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Watershed prioritization of Meghal River Basin, India using morphometric parameters: A remote sensing and GIS based approach

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Abstract
In this study, Prioritization of Meghal River basin, Gujarat, India was carried out by using remote sensing (RS) and geographical information system (GIS). Watershed Morphometric such as Bifurcation ratio, Stream Frequency, Length of overland flow, Texture Ratio, Drainage Density, Elongation Ratio, Form Factor, Circulatory Ratio and Compactness Coefficient were used for Prioritization of the basin. River basin was divided in 7 mini-watershed based on the drainage pattern i.e., 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3, 5G1D2c1 and 5G1D2c2. Based on the importance of morphometric parameter, priority ranks were assigned to the morphometric parameters of each 7 mini-watershed. Weighted aggregated rank was calculated from ranks of each parameter. Mini-watershed 5G1D2c2 with least weighted aggregated rank 3.0 is given highest priority for conservation efforts followed by 5G1D2b1, 5G1D2b3, 5G1D2b2, 5G1D2c1, 5G1D2a2 and 5G1D2a1 with weighted aggregated rank value of 3.1, 3.7, 4.0, 4.6 and 4.7 respectively.

Keywords: Watershed prioritization, morphometric analysis, remote sensing, GIS

1. Introduction
Watersheds also known as basin is a natural hydrological unit that drains overland flow to a certain watercourse or river at a specific concentration point. (Chopra *et al*., 2005; Patel *et al*., 2012) [1, 11]. It is an essential component of the hydrological cycle, and its management is crucial for the sustainable development of water resources. Watershed planning and management often requires the prioritization of watershed areas for conservation efforts. It involves the identification of areas that require conservation measures based on their ecological, social, and economic importance.(Sujatha *et al*., 2014a) [19].
The prioritization of watersheds can be done using different methods, including qualitative and quantitative approaches. Qualitative approaches rely on expert opinions, stakeholder engagement and community participation to identify priority areas. Quantitative approaches, on the other hand, use data-driven methods to identify priority areas based on their physical, ecological and socio-economic characteristics. Some of the commonly used quantitative methods for watershed prioritization include multi-criteria decision analysis (Jaiswal *et al*., 2015) [4], fuzzy logic(Sinshaw *et al*., 2021) [17], and morphometric analysis. Prioritization based on morphometric parameters such as drainage area, stream length, slope, relief, drainage density, relief ratio, basin shape, and compactness coefficient are data-driven and scalable solution that can be applied to different river basins, making it an important alternative to other prioritization methods. (Malik *et al*., 2019; Singh *et al*., 2021) [6, 16].
Remote sensing and GIS-based approaches have emerged as powerful tools for watershed prioritization, allowing for the analysis of large amounts of spatial data. Using remote sensing and GIS for prioritization of watersheds allows for efficient data acquisition, spatial analysis, and multi-criteria decision analysis, providing a scalable and objective approach to identifying priority areas for conservation measures and promoting sustainable watershed management.(Patel *et al*., 2013; Sharma & Mahajan, 2020; Thakkar & Dhiman, 2007) [12, 14, 22].
In this study, we present a remote sensing and GIS-based approach for prioritization of Meghal river basin using morphometric parameters. Meghal is one of the 71 rivers of the western peninsular region of Gujarat known as saurashtra covering an area of about 581.45 km^2. 72 km long river with basin slope 1:1000 to 1:5000 is falling in Maliya, Mendarada, Mangrol and Keshod talukas of Junagadh district. (Mansuriya, 2019) [7].

Being an agricultural watershed, the major demand of water for agriculture is affecting people's livelihood due to decline and uncertainty in agricultural income. Based on the drainage pattern of the Meghal river basin, area was subdivided into seven mini-watersheds and their prioritization was performed based on weighted rank aggregation of geomorphological parameters (Sharma & Mahajan, 2020) [14]. The results of this study can be used by policymakers and water resource managers to identify the priority areas for conservation measures, ensuring the sustainable development of resources in the Meghal river basin.

2. Materials and Methods

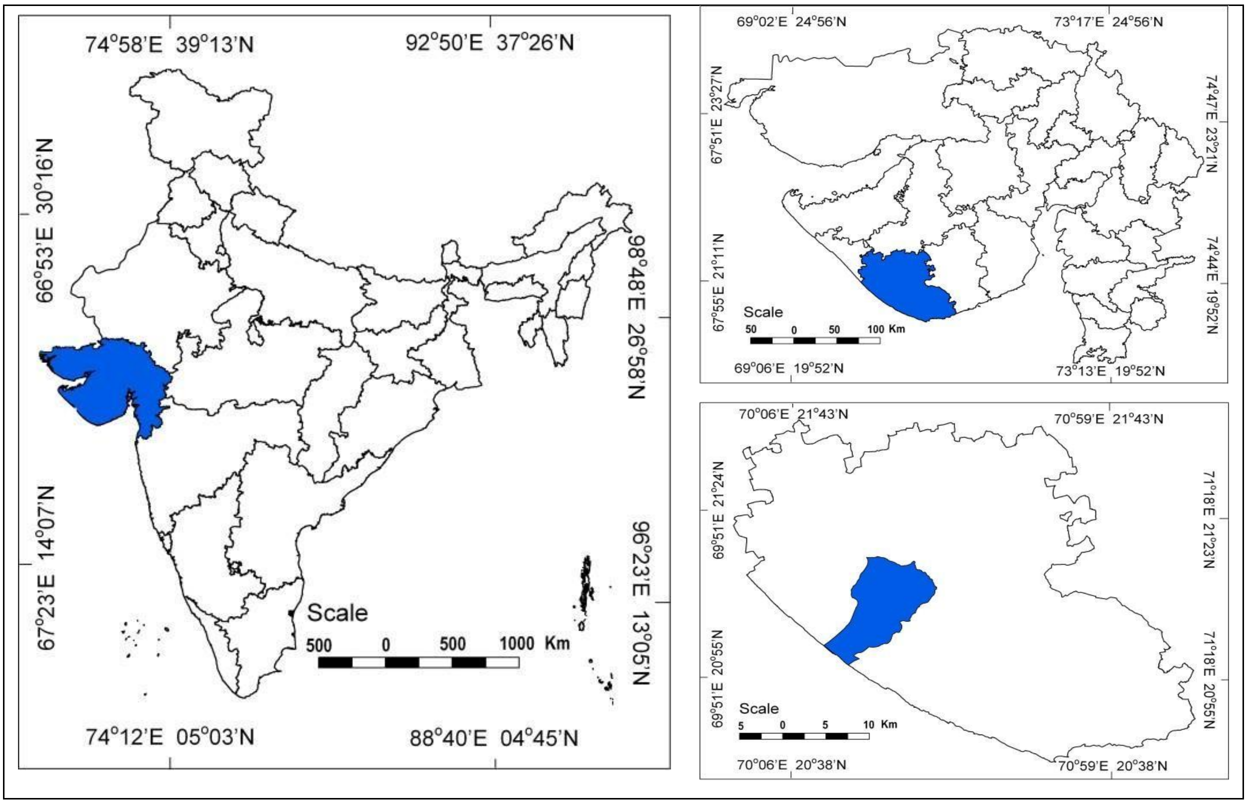
2.1 Study Area

The present study was conducted in the Meghal river basin, which is situated in the Saurashtra region of Gujarat, India and has an area of approximately 581.45 km^2, from 20° 58' N to 21° 17' N latitude and 70° 13' E to 70° 32' E longitude. The area is the part of Survey of India toposheet number 41K/08 and IRS LISS III images of 91/57 (Path/Row). The watershed code of Meghal river basin is 5G1D2 as per Soil & Land Use Survey of India. The area is characterized as a sub-tropical, semi-arid climate with average annual rainfall of 817 mm. Figure 1 displays the location map of the study area.

2.2 Data used and Methodology

Survey of India (SOI) toposheet numbers 41K/08 on 1:4000 scale was used to delineate the watershed boundary. Delineated watershed was overlaid on IRS-1C FCC data to update and modify in terms of channel numbers and lengths. Satellite images of IRS P6 of sensor LISS III, AWiFS data procured from Bhaskaracharya Institute for Space Applications and Geo-informatics, Gandhinagar were used to generate non-spatial data of sub-watersheds such as stream length, stream order, perimeter, basin length by using ArcGIS V9.2 and PCI Geomatica V10.1 software. Various thematic maps were prepared such as cadastral map, soil map, slope map, drainage map, watershed maps etc. based on visual interpretation the demarcation of watershed area was done in Meghal river basin. Based on secondary and tertiary drainage pattern of Meghal river basin, the watershed area was sub-divided into 7 mini-watersheds with codes (Figure 1) *viz*. 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3, 5G1D2c1 and 5G1D2c2.

Morphometric parameters of watershed quantify the geomorphology of watershed which reflect crucial factors affecting surface runoff and sediment loss from the watershed and aid in the process of identifying priority areas for water resource management and allocating resources effectively in watershed management are computed (Malik *et al*., 2019) [6]. Basic watershed parameters like Basin Area (A), Perimeter (P), Stream order (u), Number of streams (N_u), Length of streams (L), Mean stream length (L_m); Linear morphometric parameters like Bifurcation ratio (R_b), Drainage Density (D_d), Stream Frequency (F_s), Texture Ratio (R_t), Length of overland flow (L_o) and Shape parameters like Elongation Ratio (R_e), Form Factor (R_f), Circulatory Ratio (R_c), Compactness Coefficient (C_c) were calculated by using the equations as described in Table 1. The prioritization of the watershed is carried out using a weighted rank aggregation method, where the rankings were assigned based on the relative importance of each morphometric parameter. weighted rank aggregation method allows for systematic and transparent prioritization, considering the significance of each parameter. As linear parameters are proportional to severity of erosion in the area and Shape parameters are inversely proportional to severity of erosion in the area. The normalized data was ranked, with linear parameters ranked in descending order and shape parameters ranked in ascending order. Weighted aggregated rank was calculated by averaging the ranks of each parameter. Areas with lower weighted rank was considered higher priority for conservation efforts.



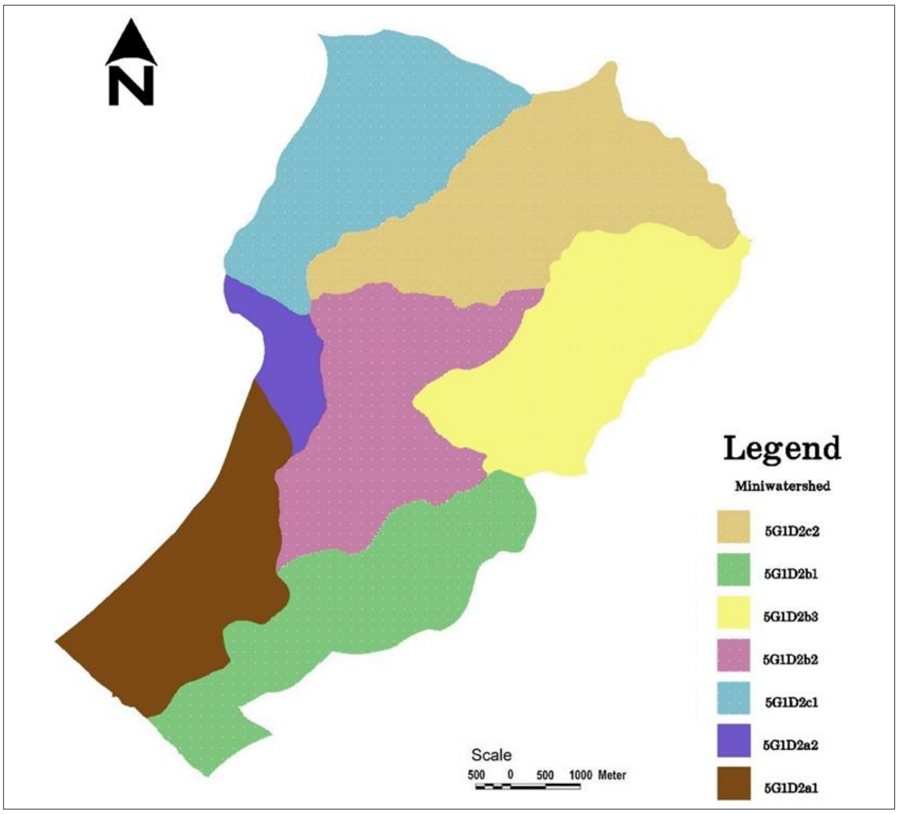


Fig 1: Location of the study area

Table 1: Formulas used to compute morphometric parameters

Morphometric parameters	Formula	Reference
Basic Parameters		
Basin Area (A)	A = Area of the Basin in km^2	(Nooka Ratnam *et al*., 2005) [10]
Perimeter (P)	P = Perimeter in km	(Nooka Ratnam *et al*., 2005) [10]
Stream order (u)	Hierarchical rank	Strahler (1964) [18]
Number of streams (N_u)	N = No. of streams	(Nooka Ratnam *et al*., 2005) [10]
Mean stream length (L_m)	$L_m = L_u / N_u$ Where, L_u is the total length of stream of order u, N_u is the total number of streams of order u	Strahler (1964) [18]
Length of streams (L)	Length of the stream	Horton (1945) [3]
Linear parameters		
Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ Where, R_b = Bifurcation Ratio, N_u = Total number of stream segment of order 'u', N_{u+1} = Number of segments of next higher order	Schumn (1956) [13]
Drainage Density (D_d)	$D_d = L_u / A$ Where, D_d = Drainage density, L_u = Total stream length of all order, A = Area of the basin	Horton (1945) [3]
Stream Frequency (F_s)	$F_u = N_u / A$ Where, Fu = Total number of streams of all order, A = Area of the Basin (km^2)	Horton (1945) [3]
Texture Ratio (R_t)	$R_t = N_u / P$ Where, N_u = Total number of streams of all orders, P = Perimeter (km)	Horton (1945) [3]
Length of overland flow (L_o)	$L_o = 1 / 2D_d$ Where, L_o=Length of the Overland Flow, D = Drainage density	Horton (1945) [3]
Shape parameters		
Elongation Ratio (R_e)	$R_e = (2 / L) \times (A / \pi)^{1/2}$ Where, R_e=Elongation Ratio, L_b=Length of basin (km), A=Area of the basin (km^2)	Schumn (1956) [13]
Form Factor (R_f)	$Rf = A / L^2$ Where, R_f = Form Factor, A = Area of the basin (km^2)	Horton (1945) [3]
Circulatory Ratio (R_c)	$Rc = 4 \pi A / P^2$ Where, R_c = Circularity Ratio, A = Area of the basin (km^2), P = Perimeter (km)	Miller (1953) [9]
Compactness Coefficient (C_c)	$C_c = 0.2821P / A^{0.5}$ Where, C_c = Compactness Constant, A=Area of the basin (km^2)	Horton (1945) [3]

3. Results and Discussions

Morphometric parameters were classified in 3 groups i.e., Basic parameters, Linear parameters and Shape parameters. Quantitative values of Morphometric parameters of each 7 mini-watershed calculated by methods is shown in table 1 is shown in Table 2 and 3.

3.1 Basic morphometric parameters

Detailed drainage network of the watershed is shown in figure 1 and is presented in table 2. From the table 2 it was observed that mini-watershed 5G1D2c2 is having maximum 34 number of streams, followed by 5G1D2b3 with 156 streams, 5G1D2b2 with 114 streams, 5G1D2b1 with 105 streams, 5G1D2c1 with 77 streams, 5G1D2a1 with 34 streams, 5G1D2a2 with 14 streams. Total length of the 1st order streams is highest i.e., 388.05 km, and that of 2nd order is 195.09 km, 3rd order is 84.0 km, 4th order is 57.29 km, 5th order is 34.50 km and the lowest is of 6th order of 25.29 km respectively. As shown in table 3, Mini-watershed 5G1D2c2 is having largest area with 144.14 km^2 followed by 5G1D2b3 with 92.16 km^2, 5G1D2c1with 86.19 km^2, 5G1D2b2 with 85.95 km^2, 5G1D2b1 with 83.39 km^2, 5G1D2a1 with 71.69 km^2 and 5G1D2c1 with lowest area of 17.94 km^2. Similar trend was observed for remaining basic morphometric parameters presented in table 3.

3.2 Linear parameters of Watershed

Watershed managers and planners can prioritize areas based on linear morphometric parameters. For example, mini-watersheds with high bifurcation ratios, stream frequencies, and drainage densities may be targeted for conservation initiatives or water resource development projects. Similarly, areas with longer lengths of overland flow or higher texture ratios may require specific measures to address erosion or flood management concerns. (Meshram *et al*., 2020) [8].

The values of bifurcation ratio (R_b) varying from 3.19 (5G1D2b2) to 4.55 (5G1D2b1) indicate the degree of branching or division of streams within each mini-watershed. Higher values in 5G1D2b1 suggest a more complex stream network, potentially indicating areas where water resources are distributed over a larger area.(Shri *et al*., 2015) Stream frequency (F_s) values varying from 0.73 (5G1D2a1) to 3.68 (5G1D2c2) reflect the density of streams in each mini-watershed. Mini-watersheds with higher stream frequencies are likely to have a greater concentration of streams in a given area. These areas could be considered as important zones for water resource preservation. (Tamma Rao *et al*., 2012) The length of overland flow (Lg) values ranging from 0.23 (5G1D2c2) to 0.68 (5G1D2a1) represent distance that water needs to travel before reaching the outlet. Areas with higher length require attention in terms of soil erosion control measures or land management practices. Texture ratio (T) values ranging from 0.79 (5G1D2a2) to 4.16 (5G1D2c2) indicate the relationship between the lengths of streams and overland flow paths. (Gomi *et al*., 2008) [2] Higher texture ratio suggests a greater dominance of stream channels over the overland flow paths. High texture ratio for 5G1D2c2 may require specific management strategies to mitigate potential flood risks or channel erosion issues. Drainage density (D_d) values varying from 0.73 (5G1D2a1) to 2.19 (5G1D2c2) reflect the density of the stream network in each mini-watershed. Higher drainage density implies a denser network of streams in the given area. Areas with higher drainage density could be of interest for conservation efforts or serve as potential locations for water supply infrastructure.(Sujatha *et al*., 2014b) [20].

3.3 Shape parameters of Watershed

By analysing shape parameters, watershed managers and planners can gain insights into the geometric attributes of each mini-watershed. Table 3 presents the shape parameters of different mini-watersheds, which were analysed as part of the watershed study. Mini-watersheds with less shape parameter values may be prioritized for conservation initiatives or water resource development projects

Elongation ratio (Re) values ranging from 0.50 (5G1D2b1) to 0.73 (5G1D2c1) represent the shape elongation of the mini-watersheds. A lower elongation ratio suggests a more elongated or stretched shape, while a higher ratio indicates a more compact or round shape. Form factor (R_f) values varying from 0.19 (5G1D2b1) to 0.42 (5G1D2c1) indicate the compactness of the mini-watersheds. A lower form factor implies a more elongated shape, while a higher value suggests a more compact or circular shape. Circulatory ratio (R_c) values ranging from 0.23 (5G1D2b1) to 0.57 (5G1D2a2) represent the ratio of the length of the watershed boundary to the circumference of a circle with the same area as the mini-watershed. A lower circulatory ratio indicates a more elongated shape, while a higher ratio suggests a more circular or compact shape. Compactness coefficient (Cc) values varying from 1.35 (5G1D2b3) to 1.71 (5G1D2b1) provide an overall compactness sub-watershed. A high value of compactness coefficient indicates more compact sub-watersheds

3.4 Weighted aggregated rank of morphometric parameters

After quantification of morphometric parameters, the priority rank was assigned to 7 mini-watersheds as shown in table 4. Weighted aggregated rank was calculated by summing ranks of all linear and shape parameters and dividing them with number of parameters. (Jothimani *et al*., 2020) [5]. As shown in Mini-watershed 5G1D2c2 with least weighted aggregated rank 3.0 is given highest priority for conservation efforts followed by 5G1D2b1, 5G1D2b3, 5G1D2b2, 5G1D2c1, 5G1D2a2 and 5G1D2a1 with weighted aggregated rank value of 3.1, 3.7, 4.0, 4.6 and 4.7 respectively.

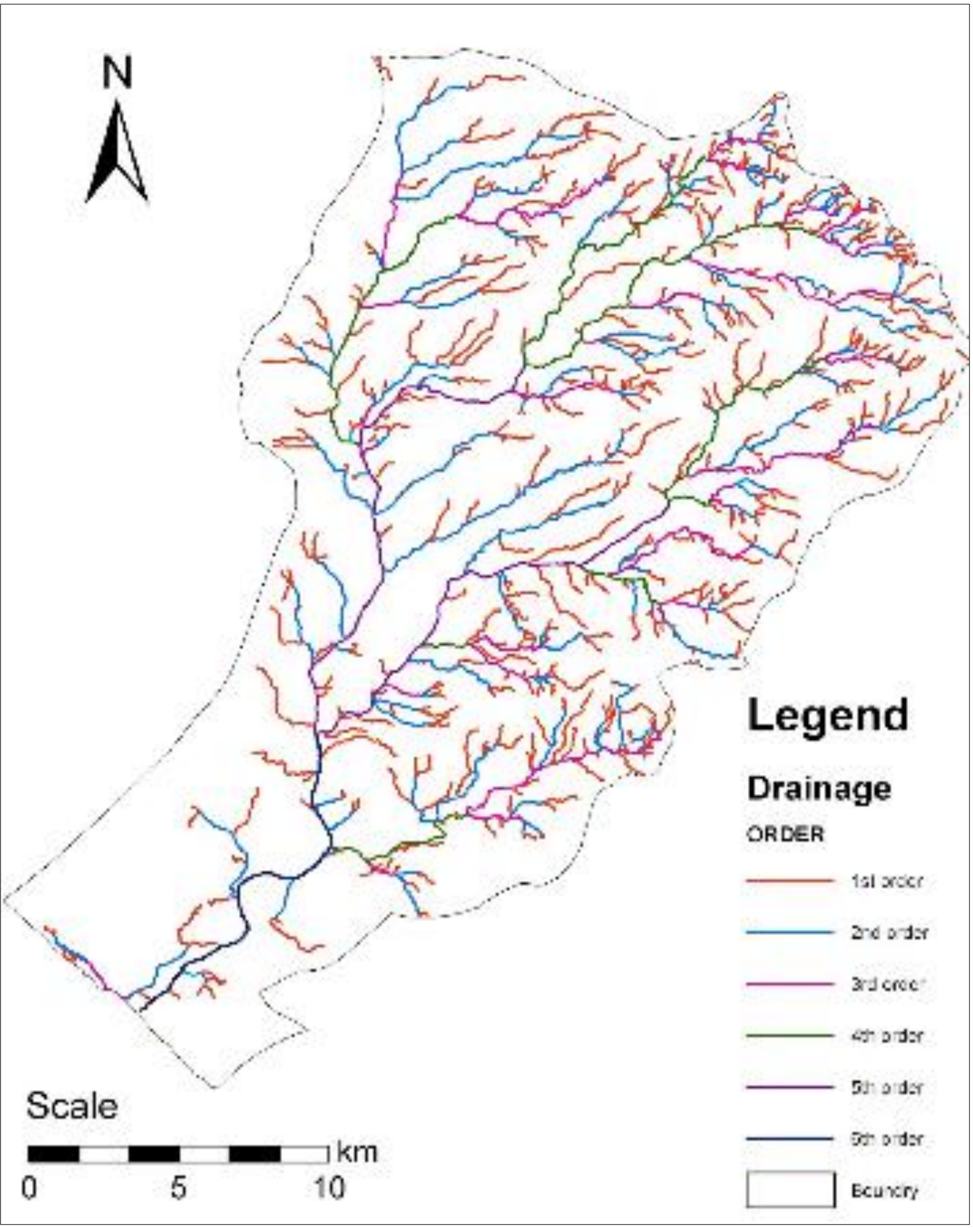


Fig 2: Drainage network of Meghal River Basin

Table 2: Details of streams in watershed

Code of Mini-Watershed	Number of streams (u)						Total
	1	2	3	4	5	6	
5G1D2a1	23	8	1	0	1	1	34
5G1D2a2	10	3	0	0	1	0	14
5G1D2b1	80	20	3	1	0	1	105
5G1D2b2	89	17	4	1	2	1	114
5G1D2b3	117	27	8	3	1	0	156
5G1D2c1	57	15	4	1	0	0	77
5G1D2c2	190	44	10	2	1	0	247
Length of streams (L), km	388.05	195.09	84.0	57.29	34.50	25.29	

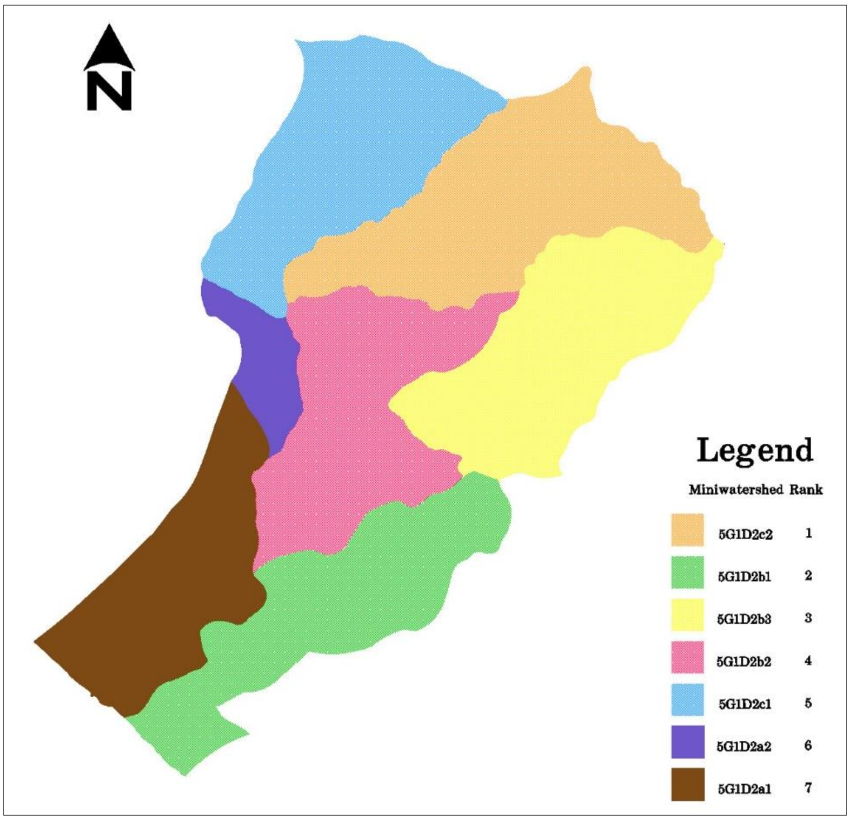


Fig 3: Prioritization map of Meghal river basin

Table 3: Morphometric parameters of watershed

Mini-watershed	Basic Parameters of Watershed					Linear Parameters of Watershed					Shape Parameters of Watershed			
	A (Km^2)	P (km)	N_u	L (km)	L_m	R_b	F_s	L_g	T	D_d	R_e	R_f	R_c	C_c
5G1D2a1	71.69	43.25	34.00	52.51	16898.32	3.85	0.73	0.68	1.21	0.73	0.62	0.31	0.29	1.44
5G1D2a2	17.94	22.03	14.00	17.35	5352.43	3.33	1.06	0.52	0.79	0.97	0.53	0.22	0.57	1.47
5G1D2b1	83.39	55.32	105.00	114.35	28199.11	4.55	2.22	0.36	2.07	1.37	0.50	0.19	0.23	1.71
5G1D2b2	85.95	52.19	114.00	156.57	24912.68	3.19	2.28	0.27	3.00	1.82	0.58	0.26	0.24	1.59
5G1D2b3	92.16	46.03	156.00	159.49	15427.70	3.34	2.59	0.29	3.46	1.73	0.67	0.35	0.27	1.35
5G1D2c1	86.19	44.63	77.00	108.85	17071.49	3.85	1.37	0.40	2.44	1.26	0.73	0.42	0.28	1.36
5G1D2c2	144.14	75.95	247.00	316.04	114440.37	3.92	3.68	0.23	4.16	2.19	0.60	0.28	0.23	1.52

Table 4: Final Priority of Mini-Watersheds

Mini-watershed	Linear Parameters of Watershed					Shape Parameters of Watershed				Weighted Aggregated Rank	Final Priority
	R_b	F_s	L_g	T	D_d	R_e	R_f	R_c	C_c		
5G1D2a1	3	7	1	6	7	5	5	6	3	4.7	7
5G1D2a2	6	6	2	7	6	2	2	7	4	4.6	6
5G1D2b1	1	4	4	5	4	1	1	1	7	3.1	2
5G1D2b2	7	3	6	3	2	3	3	3	6	4.0	4
5G1D2b3	5	2	5	2	3	6	6	4	1	3.7	3
5G1D2c1	3	5	3	4	5	7	7	5	2	4.5	5
5G1D2c2	2	1	7	1	1	4	4	2	5	3.0	1

4. Conclusion

The study was conducted to prioritize areas for conservation measures based on watershed morphometric parameters in Meghal river basin. Basin was divided into seven mini-watersheds with codes *viz*. 5G1D2a1, 5G1D2a2, 5G1D2b1, 5G1D2b2, 5G1D2b3, 5G1D2c1 and 5G1D2c2. By using remote sensing data, GIS technique, morphometric data of watershed was determined. The prioritization of the mini-watershed was performed through Weighted aggregated rank determined by assigning ranks based on the relative importance of each morphometric parameter. Mini-watershed 5G1D2c2 with least weighted aggregated rank 3.0 was given highest priority for conservation efforts followed by 5G1D2b1, 5G1D2b3, 5G1D2b2, 5G1D2c1, 5G1D2a2 and 5G1D2a1 with weighted aggregated rank value of 3.1, 3.7, 4.0, 4.6 and 4.7 respectively. The results of the study provide valuable information for policymakers and water resource managers to identify priority areas for conservation measures, contributing to the sustainable development of resources in the Meghal River basin.

5. References

1. Chopra R, Dhiman RD, Sharma PK. Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab

using remote sensing and GIS techniques. J Indian Soc Remote Sens. 2005;33(4):531-539. https://doi.org/10.1007/BF02990738
2. Gomi T, Sidle RC, Miyata S, Kosugi K, Onda Y. Dynamic runoff connectivity of overland flow on steep forested hillslopes: Scale effects and runoff transfer. Water Resour Res, 2008, 44(8). https://doi.org/10.1029/2007WR005894
3. Horton RE. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geol Soc Am Bull. 1945;56(3):275-370.
4. Jaiswal RK, Ghosh NC, Galkate RV, Thomas T. Multi Criteria Decision Analysis (MCDA) for Watershed Prioritization. Aquat Procedia. 2015;4:1553-1560. https://doi.org/10.1016/j.aqpro.2015.02.201
5. Jothimani M, Abebe A, Dawit Z. Mapping of soil erosion-prone sub-watersheds through drainage morphometric analysis and weighted sum approach: a case study of the Kulfo River basin, Rift valley, Arba Minch, Southern Ethiopia. Model Earth Syst Environ. 2020;6(4):2377-2389. https://doi.org/10.1007/s40808-020-00820-y
6. Malik A, Kumar A, Kandpal H. Morphometric analysis and prioritization of sub-watersheds in a hilly watershed using weighted sum approach. Arab J Geosci. 2019;12(4):118. https://doi.org/10.1007/s12517-019-4310-7
7. Mansuriya V, Gontiya NK. Determination of geomorphological characteristics of meghal river basin using remote sensing and GIS. AGRES – An Int e. J. 2019;8(1):72-80.
8. Meshram SG, Singh VP, Kahya E, Alvandi E, Meshram C, Sharma S. The feasibility of Multi-Criteria Decision Making Approach for Prioritization of Sensitive Area at Risk of Water Erosion. Water Resour Manag; c2020. https://doi.org/10.1007/s11269-020-02681-7
9. Miller VC. A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Project NR 389042, Tech. Rept. 3. Columbia University, Department of Geology, ONR, Geography Branch, New York; c1953.
10. Ratnam NK, Srivastava YK, Rao VV, Amminedu E, Murthy KSR. Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis — Remote sensing and GIS perspective. J Indian Soc Remote Sens. 2005;33(1):25-38. https://doi.org/10.1007/BF02989988
11. Patel DP, Dholakia MB, Naresh N, Srivastava PK. Water Harvesting Structure Positioning by Using Geo-Visualization Concept and Prioritization of Mini-Watersheds Through Morphometric Analysis in the Lower Tapi Basin. J Indian Soc Remote Sens. 2012;40(2):299-312. https://doi.org/10.1007/s12524-011-0147-6
12. Patel DP, Gajjar CA, Srivastava PK. Prioritization of Malesari mini-watersheds through morphometric analysis: a remote sensing and GIS perspective. Environ Earth Sci. 2013;69(8):2643-2656. https://doi.org/10.1007/s12665-012-2086-0
13. Schumn SA. Evolution of drainage systems and slopes in Badlands at Perth Amboy, New Jersey. Geol Soc Am Bull. 1956;67(5):597-646.
14. Sharma S, Mahajan AK. GIS-based sub-watershed prioritization through morphometric analysis in the outer Himalayan region of India. Appl Water Sci. 2020;10(7):163. https://doi.org/10.1007/s13201-020-01243-x
15. Shri K, Sumeet M, Renu D, Surjeet S. Morphometric analysis of Sonar sub-basin using SRTM data and geographical information system (GIS). Afr J Agric Res. 2015;10(12):1401-1406. https://doi.org/10.5897/AJAR2013.7907
16. Singh WR, Barman S, Tirkey G. Morphometric analysis and watershed prioritization in relation to soil erosion in Dudhnai Watershed. Appl Water Sci. 2021;11(9):151. https://doi.org/10.1007/s13201-021-01483-5
17. Sinshaw BG, Belete AM, Tefera AK, Dessie AB, Bizuneh BB, Alem HT, *et al*. Prioritization of potential soil erosion susceptibility region using fuzzy logic and analytical hierarchy process, upper Blue Nile Basin, Ethiopia. Water-Energy Nexus. 2021;4:10-24. https://doi.org/10.1016/j.wen.2021.01.001
18. Strahler AN. Quantitative geomorphology of drainage basin and channel networks. In: Chow VT, editor. Handbook of applied hydrology. New York: McGraw Hill Book Company; 1964. p. 4-39.
19. Sujatha ER, Selvakumar R, Rajasimman B. Watershed prioritization of Palar sub-watershed based on the morphometric and land use analysis. J Mountain Sci. 2014a;11(4):906-916. https://doi.org/10.1007/s11629-012-2628-7
20. Sujatha ER, Selvakumar R, Rajasimman B. Watershed prioritization of Palar sub-watershed based on the morphometric and land use analysis. J Mountain Sci. 2014b;11(4):906-916. https://doi.org/10.1007/s11629-012-2628-7
21. Tamma Rao G, Gurunadha Rao VVS, Dakate R, Mallikharjuna Rao ST, Raja Rao BM. Remote sensing and GIS based comparative morphometric study of two sub-watershed of different physiographic conditions, West Godavari District, A.P. J Geol Soc India. 2012;79(4):383-390. https://doi.org/10.1007/s12594-012-0059-2
22. Thakkar AK, Dhiman SD. Morphometric analysis and prioritization of miniwatersheds in Mohr watershed, Gujarat using remote sensing and GIS techniques. J Indian Soc Remote Sens. 2007;35(4):313-321. https://doi.org/10.1007/BF02990787