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Sub-Watershed Prioritization and PCA Analysis using Geospatial Approach: A Case Study of Nagod Area, Satna District of Central India

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Abstract
The present study analyzed the watershed morphometric characteristics of the Nagod watershed, which consists of five sub-watersheds (SW), located in the Tons basin in Central India. Conventional approaches to watershed prioritization often fall short in effectively capturing the variability present in morphometric parameters. To address these challenges, this study employed geospatial approach to enhance the identification of critical sub-watersheds within the study area. Morphometric analysis plays a crucial role in identifying areas susceptible to soil erosion, as it helps assess the physical characteristics of watersheds that influence erosion potential. By integrating morphometric data with GIS capabilities, this approach helps a more precise and effective means of pinpointing areas that are most vulnerable to erosion, thus facilitating more targeted land management and conservation strategies. Effective water resource management is essential for maintaining a sustainable living environment within a watershed. The increasing reliance on geospatial approach by decision-makers and planners is driven by their ability to enhance decision-making processes with greater precision and accuracy. Geospatial approach is invaluable for monitoring and detecting changes within a watershed, whether they result from natural processes or human activities. To assess the relationships between various watershed characteristics, morphometric analysis provides the most effective approach. The analyzed morphometric parameters play a crucial role in planning soil and water conservation strategies, particularly through the application of Principal Component Analysis (PCA), a widely used technique for reducing data dimensionality while retaining maximum variance. The drainage network, classified from order 1 to 6, encompasses five sub-watersheds labelled SW-I to SW-V. Based on the morphometric evaluation of the Nagod watershed, these sub-watersheds are grouped into high, medium, and low priority zones. The prioritization and correlation of morphometric indices highlight that certain areas, especially those with higher erosion potential, fall into the high-priority category. The findings of this research offer valuable insights for decision-makers and resource managers, especially those focused on watershed management, sustainable natural resource practices, and the mitigation of environmental degradation in the study area.
***Keywords**: Morphometric Analysis, Watershed, Geographic Information Systems, Principal Component Analysis*

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I. INTRODUCTION

The pressure on land and water resources in India has increased as a result of the rapid growth in industrialisation and demographic expansion. The demand of groundwater has increased manifold due to rapid growth of population, urbanization, expansion of irrigation activities and its unscientific management [55] and unsuitable agricultural methods and poor farm management threaten the long-term viability of land, water, and other vital resources necessary for sustaining healthy ecosystems [58]. India is encountering significant challenges in managing its groundwater resources, primarily driven by rapid population expansion, accelerated urban and industrial development, and the unpredictable nature of monsoon patterns [54]. The hydrological output of the watershed is influenced by the development of topological and structural features known as morphometric parameters. Watersheds represent intricate, multi-tiered geographical structures, formed by a series of interdependent sub-watersheds [28]. The watershed is considered a critical entity due to its integration of three key components: hydrological, biophysical, and socioeconomic systems, making its significance indisputable [20, 24, 47]. Morphometric study of watersheds is the most effective way to understand the link between various features in the research area. Morphometric studies have consistently supported the widely accepted concept that the configuration and composition of a watershed assist as evidences to a variety of geological and geomorphological events that have unfolded over time [29]**.** The status of soil erosion-prone areas and the potential for surface and water erosion are also provided with information by the morphometric analysis. Horton introduced morphometric analysis in 1932 and 1945 in order to study the origin of river networks, which were further studied by Strahler in 1952 Strahler 1964. Understanding and managing watersheds is greatly aided by the analysis of morphometric parameters, which is a vital element of hydrologic studies. A systematic examination is important for the planning of a watershed, and its stream courses encompass relief features, linear aspects, and aerial or shape aspects of the catchment [38].Watershed prioritization is helpful for soil and water conservations as well as groundwater development [52, 53]. Watersheds are thought to be more efficient and suitable for performing essential surveys and investigations, as well as planning and implementing different improvement projects such as water and soil conservation, and ensuring their long-term survival [41]. As a result, watershed management should get special attention to solve water-related challenges [13]. To understand the watershed characteristics of any area, the topography of that area should first study the drainage map made by a scale so that the direction of flow of the drainage of the study area can be known and further made through watershed. It helps in planning and development and also gives an indication of where the potential ground water can be obtained in the area [5, 14, 21, 23, 36, 44].

This study analyse different sub-watersheds under different geomorphological and topographic conditions. A watershed is an area of land in which all water that falls/drains within its bounds drains or flows downhill into a specific body of water, such as a river, lake, or ocean [2, 39]**.** To understand all characteristics of a watershed, the morphometric parameters including linear, areal, and relief aspects are examined [19, 29]. Geospatial approach methods have been widely employed by scientists to analyze watersheds. Morphometric characteristics give a quantitative catchment report, which is useful in studies like watershed prioritization, hydrologic modelling, natural resource conservation, etc.[1, 3, 8,35, 37,40, 42, 53]. The behavior and characteristics of water flow within a watershed analyzed and understood by understanding and analyzing these parameters. The potential method of extracting crucial quantitative information involves geospatial approach about watershed study. The objectives of the present study area are: (a) morphometric analysis of Nagod watershed using RS and GIS techniques (b) prioritization of watershed using morphometric analysis (c) to analyses PCA of morphometric characteristics of Nagod watershed which require need to attention.

II. STUDY AREA

The study area is located within the boundaries of Survey of India Toposheet No. 63D/05, 63D/06, 63D/07, 63D/09, 63D/10, D/11 and D/14 positioned between latitudes 24°24'27.656"N to 24°49'4.616"N and longitudes 80°21'56.854"E to 80°45'55.58"E (Fig. 1). Nagod is a town and tehsil situated in the Satna District of Madhya Pradesh, India. Based on the 2011 Census of India, the population of Nagod was 22,568, with 53% males and 47% females. The literacy rate in Nagod was 68%, which is above the national average of 59.5%. Male literacy stood at 76%, while the literacy rate for females was 60%. The total area of Nagod tehsil is 855 square kilometers, which includes 851.10 square kilometers of rural area and 4.40 square kilometers of urban area. The area is accessible by bus, taxi, and train, with the Satna-Panna main road running through the central part of the area. The nearest railway station is Satna, and the Satna-Jabalpur broad gauge line of the West-Central Railway traverses the district. The climate of the region varies from semi-arid to humid, with an average annual precipitation of around 1000 mm. During the summer months, temperatures can soar up to 46°C, whereas winter temperatures can fall to as low as 4°C. The monsoon season brings increased humidity, with levels reaching up to 75%.

The study area is situated within the Vindhyan Supergroup, which is predominantly made up of unconsolidated, soft sandstone and sand. These materials are porous, allowing for the infiltration of groundwater and the development of shallow aquifers, although water retention capabilities can differ. The region is also characterized by alluvial deposits, such as sand, clay, and shale. While sand facilitates groundwater movement, the presence of clay and shale creates impermeable barriers that restrict vertical water flow, thereby forming confined aquifers. The interaction between these geological formations plays a key role in shaping the distribution and quality of groundwater in the area, which is vital for efficient water resource management. The soils in the study area are classified as well-drained to moderately drained, exhibiting a moderate to high capacity for infiltration. The predominant land-use patterns include agriculture and forest cover, both of which are integral to the local economy and contribute significantly to the regional ecosystem.

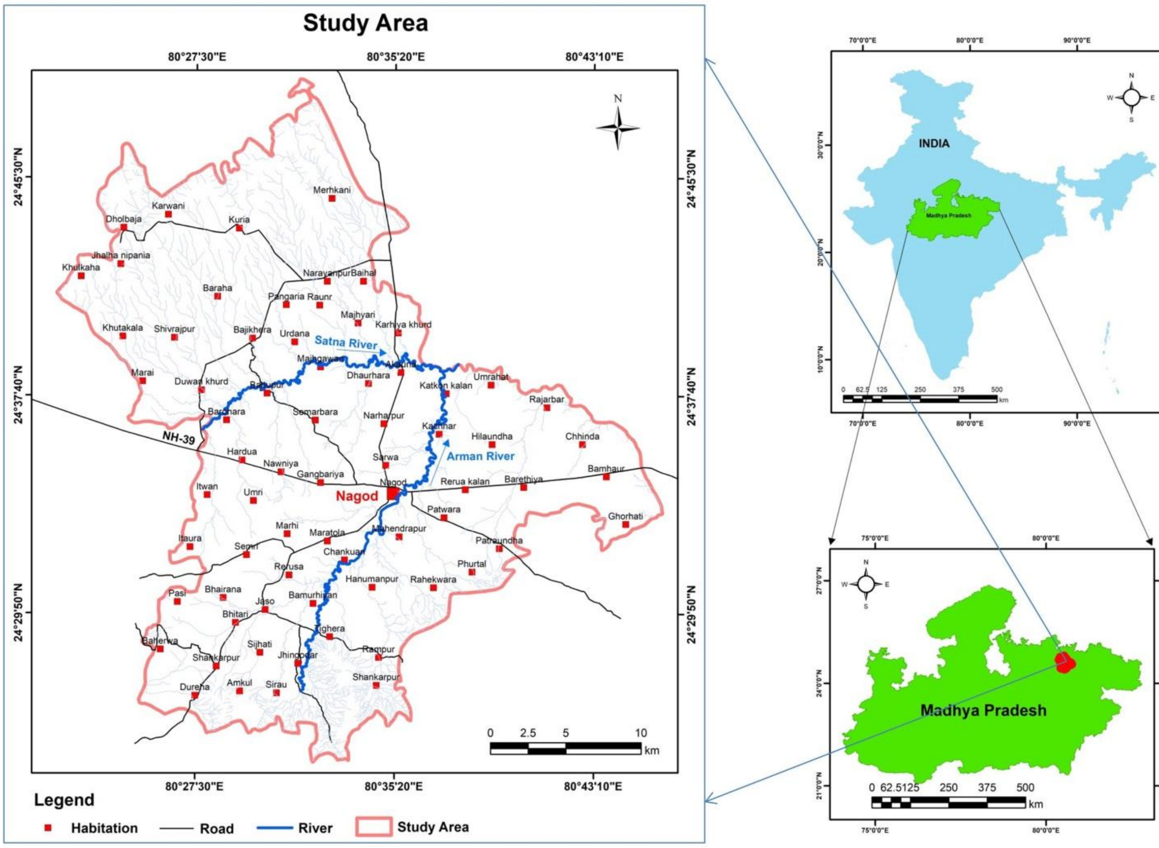

Fig. 1: Location of the Study Area

III. METHODOLOGY

This study employs geospatial approach to examine the morphometric characteristics of the Nagod study area. The necessary data for the morphometric analysis were obtained from Survey of India toposheets and processed through GIS software. The ArcGIS mosaic tool was utilized to merge and clip the georeferenced toposheets, resulting in a composite map that encompassed the entire study area. This integrated toposheet was subsequently used to digitize the stream network of the watershed. The morphometric analysis of the digital drainage network involved considerable effort, as stream ordering, naming, and proper merging or splitting at relevant points are time-consuming tasks, even with advanced GIS tools. This study considered a comprehensive set of morphometric parameters, including area, perimeter, stream order, stream number, stream length, bifurcation ratio, drainage density, stream frequency, drainage texture, basin length, form factor, elongation ratio, and texture ratio. These parameters were assessed following methodologies established in prior research [11, 12, 16, 17, 25, 36, 53]. The formulas used to calculate these morphometric parameters are outlined in Table 1, while the spatial distribution of sub-watersheds in the study area is depicted in Fig. 2. All analyses were carried out using ArcGIS software within the GIS environment, ensuring the accuracy and reliability of the results.

Table 1. Formula for computation of morphometric parameters

Linear Aspects (La)		
Stream order (U)	Hierarchical rank	Strahler (1964)
Number of Streams (Nu)	$Nu= N_1+N_2…+N_n$	Horton (1945)
Stream length in km (Lu)	$Lu= L_1+L_2….+L_n$	Horton (1945)
Mean stream Length (Lsm)	Lsm = Lu / Nu	Strahler (1964)
Bifurcation Ratio (Rb)	Rb = Nu/Nu+1	Schumm (1956)
Stream length Ratio (RL)	RL = Lu / Lu-1	Horton (1945)
Mean Bifurcation ratio(Rbm)	Avg. of Rb ratio of all orders	Strahler (1964)
Aerial Aspects (Aa)		
Basin Length (Lb)	$Lb=1.312*A^{0.568}$	Nookaratnam et al. (2005)
Circulatory Ratio (Rc)	$Rc= 4\pi A/P^2$	Miller (1953)

Compactness Constant (Cc)	Cc= $0.2821*P/A^{0.5}$	Horton (1945)
Drainage density (Dd)	Dd = Lu /A	Horton (1932)
Drainage Intensity (Di)	Di = Fs / Dd	Faniran (1968)
Drainage Texture Ratio (T)	T= Nu/P	Horton (1945)
Elongation Ratio (Re)	Re= $(2/Lb)*(A/\pi)^{0.5}$	Schumn (1956)
Form Factor (Rf)	Rf= A/Lb^2	Horton (1945)
Infiltration Number (If)	If = Fs * Dd	Faniran (1968)
Length of overland flow (Lo)	Lo = 1 / Dd*0.5	Horton (1945)
Stream frequency (Fs)	Fs = Nu/A	Horton (1932)
Relief Aspects (Ra)		
Basin relief in m (H)	H = Z - z	Strahler (1957)
Relief ratio (Rh)	Rh = H / Lb	Schumm (1956)
Ruggedness Number (Rn)	Rn=Dd*(R/1000)	Melton (1957), Strahler (1964)

IV. RESULTS AND DISCUSSION

Quantitative morphometric measurements provide information on the hydrological properties of the watershed. The research area consists of five sub-watersheds (table 2). The morphometric analysis was used to select sub-watersheds by considering numerous variables such as the linear aspect, aerial aspect, and relief aspect. Attribute analysis of morphometric parameters of linear, aerial and relief aspects shown in table no. 3 & 4. Details about the various parameters which are considered in prioritization are mentioned below:

Bifurcation ratio (Rb)

It is the proportion of stream channel of the given order (Nu) to streams of the next higher order (Nu+1). Horton (1945) utilized it as a relief as well as a dissertation index. Strahler (1957) illustrated that it tends to vary only slightly across regions, except for where geological regulation is intense. The Rb varies from order to order; these improprieties are influenced by the geomorphological growth of drainage watersheds [45]. SW-IV and SW-III have the highest bifurcation ratios, indicating a higher proportion of stream channels of a given order compared to streams of the next higher order in those watersheds. This suggests a more complex and branched stream network in SWIII and SW-IV. On the other hand, SW-V has the lowest bifurcation ratio, indicating a lower proportion of stream channels of a given order compared to streams of the next higher order in that watershed.

Basin Length (Lb)

Basin length is defined as the maximum distance between the outlet and the most distant point within the drainage basin, measured along the principal stream. It is a significant morphometric parameter, as an increased basin length typically correlates with a longer time for runoff to reach the outlet following precipitation events. This delay in runoff response is influenced by the size and configuration of the basin, which can impact the timing and intensity of hydrological responses to rainfall.

Circularity ratio (Rc)

The circularity ratio (Rc) is a quantitative measure used to characterize the shape of a watershed. It compares the area of a watershed to that of a circle with a perimeter equal to that of the watershed. In other words, both the watershed and the circle share the same perimeter, although their areas may differ [23, 45]. The Rc value is influenced by various factors, including geological formations, vegetation cover, climatic conditions, topography, and slope. This parameter is commonly employed to examine the relationship between stream frequency, watershed shape, and runoff characteristics.

Compactness coefficient (Cc)

The compactness coefficient (Cc) is a ratio that relates the perimeter of a watershed to the circumference of a circle having the same surface area as the watershed (Horton, 1945). This parameter is independent of the shape and size of the watershed but is influenced by the slope of the terrain. The findings of the present study indicate that the Cc values are lower for sub-watersheds SW-IV & SW-III and SW1, whereas SW-I & SW-II exhibit higher compactness coefficients. It was observed that Cc does not show a direct correlation with watershed size but is primarily determined by the slope characteristics of the study area.

Drainage density (Dd)

The drainage density (D) is a key parameter that links the total stream length to the area of a watershed [17]. It is influenced by various factors such as rainfall intensity, rock permeability, soil infiltration rates, and the slope of the watershed. The value of drainage density plays a significant role in shaping landforms, affecting soil erosion, and determining vegetation coverage [16,45]. Additionally, it serves as an important metric for evaluating landscape dissection, drainage efficiency, and runoff potential. The analysis reveals that SW-III exhibits the highest drainage density, signifying a greater stream length in relation to its watershed area. This indicates a higher density of streams and a more closely spaced channel network. In contrast, SW-V demonstrates the lowest drainage density, suggesting a shorter overall stream length relative to its watershed area and a more dispersed distribution of channels compared to the other study locations.

Drainage Intensity (Id)

Faniran (1968) defines drainage intensity as the ratio of stream frequency (Fs) to drainage density (Dd). Watersheds with low drainage density, texture, and intensity are more susceptible to flooding and erosion. SW-III exhibits the highest drainage intensity, reflecting a relatively higher frequency of streams in relation to its drainage density. This suggests that SW-III has a denser concentration of streams with closer channel spacing, potentially increasing its susceptibility to flooding and erosion. In contrast, SW7 shows the lowest drainage intensity, indicating a lower stream frequency relative to its drainage density. This suggests a less concentrated stream network and a reduced vulnerability to flooding and erosion when compared to the other locations analyzed in this study.

Drainage Texture ratio (T)

Drainage texture (Dt) is a measure that quantifies the total number of stream orders found within the perimeter of a watershed, as defined by Horton (1945). This parameter provides insight into the density and complexity of the stream network, reflecting how well-drained the landscape is. In the present study, watersheds such as SW-III and SW-II exhibit higher drainage textures, implying a greater number of stream orders within the watershed perimeter. This suggests that these areas possess a more intricate stream network with varying stream orders, which typically indicates higher surface runoff and more rapid drainage. On the other hand, SW-I and SW-II display lower drainage textures, characterized by fewer stream orders within the watershed boundary. This indicates a less complex network of streams, which may suggest slower runoff and less efficient drainage in these areas. The variation in drainage texture across the study area highlights differences in landscape characteristics and hydrological behavior among the watersheds.

Elongation Ratio (Re)

Schumm (1956) introduced the concept of the elongation ratio to characterize basin shape, defining it as the ratio of the maximum basin length to the diameter of a circle with an equivalent area to that of the study basin. An elongation ratio of 0 indicates a highly elongated basin, whereas a ratio of 1.0 corresponds to a perfectly circular, spherical shape, suggesting that higher elongation ratios are associated with more spherical basin geometries. Conversely, elongation ratios between 0.6 and 0.8 typically correspond to basins with high relief and steep slopes [45]. In the study area, the elongation ratio ranges from 0.059 to 0.63, with an average value of 0.608 (Table 5).

Form Factor (Rf)

The form factor, as defined by Horton (1932), is a numerical index commonly used to characterize the shape of individual drainage basins. In the study area, the presence of narrow basins with greater lengths results in lower form factor values, as the factor is influenced by basin morphology rather than a single variable. Typically, form factor values range between 0 and 1, with lower values indicating longer, more elongated basins, which are associated with prolonged drainage times and lower peak flows. Conversely, higher form factor values correspond to more compact basins with shorter drainage times and higher peak flows. In the study area, form factor values vary from 0.28 to 0.31, with an average of 0.292 (Table 5), indicating predominantly elongated basin shapes with relatively low peak flow rates.

Infiltration Number (If)

The number of watersheds within the study area is analyzed based on drainage density and stream frequency, providing insights into the infiltration characteristics of the hydrological system. Infiltration number values in the study area range from 0.62 to 4.36, with an average value of 2.616 (Table 5). This suggests that lower infiltration numbers are associated with reduced infiltration capacity, leading to higher runoff rates, whereas higher infiltration numbers indicate increased infiltration, resulting in reduced runoff and enhanced groundwater recharge.

Length of overland flow (Lo)

The overland flow in the study area is defined as the average horizontal distance of the flow path from the watershed divide to the stream within the first-order basin. It is approximately inversely proportional to drainage density, as described by Chorley (1969). Steep, rocky terrains with sparse vegetation tend to generate higher runoff compared to flat plains with dense vegetation, as the latter facilitates greater water infiltration and retention. Areas with lower overland flow values tend to store water for longer durations due to enhanced infiltration rates, which may be influenced by the presence of geological formations such as sandstone, limestone, and shales. Although drainage parameters are present in the study area, their relevance to groundwater is not discussed here due to their limited applicability. The overland flow lengths across different watersheds in the study area range from 0.27 to 0.57, with an average value of 0.350 (Table 5).

Mean bifurcation ratio (Rbm)

The mean bifurcation ratio is a hydrological parameter that represents the average ratio of the number of streams in a given order to the number of streams in the next higher order within a drainage basin. It provides insights into the drainage network's branching pattern, reflecting the degree of geometric and hydrological organization. This ratio is commonly used to analyze basin shape, structure, and the influence of geological and geomorphological factors on drainage development.

Stream Frequency (Fs)

Stream frequency (FS) is defined as the total number of streams per unit area within the study basin and is calculated by dividing the total number of streams by the total drainage basin area. In the analyzed watershed, FS values range from 0.71 to 2.33, with an average of 1.56 (Table 5). The stream frequency for the study area is further refined by multiplying FS with drainage density to assess hydrological connectivity. Moreover, the infiltration number, which integrates stream frequency and drainage density, serves as an indicator of infiltration capacity—higher values signify reduced infiltration rates and increased runoff potential, whereas lower values are associated with enhanced infiltration and reduced runoff.

Table 2. Sub-watershed wise input morphometric parameters

Sr. No.	Details of Sub Watershed	Basin Area (A) (km^2)	Perimeter (P) (km)
1.	SW-I	193.26	85.17
2.	SW-II	228.07	89.21
3.	SW-III	134.26	57.41
4.	SW-IV	98.94	54.36
5.	SW-V	176.44	74.91

Table 3. Linear Aspect of morphometric parameters

Sub Watershed (SW)	Stream Order						Mean Bifurcation ratio
	I	II	III	IV	V	VI	
SW I							
No. of stream (Nu)	208	41	10	3	1	-	3.87
Stream length (Lu)(km)	156.24	83.25	37.04	16.15	17.61	-	
Mean stream length (km) (Lsm)	0.75	2.03	3.70	5.38	17.61	-	
Stream length ratio(km) (Rl)	0.53	0.44	0.44	1.09	0	-	
Bifurcation Ratio (Rb)	5.07	4.10	3.33	3.00	0	-	
SW II							
No. of stream (Nu)	194	47	13	3	1	-	3.77
Stream length Lu (km)	164.27	86.2	76.88	9.94	11.86	-	
Mean stream length (km) (Lsm)	0.85	1.83	5.91	3.31	11.86	-	
Stream length ratio(km) (Rl)	0.52	0.89	0.13	1.19	0	-	
Bifurcation Ratio (Rb)	4.13	3.62	4.33	3.00	0	-	
SW III							
No. of stream (Nu)	233.00	60.00	15.00	4.00	1.00	-	3.91
Stream length Lu (km)	128.36	48.61	42.91	21.62	9.77	-	
Mean stream length (km) (Lsm)	0.55	0.81	2.86	5.41	9.77	-	
Stream length ratio(km) (Rl)	0.38	0.88	0.50	0.45	0	-	
Bifurcation Ratio (Rb)	3.88	4.00	3.75	4.00	0	-	
SW IV							
No. of stream (Nu)	171.00	43.00	9.00	1.00	1.00	-	4.69
Stream length Lu (km)	88.20	42.78	31.45	7.56	12.25	-	
Mean stream length (km) (Lsm)	0.52	0.99	3.49	7.56	12.25	-	
Stream length ratio(km) (Rl)	0.49	0.74	0.24	1.62	0	-	
Bifurcation Ratio (Rb)	3.98	4.78	9.00	1.00	0	-	
SW V							
No. of stream (Nu)	97.00	23.00	3.00	0.00	2.00	1.00	2.78

Stream length Lu (km)	68.01	47.99	21.38	0.00	15.23	1.15	
Mean stream length (km) (Lsm)	0.70	2.09	7.13	0.00	7.62	0.87	
Stream length ratio(km) (Rl)	0.71	0.45	0.00	0.00	0.08	0	
Bifurcation Ratio (Rb)	4.22	7.67	0.00	0.00	2.00	0	

Table 4. Aerial and Relief Aspect of morphometric parameters

Parameters	**SW I**	**SW II**	**SW III**	**SW IV**	**SW V**
Aerial Aspects (Aa)					
Drainage Density (Dd)	1.61	1.53	1.87	1.84	0.87
Basin Length (Lb)	26.08	28.65	21.20	17.83	24.77
Stream Frequency (Fs)	1.36	1.13	2.33	2.27	0.71
Drainage Texture ratio (T)	3.09	2.89	5.45	4.14	1.68
Form Factor (Rf)	0.28	0.28	0.30	0.31	0.29
Circulatory Ratio (Rc)	0.33	0.36	0.51	0.42	0.39
Elongation Ratio (Re)	0.60	0.59	0.62	0.63	0.60
Compactness Constant (Cc)	1.73	1.67	1.40	1.54	1.59
Drainage Intensity (Id)	0.85	0.74	1.25	1.23	0.82
Length of overland flow (Lo)	0.31	0.33	0.27	0.27	0.57
Infiltration Number (If)	2.18	1.73	4.36	4.19	0.62
Relief Aspects (Ra)					
Basin Relief (R)	161.00	199.00	259.00	251.00	126.00
Relief ratio (Rr)	6.17	6.94	12.22	14.08	5.09
Ruggedness Number (Rn)	0.26	0.30	0.48	0.46	0.11

Table 5. Morphometric parameters for watershed prioritization

Prioritization Parameters	**SW I**	**SW II**	**SW III**	**SW IV**	**SW V**
Basin Length (Lb)	26.08	28.65	21.20	17.83	24.77
Circulatory Ratio (Rc)	0.33	0.36	0.51	0.42	0.39
Compactness Constant (Cc)	1.73	1.67	1.40	1.54	1.59
Drainage Density (Dd)	1.61	1.53	1.87	1.84	0.87
Drainage Intensity (Id)	0.85	0.74	1.25	1.23	0.82
Drainage Texture ratio (T)	3.09	2.89	5.45	4.14	1.68
Elongation Ratio (Re)	0.60	0.59	0.62	0.63	0.60
Form Factor (Rf)	0.28	0.28	0.30	0.31	0.29
Infiltration Number (If)	2.18	1.73	4.36	4.19	0.62
Length of overland flow (Lo)	0.31	0.33	0.27	0.27	0.57
Mean bifurcation ratio (Rbm)	3.87	3.77	3.91	4.69	2.78
Stream Frequency (Fs)	1.36	1.13	2.33	2.27	0.71
Compound Value	3.52	3.63	3.62	3.28	2.97
Priority	Moderate	High	High	Moderate	Low

WATERSHED PRIORITIZATION

Watershed prioritization is a critical process in the management and conservation of water resources, aiming to identify and allocate resources to areas that require the most crucial intervention.

Watershed priority was determined by computing the compound value (Cp) of morphometric parameters in the research area. Table provides the morphometric criteria used to prioritize watersheds, whereas Fig. depicts the final prioritized map of the research area. Watersheds are divided into three priority zones (Fig.2) based on their compound value (Cp) and the range is illustrated in table 5.

High Priority

SW-II and SW-III watersheds are classified as high priority. These watersheds have steep slopes, high drainage density, high compactness constant, and a high compound value. These can be classed as highly severe erosion susceptibility watershed zones, requiring rapid attention to soil conservation techniques, gully control structures, and grass streams to protect topsoil loss in the research area.

Medium Priority

The SW I and SW IV watersheds are classified as medium priority. These watersheds have moderate slopes, drainage intensity, stream frequency, and a medium compound value.

Low Priority

The SW V watersheds are classified as low priority. This sub-watershed has lower slopes, low drainage density, circulatory ratio, and low compound values. This watershed is in the very mild erosion susceptibility zone and may require agronomic interventions to prevent sheet and rill erosion.

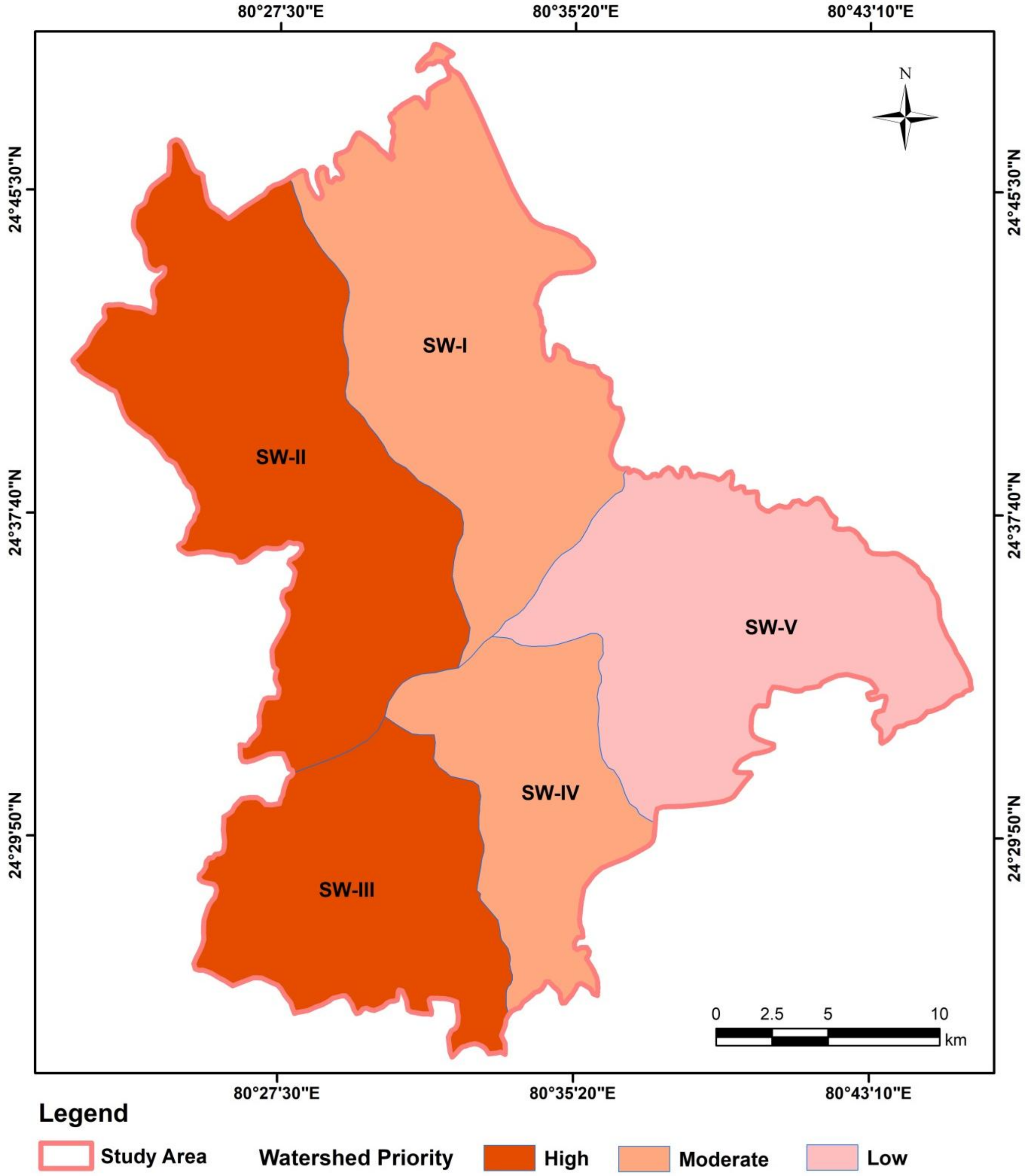

Fig. 2: Watershed prioritization of the Study Area

Principal Component Analysis

Principal Component Analysis (PCA) is applied to assess the correlation matrix and identify dominant parameters that exert the most significant influence on watershed dynamics, thereby enabling the dimensionality reduction of geomorphic parameters. The PCA computations are conducted using SPSS version 26.0, employing the first-factor loading matrix, rotated factor loading matrix, and varimax rotation method to enhance factor interpretability. To guide the implementation of soil and water conservation measures, a predefined ranking system based on geomorphic parameter analysis is utilized. Principal Component Analysis (PCA) was performed on 12 relevant morphometric parameters (Table 5) to effectively capture the relationships among these variables. These relationships are represented by the percentage of variance explained by the input morphometric parameters (Table 6). As shown in Table 7, the first principal component exhibits a strong correlation with Rf and Fs, a satisfactory correlation with Id, If, and T, and a moderate correlation with Re and Rc. The principal component matrix, derived from the correlation matrix, indicates that the components are ranked in decreasing order of importance based on their eigenvalues, as observed in the related tables. Interpretation of the rotated principal components is achieved through component loadings, highlighting their connections to the original variables. This analysis demonstrates the effectiveness of PCA in identifying and excluding less significant morphometric parameters while grouping the remaining variables into meaningful physical factors, with two principal components accounting for 74.431 % and 92.082 % of the total variance (Table 7). The component matrix and the rotated matrix are presented in Table 6.

Table 6.-Inter-correlation matrix of major morphometric parameters

Correlation Matrix[a]													
		Lb	Rc	Cc	Dd	Id	T	Re	Rf	If	Lo	Rbm	Fs
Correlation	Lb	1.000	-.655	.695	-.465	-.925	-.605	-.989	-.975	-.770	.333	-.569	-.792
	Rc	-.655	1.000	-.994	.398	.821	.763	.687	.716	.692	-.259	.194	.702
	Cc	.695	-.994	1.000	-.334	-.821	-.707	-.712	-.764	-.659	.188	-.168	-.672
	Dd	-.465	.398	-.334	1.000	.675	.887	.585	.411	.904	-.987	.902	.889
	Id	-.925	.821	-.821	.675	1.000	.855	.964	.902	.925	-.548	.626	.938
	T	-.605	.763	-.707	.887	.855	1.000	.711	.581	.954	-.812	.682	.948
	Re	-.989	.687	-.712	.585	.964	.711	1.000	.957	.855	-.460	.650	.873
	Rf	-.975	.716	-.764	.411	.902	.581	.957	1.000	.736	-.275	.520	.756
	If	-.770	.692	-.659	.904	.925	.954	.855	.736	1.000	-.823	.823	.999
	Lo	.333	-.259	.188	-.987	-.548	-.812	-.460	-.275	-.823	1.000	-.897	-.803
	Rbm	-.569	.194	-.168	.902	.626	.682	.650	.520	.823	-.897	1.000	.814
	Fs	-.792	.702	-.672	.889	.938	.948	.873	.756	.999	-.803	.814	1.000
a. This matrix is not positive definite.													

Table 7.-Total variation of major morphometric parameters analysed through PCA

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.932	74.431	74.431	8.932	74.431	74.431
2	2.118	17.652	92.082	2.118	17.652	92.082
3	.875	7.289	99.371			
4	.075	.629	100.000			
5	1.004E-013	1.037E-013	100.000			
6	1.004E-013	1.033E-013	100.000			
7	1.002E-013	1.017E-013	100.000			
8	1.001E-013	1.007E-013	100.000			
9	-1.000E-013	-1.001E-013	100.000			
10	-1.002E-013	-1.020E-013	100.000			
11	-1.004E-013	-1.031E-013	100.000			
12	-1.008E-013	-1.067E-013	100.000			
Extraction Method: Principal Component Analysis.						

V. CONCLUSION

The watershed analysis was conducted using remote sensing and GIS methodologies, with a focus on morphometric characterization. The hydrogeological features of study area are characterized by undulating topography, and hydroological investigations suggest that the dominant lithology exhibits high permeability. Bifurcation ratio (Rb) values indicate minimal structural disturbances within the watershed delineations. Watersheds exhibiting low drainage density values are indicative of moderate runoff potential and moderate to high permeability, likely attributable to the underlying sandstone formations. Drainage density generally shows an inverse relationship with the length of land flow, serving as a key indicator of watershed drainage efficiency. The observed dendritic drainage pattern suggests an absence of uniform structural control and tectonic influence on basin morphology. Remote sensing and GIS technologies have proven importance for effective drainage management and hydrological resource planning. Morphometric analyses are essential for developing strategic approaches to groundwater resource management. This study highlights the significance of watershed prioritization based on morphometric parameter analysis of the Nagod Watershed area, employing remote sensing, GIS, and Principal Component Analysis (PCA). These advanced methodologies have demonstrated considerable efficacy in delineating hydrological characteristics and facilitating objective watershed prioritization. This prioritization is crucial for developing targeted conservation strategies, as it enables the identification of the most vulnerable sub-basins that require prompt and focused management efforts. The strategic construction of water conservation structures within these prioritized sub-basins can effectively attenuate runoff, reduce soil erosion, and promote aquifer recharge, thereby supporting sustainable watershed management.

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