GEO-EYE

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Geomorphological and Morphometric Characterization of the Lokapavani River Basin, Mandya District, Karnataka, Using Remote Sensing and GIS Techniques

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Abstract

An assessment of the Lokapavani River Basin was carried out to analyze various drainage morphometric parameters using Remote Sensing (RS) and Geographic Information System (GIS) techniques. Drainage basin or watershed analysis based on morphometric parameters is crucial for effective watershed management and planning. The delineation of the drainage network was achieved using Digital Elevation Model (DEM) data, specifically Cartosat DEM, processed through ArcGIS software to extract key hydrological parameters of the basin. The Lokapavani River Basin covers an area of approximately 483.69 km² with a perimeter of 122.55 km. The computed morphometric parameters were categorized into three broad aspects: Linear, Areal and Relief. Under the Linear aspects, the highest stream order identified is sixth order, and the mean bifurcation ratio of 4.18 indicates that the basin is in a mature stage of geomorphic evolution. In the Aerial aspects, the drainage density (1.94) suggests a coarse drainage texture, while the stream frequency (2.56) reflects a moderate drainage network. The circularity ratio, form factor, elongation ratio, and shape factor collectively indicate that the basin possesses an elongated shape. Furthermore, the constant of channel maintenance and length of overland flow suggest the basin has a moderate slope and moderate permeability. Within the Relief aspects, the basin relief and relief ratio denote moderate to high relief and moderate slope conditions, while the dissection index value reveals that the basin is moderately dissected. The hypsometric integral value (0.46) further supports that the Lokapavani River Basin is in a mature geomorphic stage. Geomorphologically, the study area comprises pediments, pediplains, valley fills, structural hills, and residual hills. The predominant soil types in the basin include sandy clay, clay, clay loam and sandy clay loam, which influence both infiltration characteristics and run-off behaviour across the basin.

Keywords: Morphometry, Bifurcation Ratio, Drainage Density, Digital Elevation Model (DEM), Hypsometric Integral, Pediments and Pediplains

1 Introduction

Geomorphology refers to the study of the characteristics, configuration and evolution of landforms and their associated properties. Morphometry is the measurement and mathematical analysis of the Earth's surface configuration, including the shape and dimensions of landforms[1]. According to Strahler (1964)[29], morphometric analysis provides a quantitative description of basin geometry to better understand factors such as initial slope, rock hardness, structural controls, and the geological and geomorphic evolution of a drainage basin.

Morphometry serves as a mathematical approach focused on describing the topographic relief and surface features of the Earth[7, 18]. It encompasses both the characteristics of the land surface and the drainage channels within the basin boundary. A watershed is a natural hydrological unit that drains surface run-off to a common outlet such as a stream, channel or river[31]. The study of watersheds provides valuable insights into basin characteristics including elevation, slope, surface morphology, run-off behavior, soil texture, landforms and land use.

Morphometric characteristics serve as essential tools in quantitative watershed analysis, enabling the assessment of basin behavior through three primary aspects: Linear, Areal, and Relief parameters. Linear aspects include: stream order, stream number, stream length, mean stream length, bifurcation ratio, and mean bifurcation ratio. Areal aspects include: drainage density, stream frequency, drainage texture, drainage intensity, circularity ratio, form factor, and constant of channel maintenance. Relief aspects include: basin relief, relief ratio, ruggedness number, and dissection index. The definitions and formulas of these parameters remain consistent with those reported in earlier morphometric studies[31]. The integration of Geospatial technologies such as Geographic Information Systems (GIS) and Remote Sensing (RS) has made the analysis of hydrological and geomorphic processes more accurate, efficient, and spatially comprehensive. Hypsometric analysis describes the relationship between horizontal cross-sectional basin area and elevation[2]. Hypsometry measures land elevations relative to mean sea level, and the resulting hypsometric curve represents a cumulative distribution of elevation effectively. The shape of the hypsometric curve reflects the geomorphic stage of a basin: Young stage: Convex upward curve ($Hi > 0.6$) representing steep terrain with active erosion. Mature stage: S-shaped curve ($0.3 \leq Hi \leq 0.6$) indicating equilibrium between erosion and deposition. Old stage: Concave upward curve ($Hi < 0.3$) signifying a subdued landscape with limited erosional activity[18, 30]. The hypsometric integral (Hi) defined as the area under the hypsometric curve is used to quantify the degree of basin development and evaluate the geomorphic evolution of a catchment.

Lineament analysis is another important component of geomorphological interpretation. Lineaments are linear features on the Earth's surface that represent geological structures such as faults, fractures, tectonic boundaries, and lithological contacts. Lineament density, defined as the total lineament length per unit area, is a key indicator of rock permeability and groundwater potential. Regions exhibiting high lineament density often correspond to zones of enhanced permeability and better groundwater prospects. The Morphometric calculation process analyzes and describes the geomorphological feature of the area. The results can further be extended to study and compare basins of different sizes and evaluate the groundwater recharge potential, prioritize sub-watersheds and suitable sites for rainwater harvesting[20].

2 Study area

The Lokapavani River is a perennial tributary of the Cauvery River, located in the Mandya District of Karnataka, India. The river originates near Honakere and flows through the Arighatta Hills before joining the Cauvery River at Sangam, near Srirangapatna. The basin encompasses four taluks that are Nagamangala, Pandavapura, Srirangapatna, and Mandya and traverses approximately 150 villages along its course. Geographically, the Lokapavani River Basin lies between 12°30′ to 12°45′ North latitudes and 76°25′ to 76°50′ East longitudes, occupying a central position within the Cauvery River Basin in Karnataka. The basin covers an area of about 483.69 km² with a perimeter of 122.55 km. The river itself is approximately 48.59 km in length and has an average width of about 150 feet [Fig. 1].

The elevation within the basin ranges from a maximum of 1109 m above mean sea level (MSL) to a minimum of 668 m, reflecting moderate topographic variation. The annual rainfall in the catchment area ranges between 700 mm and 800 mm, supporting both surface flow and groundwater recharge. Two dams have been constructed across the Lokapavani River one at Bolenahalli in Melkote Hobli and the other at Uyyanahalli in Nagamangala Taluk. These structures primarily serve for irrigation, facilitating water diversion for agricultural purposes in the surrounding region.

3 Material and Methods

In the present study, Survey of India (SOI) toposheets on a 1:50,000 scale were utilized for the preparation of base maps. The toposheets bearing numbers 57D/9, 57D/10, 57D/11, 57D/14, and 57D/15 were procured from SOI. These toposheets were georeferenced and mosaicked in ArcGIS 10.2.2, after which the study area was subset to represent the Lokapavani River Basin.

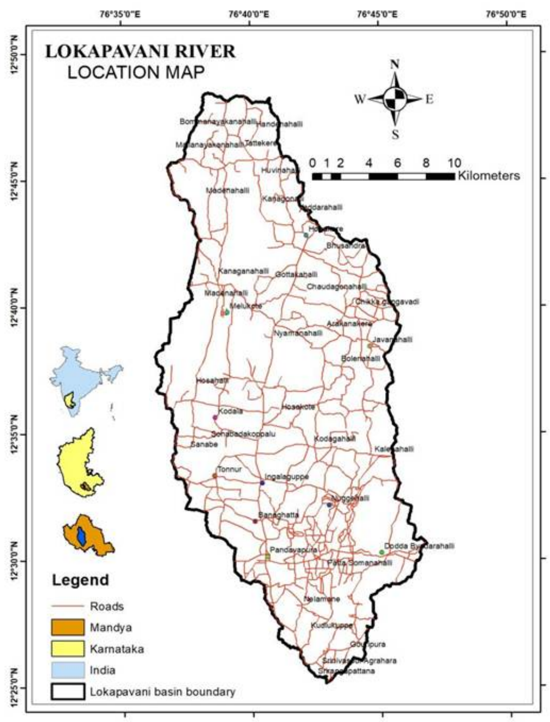

Fig. 1: Location map of the Lokapavani River Basin

The Cartosat Digital Elevation Model (DEM), Version 3, obtained from the Bhuvan (ISRO) portal, was employed for basin boundary delineation and drainage extraction. The delineation process involved the creation of a pour point within ArcGIS 10.2.2. Using Spatial Analyst → Hydrology tools, the DEM Fill, Flow Direction, and Flow Accumulation layers were generated. Flow accumulation was particularly crucial in defining the direction of flow for each cell within the basin. The pour point was then placed at the outlet of the basin, and the basin boundary was delineated using the Watershed tool. The extracted boundary was refined using the Extract by Mask tool and subsequently converted from raster to polygon format to obtain a precise outline of the basin. The mosaicked toposheet was overlaid with the delineated basin boundary in ArcGIS to prepare the thematic base map of the study area. The area and perimeter of the basin were computed using the attribute table in ArcGIS. The drainage network was then generated through the Hydrology tools by executing a sequence of operations: Fill → Flow Direction → Flow Accumulation → Map Algebra → Raster Calculation → Stream Order → Stream to Feature. The resultant stream network was validated by comparing the stream number and order derived from the DEM with those interpreted from the SOI toposheets. The discrepancy was found to be less than 10%, indicating acceptable accuracy. The geomorphic properties such as lineaments, slope, and relief are extracted from DEM using Arc tools in Arc GIS. For hypsometric analysis, the relationship between elevation and basin area was derived using Spatial Analyst tools. specifically Reclassify, Zonal, and Zonal Statistics as Table functions in ArcGIS. The obtained data were exported to Microsoft Excel to compute the Hypsometric Integral (Hi) and to generate the Hypsometric Curve. The geology and geomorphology shapefiles for the Mandya District were obtained from the Bhukosh (Geological Survey of India) portal, while the soil data and landforms were digitized within the study area to produce thematic layers of the Lokapavani River Basin.

4 Results and Discussion

The quantitative morphometric parameters provide valuable insights into the hydrological characteristics and drainage behavior of a catchment. These parameters are broadly categorized into Linear aspects, Areal aspects, and Relief aspects, each reflecting different geomorphological and hydrological properties of the basin. The calculated values are based on the mathematical formulae[20].

Linear Aspects:

The linear aspects of a watershed are primarily concerned with the stream system and its network characteristics, representing the one-dimensional properties of the drainage basin. These aspects describe the hydrological and structural controls influencing drainage development and flow patterns. The key parameters under this category include stream number, stream order, stream length, mean stream length, bifurcation ratio, and mean bifurcation ratio.

Stream Order (U): The stream order denotes the hierarchical position of streams within a watershed and serves as an indicator of the degree of stream branching. In this study, stream ordering was carried out using the method proposed by Strahler (1964)[29]. According to Strahler's classification, when two streams of the same order converge, the downstream segment is designated as the next higher order. This hierarchical process continues until the main trunk stream attains the maximum order within the drainage basin. Based on this system, the Lokapavani River Basin has been identified as a 6^{th} order stream ([Table. 1] and [Fig. 2]).

Stream Number (Nu): The stream number (Nu) refers to the total number of stream segments present within each stream order of a drainage basin. It is generally proportional to the size of the watershed and reflects the development and branching intensity of the drainage network. In the Lokapavani River Basin, a total of 1,242 stream segments have been identified. The distribution of streams across different orders is presented in [Table. 1]. The data clearly indicate that the number of stream segments decreases with increasing stream order, which is a characteristic pattern observed in well-developed drainage basins.

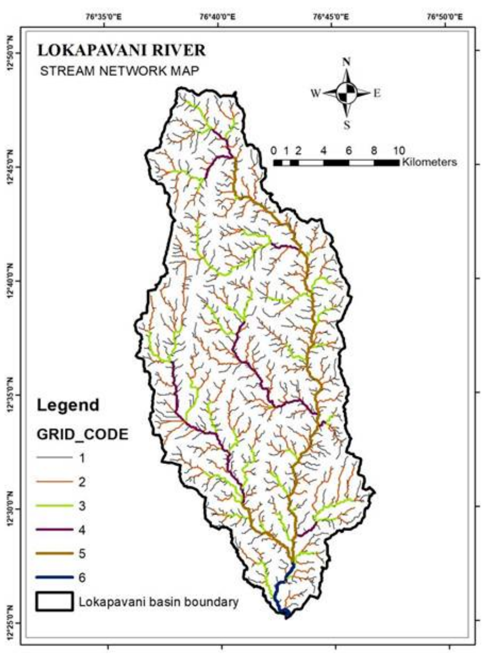

Fig. 2: Stream Network map of the Lokapavani River Basin

Stream Length (Lu): The total stream length within a catchment is determined by summing the lengths of individual stream segments in each subsequent order[18]. The stream length is measured from the mouth to the drainage divide[19]. Horton's stream length suggests a geometric relationship between the number of stream segments in successive stream orders and Landforms[12]. Stream lengthis one of the most important hydrological characteristics of the area as it gives information about surface run-off characteristics[22]. The stream lengths of various segments are measured by using GIS software. In the present study, the total length of all streams in the Lokapavani River Basin is 938.45 kms [Table. 1]. Many number of streams with relatively small in length are observed in steep slope and finer texture of the basin. Longer length of the streams is generally indicative of flatter catchment[2].

Mean Stream Length (Lsm): The mean stream length (Lsm) is an important morphometric parameter that reflects the characteristics of the drainage network and the geomorphic setting of the watershed[29]. It is calculated by dividing the total length of streams of a given order by the corresponding number of stream segments within that order. The mean stream length values for each stream order in the Lokapavani River Basin are presented in [Table. 1] providing insights into the hydrological and topographical variations across the basin.

Stream Length Ratio (RL): The stream length ratio (Rl) is defined as the ratio of the mean stream length of a given order to that of the next lower order[8]. This parameter provides insights into the hydrological characteristics, surface flow behavior, and the erosional stage of a watershed[4]. Variations in the stream length ratio between successive orders often indicate the geomorphic development and the transition of streams toward a late youth stage[19]. In the present study, the stream length ratio within the Lokapavani River Basin ranges from 0.243 to 4.60 [Table. 1] suggesting spatial variability in slope, lithology, and structural influence across the basin.

Table 1: Linear Aspects of the Lokapavani River Basin

Stream order (U)	1st Order	2nd Order	3rd Order	4th Order	5th Order	6th Order	Total
Stream Number (Nu)	980	211	40	8	2	1	1242
Stream length (Lu)	483.64	248.12	107.65	43.25	49.74	6.05	938.45
Mean stream length (Lsm)	0.493	1.175	2.69	5.40	24.87	6.05	
Stream length ratio (RL)	2.383	2.28	2.007	4.60	0.243		
Bifurcation ratio (Br)	4.644	5.27	5	4	2		
Mean bifurcation ratio (Mbr)				4.18			

Bifurcation Ratio (Rb): The bifurcation ratio (Rb) is defined as the ratio of the number of stream segments of a given order to the number of segments of the next higher order[27]. It is a dimensionless parameter that reflects the degree of branching within a drainage network. According to Horton (1945)[12], the bifurcation ratio serves as an important index of relief and dissection, typically ranging between 2 and 5 for natural watersheds. Variations in the bifurcation ratio between successive orders are often influenced by lithological, geological, and structural controls within the basin. Higher bifurcation ratios are generally associated with elongated watersheds and indicate strong structural influence and well-dissected terrain, while lower values are characteristic of flat or rolling landscapes with minimal structural disturbance[2, 10, 12]. In the present study, the mean bifurcation ratio (Rb) of the Lokapavani River Basin is calculated to be 4.18 [Table. 1] indicating a moderately dissected basin with structural control influencing its drainage development.

Aerial Aspects:

The area of the watershed/basin can directly reflect the overall volume of water. It is one of the important parameters because a basin/watershed's overall area is projected into the horizontal plane[17]. It is denoted by a letter 'A'. The overall area of the Lokapavani River Basin is 483.69 sq.km. The watershed's outer boundary that encloses its area is defined as the watershed perimeter. It is denoted by 'P'. The total perimeter of the Lokapavani River Basin is 122.55 km, and the length of the basin is 48.59 km. The Aerial aspects of the drainage basin such as basin area, basin perimeter, drainage density, stream frequency, drainage texture, drainage intensity, elongation ratio, circularity ratio, form factor, constant of channel maintenance, texture ratio, elongation ratio, length of overland flow, shape factor and compactness coefficient are calculated and results have been given in [Table. 2].

Drainage Density (Dd): the drainage density is the total length of streams of all orders (km) per drainage area (km²). Horton has introduced drainage density (Dd) as an expression to indicate the closeness of spacing of channels [Fig. 3]. The significance of drainage density is recognized as a factor determining the time travel by water[27]. If it is 1.24-2.49 then has coarse texture, 2.49-3.73 then the texture is moderate. If the value is 3.73-4.97 then the texture is fine while more than 4.97 it is very fine. The drainage density of Lokapavani river basin is 1.94 [Table. 2] which is low and that implies the surface run-off is low, and infiltration capacity is high depending on precipitation intensity. This indicates dense vegetation and the presence of permeable rocks with low relief.

Stream Frequency (Fs): Horton (1964) defined stream frequency as the ratio of the basin's total area to the number of streams (Nu). It is an index of various stages of landscape development and depends on the nature and amount of rainfall, the nature of rock and soil permeability of the region. The stream frequency of the Lokapavani River Basin is 2.56/km². [Table. 2] generally suggests a moderate drainage network. The ground has a moderate ability to absorb water, leading to a balance of surface run-off and groundwater infiltration. here the stream frequency is low, which have high infiltration rates and very permeable rock.

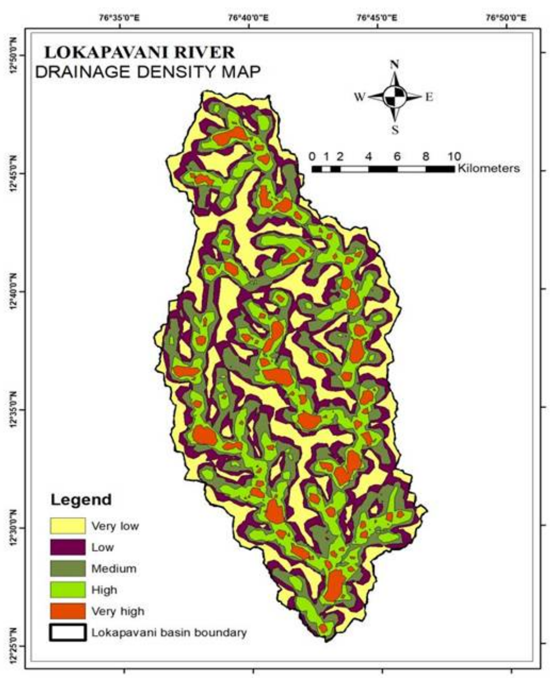

Fig. 3: Drainage Density map of the Lokapavani River Basin

Drainage Texture (Dt): The concept of drainage texture refers to the relative spacing of drainage lines, as described by Smith in 1950[28]. Drainage texture (T) varies depending on numerous factors, including climate, lithology, relief, infiltration capacity, vegetation cover, and the stage of drainage development[12]. Massive and resistant rock formations exhibit a coarse drainage texture, while areas underlain by soft or weak rock tend to display a finer drainage texture. As per Smith's classification from 1950, drainage basins are categorized into four groups: coarse (< 4 per km), intermediate (4–10 per km), fine (10–15), and ultra-fine (> 15 per km), based on their drainage texture. The drainage texture of the Lokapavani River Basin is calculated to be 10.13 [Table. 2] which provides insights into permeability and the potential for groundwater recharge. A higher drainage texture implies greater permeability and better groundwater recharge potential[6].

Drainage Intensity(Di): The drainage intensity (Di) is defined as the ratio of stream frequency to drainage density[9]. In the present study, the Lokapavani River Basin exhibits a low drainage intensity value of 1.32 [Table. 2]. This relatively low value suggests that drainage density and stream frequency exert minimal influence on the extent to which the surface has been lowered by agents of denudation. Consequently, surface run-off is not efficiently removed from the watershed or sub-watershed, indicating a moderate infiltration rate and potential susceptibility to localized flooding and erosion under high-intensity rainfall conditions.

Circularity Ratio (Rc): The circularity ratio (Cr) is defined as the ratio of the basin area to the area of a circle having the same perimeter as the basin[32]. A circularity ratio value of 1 represents a perfectly circular basin, while values less than 1 indicate increasing irregularity and deviation from a circular shape. It is calculated using the formula $Cr = 4\pi (A / P^2)$, where A is the basin area and P is the basin perimeter. The circularity ratio for the Lokapavani River Basin is 0.40 [Table. 2], indicating that the basin has an elongated shape.

Form Factor (Ff): The form factor (Ff) is defined as the ratio of the total drainage area to the square of the basin length[13]. The value of the form factor ranges from 0 indicating a highly elongated basin shape to 1 representing a circular basin. It shows a direct relationship with peak discharge and also helps in predicting the flow intensity of a drainage basin[12]. The form factor value for the Lokapavani River Basin is 0.25 [Table. 2], which indicates that the basin possesses an elongated shape.

Constant of Channel Maintanance (C): According to Schumm (1956)[27], the constant of channel maintenance (C) is the inverse of drainage density. It reflects not only the influence of rock type, permeability, climatic regime, vegetation, and relief, but also the effects of erosion duration and climatic history. Generally, lower C values for a basin indicate lower rock permeability, whereas higher C values suggest greater permeability. In the case of the Lokapavani River Basin, the constant of channel maintenance is calculated to be 0.51 [Table. 2] indicating moderate to high permeability, moderate slope and moderate surface run-off characteristics.

Texture Ratio (Rt): According to Schumm (1965)[27], the texture ratio is an important parameter in drainage morphometric analysis, as it reflects the influence of underlying lithology, infiltration capacity, and the relief characteristics of the terrain. It is defined as the ratio of the number of first-order streams to the perimeter of the basin. The texture ratio of the Lokapavani River basin is 7.99 [Table. 2] indicating a very coarse drainage texture, which may be associated with impermeable subsurface materials, steep slopes or both.

Elongation Ratio (Re): According to Schumm (1965)[27], the elongation ratio is defined as the ratio of the diameter of a circle having the same area as the basin to the maximum basin length. Strahler (1952)[30] noted that the elongation ratio typically ranges between 0.6 and 1.0 across a wide variety of climatic and geological conditions. Watershed slopes can be classified based on the elongation ratio as follows: circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7), and more elongated (< 0.5). The computed elongation ratio for the Lokapavani River Basin is 0.57 [Table. 2] which classifies the basin as elongated.

Length of Overland Flow (Lg): The length of overland flow refers to the distance water travels over the ground surface before it becomes concentrated in stream channels. According to Horton (1945)[12], it is approximately equal to half of the reciprocal of the drainage density. Based on the classification by Sukristiyanti et al. (2018), there are three classes of overland flow length (Lg): low (< 0.2), moderate (0.2–0.3), and high (> 0.3). The length of overland flow in the Lokapavani River Basin is 0.25 [Table. 2] which falls within the moderate range. This indicates a moderate slope, moderate run-off and good infiltration capacity within the basin.

Shape Factor (Fs): The shape factor is defined as the ratio of the square of the basin length to the area of the basin[13]. A lower shape factor indicates a more circular basin shape, which typically results in higher run-off.

Conversely, a higher shape factor suggests a more elongated basin, which is associated with lower run-off potential. The shape factor of the Lokapavani River basin is 4.87 [Table. 2], indicating that the basin is elongated in shape and therefore likely to have lower run-off characteristics.

Compactness Coefficient (Cc): According to Gravelius (1914)[11], compactness coefficient of a basin is the ratio of perimeter of basin to circumference of circular area, which equals the area of the basin. If Cc = 1: the basin is perfectly circular and Cc>1: the basin is more elongated and/or irregular in shape. The Cc of the Lokapavani River Basin is calculated to be 1.57 [Table. 2] which indicates that the basin is elongated in shape and/or irregular shape.

Table 2: Aerial Aspects of the Lokapavani River Basin

Morphometric Parameter	Formula/Method	Value
Basin Area(A)	GIS Software	483.69 Sqkm
Basin Perimeter(P)	GIS Software	122.55 Km
Basin Length (Lb)	GIS Software	48.59 km
Drainage Density (Dd)	Dd=Lu/A	1.94
Stream Frequency (Fs)	Fs=Nu/A	2.56
Drainage Texture (Dt)	Dt=Nu/P	10.13
Drainage Intensity(Di)	Di=Fs/Dd	1.32
Circularity Ratio (Rc)	$Rc=4\pi (A/P^2)$	0.40
Form Factor (Ff)	$Ff = A / (Lb)^2$	0.25
Constant of Channel Maintanance (C)	C=A/Lu	0.51
Texture Ratio (Rt)	Rt=N1/P	7.99
Elongation Ratio (Re)	√(4*A/P)/Lb	0.57
Length of Overland Flow (Lg)	Lg=1/(2Dd)	0.25
Shape Factor (Fs)	$Sf = (Lb)^2/ A$	4.87
Compactness Coefficient (Cc)	$Cc = 0.2821 * P / A^{0.5}$	1.57

Relief Aspects:

Basin Relief (H): The total relief of a basin represents the difference in elevation between its highest point and the lowest point along the valley floor. It serves as a key indicator of the drainage system's elevation characteristics[25]. Basin relief is a crucial morphometric parameter for understanding the denudational processes of a watershed and plays a vital role in landform development, drainage evolution, and the regulation of surface and subsurface water flow. Additionally, it influences the permeability, erosional behavior, and overall morphodynamic characteristics of the terrain[26]. The Basin Relief of the Lokapavani River Basin is 441 [Table. 3] indicates a moderate to high relief, suggesting noticeable elevation variation within the Lokapavani River Basin. This typically reflects moderate slopes, active fluvial processes, and a developing erosional stage.

Relief Ratio (Rh): The 'Rhl' is the ratio between the total relief and the lengthiest measurement of the basin parallel to the main drainage line[27]. A relief ratio of 0.009 [Table. 3] indicates moderate relief and slope within the basin. This suggests a balanced run-off and erosion potential, typical of a basin with moderate elevation variation and drainage efficiency.

Relative Relief: The maximum basin relief is calculated from the highest point on the basin perimeter to the mouth of the stream. To calculate Relative Relief (Rr), we use the formula proposed by Melton (1957). Rr= (H/P)*1000. A relative relief value of Lokapavani River Basin is 3.60 [Table. 3] indicates moderate relief intensity, suggesting that the Basin exhibits moderate terrain ruggedness, with a balanced slope profile conducive to both surface run-off and groundwater infiltration.

Ruggedness Number (Rn): Strahler's (1968) ruggedness number is the product of the basin relief and the drainage density. Values close to 1 generally denote dissected terrain with significant relief, while values below 0.3 indicate low relief and gentle slopes. Rn value of Lokapavani River Basin is 0.85 [Table. 3] indicates moderate terrain ruggedness. It reflects considerable relief and moderate drainage density, suggesting that the basin experiences moderate surface run-off, erosion potential, and structural control on drainage development.

Dissection Index (Dis): The dissection index is a ratio of the maximum relative relief to the maximum absolute relief. Dis for Lokapavani River Basin is 0.39 [Table. 3] (on a 0–1 scale) indicates a moderately dissected terrain.

Slope:

The slope map of the Lokapavani River Basin [Fig. 2] was derived from Cartosat DEM using ArcGIS to analyze the terrain characteristics and surface steepness. The slope represents the rate of elevation change over a specific horizontal distance and is a crucial parameter influencing surface run-off, soil erosion, infiltration, and landform development. The slope in the study area has been categorized into six classes ranging from 0 to 13,200 (map units). The lower slope values (0–877,000), represented by light to dark green shades, dominate most parts of the basin, indicating gentle to moderately sloping terrain. These areas are generally associated with pediplains and valley fills, where the run-off is relatively slower, promoting infiltration and groundwater recharge. Conversely, the higher slope values (2,740,000–13,200,000), shown in orange to red colors, are concentrated along the southern and central parts of the basin, particularly near the channel courses and hilly regions. These zones exhibit steep gradients and escarpments, which facilitate rapid surface run-off and increase the susceptibility to soil erosion and mass wasting. Overall, the slope variation in the Lokapavani River Basin reflects significant topographic heterogeneity. The northern and central regions are characterized by gently undulating terrain, while the southern and southwestern portions show steeper slopes, indicating active geomorphic processes and structural control on the drainage pattern.

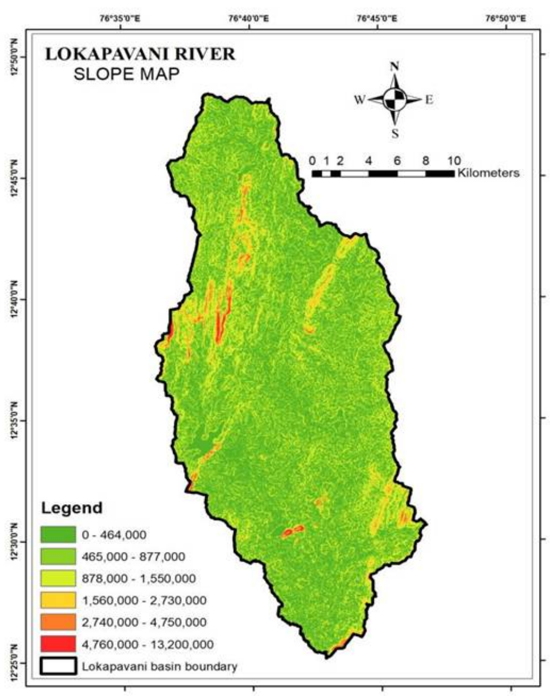

Fig. 4: Slope map of the Lokapavani River Basin

Table 3: Relief Aspects of the Lokapavani River Basin

Parameter	Formula/Method	Result	Interpretation
Basin Relief (H)	H = Max elevation(Z) - Min Elevation (z)	441	Moderate to high relief
Relief Ratio (Rh)	Rhl = H / Lb	0.009	Moderate slope
Relative Relief (Rr)	Rhp = H*1000/P	3.60	Moderate relief intensity
Absolute Relief (Ra)	GIS Software	1109	-
Ruggedness Number (Rn)	Rn = Dd * (H / 1000)	0.85	Moderately rugged terrain
Dissection Index (Dis)	Dis = H / Ra	0.39	Moderately dissected terrain

Hypsometric Analysis:

Hypsometry refers to the relative distribution of an area at different elevations within a given region, and the hypsometric curve (HC) represents the area–elevation relationship, illustrating how the basin area is distributed with respect to elevation[30]. Comparison of the shapes of hypsometric curves among different watersheds developed under similar geologic and geomorphic conditions provides valuable insights into the evolutionary history of hillslope processes. The hypsometry of a drainage basin can be represented either graphically, through a hypsometric curve (HC), or quantitatively, using the hypsometric integral (Hi)[34]. The hypsometric curve expresses the relationship between the volume of the remaining rock mass within the basin and the amount of material removed by erosion, thereby indicating the extent of landscape dissection[3, 14]. The form of hypsometric curve and the value of the integral are important elements in topographic form[16]. The hypsometric integral (Hi) is derived from the area under the hypsometric curve and is typically expressed as a percentage.

According to Strahler (1952)[30], the shape of the hypsometric curve reflects the geomorphic stage of a basin:

- Youthful stage: Convex-upward curve (Hi > 0.60), indicating a highly erosive landscape prone to landslides.
- Mature stage: S-shaped curve (0.30 > Hi < 0.60), representing a balanced state between erosion and deposition.
- Old or monadnock stage: Concave-upward curve (Hi < 0.30), indicating a subdued relief with limited erosional activity.

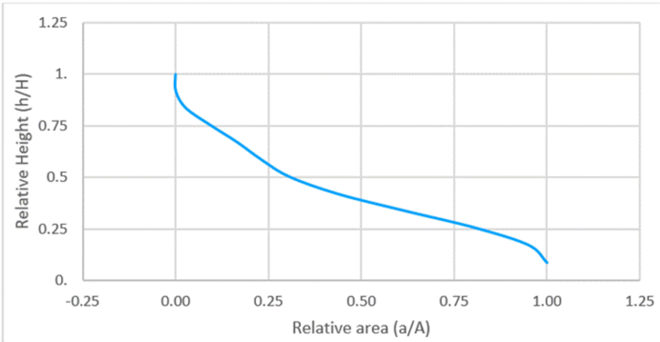

Fig. 5: Hypsometric curve of the Lokapavani River Basin

Table 4: Hypsometric Integral (HI) values of the Lokapavani River Basin

Value	Min	Max	Mean	Area accumalation (a)	a/A where A =483.65	h	h/H where H =440	HI
1	997	1033	1010	0.0296	0.000061	440	1	0.361
2	958	994	966.6	0.5372	0.0011	404	0.9181	0.239
3	920	957	932.4	13.532	0.0279	368	0.8363	0.335
4	883	919	899.6	45.868	0.0948	331	0.7522	0.463
5	845	882	864.9	80.245	0.1659	295	0.6704	0.537
6	807	844	825.3	111.425	0.2303	258	0.5863	0.497
7	769	806	785.2	148.126	0.3062	221	0.5022	0.438
8	732	768	748.9	211.452	0.4371	184	0.4181	0.469
9	694	731	712.1	298.131	0.616	148	0.3363	0.491
10	656	693	674.6	391.253	0.808	111	0.2522	0.505
11	618	655	637.6	460.245	0.9515	74	0.1681	0.531
12	580	617	606.3	483.655	1	37	0.0840	0.713
								Mean = 0.46

The hypsometric curve for the Lokapavani River Basin is S-shaped [Fig. 5] and the computed hypsometric integral (Hi) value of 0.46 [Table. 4] signifies that the basin is in the mature stage of geomorphic evolution. This indicates a landscape that has undergone substantial denudation but retains moderate relief and active fluvial processes.

Lineament and Lineament Density:

Lineaments are curvilinear or linear features on the Earth's surface, commonly identified from satellite imagery based on their distinct linear alignments. A lineament may represent a joint, fault, fracture, or elongated geological structure as well as topographic linearity or the straight course of streams[15, 21]. These features are of great hydrogeological significance, as they often act as pathways for groundwater movement, indicating zones of enhanced permeability. The presence of lineaments generally suggests favorable conditions for groundwater occurrence, with high lineament density zones corresponding to greater groundwater potential, and vice versa[24]. In this study, the lineament density was computed by dividing the total number of lineaments within the basin by its total area and subsequently classified into five categories: very low (0–75), low (75–150), moderate (150–225), high (225–300), and very high (300–378). Areas exhibiting high to very high lineament density indicate zones of strong structural influence and enhanced groundwater potential. The lineaments and lineament density map of the Lokapavani River Basin is presented in [Fig. 5].

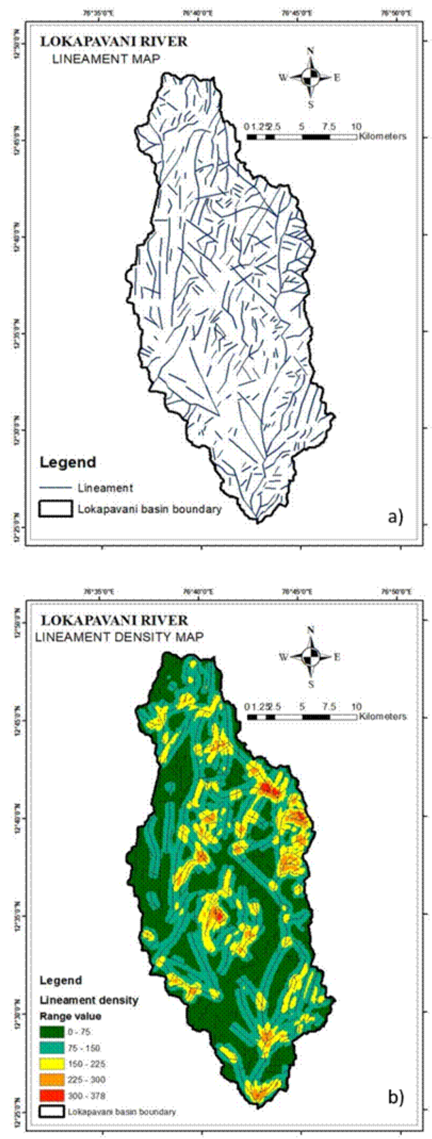

Fig. 5: a) Lineament, b) Lineament Density map of the Lokapavani River Basin

Lithology:

The lithological characteristics of the Lokapavani River Basin were analyzed using geological data, and a detailed lithology map has been prepared to represent the spatial distribution of rock formations [Fig. 6]. The study area is predominantly composed of Archaean crystalline rocks, primarily belonging to the Peninsular Gneissic Complex (PGC), which forms the fundamental geological framework of southern Karnataka. The major rock type present in the basin is Granite Gneiss (77.85%), which forms the dominant litho unit and provides the structural and lithological foundation of the region.

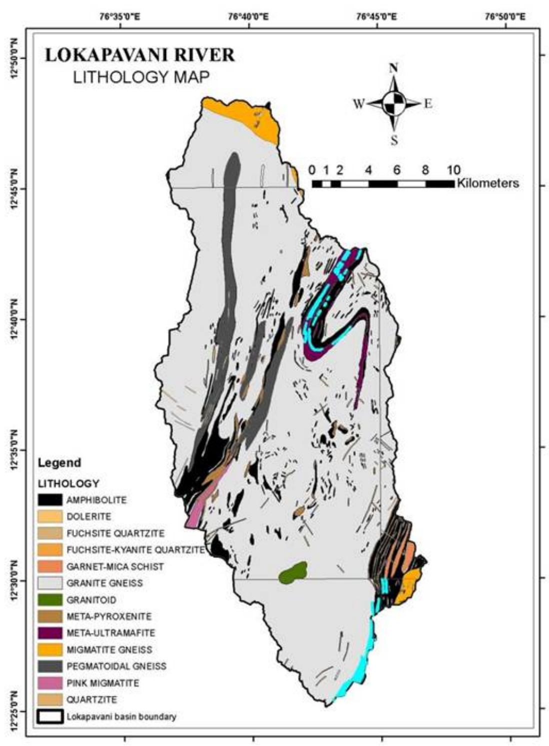

Fig. 6: Lithology map of the Lokapavani River Basin

Table 5: Area of Lithological units of the Lokapavani River Basin

Lithological units	Area (Sq.km)	Area (%)
Granite Gneiss	376.55	77.85
Amphibolite	46.72	9.66
Pegmatoidal Gneiss	24.66	5.1
Migmatite Gneiss	9.52	1.97
Meta Ultramafite	7.73	1.6
Meta Pyroxenite	5.56	1.15
Dolerite	2.95	0.61
Garnet-Mica Schist	2.41	0.5
Pink Migmatite	2.03	0.42
Granitoid	1.93	0.40
Quartzite	1.45	0.30
Fuchsite-Kyanite-Quartzite	1.35	0.28
Fuchsite Quartzite	0.67	0.14

Other significant lithological units include Amphibolite (9.66%), Pegmatoidal Gneiss (5.1%), Migmatite Gneiss (1.97%), Meta Ultramafite (1.6%), and Meta Pyroxenite (1.15%). Minor rock types identified in the area are Dolerite (0.61%), Garnet-Mica Schist (0.5%), Pink Migmatite (0.42%), Granitoid (0.40%), Quartzite (0.30%), Fuchsite-Kyanite-Quartzite (0.28%), and Fuchsite Quartzite (0.14%). The total area (sq.km) and area percentage of rock types are tabulated in [Table. 5].

Geomorphology:

The use of Remote Sensing technology for geomorphological studies has definitely increased its importance due to the establishment of its direct relationship with allied disciplines such as geology, soils, vegetation/landuse and hydrology[23]. The fundamental framework of the geomorphological classification scheme is a geomorphic unit. Studies on the geomorphic units serve as basic descriptions in geomorphologic mapping which is a prerequisite for any landform analysis and to understand the influence of the landform on the intensity of natural hazards in the given area[5]. The geomorphology of the Lokapavani River Basin has been interpreted using remote sensing and GIS techniques, and a geomorphological map has been prepared to depict the various landforms present in the area [Fig. 7].

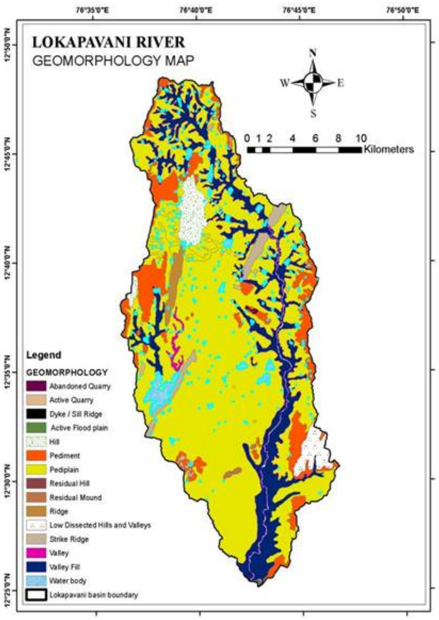

Fig. 7: Geomorphology map of the Lokapavani River Basin

The basin exhibits a wide range of geomorphic features shaped by lithological control, erosional processes, and structural influences. The dominant landform is the pediplain, covering about 63.56% of the basin area. It represents an extensive, gently undulating erosional surface formed by the coalescence of pediments through long-term weathering and slope retreat. The valley fill units constitute about 16.38% of the area and consist of unconsolidated alluvial deposits along stream channels, serving as important groundwater recharge zones. Pediments, occupying 9.27% of the basin, form transitional surfaces between hills and plains and indicate moderate denudation. Other significant landforms include hills (2.46%), strike ridges (1.67%), low dissected hills and valleys (1.58%), ridges (0.96%), and valleys (0.43%), representing moderately to strongly dissected terrains controlled by lithological resistance and structural lineaments. Residual hills and mounds (0.23%) are remnants of resistant rock masses left after prolonged erosion, while active floodplains (0.02%) are confined to narrow zones along the main river channels, reflecting recent fluvial activity. Water bodies occupy about 2.30% of the total basin area, comprising reservoirs, tanks, and natural ponds that play a vital role in surface water storage and irrigation. The total area (sq.km) and area percentage of landform types in the study area are tabulated in [Table. 6].

Table 6: Area of Geomorphological Units of the Lokapavani River Basin

Geomorphological units	Area (Sq.km)	Area(%)
Pediplain	307.43	63.56
Valley fill	79.22	16.38
Pediment	44.83	9.27
Hill	11.89	2.46
Water body	11.13	2.30
Strike Ridge	8.07	1.67
Low dissected hill and Valley	7.64	1.58
Ridge	4.64	0.96
Valley	2.07	0.43
Residual hill and Residual mound	1.11	0.23
Active Floodplain	0.09	0.02

Soil:

The soil characteristics of the Lokapavani River Basin were analyzed and a soil map was prepared to delineate the spatial distribution of different soil types [Fig. 8]. The study area exhibits a diverse range of soils formed under varying lithological, topographical, and climatic conditions. The major soil types identified include Sandy Clay Loam, Clay, Sandy Clay, Loamy, Clay Loam and Sandy Loam. The total area (sq.km) and area percentage of each soil type is tabulated in [Table. 7]. Sandy clay loam and clay soils dominate the basin, indicating moderate to low permeability and high water-holding capacity, which favor agricultural activities. The spatial variation in soil texture reflects the influence of the underlying gneissic lithology and fluvial processes. Overall, the basin's soils are moderately fertile and support a variety of crops, contributing significantly to the region's agricultural potential.

Table 7: Area of soil types of the Lokapavani River basin

Soil types	Area (Sq.km)	Area(%)
Sandy Clay Loam	140.75	28.75
Clay	134.56	27.48
Sandy Clay	102.79	21
Loamy	60.51	12.36
Clay Loam	32.39	6.6
Sandy Loam	8.52	1.71

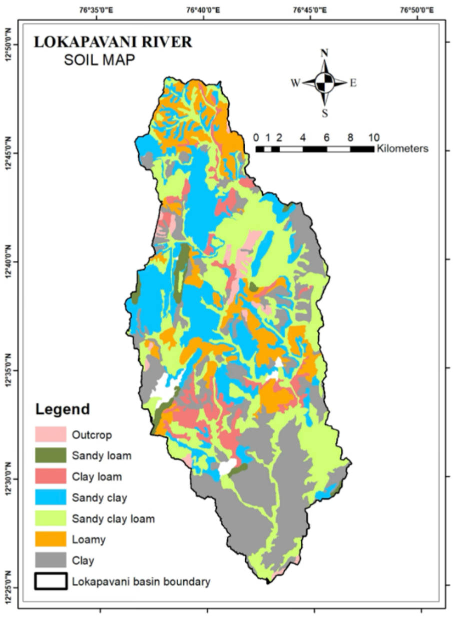

Fig. 8: Soil map of the Lokapavani River Basin

5 Conclusion

The morphometric, geological, and geomorphological analysis of the Lokapavani River Basin using Remote Sensing (RS) and Geographic Information System (GIS) techniques provides a comprehensive understanding of the basin's hydrological characteristics, drainage behavior, and geomorphic evolution. The integration of DEM data and spatial analysis in ArcGIS facilitated precise delineation of the drainage network and computation of key morphometric parameters. The study area, covering an area of approximately 483.69 km², and basin perimeter of 122.55, exhibits a sixth-order drainage system, with a mean bifurcation ratio of 4.18, indicating moderate structural control and a well-developed drainage network. The drainage density (1.94 km/km²) and stream frequency (2.56) suggest a coarse drainage texture with low surface run-off and high infiltration potential. The elongation ratio (0.57), form factor (0.25), and circularity ratio (0.40) collectively reveal that the basin is elongated in shape, implying delayed peak discharge and extended run-off duration, which are favorable for groundwater recharge. Relief parameters such as basin relief (441 m), relief ratio (0.009), and ruggedness number (0.85) indicate moderate to high relief and moderate slope conditions, suggesting active erosional and depositional processes. The dissection index (0.40) and hypsometric integral value (0.46) further confirm that the basin is in a mature geomorphic stage, representing a landscape in dynamic equilibrium between erosion and deposition. Geologically, the basin is dominated by Granite Gneiss (77.85%), followed by Amphibolite and Pegmatoidal Gneiss, reflecting the influence of the Peninsular Gneissic Complex on the region's lithological composition. The geomorphic units, including pediplains (63.56%), valley fills (16.38%), and pediments (9.27%), denote a terrain shaped by prolonged denudation and fluvial processes. The lineament density pattern highlights structurally controlled zones with higher groundwater potential, particularly along major fracture systems. Soil analysis reveals that sandy clay loam (28.75%) and clay (27.48%) are the predominant soil types, indicating moderate infiltration and high agricultural suitability. The overall landform–lithology–soil association indicates a basin with favorable hydrological and geomorphological conditions for sustainable water resource management and agricultural development.

In summary, the morphometric characteristics, geological framework, and geomorphic setup of the Lokapavani River Basin demonstrate a mature, moderately dissected basin with significant potential for groundwater recharge, soil conservation, and watershed management initiatives. The findings of this study can serve as a scientific basis for integrated watershed planning, land use optimization, and sustainable resource management within the basin.

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