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Morphometric Analysis of Waghora Micro Watershed of Jam River Basin Using ALOS-PALSAR DEM

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Intergrating Remote sensing and Geographic Information System(GIS) Proves useful for Evaluating and understanding morphometric parameters, especially Watershed Management of - Soil and Water Conservation at microlevel for sustainable Natural Resource management. The Linear , Areal and Relief characteristics of the basins Drainage can be analytsed Morphometrically. In this investigation, geospatial techniques were employed to assess the hydrological features of the Waghora Micro watershed within the Jam River basin, covering an area of 13.03 km². Utilizing the ALOS-PALSAR RTC DEM -12.5 m resolution, the basin and drainage network were delineated using ArcGIS software. The analysis revealed a dendritic drainage pattern within the Waghora micro-watershed, with drainage streams delineated up to the fourth order. The ratio of bifurcation

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(Rb) can be ranged within ~ 3 - 4.66, with an mean average of 3.76, showcases Geologic Structures are undistorted and the drainage system sorted by moderate peaks and lower orer streams. Additional morphometric parameters were assessed, using Form-factor(Rf), Circulatory-Ratio(Rc), and finally Elongation-Ratio(Re) values of 0.32, 0.68, and 0.62 respectively. This is a clear indication of Micro watershed being moderately Elongated with time. The Estimated Relief, Relief Ratio(Rr), relative Relief (RR) and Ruggedness Ratio Number were determined to be 75 m, 1.2, 0.97, respectively, indicating a moderate erosion potential. Overall, the study underscores the necessity for implementing – Soil and Water Conservation measures to be taken within the watershed. These findings hold significant implications for various stakeholders, including managers and decision-makers involved in Management of Watersheds and Conservation of the Natural resources using sustainable initiatives.

Keywords: Morphometric analysis; ArcGIS; remote sensing; DEM; watershed management; AlOS-DEM.

1. INTRODUCTION

The imperative of promptly addressing agricultural land degradation is underscored, coupled with advocacy for the implementation of production systems aimed at conserving soil quality to guarantee the long-term sustainability of agriculture [1]. In order to effectively address and mitigate the impacts of land degradation, watershed planning is essential. Watershed planning involves the careful management and organization of land use within a specific watershed area to ensure that it continues to provide essential goods and services without compromising soil productivity and water resources [2]. Effective land and water management strategies tailored to each watershed are essential [3].

Watershed morphometric analysis is employed to characterize the hydrological response behavior [4], soil water conservation measure [5] Diverse morphometric analyses offer insights into the physical attributes of watersheds, facilitating applications in land use planning, soil conservation, terrain elevation, and soil erosion management [6] and addressing the immediate need to assess the magnitude of issues related to waterlogging, alkalinity, and salinity is imperative, necessitating the establishment of assessment norms and the identification of appropriate technologies for prevention, reclamation, and management [7].

Integrating morphometric parameters with thematic maps, including land use/cover, soil, and drainage density information, aids in the decision-making process for water resources management in areas with poor contouring, contour bunds can be constructed to enhance groundwater recharge and facilitate [8]. Morphometric analysis outcomes offer a foundation for policymakers and planners to formulate erosion control strategies [9,10] Further more we can use this analysis to understand the drain patterns which will help in building preventive strategies (Root Blocking, Strain Resilience) as well as be a building block for Water harvesting(Micro Funneling). Maximizing the natural resources and reusing them strategically will further help in maintaining the Floura and Fauna of the Land. And lastly while developing any structure for manmade use (Buildings, Roads, Highways, etc) these patterns will help us construct new structures resilient to the natural deformations that can be caused due to the lands natural attributes [11,12]. These measures also furnish valuable insights for decision-makers and policymakers to devise pre-assessment strategies for peak flooding events and sustainable land-use policies [13]. Remote sensing and GIS-based approaches are superior to conventional methods for evaluating drainage morphometry, landforms, and land resources, as well as understanding their interrelationships for river basin planning and management [8,14-18].

The Waghora micro watershed Jam River basin showcases a diverse array of physiographic units. However, the management of this area suffers from inconsistent land use practices and inadequate measures issues. This can be further elaborated by analyzing the lands history. We have consistently observed patterns such as waterlogged soil every year which could be due to the permeability of the soils and subsurface, soil compactness which can be due to the ruggedness and terrain formation. Understanding these issues are vital for resolving soil Erosion problems which we will study using morphometric analysis. We know that soil erosion disrupts all the natural hydrological processes. It compromises the soils structure, integrity and accelerates erosion. Addressing these challenges requires holistic approaches that integrate land cover assessment with morphometric analysis to devise targeted land management strategies. Understanding the linear, aerial, and relief features of the watershed is crucial for effectively characterizing it and directing developmental efforts towards optimizing its natural resources. With this goal in mind, an endeavor was undertaken to evaluate the watershed's morphometric parameters utilizing Remote Sensing (RS) and Geographic Information System (GIS) tools.

2. METHODOLOGY

2.1 Study Area

The Waghora microwatershed is situated in the southern region of Sausar tehsil within the Chhindwara district of Madhya Pradesh, India. It constitutes a part of the Jam River basin and is situated between 21º 33' 36" to 21 º 36' N latitude and 78 º 45' 36" to 79 º 48' 36" E longitude. The watershed covers an area of about 1303 ha, this watershed is identified and labeled as 4E8E5a3 according to the Soil and Land Use Survey of India (2017). Within this area, elevations vary from 328 meters to 479 meters. The region experiences an annual rainfall of 1211.7 mm, characterized by a subtropical, dry, and subhumid climate, featuring distinct seasons including summer (March to May), monsoon (June to September), post-monsoon (October to November), and winter (December to February). The mean annual temperature stands at 25.4°C, with summer reaching a mean maximum of 41.70 °C and winter recording a mean minimum of 11.70°C. The study area map is shown below in Fig. 1.

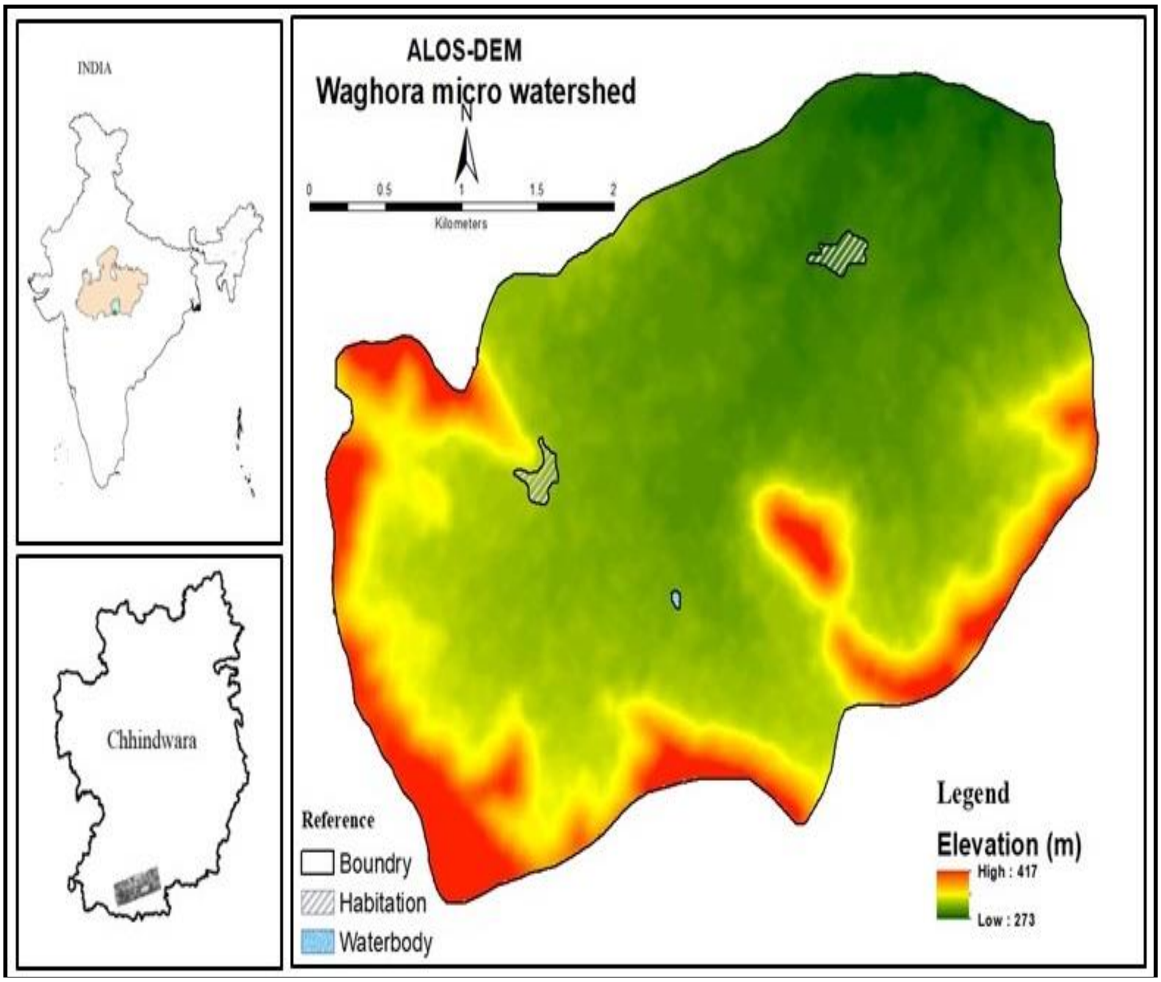

Fig. 1. Location map of waghora micro-watershed of Jam river basin

2.2 Materials and Methods

The study utilizes the High-Resolution ALOS-PALSAR RTC DEM obtained from the Alaska Satellite Facility, featuring a spatial resolution of 12.5 meters, for the purpose of identifying and extracting the drainage network to conduct morphometric analysis. The use of the PALSAR active microwave sensor operating at L-band frequency facilitates the generation of high-resolution DEM products immune to weather conditions and suitable for day and night observations. Additionally, the ALOS-PALSAR RTC DEM undergoes processing, including conversion from orthometric height to ellipsoid height, to ensure consistency with other DEM elevations. This dataset's fine spatial resolution enables the detection of even shallow and narrow drainage networks that may be missed by coarser resolution products. The extraction of the watershed and stream networks from the ALOS-PALSAR DEM is automated using the Model Builder tool in ArcGIS 10. This toolset employs a graphical interface where various geoprocessing tools and their respective parameters are interconnected to process input data. Preprocessing steps involve utilizing a fill tool to rectify sinkhole errors in the input DEM, followed by flow direction analysis for each pixel using a deterministic eight-node approach [18], which analyzes the eight directions from a pixel where water flows outward. This flow direction raster

Table 1. Formula for calculating morphometric parameters

Sr No.	Morphometric Parameters	Formulae	Reference
(A)	***Linear aspect***		
1.	Stream Order	Hierarchical rank	[25]
2.	Stream number (Nu)	Nu = N1 + N2 + …… + Nn where N1 = Order of stream	[26]
3.	Stream Length (Lu)	Lu = L1 + L2 + …… + Ln where L = Length of the basin	[26]
4.	Mean stream length (Lsm)	Lsm = Lu/Nu where Lu = Total stream length of order ‘u’ Nu = Total no. of stream segments of order ‘u’	[25]
5.	Stream length ratio (Lur)	Lur = Lu/Lu – 1 where Lu = Total stream length of order ‘u’	[26]
6.	Bifurcation Ratio (Rb)	$Rb=N_u/N_{u+1}$ where Nu = Total steam segments of order ‘u’ Nu + 1 = stream length of its next higher order	[27]
7.	Rho coefficient (ρ)	ρ = RL/Rb where RL = stream length ratio; Rb = bifurcation ratio	[26]
(B)	***Areal aspect***		
1.	Basin area (A), km2	Area enclosed within the boundary of watershed divide	[25]
2.	Basin length (Lb), km	Lb =Distance between outlet and farthest point of basin boundary	[26]
3.	Basin perimeter (P),km	P = Outer boundary of drainage basin	[27]
4.	Drainage Density (D)	D=Lu/A where Lu = Total stream length of all orders; A = Basin area	[26]
5.	Length of overland flow (Lg)	Lg = 1/2 × Dd where Dd = Drainage density	[26]
6.	Stream Frequency (Fs)	Fs=Nu/A where Nu = Total no. of streams of all orders; A = Basin area	[28]
7.	Drainage Texture (Rt)	Rt=Nu/P where Nu = Total no. of streams of all orders; P = Perimeter (km)	[27]

8.	Elongation Ratio (Re)	Re=2/Lb sqrt (A/π) where A = Basin area; Lb = Basin length	[28]
9.	Form Factor (Rf)	Rf=A/Lb2 where A = Basin area; Lb2 = Square of basin length	[28]
10.	Circularity Ratio (Rc)	Rc=4*π *A/P2 where A = Basin area (km2); P2 = Square of the perimeter (km2)	[29]
11.	Constant of channel maintenance	C = 1/Dd where Dd = Drainage density	[27]
12.	Compactness coefficient	Cc = 0.2821P/A0.5 where P = Basin perimeter; A = Basin area	[26]
(c)	***Relief aspects***		
8.	Basin relief (H)	(Maximum elevation – Maximum elevation)	[25]
9.	Relief Ratio(Rh)	Rh = R/L where H = Maximum basin relief; Lb = Basin length	[27]
10.	Ruggedness number (Rn)	Rn = Dd*(Rh/1000) Where Dd= drainage density; Rh=relief ratio	[25]

output is also employed to compute flow accumulation, which in turn aids in generating streams by setting a critical threshold as per recommendations from previous studies for morphometric analysis [20-23]. similar methodology were used by Aziz et al.[24] Subsequently, generated streams are used for snapping pour points, facilitated by a point shapefile, which serves as input for extracting the watershed. Additionally, the input DEM is utilized to extract aspect, contour, and slope information for the study area.

2.3 Morphometric Indices

The morphometric indices include calculation of majorly three aspects, namely, linear, areal, and relief which consists of various parameters, respectively. Linear aspects include morphometric parameters such as stream order (Nu), stream length (L), bifurcation ratio (Rb), stream length ratio (Rl), mean stream length (Lµ), Rho coefficient (ρ), whereas areal aspects include stream frequency (Fs), drainage density (Dd), drainage texture (Rt), circularity ratio (Rc), form factor (Ff), and elongation ratio (Re), and the relief aspects includes relief ratio (Rh), relative relief (Rhp), ruggedness number (Rn), and length of overland flow (Lg).The respective mathematical formulas used to assess the morphometric indices are given in Table 1.

3. RESULT AND DISCUSSION

This research presents a morphometric analysis of the Waghora micro watershed, examining it from three distinct perspectives: Linear, Areal, and Relief. Additionally, the study evaluates the slope, aspect, and drainage density of the basin, providing crucial insights into watershed management. These parameters are explained further based on various hydrological factors listed:

3.1. Linear Aspects

The linear aspect encompasses all linear features within a drainage basin, including Stream Order (w), Stream Number (Nu), Bifurcation Ratio (RbF), Stream length (km), and their respective means, as illustrated in Table 2.

3.1.1. Stream order and number of streams

Establishing the stream order (Nu) serves as the initial phase in morphometric analysis of a watershed. As depicted in Table 2 and presented in Fig 2(a), the data reveals that the Waghora micro-watershed exhibited a fourth-order drainage stream. Specifically, there were 51 streams of first order, while the second, third, and fourth-order streams numbered 14, 3, and 1 respectively. The decrease in the number of stream segments with ascending stream order aligns with the principles outlined in Horton's laws [26].

Table 2. Morphometric parameters (linear aspects) of Waghora micro-watershed

Stream Order (w)	No. of Streams (Nu)	Total Length of Streams (Lu) (km)	Mean Length of Streams (km)	Length Ratio (RL)	Bifurcation Ratio (RbF)	Mean Bifurcation Ratio (Rbm)	Rho coefficient (ρ)
1	51	19.74	0.38		3.64	3.76	
2	14	7.87	0.56	0.39	4.66		0.10
3	3	5.59	1.86	0.71	3		0.15
4	1	3.36	3.36	0.60			0.2
Total	69	36.57			11.3		0.45

3.1.2 Stream length

In the Waghora micro-watershed, the lengths of streams of orders 1, 2, 3, and 4 measured 19.74 km, 7.87 km, 5.59 km, and 3.36 km respectively. The combined length of all streams in this watershed was calculated to be 36.57 km. Notably, it was observed that the total length of stream segments was highest for first-order streams and decreased progressively with higher stream orders. This pattern echoes findings reported by Deka et al. [17] in their study conducted in the Dhemaji District of Assam, India.

3.1.3 Mean stream length

The mean stream length values for the Waghora micro-watershed were computed for all four orders, yielding 0.38, 0.56, 1.86, and 3.36 as shown in Table 2 for stream orders 1, 2, 3, and 4 respectively. Notably, these values exhibit an increasing trend with the order. This finding is consistent with the results reported by Premanand et al. [5]

3.1.4. Stream length ratio

The stream length ratio within the Waghora micro watershed ranged between 0.39 and 0.70. Notably, there was an observed ascending trend in the stream length ratio from lower to higher orders, suggesting a mature geomorphic stage. These results align with those reported by Nayar et al. [30] in their study of the Kosasthalaiyar River in India.

3.1.5. Bifurcation ratio

The bifurcation ratio represents the ratio of stream segments of a particular order to those of the next higher order. According to various studies, a ratio of less than five (5) is typically classified as low, while a ratio exceeding five (5) falls into the high category. A low classification suggests that the drainage pattern is unaffected by geological structures, whereas a high classification indicates that geological structures influence the drainage pattern. Within this basin region, the bifurcation ratio ranges from 3 to 4.66, indicating minimal structural disturbance. The mean bifurcation ratio is calculated at 3.76.

The bifurcation ratio holds significance in examining drainage basins as it aids in interpreting basin shape and runoff behavior. Higher bifurcation ratio values correspond to increased flood risk. Therefore, the low bifurcation ratio observed in our area suggests a low flood risk. The bifurcation ratio of the Waghora micro-watershed was not the same from one order to the next which might be due to the possible variations in basin geometry and lithology. A similar finding was also reported by the study of Desai et al. [31]

The Rbm is the mean of all the sum of the values. The value of Rbwmin the research area was 3.76 (Table.2). The watershed mean bifurcation ratio indicates that there is negligible influence of geological features on the drainage network, due to the variation in geology and lithology in the watershed [32].

3.1.6 Rho coefficient (ρ)

The Rho coefficient signifies the correlation between drainage density and the physiographic maturity of a watershed, offering insights into the water storage capacity within it. Elevated Rho coefficient values denote a greater capacity for water storage. In the case of the Waghora micro watershed, the computed Rho coefficient stands at 0.45, indicative of a high hydrological storage capacity, particularly during flood periods [17].

3.2 Areal Aspects

The areal aspects of a watershed encompass diverse areal components, including Area (km²), length (km), Perimeter (km), Drainage Density (Dd), Elongation Ratio (Re), Drainage Texture (T), Stream Frequency (Fs), Form Factor (Ff), and Circulatory Ratio (Rc). These findings are detailed in Table 3.

3.2.1 Basin area, length and perimeter

The runoff rate of a drainage basin is contingent upon both its area and physiography. Generally, smaller basin areas (A) tend to yield larger runoff, whereas larger areas lead to diminished runoff. For the Waghora micro-watershed, the basin area, length, and perimeter were measured at 13.03 km², 5.63 km, and 15.55 km respectively.

3.2.2 Drainage density

Drainage density (Dd) quantifies the total length of stream segments across all orders per unit area of the watershed. In the case of the Waghora micro-watershed, the computed drainage density was determined to be 2.80 km/km². This figure may be attributed to factors such as permeable subsurface material, dense vegetation cover, and relatively low relief [33,34].

3.2.3 Drainage pattern

“The drainage pattern (Dp) reflects the impact of slope, lithology, structure and it helps in recognizing the stage in the cycle of erosion. The drainage pattern for the Waghora micro-watershed was found to be dendritic and radial which indicates that the time of formation of the drainage basin was longer” [35].

3.2.4 Length of overland flow

The length of overland flow (Lg) represents the distance water travels over the land surface before converging into distinct stream channels [25]. In the Waghora micro-watershed, the calculated length of overland flow is 1.4 km. A higher value of Lg suggests gentle slopes and longer flow paths [36], facilitating increased infiltration and reduced runoff [37] within the study area.

3.2.5 Stream frequency

Stream frequency (Fs) is influenced by lithology, slope gradient, stage of fluvial cycle, and surface runoff. In the Waghora micro-watershed, the calculated stream frequency is notably high at 5.29. This suggests the presence of impermeable subsurface materials, limited infiltration, and low relief conditions, potentially accompanied by reduced erosion [38]. 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 [39].

3.2.6 Drainage texture

Drainage texture (Dt) denotes the spacing between drainage lines and provides insights into basic lithology, infiltration capacity, and topographic relief. In the Waghora micro-watershed, the calculated drainage texture value is 14.83, indicating a very fine texture. A watershed with a very fine texture or a high drainage texture value (>8) suggests an increased risk of soil erosion.

3.2.7 Elongation ratio

The elongation ratio (Re) serves as an indicator of the river basin's shape, influenced by both climatic and geological factors. Three classes are typically used to classify Re: less elongated (< 0.7), oval (0.8 – 0.9), and circular (>0.9) [24,40,41]. In the case of the Waghora micro-watershed in India, the elongation ratio was measured at 0.72, indicating a moderately elongated shape, with moderate relief and slope in the study area.

3.2.8 Form factor

The calculated value of the form factor for the Waghora micro-watershed was 0.41. A lower value of form factor <0.78 indicated that the shape of the basin was elongated s it has low peak flows for longer duration. A low form factor (0.32) was also observed by [5,42] in the Patapur Micro-watershed in North-Eastern Dry Zone of Karnataka India indicating a flatter peak of flow for a longer duration in the basin.

3.2.9 Circularity r atio (Rc)

The circulatory ratio (Rc) is primarily influenced by factors such as geology, slope, structure, relief, stream frequency, climate, length, and land use/land cover within the basin area. Higher values of the circulatory ratio correspond to increased flood hazard during peak times at the outlet point. In the case of the Waghora micro-watershed, the circulatory ratio was recorded at 0.68, suggesting an elongated basin with permeable sub-soil, associated with high discharge of runoff materials [28]. Similarly, Narmatha et al. [43] observed a comparable circulatory ratio (0.61) in the Ponnaiyar River basin of Tamil Nadu, India, indicating low runoff discharge and highly permeable sub-soil.

3.2.10 Constant of channel maintenance

The computed constant of channel maintenance (C) for the Waghora micro-watershed was determined to be moderate at 0.35 km^2/m. This moderate value suggests moderate permeability, slope, and surface runoff within the area [44,45].

3.2.11 Compactness coefficient

The compactness coefficient (Cc) directly correlates with erosion risk assessment [46]. Lower Cc values imply reduced vulnerability to risk factors, while higher values suggest increased vulnerability, necessitating conservation measures [47]. In the case of the Waghora micro-watershed, the compactness coefficient was measured at 1.20, indicating a moderate erosion status within the studied area [45].

3.3 Relief Aspects

The results of morphometric parameters related to relief aspects of the Waghora micro-watershed are presented in Table 3.

3.3.1. Basin relief

Basin relief (H) denotes the variation in elevation between the lowest and highest points within a basin. In the Waghora micro-watershed, the computed basin relief was 75 meters. A lower basin relief value suggests increased infiltration and reduced runoff, aligning with the conclusions drawn by Chaudhari and Kumar [44].

3.3.2 Relief ratio

The relief ratio (Rh) serves as a gauge of the general steepness of a drainage basin, aiding in the assessment of erosion intensity along its slopes. Typically, the relief ratio tends to rise with diminishing drainage area and size of the watershed within a given drainage basin [48]. In the case of the Waghora micro-watershed, the calculated relief ratio was determined to be 1.2, suggesting gentle slopes within the study area. These findings parallel those reported by Sahu et al. [48] for a comparable watershed in the Nagpur district of Maharashtra, India.

3.3.3 Ruggedness number

The ruggedness number (Rn) serves as an indicator of a basin's susceptibility to soil erosion, with higher values indicating increased proneness and vice versa. In the case of the Waghora micro-watershed, the calculated ruggedness number stood at 0.97. Watersheds characterized by high Rn values typically undergo dynamic geomorphic processes, featuring long and steep slopes punctuated by abrupt breaks due to rejuvenation. Consequently, such catchments exhibit heightened susceptibility to soil erosion, sediment load generation, mass movements, and heightened response to increased peak discharge. This finding resonates with results reported by Singh et al. [49] in the Dudhani watershed, India, suggesting very low infiltration, elevated surface runoff, and an increased risk of soil erosion.

Table 3. Areal Aspects of Waghora micro-watershed

S.no.	Areal Aspect	Value
1	Basin Area (km^2)	13.03
2	Perimeter (km)	15.44
3	Basin Length (km)	5.63
4	Drainage Density (km/km^2)	2.80
5	Length of overland flow	1.4
6	Stream Frequency (Fs)	5.29
7	Drainage Texture (T)	14.83
8	Elongation ratio	0.72
9	Form factor	0.41
10	Circularity Ratio (Rc)	0.68
11	Constant of channel maintenance (c)	0.35
12	Compactness of coefficient (Cc)	1.20

Table 4. Morphometric characteristics (relief aspects) of Waghora micro-watershed

S.No.	Relief parameters	Value
1	Maximum elevation, m	373
2	Minimum elevation, m	248
3	Basin relief (H), m	75
4	Relief ratio (Rh)	1.2
5	Ruggedness number (Rn	0.97

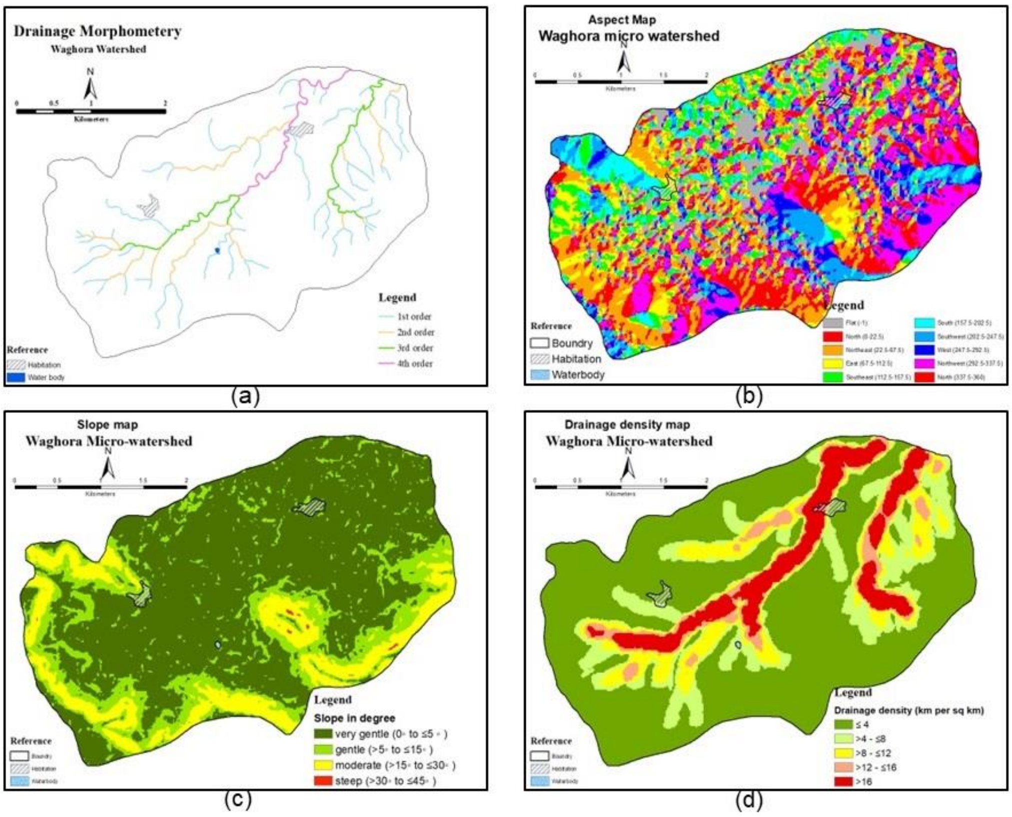

Fig. 2. (a) Drainage Basin Map; (b) Slope Map; (c) Aspect Map; (d) Drainage Density Map

3.4. Aspect

Aspect indicates the direction of a slope. In this context, slope directions are categorized based on degrees: from 0–22.5° as north, from 22.5–67.5° as northeast, and so forth. In the present study, the aspect is south-facing, as illustrated in Fig. 2b. This suggests that the south-facing slope tends to have greater vegetation cover and moisture content in comparison to the north-facing slope.

3.5 Slope

Slope defines the steepness of the area. In the Waghora micro-watershed, the maximum height is 417 m, whereas the minimum height is 273 m. Here, the slope is divided into five classes, (Illustrated in Fig. 2c) (0° to ≤5 °) is very gentle, (>5° to ≤15°) is gentle, (>15° to ≤30°) is moderate, (>30° to ≤45°) steep. Slope map showed that the basin is ranging from Very Gentle to moderate slope pattern. A very gentle slope is great for groundwater infiltration as it has less runoff comparted to steep or higher slopes. The morphometric factor associated with slopes shows the Hydrology of the Runoff Volumes and Concentration time [50], While a higher slope is associated with Higher Erosion [51,52].

3.6 Drainage Density

We define the drainage density of the basin as the total Length of Stream per unit area. In this study, drainage density is classified into five categories, as illustrated in Fig. 2d: very low (≤4 km/km²), low (>4 km/km² to ≤8 km/km²), moderate (>8 km/km² to ≤12 km/km²), high (>12 km/km² to ≤16 km/km²), and very high (>16 km/km² to 34.32 km/km²).On the Map red indicates areas of highest drainage densities – inferring presence of gullies. While the Majority of the basin has Very Low – Low Drainage Density.

4. CONCLUSION

We Studied the morphometric characteristics using Remote Sensing and GIS techniques for Waghora micro-watershed in Jam River Basin, India. By analyzing and understanding the drainage morphometric parameters, aspects of hydrology and morphology of the watershed were depicted. From this Paper we understood the classification and management of watersheds using various factors such as Stream length, Drainage Systems, Topology of land, water division, the geomorphologic setup etc. What we understand now is that the watershed has fourth order drainage streams with a total length of 36.57 kms in Stream length. This is based on the morphometric studies. Due to the Dendritic type of Basin drainage system, we understand various topological aspects such as infiltration rate, runoff and so on. Furthermore, due to the low bifurcation ratio and the primary drainage pattern – Dendritic, we get a clear indication of low structural disturbance to the watershed along with the elongated nature further is observed due to low value of form factors, elongation ratio as well as circularity ratio. We also see that the area is permeable at the subsurface, has dense vegetation cover and a relatively low relief, all this is from the lower drainage density. From this analysis and results we can observe that the Erosion can be predicted with our studies in particular to watershed prioritization. We can further Explore drainage morphologies for exploring, and selecting water storage structures such as ponds, check dams, percolation tanks etc. At microlevel of natural resource management, the planning and decision making can be made based on these studies particularly for sustainable watershed development programs as they will greatly value any terrain for its resources. In near future, these studies are crucial in investigating the hydro-geological and geo-physical aspects for efficient and effective watershed management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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