing basin geometry, drainage characteristics and relief were evaluated. The compound-parameter approach provided a systematic relative prioritization of all subwatersheds, with SW-6, SW-15, SW-11, SW-3 and SW-12 occupying the first five positions, respectively, while SW-4 received the lowest relative priority. The results demonstrate that the final prioritization represents the combined influence of multiple morphometric characteristics rather than any single parameter.

Integration of LULC, soil and slope characteristics provided further spatial information for identifying appropriate conservation interven-

tions. The 2024 LULC analysis showed barren land as the dominant class (45.76%), followed by vegetation (33.13%) and dense vegetation (15.97%). Based on the integrated spatial analysis, 186 candidate conservation structures were identified, comprising 30 nala bunds, 62 percolation tanks, 33 check dams and 61 farm ponds. Their distribution varied among subwatersheds according to local LULC, soil, slope and site-suitability conditions. Thus, the developed framework provides a spatially explicit basis for sequencing conservation interventions and developing subwatershed-specific soil and water conservation strategies. The derived ranking represents relative morphometric priority and should not be interpreted as a direct quantitative estimate of soil-loss magnitude.

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