GIS And Remote Sensing Based Morphometric Analysis of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India

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ABSTRACT

Morphometric analysis provides a quantitative understanding of the drainage characteristics, basin geometry, relief, and hydrological behaviour of a river basin. The present study focuses on the morphometric assessment of the Dadi River Watershed in Amravati Taluka, Amravati District, Maharashtra, India, using Remote Sensing and Geographic Information System (GIS) techniques. The drainage network and basin characteristics were delineated using CartoSat-1 PAN CartoDEM (30 m spatial resolution) data and analysed in a GIS environment. Various morphometric parameters representing linear, areal, and relief aspects were calculated to understand the structural and physiographic characteristics of the watershed. The Dadi River Watershed exhibits a dendritic to sub-dendritic drainage pattern with a maximum stream order of 5, suggesting that the drainage network may reflect the influence of the watershed's lithological and structural setting. First-order streams constitute approximately 80.13% of the total stream network. The mean bifurcation ratio of 4.54 suggests that the drainage network may not be strongly influenced by geological structural disturbances. The drainage density and stream frequency are 3.39 km/km² and 7.76 streams/km², respectively, indicating a moderately developed drainage network. The elongation ratio, circularity ratio, and form factor are 0.70, 0.46, and 0.39, respectively, indicating an elongated to irregular basin shape. The relief analysis indicates an elevation difference of 108.57 m across the watershed, reflecting variations in terrain elevation. The results demonstrate that GIS and Remote Sensing techniques provide an effective approach for evaluating the morphometric characteristics of the Dadi River Watershed. The findings can support watershed planning, groundwater and surface-water resource management, soil conservation, and sustainable development of the watershed.

Keywords: Morphometric Analysis, GIS, Remote Sensing, Stream Network, Dadi River Watershed

INTRODUCTION

Morphometric analysis is a quantitative approach used to evaluate the geometric characteristics and physical configuration of a drainage basin and its associated landforms. It provides a systematic means of describing the organization of a drainage network and the dimensional characteristics of a basin through measurable parameters (Clarke, 1966). Drainage basins represent fundamental geomorphic units in which the arrangement of streams, basin shape, drainage texture, and relief characteristics can be quantitatively examined to understand the development and spatial organization of the fluvial system (Abrahams, 1984; Huggett & Cheesman, 2002).

The morphometric characteristics of a drainage basin are commonly evaluated under three major components: linear, areal, and relief aspects. The linear aspect includes parameters such as stream order, stream number, stream length, and bifurcation ratio, which describe the hierarchical arrangement and geometry of the drainage network. The areal aspect comprises parameters related to basin size, drainage density, stream frequency, drainage texture, form factor, elongation ratio, and circularity ratio, which provide information about basin geometry and drainage characteristics. The relief aspect deals with parameters such as basin relief, relief ratio, slope, and ruggedness, which represent the elevation variation and terrain configuration of the basin (Strahler, 1957, 1964).

The development and organization of a drainage network are influenced by several physiographic and geological factors, including lithology, geological structure, relief, slope, and surface characteristics. Variations in these controlling factors can produce differences in drainage pattern, stream development, basin geometry, and relief characteristics. Quantitative morphometric analysis therefore provides a useful framework for examining drainage characteristics in relation to the physical conditions of a basin (Horton, 1945; Zende & Nagrajan, 2011).

The systematic study of drainage-basin morphometry was initially developed through the pioneering contributions of Horton (1932, 1945). His work established a quantitative basis for analysing drainage networks and basin characteristics. Subsequently, several geomorphologists further developed these concepts, particularly through studies of stream ordering, bifurcation characteristics, basin geometry, drainage composition, and relief. Strahler (1957, 1964) advanced the quantitative analysis of drainage basins by establishing systematic approaches to stream ordering and morphometric measurements, which have since been widely applied in drainage-basin studies.

The integration of Remote Sensing and Geographic Information System (GIS) techniques has improved the efficiency of morphometric analysis. GIS provides an effective environment for delineating basin boundaries, extracting drainage networks, measuring stream characteristics, and calculating morphometric parameters from spatial and elevation data. Digital Elevation Models (DEMs) and remotely sensed data can therefore be used to analyse drainage-basin geometry and relief characteristics within a systematic spatial framework (Magesh et al., 2011; Pande & Moharir, 2017).

Although morphometric analysis has been applied to numerous drainage basins in different geological and physiographic settings, detailed quantitative information on the morphometric characteristics of the Dadi River Watershed in Amravati District, Maharashtra, remains limited. The present study addresses the following research question: What are the principal linear, areal, and relief characteristics of the Dadi River Watershed, and what do these parameters reveal about its drainage-network organization and basin geometry? The novelty of this study lies in providing a systematic, watershed-specific morphometric characterization using Remote Sensing and GIS techniques based on CartoSat-1 PAN CartoDEM data with a spatial resolution of 30 m. The findings establish a quantitative baseline for future watershed investigations and may inform regional watershed planning and water-resource management. However, implications for groundwater potential, infiltration, runoff, and soil erosion require further investigation using independent geological, hydrological, or field-based data.

Study Area

The Dadi River Watershed is located in Amravati Taluka, Amravati District, Maharashtra, India. The geographical location and extent of the study area are shown in Figure 1. The watershed represents a distinct drainage unit suitable for quantitative morphometric investigation. It lies between approximately 21°01′30″ N and 21°06′00″ N latitude and 77°47′30″ E and 77°55′00″ E longitude, covering an area of approximately 61.63 km².

The drainage network and watershed boundary were delineated using Remote Sensing data and a Digital Elevation Model (DEM) within a GIS environment. Survey of India (SOI) topographical sheet No. 55G/16 was used as a reference for the study area. The Dadi River is the principal drainage channel of the watershed and receives water from its tributaries. It joins the Pedhi River at approximately 21°04′45″ N latitude and 77°47′35″ E longitude. This confluence connects the watershed's drainage network with the wider regional drainage system.

Geologically, the study area is predominantly underlain by Deccan Trap Basalt of Upper Cretaceous to Lower Eocene age. These basaltic formations occur across parts of Amravati District (CGWB, 2019). Elevation data were obtained from the CartoSat-1 PAN CartoDEM with a spatial resolution of 30 m. The watershed elevation ranges from approximately 261.39 m to 369.96 m above mean sea level (amsl), giving a total relief of 108.57 m.

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The climate of the study area is generally hot and dry. The year is divided into three seasons: the cold season from November to February, the hot season from March to May, and the monsoon season from June to October. Rainfall occurs mainly during the southwest monsoon (Groundwater Surveys and Development Agency, Amravati District, n.d.).

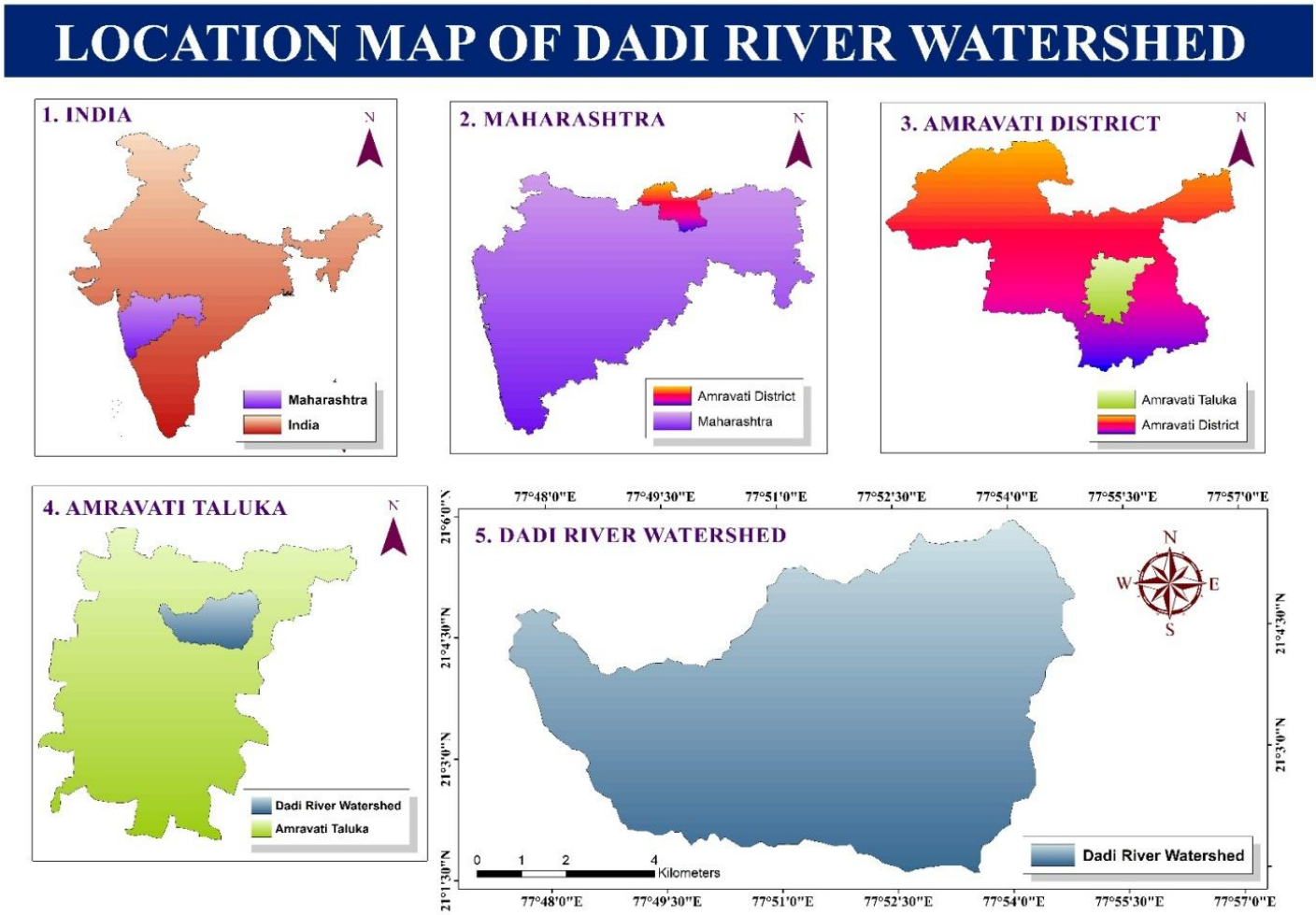


Figure 1. Location Map of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India. (Source: Administrative boundaries and regional context derived from Survey of India (SOI) Nakshe Portal open datasets; watershed boundary delineated using CartoSat-1 PAN CartoDEM (30 m spatial resolution) and the pour-point method in ArcGIS 10.2. Map prepared by Abhishek A. Kadu.)

Datasets Used And Software

The datasets used for the morphometric analysis of the Dadi River Watershed included a 30 m spatial resolution CartoSat-1 PAN CartoDEM and a Survey of India (SOI) topographical sheet. The CartoDEM data were obtained from the Indian Space Research Organization's (ISRO) Bhoonidhi portal and used to represent the elevation characteristics of the study area and support watershed delineation and drainage network extraction. The SOI topographical sheet No. 55G/16 at a scale of 1:50,000 was georeferenced in ArcGIS 10.2 and used as a reference for locating the Dadi River and comparing the extracted drainage network with the mapped drainage features. The spatial data were projected to the WGS 1984 UTM Zone 43N coordinate reference system to maintain spatial consistency during GIS analysis.

The processing and analysis of the spatial datasets were carried out using ArcGIS 10.2. The software was used for DEM processing, watershed delineation, drainage network extraction, and calculation of the selected morphometric parameters. The Spatial Analyst and ArcHydro tools were used for hydrological processing, including drainage extraction and watershed delineation. These datasets and GIS tools provided the spatial framework for the morphometric analysis of the Dadi River Watershed.

METHODOLOGY

The morphometric analysis of the Dadi River Watershed was carried out using Remote Sensing and Geographic Information System (GIS) techniques. The methodology involved DEM processing, watershed delineation, extraction of the drainage network, determination of stream order, and calculation of selected linear, areal, and relief morphometric parameters. The results obtained from the GIS-based analysis were systematically evaluated to understand the morphometric characteristics of the Dadi River Watershed. The overall methodological workflow adopted for the study is presented in Figure 2.

Dem Acquisition And Preprocessing

The CartoSat-1 PAN CartoDEM (30 m spatial resolution) Digital Elevation Model (DEM) was obtained from the Indian Space Research Organization's (ISRO) Bhoonidhi portal (https://bhoonidhi.nrsc.gov.in/bhoonidhi/). The downloaded DEM tile was provided in GeoTIFF (.tif) format and used as the primary elevation dataset for delineating the Dadi River Watershed and extracting its drainage network. The DEM was imported into ArcGIS 10.2 and projected to the WGS 1984 UTM Zone 43N coordinate reference system using the Project Raster tool.

Hydrological preprocessing was performed on the complete projected DEM before watershed delineation. The Fill tool under the Hydrology toolset of the Spatial Analyst toolbox was applied to remove surface depressions and facilitate continuous flow routing. Subsequently, the Flow Direction tool was used to determine the direction of surface flow from each raster cell. The resulting flow-direction raster was then used as input to the Flow Accumulation tool under the Hydrology toolset of the Spatial Analyst toolbox to calculate the accumulated upstream flow for each cell. The resulting flow-accumulation raster was used for drainage network extraction and watershed delineation.

Drainage Network Extraction And Stream Ordering

The drainage network was extracted from the flow-accumulation raster using the Raster Calculator under Map Algebra in the Spatial Analyst toolbox of ArcGIS 10.2. The conditional expression Con ("Flow Accumulation" > 50, 1, 0) was applied to identify stream cells, assigning a value of 1 to cells with flow-accumulation values greater than 50 and 0 to the remaining cells. A flow-accumulation threshold of 50 cells was selected based on a visual comparison of the extracted drainage network with the drainage features shown on the georeferenced Survey of India (SOI) topographical sheet No. 55G/16 at a scale of 1:50,000. The extracted network showed general spatial correspondence with the drainage features represented on the SOI sheet, supporting the selection of the 50-cell threshold for representing the drainage pattern of the study area. The SOI sheet was used as a reference for this qualitative assessment; however, the comparison did not constitute a quantitative validation of stream number or total drainage length, and a quantitative sensitivity assessment of alternative thresholds was not performed.

The Stream Order tool under the Hydrology toolset of the Spatial Analyst toolbox was used to assign stream orders according to the Strahler method (Strahler, 1957, 1964). The resulting stream-order raster was converted into a vector drainage network using the Stream to Feature tool.

Watershed Delineation And Boundary Validation

Watershed delineation was performed in ArcGIS 10.2 using the Hydrology tools in the Spatial Analyst toolbox. First, the Basin tool was applied to the flow-direction raster to generate a basin raster. A pour point was identified at the confluence of the Dadi River and the Pedhi River using a georeferenced Survey of India (SOI) topographical sheet. A point shapefile representing the pour point was created using the WGS 1984 UTM Zone 43N coordinate reference system. The Watershed tool was then applied using the flow-direction raster and the pour point data to delineate the contributing watershed area. The resulting watershed raster was converted into a polygon using the Raster to Polygon tool and clipped to the required study area using the Clip tool. The extracted drainage network and watershed boundary were compared with the georeferenced SOI topographical sheet to assess their spatial correspondence.

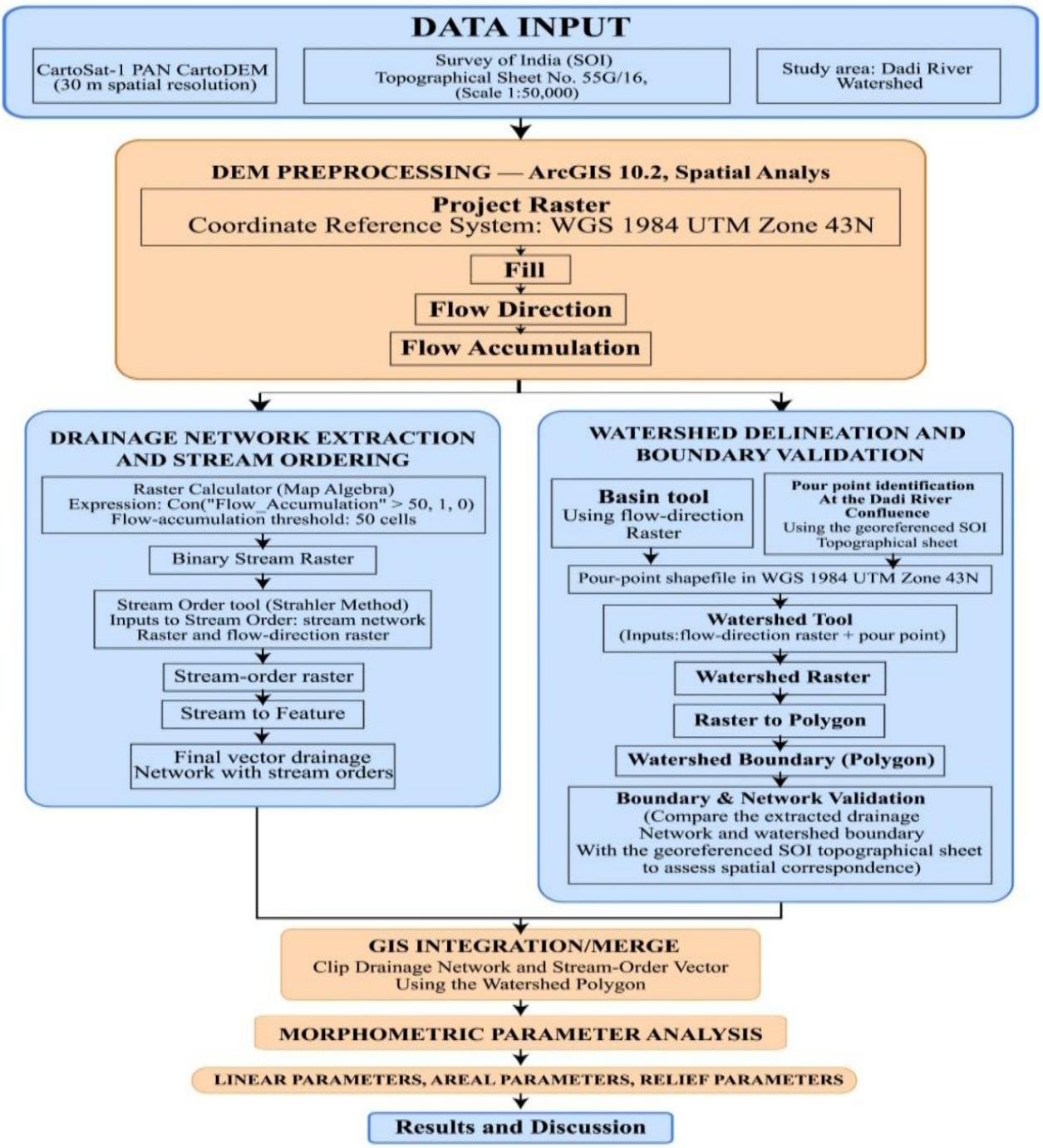


Figure 2. Methodological Workflow for Morphometric Analysis of the Dadi River Watershed.

RESULTS AND DISCUSSION

Linear Aspects

Stream Order (S_u) and Stream Number (N_u)

Stream order represents the hierarchical arrangement of a drainage network. In the present study, the Strahler method was used to classify streams, whereby unbranched streams are assigned first order, and the junction of two streams of the same order forms a stream of the next higher order (Strahler, 1957). The drainage network and stream ordering of the Dadi River Watershed are shown in Figure 3. The watershed exhibits a dendritic drainage pattern, with streams extending up to the fifth order. The number of stream segments generally decreases with increasing stream order. The stream number (N_u) was determined for each order, and the results are presented in Table 2 (Horton, 1945).

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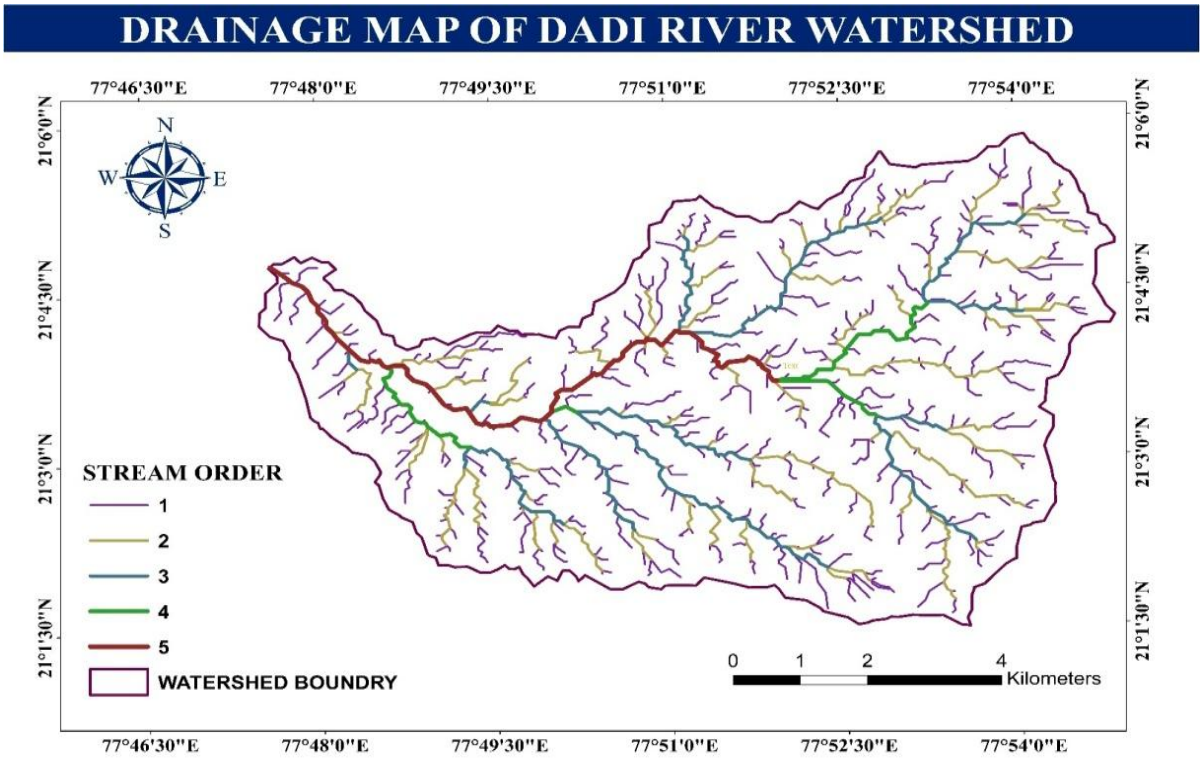


Figure 3. Drainage Network and Stream Order Map of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India. (Source: CartoSat-1 PAN CartoDEM, 30 m spatial resolution. Drainage network extraction and stream ordering performed using ArcGIS 10.2. Map prepared by Abhishek A. Kadu.)

Table 1. Formulae Used for the Computation of Morphometric Parameters.

Aspects	Morphometric parameter	Formula / Method	Reference
Linear aspects	Stream order (S_u)	Hierarchical ranking of stream segments according to the Strahler method	Strahler, 1957
	Stream number (N_u)	$N_u = N_1 + N_2 + \ldots + N_u$; Where, N_u = number of stream segments of order "u"	Horton, 1945
	Stream length (L_u), km	$L_u = L_1 + L_2 + \ldots + L_n$; Where, L_u = for stream segments of order "u"	Horton, 1945
	Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$ Where, L_u=total stream length of order 'u' N_u= Total number of stream segments of order "u"	Strahler, 1964
	Stream length ratio (R_L)	$R_L = L_{sm,u} / L_{sm,u-1}$; Where, L_{sm}= Mean stream length of the given order "u", L_{sm-1}=Mean stream length of the next lower order (u - 1)	Horton, 1945
	Bifurcation ratio (R_b)	$R_b = N_u/N_u+1$; where, N_u=Total number of stream segment of order "u", N_u+1=Number of segments of next higher order.	Schumm, 1956
	Mean bifurcation ratio (R_{bm})	(R_{bm})=Average bifurcation ratio of all orders.	Strahler, 1964
	Basin length (L_b)	The straight line from the mouth of the basin to the farthest point on the basin perimeter.	Schumm, 1956
	Rho coefficient (ρ)	$\rho = R_L/R_b$; Where R_L=Stream length ratio, R_b= Bifurcation ratio	Horton, 1945
	Basin area (A), km^2	ArcGIS Spatial Analyst / Polygon Geometry	Schumm, 1956
	Basin length (L_b), km	ArcGIS Measurement Tool (Straight-line distance from mouth to	Schumm,

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		farthest point)	1956
	Basin perimeter (P), km	ArcGIS Polygon Boundary Extraction	Author's estimation using ArcGIS 10.2
	Drainage density (D_d), km/km^2	$D_d=L_u/A$ Where, L_u= Total stream length of order "u" A = area basin	Strahler, 1964
	Form factor (R_f)	$R_f=A/L_b^2$; where, A=Area of watershed, L_b^2= Square of Basin length.	Horton, 1932
	Circularity Ratio (R_c)	$R_c=4\pi A/P^2$; where, A=Area of watershed, π= 3.14, P^2=Square of basin perimeter of watershed.	Miller, 1953
	Elongation Ratio (R_e)	$R_e=(2*\sqrt{(A/\pi)})/L_b$; where, A = area of watershed, π = 3.14, and L_b = basin length.	Schumm, 1956
	Stream Frequency (F_s)	$F_s=N_u/A$; Where "N_u" is the total number of streams of all order A is area basin	Horton, 1945
	Drainage Texture (R_t)	$R_t=N_u/P$; where, N_u=Total number of streams of all orders, P=Perimeter of watershed.	Horton, 1945
Areal aspects	Constant Channel Maintenance (C_c)	$C=1/D_d$; where, D_d=Drainage density.	Schumm, 1965
	Infiltration Number (I_f)	$I_f=F_s*D_d$; where, F_s=Stream frequency, D_d=Drainage density.	Faniran, 1968
	Length of overland Flow (L_{of})	$L_{of}=1/(2*D_d)$; where, D_d=Drainage density	Horton, 1945
Relief aspect	Basin relief (B_h)	Vertical distance between the lowest and highest points of watershed.	Hadley and Schumm, 1961
	Relief Ratio (R_h)	$R_h=B_h/L_b$; where, B_h=Basin relief, L_b=Basin length.	Schumm, 1965
	Ruggedness number (R_n)	$R_n=B_h*D_d$; where, B_h=Basin relief, D_d=Drainage density.	Patton & Baker, 1976

Stream length (L_u)

Stream length (L_u) represents the total length of stream segments belonging to a particular stream order. In the present study, the length of individual stream segments was measured using GIS, and the total stream length was calculated separately for each stream order (Horton, 1945). The calculated stream lengths are presented in Table 2.

Mean stream length (L_{sm})

Mean stream length (L_{sm}) represents an important characteristic of the drainage network and its relationship with the watershed surface characteristics (Strahler, 1964). It is calculated by dividing the total stream length of a particular stream order by the corresponding number of stream segments. For the Dadi River Watershed, the L_{sm} values range from 0.29 to 10.61 km, indicating variation in the average length of stream segments across different stream orders.

Stream length ratio (R_L)

Stream length ratio (R_L) is the ratio of the mean stream length of a given order to that of the immediately lower order. It indicates the variation in mean stream length between successive stream orders and reflects the

characteristics of the drainage network. The value of R_L may vary with changes in slope, topography, lithology, and geological structure of the watershed. In the present study, R_L was calculated for successive stream orders using the formula given in Table 1 (Horton, 1945).

Bifurcation ratio (R_b)

The bifurcation ratio (R_b) is defined as the ratio of the number of stream segments of a given order to that of the next higher order. It is used to characterize the branching pattern of the drainage network and examine the influence of geological structure and lithology on drainage development (Strahler, 1957, 1964). Variations in bifurcation ratio among successive stream orders may be associated with differences in geological structure, lithology, and watershed topography (Strahler, 1964). Generally, lower values may indicate limited structural control over the drainage network, whereas higher values may suggest greater structural complexity (Strahler, 1964; Magesh et al., 2013). For the Dadi River Watershed, the bifurcation ratio values range from 3.25 to 5.92 (Table 2).

Mean bifurcation ratio (R_{bm})

The mean bifurcation ratio (R_{bm}) represents the arithmetic mean of the bifurcation ratios calculated for successive stream orders. It provides an overall measure of the branching characteristics of the drainage network. In the present study, the mean bifurcation ratio of the Dadi River Watershed was calculated as 4.54 (Table 2). This value falls within the general range of 3.0–5.0 reported by Strahler (1964), suggesting that the drainage network may not be strongly influenced by geological structural disturbances. However, this interpretation should be considered cautiously, as additional geological evidence is required to establish the extent of structural control.

Rho coefficient (ρ)

The rho coefficient (ρ) is a dimensionless morphometric parameter that expresses the relationship between stream length ratio and bifurcation ratio and may provide insights into the hydrological characteristics of a drainage network (Horton, 1945). In the present study, the rho coefficient was calculated as the ratio of the stream length ratio (R_L) to the bifurcation ratio (R_b) for successive stream orders. The calculated values for the Dadi River Watershed are presented in Table 2. These values describe the relationship between stream length and stream branching characteristics; their hydrological implications should be interpreted cautiously in conjunction with other watershed characteristics.

Table 2. Linear Morphometric Parameters of the Dadi River Watershed.

Stream Order (S_u)	**Stream Number (N_u)**	**Stream Length (L_u)**	**Mean Stream Length (L_{sm})**	**Stream Length Ratio** (R_L)	**Rho Coefficient (ρ)**	**Bifurcation Ratio (R_b)**	**Mean Bifurcation Ratio (R_{bm})**
1	383	109.55	0.29	-	-	4.97	
2	77	52.32	0.68	2.38	0.40	5.92	
3	13	28.71	2.21	3.25	1.00	3.25	
4	4	7.83	1.96	0.89	0.22	4.00	
5	1	10.61	10.61	5.42	-	-	4.54

Areal Parameters

Basin Area (A), Basin Length (L_b), and Basin Perimeter (P)

Basin area, basin length, and basin perimeter are important morphometric parameters that describe the size and geometry of a drainage basin. For the Dadi River Watershed, the basin area was calculated as 61.63 km², the basin length was measured as 12.61 km, and the basin perimeter was determined as 40.9 km using GIS

techniques. These parameters describe the spatial dimensions of the watershed and provide the basis for further analysis of its areal morphometric characteristics.

Drainage Density (D_d)

Drainage density is defined as the ratio of the total length of streams in a watershed to the total area of the watershed. Low drainage density is generally associated with permeable subsurface materials, dense vegetation, and low relief, whereas high drainage density is commonly associated with less permeable materials, sparse vegetation, and high relief (Strahler, 1964). In the present study, drainage density was calculated for the Dadi River Watershed using the formula given in Table 1. The calculated value was 3.39 km/km², indicating a moderately developed drainage network. This value describes the drainage characteristics of the watershed; however, interpretations concerning subsurface permeability, infiltration, vegetation cover, runoff response, groundwater recharge potential, and flood susceptibility require additional supporting evidence.

The drainage density map of the Dadi River Watershed was prepared using Remote Sensing and GIS techniques in ArcGIS 10.2. The DEM-derived drainage network was used as the input polyline dataset for the Line Density tool available in the Spatial Analyst toolbox. This tool calculated the concentration of drainage lines within a specified neighbourhood around each output raster cell, producing a raster representing the spatial variation in drainage-line density. The resulting raster was clipped or masked to the Dadi River Watershed boundary to restrict the analysis to the study area.

The drainage-line density raster was classified into five categories using the Natural Breaks (Jenks) classification method: Very Low (0–1.5561), Low (1.5561–3.2036), Moderate (3.2036–4.8055), High (4.8055–6.5446), and Very High (6.5446–11.6246). These classes represent different levels of drainage-line concentration across the watershed. The resulting map was used to examine the spatial distribution of drainage density within the study area (Figure 4)

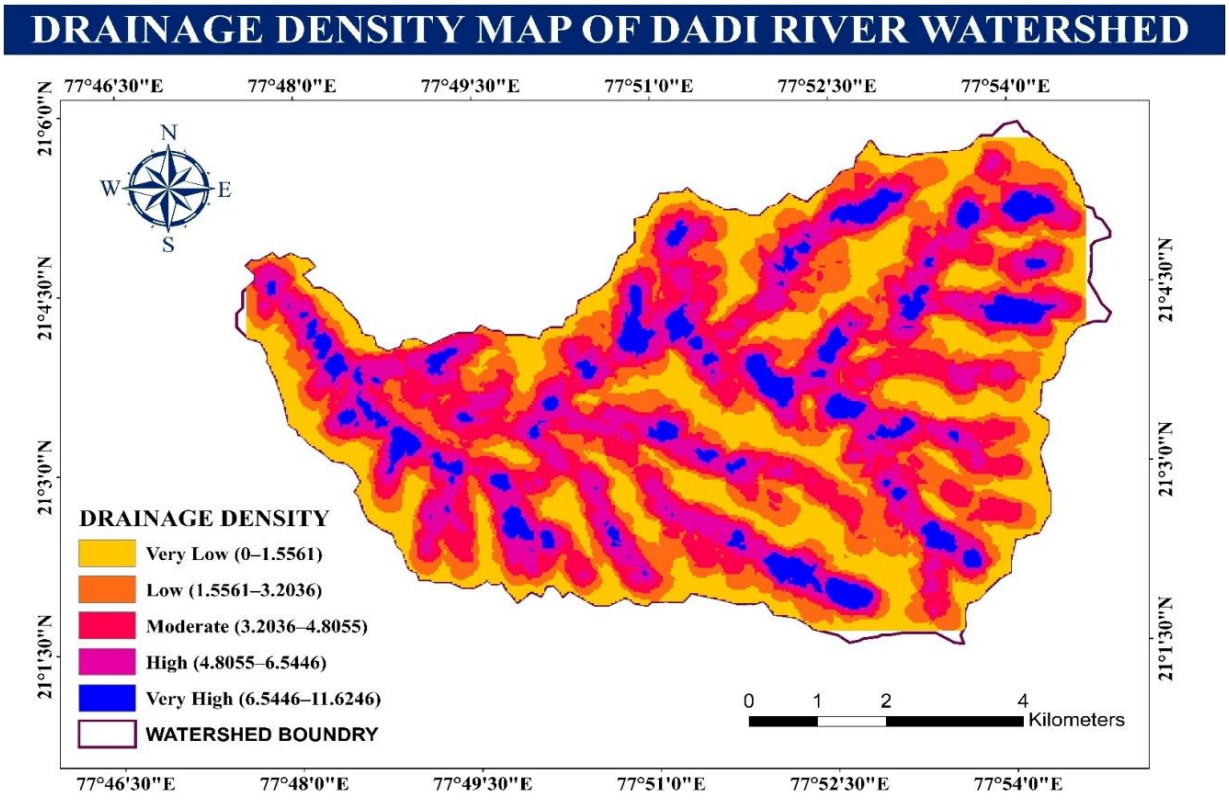


Figure 4. Spatial Distribution and Classification of Drainage-Line Density in the Dadi River Watershed. (Source: Drainage-line density raster generated from the extracted drainage network derived from CartoSat-1 PAN CartoDEM (30 m spatial resolution) using the Line Density tool in ArcGIS 10.2. The resulting raster was classified into five categories using the Natural Breaks (Jenks) method. Map prepared by Abhishek A. Kadu.)

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Form Factor (R_f)

Form factor is a dimensionless morphometric parameter used to describe the shape of a drainage basin (Horton, 1932). It is calculated as the ratio of the basin area to the square of its basin length. Lower values generally indicate an elongated basin, whereas higher values indicate a more circular basin. In the present study, the form factor of the Dadi River Watershed was calculated as 0.39, indicating a relatively elongated basin shape.

Circularity Ratio (R_c)

Circularity ratio is a dimensionless morphometric parameter that expresses the degree of circularity of a drainage basin. It is calculated as the ratio of the basin area to the area of a circle having the same perimeter as the basin (Miller, 1953). Its value ranges from 0 to 1, with values closer to 1 indicating a more circular basin shape. The circularity ratio of the Dadi River Watershed was calculated as 0.46, indicating a relatively elongated to irregular basin shape. Although basin geometry may influence runoff concentration and hydrological response, these effects also depend on rainfall characteristics, slope, soil properties, and other watershed conditions.

Elongation Ratio (R_e)

The elongation ratio is defined as the ratio of the diameter of a circle having an area equal to that of a drainage basin to the maximum basin length (Schumm, 1956). Its value ranges from 0 to 1, with values approaching 1 indicating a nearly circular basin, whereas lower values indicate a more elongated shape. In the present study, the elongation ratio of the Dadi River Watershed was calculated as 0.70, indicating a moderately elongated basin shape.

Stream Frequency (F_s)

Stream frequency is defined as the total number of stream segments of all orders per unit area of a drainage basin (Horton, 1932). In the present study, stream frequency was calculated using the formula given in Table 1. The Dadi River Watershed contains 478 stream segments within an area of 61.63 km², resulting in a stream frequency of 7.76 streams/km²**.** This value indicates the number of stream segments per unit area and characterizes the drainage network. However, its implications for infiltration and runoff require consideration of other morphometric, geological, and hydrological factors.

Drainage Texture (R_t)

According to Horton (1945), drainage texture is an important geomorphological parameter that describes the relative spacing of stream channels and is related to the number of stream segments and the drainage watershed perimeter. Weak rocks generally favour fine drainage texture, whereas hard, resistant rocks tend to develop coarse drainage texture. Climate and vegetation also influence drainage development. According to Smith (1950), drainage texture is classified as very coarse when the value is less than 2, coarse from 2 to 4, medium from 4 to 6, fine from 6 to 8, and very fine when the value exceeds 8. The drainage texture of the Dadi River Watershed was calculated as 11.69 km^{-1} (Table 1), indicating that the study area falls under the very fine drainage texture category according to Smith (1950).

Constant Channel Maintenance (C_c)

Constant channel maintenance represents the area of a drainage basin required to sustain a unit length of stream channel (Schumm, 1956). It is inversely related to drainage density and is influenced by factors such as lithology, soil properties, climate, and vegetation. In the present study, the constant channel maintenance of the Dadi River Watershed was calculated as 0.30 km²/km, indicating that approximately 0.30 km² of basin area corresponds to each kilometre of stream channel. This value is consistent with the inverse relationship between constant channel maintenance and drainage density.

Infiltration Number (I_f)

The infiltration number is calculated as the product of drainage density and stream frequency (Faniran, 1968). It is a morphometric indicator of drainage characteristics and may provide a preliminary indication of infiltration and runoff potential. Higher values may suggest greater surface-runoff potential; however, this interpretation depends on soil properties, lithology, land cover, and rainfall conditions. In the present study, the infiltration number of the Dadi River Watershed was calculated as 26.31. Its hydrological implications require confirmation using independent hydrological or soil data.

Length of Overland Flow (L_{of})

Length of overland flow is defined as the average distance that surface runoff travels over the ground before reaching a defined stream channel (Horton, 1945). It is commonly estimated as the reciprocal of twice the drainage density. In the present study, the length of overland flow of the Dadi River Watershed was calculated as 0.15 km (Table 1). This value represents a relatively short estimated overland-flow distance, based on the drainage density of the watershed.

Relief Aspect

Basin Relief (B_h)

Basin relief represents the vertical difference between the highest and lowest elevations within a watershed. In the present study, the maximum and minimum elevations of the Dadi River Watershed were derived from the 30 m-resolution CartoSat-1 PAN CartoDEM. The basin relief was calculated as 108.57 m, representing the total elevation difference within the watershed.

Relief Ratio (R_h)

The relief ratio (R_h) is calculated as the ratio of the total basin relief (B_h) to the maximum length (L_b) of the watershed (Schumm, 1965). To maintain dimensional consistency, the basin relief was converted from meters to kilometers (B_h = 0.10857 km) before dividing by the basin length (L_b = 12.61 km), resulting in a dimensionless ratio:

$$R_h = B_h / L_b$$

$$= 0.10857 \text{ km} / 12.61 \text{ km}$$

$$= 0.0086$$

In the present study, the relief ratio of the Dadi River Watershed was calculated as 0.0086. This relatively low value indicates a low overall relief gradient relative to the watershed length. However, local slope variations and runoff characteristics require separate assessment.

Ruggedness Number (R_n)

The ruggedness number (R_n) is calculated as the product of basin relief (B_h) and drainage density (D_d) (Patton & Baker, 1976). To ensure a dimensionless index and correct unit conversion, the basin relief was converted into kilometers (0.10857 km) to match the unit of drainage density (3.39 km/km²):

$$Rn = Bh \times Dd$$

$$= 0.10857 \text{ km} \times 3.39 \text{ km/km}^2$$

$$= 0.368 \approx 0.37 \text{ (Dimensionless)}$$

The calculated ruggedness number of 0.37 represents the combined influence of basin relief and drainage density. Its interpretation in terms of terrain ruggedness should be considered alongside the watershed's elevation and slope characteristics

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Slope Map

Slope represents the steepness of the land surface and influences the downslope movement of water and soil materials under gravity (Strahler, 1956). It is an important terrain parameter for understanding surface gradients and their potential influence on runoff and erosion processes. In the present study, the slope map of the Dadi River Watershed was generated from the 30 m-resolution CartoSat-1 PAN CartoDEM using the Slope tool in the Spatial Analyst extension of ArcGIS 10.2 (Figure 5).

The slope map indicates that a major portion of the watershed is characterized by very gentle to gentle slopes, while moderate to very steep slopes occur in localized areas. This distribution indicates that the watershed is predominantly composed of low-gradient terrain, with steeper sections occurring in limited parts of the study area. Steeper slopes may facilitate more rapid downslope movement of surface water and increase susceptibility to soil erosion, depending on soil properties, land cover, rainfall intensity, and other local conditions. The slope distribution therefore provides useful terrain information for watershed management and soil conservation planning.

For map preparation, the slope output was measured in degrees and clipped to the watershed boundary. The resulting slope raster was classified into five categories: Very Gentle (0.0022–0.8154°), Gentle (0.8154–2.3063°), Moderate (2.3063–7.5922°), Steep (7.5922–17.8930°), and Very Steep (17.8930–34.5640°). These classes represent the slope distribution derived from the DEM and are presented in Figure 5.

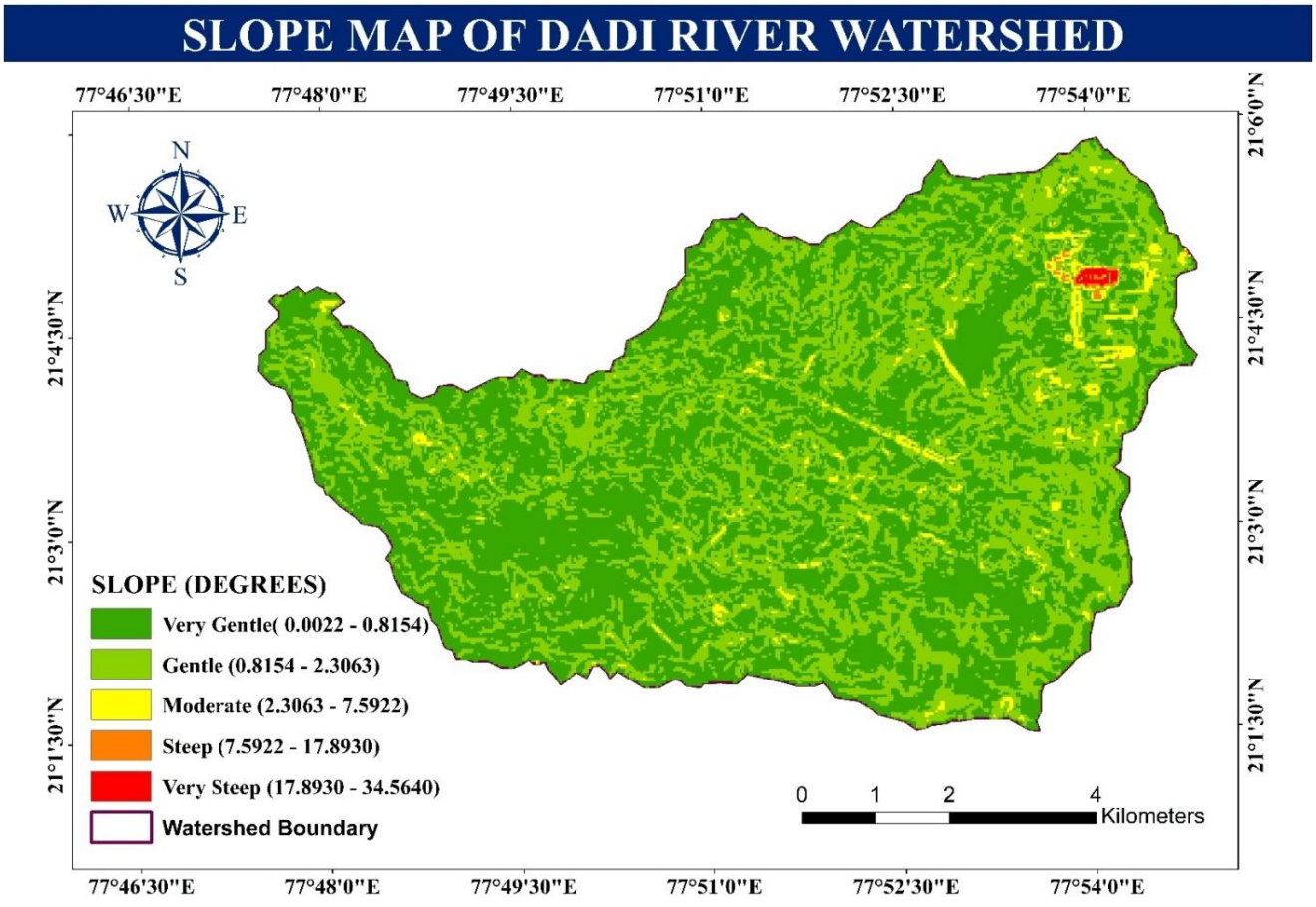


Figure 5. Slope Map of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India. (Source: CartoSat-1 PAN CartoDEM, 30 m spatial resolution. Slope analysis and classification performed using ArcGIS 10.2. Map prepared by Abhishek A. Kadu.)

Aspect Map

The aspect map of the Dadi River Watershed was generated from the 30 m-resolution CartoSat-1 PAN CartoDEM using the Aspect tool in the Spatial Analyst extension of ArcGIS 10.2 (Figure 6). The resulting

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aspect raster was clipped to the watershed boundary and classified into nine categories: Flat (−1), North (0–22.5° and 337.5–360°), Northeast (22.5–67.5°), East (67.5–112.5°), Southeast (112.5–157.5°), South (157.5–202.5°), Southwest (202.5–247.5°), West (247.5–292.5°), and Northwest (292.5–337.5°).

The aspect map shows spatial variations in slope orientation across the Dadi River Watershed. These directional differences represent the orientation of the land surface and may influence the amount of solar radiation received by different slopes. Consequently, aspect may contribute to variations in surface heating and local moisture conditions, depending on climatic, soil, and land-cover characteristics. However, the aspect map alone does not establish differences in soil moisture, vegetation distribution, or groundwater recharge.

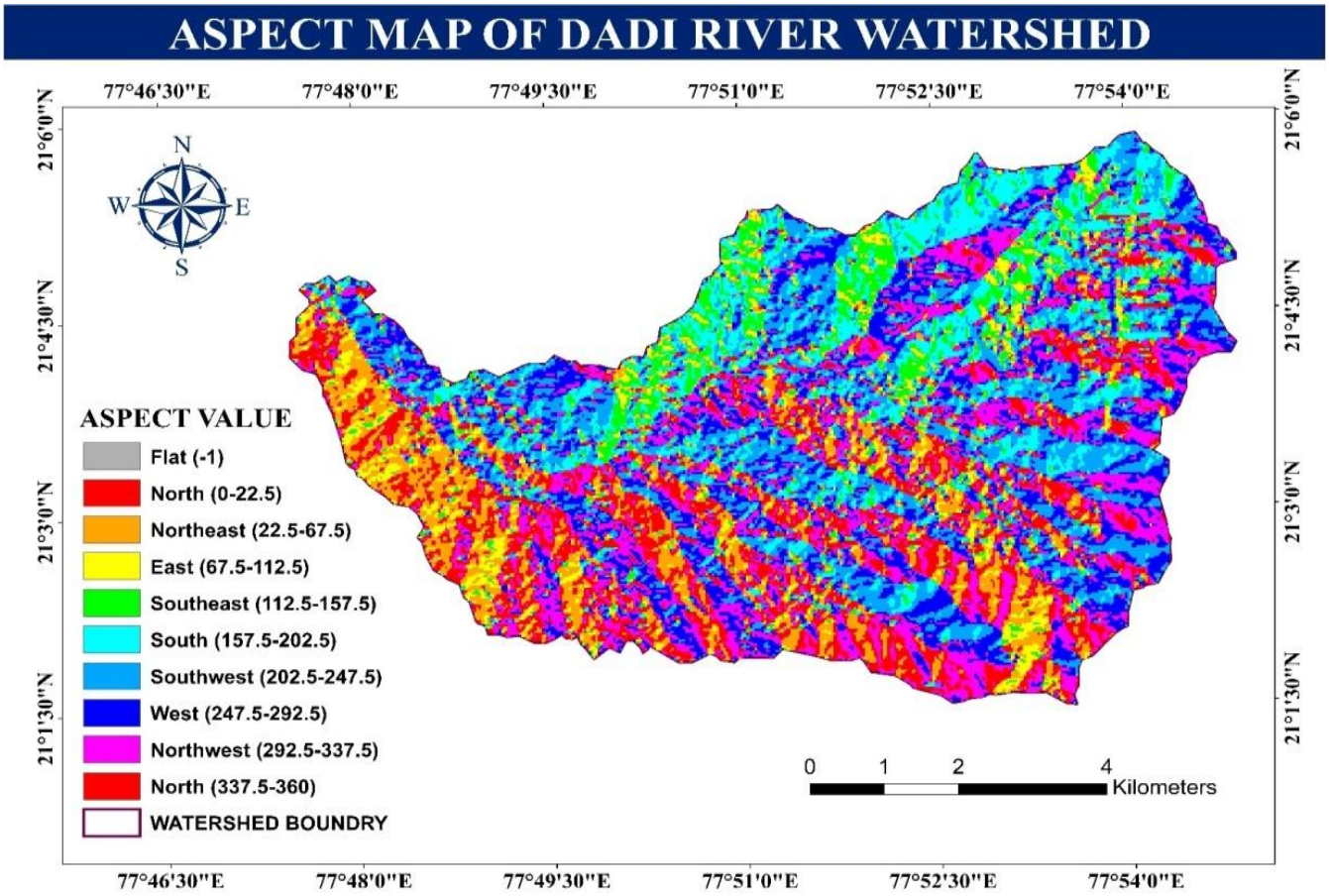


Figure 6. Aspect Map of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India. (Source: CartoSat-1 PAN CartoDEM, 30 m spatial resolution. Aspect analysis and classification performed using ArcGIS 10.2. Map prepared by Abhishek A. Kadu.)

Hillshade Map

The hillshade map of the Dadi River Watershed was generated from the 30 m-resolution CartoSat-1 PAN CartoDEM using the Hillshade tool in the Surface toolset of the Spatial Analyst toolbox in ArcGIS 10.2 (Figure 7). The tool was applied to simulate terrain illumination and visualize variations in surface relief and orientation. The resulting hillshade raster was classified into four categories using the Symbology settings in ArcGIS 10.2: Low Illumination (59–146), Moderate-Low Illumination (146–180), Moderate-High Illumination (180–197), and High Illumination (197–238).

The hillshade map illustrates spatial variations in simulated illumination across the Dadi River Watershed, highlighting terrain features, surface relief, and changes in topographic orientation. The four illumination classes represent differences in shading intensity and help visualize the spatial configuration of the terrain. These classes are used for visual interpretation of topography and should not be interpreted as direct measurements of elevation, slope, or actual solar radiation.

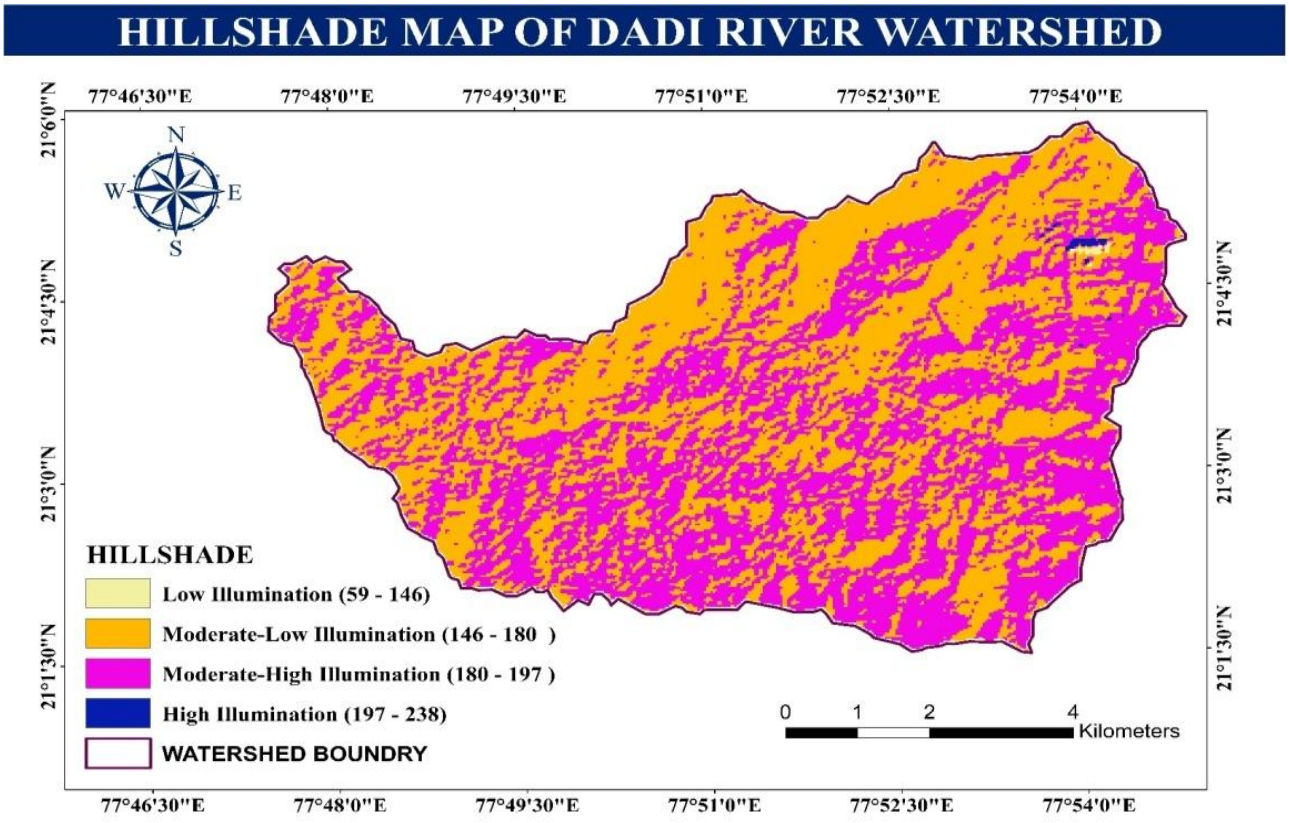


Figure 7. Hillshade Map of the Dadi River Watershed, Amravati Taluka, Amravati District, Maharashtra, India. (Source: CartoSat-1 PAN CartoDEM, 30 m spatial resolution. Hillshade analysis and classification performed using ArcGIS 10.2. Map prepared by Abhishek A. Kadu.)

Table 3. Summary of Morphometric Parameters of the Dadi River Watershed.

Morphometric Parameter	**Symbol**	**Result**
Basin Area	A	61.63 km²
Basin Length	L_b	12.61 km
Perimeter	P	40.9 km
Mean Bifurcation ratio	R_{bm}	4.54
Drainage Density	D_d	3.39 km/km²
Form Factor	R_f	0.39
Circularity Ratio	R_c	0.46
Elongation Ratio	R_e	0.70
Stream Frequency	F_s	7.76 streams/km²
Drainage Texture	R_t	11.69 km^{-1}
Constant Channel Maintenance	C_C	0.30 km²/km
Infiltration Number	I_f	26.31
Length of Overland Flow	L_{of}	0.15 km
Basin Relief	B_h	108.57 m
Relief Ratio	R_h	0.0086
Ruggedness Number	R_n	0.37

CONCLUSION

The present study examined the morphometric characteristics of the Dadi River Watershed in Amravati Taluka, Amravati District, Maharashtra, India, using remote sensing and GIS techniques. The analysis was based on the 30 m-resolution CartoSat-1 PAN CartoDEM and ArcGIS 10.2. The watershed covers an area of 61.63 km² and exhibits a fifth-order drainage network comprising 478 stream segments. The drainage pattern is predominantly dendritic to sub-dendritic, indicating a branching drainage network whose development may be influenced by lithological and structural conditions.

The linear morphometric analysis yielded a mean bifurcation ratio of 4.54. This value falls within the general range commonly reported for drainage networks, although the degree of geological structural control cannot be established from the bifurcation ratio alone. The drainage density of 3.39 km/km² and stream frequency of 7.76 streams/km² quantify the drainage-network characteristics of the watershed. The areal morphometric parameters, including a form factor of 0.39, circularity ratio of 0.46, and elongation ratio of 0.70, indicate a relatively elongated to irregular basin shape. The relief analysis yielded a basin relief of 108.57 m, a relief ratio of 0.0086, and a ruggedness number of 0.37, describing the watershed's elevation range and combined relief–drainage characteristics.

The slope analysis indicates that gentle slopes predominate across the watershed, with localized areas of moderate to very steep slopes. The aspect and hillshade maps illustrate variations in slope orientation and terrain configuration. Together, these DEM-derived characteristics provide a spatial description of the watershed's topography. However, interpretations concerning infiltration, groundwater recharge, runoff, and soil erosion require additional evidence from field observations and hydrological, geological, and soil data.

Overall, the integration of remote sensing, DEM-derived terrain analysis, and GIS-based morphometric assessment provides a useful basis for characterizing the Dadi River Watershed. The findings can support preliminary watershed management and soil and water conservation planning. Future studies incorporating detailed geological, soil, land-use/land-cover, rainfall, and groundwater data would help strengthen the interpretation of hydrological processes and identify suitable locations for recharge and water-conservation measures.

REFERENCES

1. Abrahams, A. D. (1984). Channel networks: A geomorphological perspective. *Water Resources Research, 20*(2), 161–188. https://doi.org/10.1029/WR020i002p00161
2. Central Ground Water Board. (2019). Aquifer mapping and management of ground water resources: Amravati district, Maharashtra. Ministry of Jal Shakti, Government of India.
3. Clarke, J. I., 1966. Morphometry from Maps, Essays in geomorphology. Elsevier Publ. Co., New York, 235-274.
4. Faniran, A. (1968). The index of drainage intensity—a provisional new drainage factor. *Australian Journal of Science, 31*, 328–330.
5. Groundwater Surveys and Development Agency. (n.d.). *GSDA: Amravati district*. Government of Maharashtra. https://amravati.gov.in/en/departments/gsda/
6. Hadley, R. F., & Schumm, S. A. (1961). Sediment sources and drainage basin characteristics in upper Cheyenne River basin. *U.S. Geological Survey Water-Supply Paper 1531-B*, 137–196.
7. Horton, R. E. (1932). Drainage-basin characteristics. *Transactions, American Geophysical Union, 13*(1), 350–361. https://doi.org/10.1029/TR013i001p00350
8. Horton, R. E. (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin, 56*(3), 275–370. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2
9. Huggett, R. J., & Cheesman, J. (2002). *Topography and the environment*. Pearson Education.
10. Magesh, N. S., Chandrasekar, N., & Soundranayagam, J. P. (2011). Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu,

India: A GIS approach. *Environmental Earth Sciences, 64*(2), 373–381. https://doi.org/10.1007/s12665-010-0860-4

11. Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N., & Jini, K. V. (2013). Geographical information system-based morphometric analysis of Bharathapuzha river basin, Kerala, India. *Applied Water Science, 3*(2), 467–477. https://doi.org/10.1007/s13201-013-0095-0
12. Miller, V. C. (1953). *A quantitative geomorphic study of drainage basin characteristics in Clinch Mountain area, Virginia and Tennessee* (Technical Report No. 3). Office of Naval Research, Department of Geology, Columbia University.
13. Pande, C. B., & Moharir, K. (2017). GIS based quantitative morphometric analysis and its consequences: A case study from Shanur River Basin, Maharashtra, India. *Applied Water Science, 7*, 861–871. https://doi.org/10.1007/s13201-015-0298-7
14. Patton, P. C., & Baker, V. R. (1976). Morphometry and floods in small drainage basins subject to diverse hydrogeomorphic controls. *Water Resources Research, 12*(5), 941–952.
15. Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological Society of America Bulletin, 67(5), 597–646.
16. Smith, K. G. (1950). Standards for grading the texture of erosional topography. *American Journal of Science, 248*, 655–668.
17. Strahler, A. N. (1956). Quantitative slope analysis. *Geological Society of America Bulletin, 67*(5), 571–596. https://doi.org/10.1130/0016-7606(1956)67[571:QSA]2.0.CO;2
18. Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. *Eos, Transactions American Geophysical Union, 38*(6), 913–920. https://doi.org/10.1029/TR038i006p00913
19. Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel networks. In V. T. Chow (Ed.), *Handbook of applied hydrology* (Section 4-II). McGraw-Hill.
20. Zende, A. N. and Nagrajan, R., 2011. Drainage Morphology Approach for Water Resources Development of Sub–Watershed in Krishna Basin. International Journal of Computer & Communication Technology, 2(8), 13-21.