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"MORPHOMETRIC ANALYSIS OF THE LOWER GHATAPRABHA SUB-WATERSHEDS (1 & 2) IN BAGALKOTE DISTRICT, KARNATAKA"

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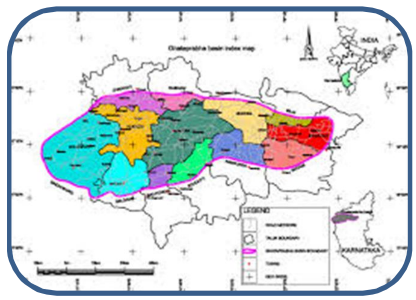

ABSTRACT—

The present study aims to comprehensively analyze the drainage network characteristics, basin geometry, and relief parameters of the Lower Ghataprabha sub-watersheds (1 & 2) located in Bagalkote District, covering a total geographical area of 1639.87 km². A systematic morphometric analysis was carried out using standard quantitative techniques integrated with Remote Sensing (RS) and Geographic Information System (GIS) tools to evaluate the hydrological and geomorphic behaviour of the basin. The analysis reveals that the watershed is characterized by a well-developed 7th-order drainage system, comprising 4,388 stream segments with a cumulative stream length of 3,081.12 km, indicating a highly organized and mature fluvial network.

The linear morphometric parameters, including stream order, stream length, and bifurcation ratio, demonstrate a clear hierarchical structure and suggest strong structural control, possibly influenced by underlying lithology and tectonic features. The observed mean bifurcation ratio further indicates moderate to high structural disturbances affecting the drainage pattern. The dominance of lower-order streams reflects active headward erosion and ongoing geomorphic processes within the basin. Areal parameters such as drainage density, stream frequency, elongation ratio, and circularity ratio collectively indicate that the basin is moderately elongated with low-to-moderate drainage density. This suggests relatively permeable subsurface conditions, moderate infiltration capacity, and reduced surface runoff. The elongated shape of the basin plays a significant role in hydrological response, resulting in delayed peak discharge and a longer runoff duration, thereby reducing the intensity of flood events compared to more circular basins.

Relief aspects of the watershed, including basin relief and relief ratio, highlight substantial topographic variation ranging from 404 m to 628 m above mean sea level, reflecting moderate vertical dissection and slope variability. The computed ruggedness number indicates a terrain with considerable irregularity, which enhances the potential for soil erosion and sediment transport, especially during periods of intense rainfall. These relief characteristics, in combination with limited vegetation cover and semi-arid climatic conditions, contribute to the overall vulnerability of the watershed to land degradation processes.

Overall, the integrated morphometric assessment reveals that the Lower Ghataprabha watershed represents a structurally influenced, moderately dissected basin exhibiting characteristics of a mature geomorphic stage. The interplay of linear, areal, and relief parameters provides critical insights into the *basin's hydrological behaviour, erosion susceptibility, and landscape evolution. The findings of this study are highly significant for watershed management, as they offer a scientific basis for prioritizing soil and water conservation measures, improving groundwater recharge, and planning sustainable land-use practices in the region.*

KEYWORDS: *Morphometric Analysis, Watershed Management, Drainage Network, Bifurcation Ratio*

INTRODUCTION

Morphometric analysis is a quantitative approach used to measure and evaluate the shape, size, and geometric characteristics of natural features such as landforms, river basins, watersheds, and drainage networks. It provides a scientific basis for understanding the spatial arrangement and structural organization of drainage systems, which are fundamental to the study of landscape evolution and hydrological processes. By applying mathematical and statistical techniques, morphometric analysis enables the systematic interpretation of terrain features and their influence on runoff, infiltration, erosion, and sediment transport (Horton, 1945; Strahler, 1958).

The analysis of morphometric parameters is generally categorized into linear, areal, and relief aspects, each reflecting different dimensions of watershed characteristics. Linear parameters, such as stream order and bifurcation ratio, provide insights into the hierarchical structure and structural control of drainage networks. Areal parameters, including drainage density and basin shape indices, help in assessing infiltration capacity, runoff potential, and hydrological response. Relief parameters, such as basin relief and ruggedness number, indicate elevation variation and terrain complexity, which directly influence erosion processes and slope dynamics (Schumm, 1956; Miller, 1953).

Morphometric studies play a crucial role in various scientific and applied fields, including Hydrology, Geomorphology, watershed management, and environmental planning. In recent decades, the integration of Remote Sensing (RS) and Geographic Information System (GIS) technologies has significantly enhanced the accuracy, efficiency, and reproducibility of morphometric analysis. These tools allow for the extraction of drainage networks and terrain attributes from Digital Elevation Models (DEMs), facilitating detailed spatial analysis even in data-scarce regions.

In semi-arid environments, where water availability is limited and land degradation is a major concern, morphometric analysis becomes particularly important. It helps in identifying erosion-prone areas, evaluating groundwater potential zones, and supporting sustainable land-use planning. Thus, morphometric evaluation serves as a vital tool for understanding watershed behaviour and for developing effective strategies for soil and water resource management.

Study Area

The Lower Ghataprabha watershed is situated in the northern part of Karnataka, within Bagalkote District, and forms an important sub-basin of the Krishna River system**. Geographically, the watershed extends between latitudes 15°45′ to 16°40′ N and longitudes 74°15′ to 76°00′ E, covering a semi-arid plateau region characterized by hot and dry climatic conditions.** The basin is bounded by the Malaprabha River basin to the south, Maharashtra to the west, and the Krishna River basin to the north, indicating its hydrological and geographical significance within the larger Deccan plateau drainage system. Physiographical, the study area exhibits a diverse terrain consisting of sandstone formations, undulating plateau surfaces, stony riverbanks, and occasional escarpments and cliffs. The river channel becomes wider in the downstream reaches, particularly near the confluence, where it attains widths ranging from 300 to 646 meters. These geomorphic features reflect the influence of lithology and long-term fluvial processes on landscape evolution (Schumm, 1956). The Ghataprabha River flows through major administrative units such as Mudhol, Bilagi, and Bagalkot taluks before taking a south-easterly course, indicating structural and topographic control over its flow direction.

The watershed encompasses several important settlements, including Chiksangama, Veerapur, Yadahalli, Kaladgi, Sharadal, Chinchakhandi, Mudhol, Jaliber, and Malali, which are primarily dependent on agriculture and river-based resources. The region is well connected through transportation networks such as State Highway 34 and National Highway 218, along with railway infrastructure including Bagalkot and Mugalolli stations, facilitating socio-economic development.Land use in the study area is predominantly agricultural, with major crops including sugarcane, pulses, grapes, and bajra (pearl millet), reflecting adaptation to semi-arid climatic conditions. However, forest cover is extremely limited (approximately 81.1 hectares), indicating ecological vulnerability and reduced natural protection against soil erosion. The presence of minimal cultivable wasteland further suggests intensive land utilization. Hydrologically, the watershed is influenced by upstream tributaries such as the Hiranyakeshi River and Markandeya River, which contribute to its integration within the broader Krishna basin system.

The combination of semi-arid climate, varied topography, and intensive agricultural practices makes the Lower Ghataprabha watershed a critical region for morphometric evaluation, particularly in the context of water resource management, soil conservation, and sustainable land-use planning (Horton, 1945; Strahler, 1958). Figure 1 illustrates the geographical location and spatial extent of the study area.

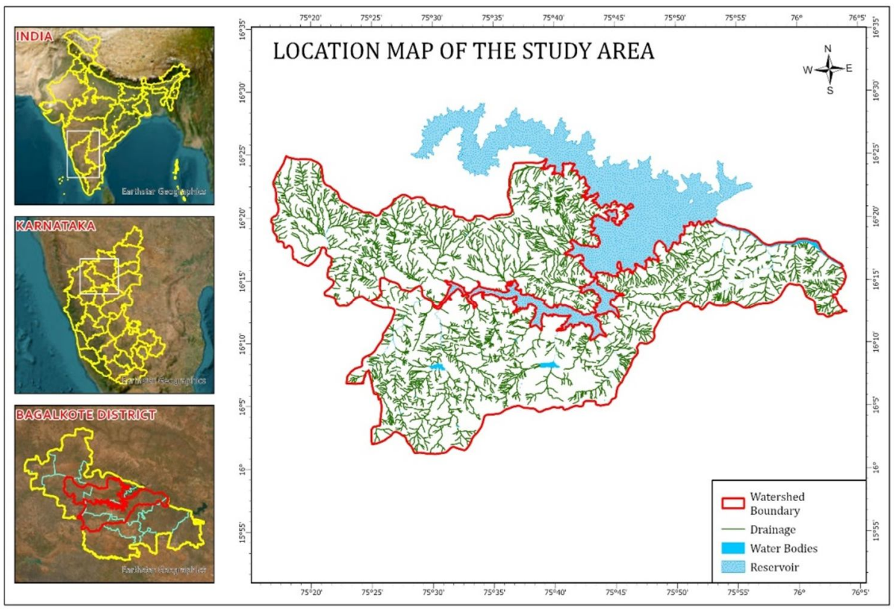

Figure 1: Location of the study area.

Materials and Methods

The morphometric analysis of the watershed was carried out using integrated Remote Sensing (RS) and Geographic Information System (GIS) techniques, which provide an efficient and accurate framework for terrain analysis and hydrological assessment. ASTER Digital Elevation Model (DEM) data with appropriate spatial resolution and Survey of India (SOI) topographic sheets on a 1:50,000 scale were utilized to prepare base maps and to extract drainage and watershed characteristics.

The drainage network of the watershed was delineated through careful digitization of SOI toposheets, supplemented by DEM-based hydrological tools. Stream segments were identified, and their frequency and lengths were computed for different stream orders. Fundamental basin parameters, including (a) drainage area, (b) basin perimeter, (c) basin length, (d) stream order, and (e) mean stream length, were derived as primary morphometric variables.

Based on these primary parameters, secondary morphometric indices were calculated using standard mathematical formulae. These include (i) bifurcation ratio, (ii) drainage density, (iii) stream frequency, (iv) elongation ratio, (v) circularity ratio, and (vi) form factor. These indices are widely used to evaluate the structural control, hydrological response, and geomorphic evolution of drainage basins (Horton, 1945; Strahler, 1964; Schumm, 1956).

A comprehensive analysis of morphometric characteristics was subsequently performed by classifying the parameters into linear, areal, and relief aspects. Each parameter was systematically computed, interpreted, and correlated to understand the basin's hydrological behaviour, erosion potential, and terrain characteristics. Frequently used parameters in this study include drainage area, stream order, stream length, bifurcation ratio, drainage density, and relief ratio, which together provide an integrated understanding of watershed dynamics.

RESULTS AND DISCUSSION

Morphometry refers to the quantitative measurement and analysis of the configuration, shape, and spatial organization of the Earth's surface features (Clarke, 1966). It provides a scientific basis for understanding the structural and functional characteristics of drainage basins and their influence on hydrological processes. Morphometric investigation is typically carried out by evaluating three major categories of parameters: (i) linear aspects, (ii) areal aspects, and (iii) relief aspects, each representing different dimensions of basin and slope contributions (Nag & Chakraborty, 2003).

The results of the morphometric analysis are presented in Tables 1 and 2 (A, B, and C), which summarize the computed values of various parameters, including stream order, stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio (Rbm), relief ratio (Rh), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), circularity ratio (Rc), elongation ratio (Re), and length of overland flow (Lg).

These parameters collectively describe the geometric, hydrological, and structural characteristics of the watershed. The spatial distribution and hierarchical organization of the drainage network are illustrated in Figure 2, which depicts the drainage pattern and associated water bodies of the study area.

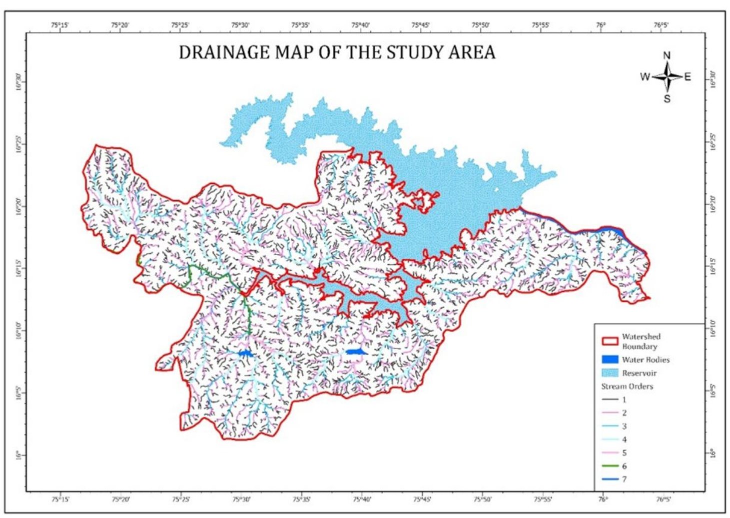

Figure 2: Drainage Network & Water Bodies of the study area.

Table 1:

Parameter	Equation
1. Linear	
A. Stream Order (Strahler,1964)	Hierarchical Rank
B. Stream Number (Horton,1945)	Nu, No of Streams
C. Stream Length (Horton,1945)	Lu, Streams Length
D. Mean Stream Length (Lsm) (Schumn, 1956)	Lsm=Lu/Nu
E. Stream length ratio (Horton,1945)	RL=Lu/Lu-1
F. Bifurcation Ratio (Rbm) (Schumn, 1956)	Rb=Nu/Nu+1; Here, Nu=Total number of stream segment of order'u',Nu+1=Number of segment of next higher order.
2. Areal	
A. Drainage Density (Dd) (Horton, 1932)	Dd=L/A; Here, L=Total length of streams; A=Area of basin
B. Stream Frequency (Fs) (Horton, 1932)	Fs = N/A; Here, N=Total number of streams; A=Area of basin
C. Drainage Texture (Rt) (Horton, 1932)	Rt = N1/P ; where, N1=Number of 1st order streams, P=Perimeter of basin.
D. Form factor (Rf) (Horton, 1932)	Rf=A/(Lb)2; Here, A=Area of basin; Lb=Basin length
E. Circulatory ratio (Rc) (Miller, 1953)	Rc=4πA/P2; where, A=, π=3.14, P=Perimeter of basin
F. Elongation ratio (Re) (Schumn, 1956)	Re=2√(A/π)/Lb; Here, A=Area of basin, π=3.14 and Lb=Basin length
3. Relief	
A. Maximum Basin Height(H)	H
B. Minimum Basin Height(h)	h
C. Basin relief (Bh) (Schumm, 1956)	Bh=H-h
D. Relief Ratio (Rh) (Schumm, 1956)	Rh=Bh/Lb, Here, Bh Basin Relief, Lb=Length of Basin
E. Ruggedness Number (Rn) (Schumm, 1956)	Rn=Bh*Dd Here, Bh Basin Relief, Dd=Drainage Density

Table 2(A)
Study Area Linear Aspect:

Area in km2	Length (km)	Stream orders (U)								Stream lengths (Lu)							
		1	2	3	4	5	6	7	Total	1	2	3	4	5	6	7	Total
1639.87	32	3274	837	197	61	18	1	1	4388.00	1738.09	753.81	322.89	183.07	50.40	32.88	9.30	3081.12

Mean Stream length (Lsm)in Km								Stream length ratio (Rl)						
1	2	3	4	5	6	7	Average	R 2/1	R 3/2	R 4/3	R 5/4	R 6/5	R 6/7	Average
0.53	0.90	1.63	3.0	2.80	32.8	9.29	7.29	0.43	0.42	0.56	0.27	0.65	0.28	0.43

Bifurcation ratio (Rb)						
Rb 1/2	**Rb 2/3**	**Rb 3/4**	**Rb 4/5**	**Rb 5/6**	**Rb 6/7**	**Mean Bifurcation ratio (Rb)**
4.912	5.248731	4.229508	4.388889	19	2	6.629786

Table 2(B)
Study Area Areal Aspect:

Drainage density	Drainage Texture	Stream Frequency	Elongation ratio	Circularity ratio	Form factor	Ruggedness Number
1.88	6.53	2.68	0.71	0.08	1.60	420.87

Table 2(C):
Study Area Relief Aspect:

Elevation in 'm'		Basin relief	Relief ratio
Max 'H'	Min 'h'	(Bh)	(Rh)
628	404	224	7

4. Results and Discussion

Morphometric analysis provides a quantitative framework to evaluate the geometry, structure, and evolution of drainage basins. The results are interpreted under three major categories: (i) linear aspects, (ii) areal aspects, and (iii) relief aspects, which collectively explain the hydrological behaviour and geomorphic development of the watershed (Clarke, 1966; Nag & Chakraborty, 2003).

4.1 Linear Aspects

Linear aspects describe the structural organization and hierarchical arrangement of the drainage network. The parameters analysed include stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio.

A) Stream Order (U)

Based on the Strahler (1964) classification system, the drainage network of the study area is identified as a 7th-order basin, comprising a total of 4,388 stream segments. The distribution of streams across orders shows a clear exponential decrease: 3,274 first-order, 837 second-order, 197 third-order, 61 fourth-order, 18 fifth-order, and one each of sixth and seventh order streams.

This systematic decline in stream frequency with increasing order is characteristic of natural drainage systems and reflects a well-developed hierarchical organization. The dominance of lower-order streams indicates active headward erosion and dissection processes in the upper reaches of the basin (Horton, 1945).

B) Stream Length (Lu)

The total stream length of the basin is 3,081.12 km, with first-order streams contributing the largest share (1,738.09 km), followed by second-order (753.81 km) and progressively decreasing in higher orders.

The concentration of stream length in lower orders indicates intense dissection and high drainage density in headwater regions, which is typical of dendritic to sub-dendritic drainage patterns developed over relatively homogeneous lithology (Strahler, 1958).

C) Mean Stream Length (Lsm)

The mean stream length shows a progressive increase from 0.53 km in first-order streams to 32.87 km in sixth-order streams, with an overall average of 7.29 km.

This trend reflects the natural geomorphic process of channel integration, where smaller tributaries merge to form longer and more efficient channels. The increase in mean stream length with stream order indicates improved flow efficiency and sediment transport capacity downstream (Schumm, 1956).

D) Stream Length Ratio (Rl)

The average stream length ratio is 0.43, ranging between 0.27 and 0.65.Such relatively low values suggest that the basin is in an early to mature stage of geomorphic evolution, where lower-order streams dominate the network and higher-order channels are still developing. Variations in stream length ratio also indicate the influence of lithological heterogeneity and slope variation.

E) Bifurcation Ratio (Rb)

The bifurcation ratio varies significantly between stream orders, with values of 4.91, 5.24, 4.22, 4.38, 19, and 2, resulting in a mean bifurcation ratio of 6.62.

A mean Rb value greater than 5 indicates strong structural control over the drainage network, likely due to geological factors such as faults, fractures, or lithological variations. High variability in Rb values further suggests localized tectonic disturbances affecting stream branching patterns (Strahler, 1964).

4.2 Areal Aspects

Areal aspects provide insights into basin shape, runoff characteristics, and hydrological response. The study area has a basin area of 1639.87 km^2 and a perimeter of 501 km.

A) Drainage Density (Dd)

The drainage density is 1.88 km/km^2, indicating a low-to-moderate drainage density.

This suggests:

- Permeable subsurface materials
- Moderate infiltration capacity
- Reduced surface runoff

Such conditions are typical of basins developed over resistant lithology and indicate a moderately dissected and mature landscape (Horton, 1932).

B) Stream Frequency (Fs)

- The stream frequency is 2.68 $streams/km^2$, representing a moderate value.
- This reflects a balanced interaction between climate, lithology, and relief, indicating efficient drainage without excessive channel development.

C) Drainage Texture (Rt)

- The drainage texture value of 6.53 falls within the moderate category, indicating a well-integrated drainage network.
- This suggests moderate relief and resistance of underlying rock formations, supporting stable drainage development (Smith, 1950).

D) Elongation Ratio (Re)

The elongation ratio of 0.71 indicates that the basin is moderately elongated.

Hydrological implications:

- Lower peak discharge
- Longer runoff duration
- Reduced flood intensity

Such basins are generally less prone to flash flooding compared to circular basins (Schumm, 1956).

E) Circularity Ratio (Rc)

The circularity ratio of 0.08 is extremely low, indicating a highly irregular and elongated basin shape.

This reflects:

- Structural influence
- Uneven topography
- Longer flow paths

Such basins typically exhibit delayed hydrological response and reduced flood peaks (Miller, 1953).

F) Form Factor (Rf)

The reported form factor value (1.60) appears scientifically inconsistent, as form factor values generally range between 0 and 1.

This suggests a possible calculation error. However, based on elongation ratio and circularity ratio, the basin can be interpreted as elongated rather than circular, indicating slower runoff concentration and reduced flood hazard.

4.3 Relief Aspects

Relief aspects describe the vertical dimension of the basin and its influence on erosion and runoff.

A) Basin Relief and Relief Ratio

The basin has:

- Maximum elevation (H): 628 m
- Minimum elevation (h): 404 m
- Basin relief (Bh): 224 m

The relief ratio is reported as 7, which appears unusually high and may require recalculation.

Moderate basin relief indicates:

- Moderate slope gradients
- Active erosion processes
- Controlled runoff velocity

These characteristics influence both sediment transport and geomorphic evolution (Schumm, 1956).

B) Ruggedness Number (Rn)

The ruggedness number is 420.87, indicating extremely high terrain roughness.

This suggests:

- High erosion susceptibility
- Rapid sediment transport
- Strong interaction between slope and drainage density

However, this value appears significantly high and may need verification, as typical ruggedness numbers are generally much lower. Despite this, the terrain can be interpreted as moderately to highly dissected, especially under semi-arid climatic conditions.

CONCLUSION:

The present study provides a comprehensive morphometric evaluation of the Lower Ghataprabha sub-watersheds (1 & 2) located in Bagalkote District, highlighting the structural, hydrological, and geomorphic characteristics of the basin. The analysis reveals that the watershed is a 7th-order drainage system, indicating a well-developed and mature fluvial network. The systematic variation in linear parameters, particularly stream order, stream length, and bifurcation ratio, demonstrates a clearly defined hierarchical organization of the drainage network. The relatively high mean bifurcation ratio suggests significant structural control, likely governed by underlying geological formations, fractures, and lithological variations, which influence stream branching and flow patterns.

The areal morphometric parameters indicate that the basin is moderately elongated, as reflected by elongation ratio and circularity ratio values. The low-to-moderate drainage density suggests the presence of relatively permeable subsurface materials, allowing moderate infiltration and reducing surface runoff intensity. These characteristics collectively imply a hydrological system that responds gradually to rainfall events, resulting in delayed peak discharge and reduced flood intensity compared to more compact basins. However, the moderate stream frequency and drainage texture indicate that the basin maintains an efficient drainage network capable of transporting runoff effectively.

Relief parameters, including basin relief and ruggedness number, highlight moderate to significant topographic variation, which plays a crucial role in controlling erosion and sediment transport processes. The interplay between slope gradients, drainage density, and limited vegetation cover enhances the basin's susceptibility to soil erosion, particularly during high-intensity rainfall events. Although the elongated basin shape reduces flood peaks, the potential for increased sediment yield remains high due to terrain irregularity and semi-arid climatic conditions.

Overall, the morphometric characteristics suggest that the watershed is shaped by a combination of resistant lithology, structural influences, and moderate geomorphic activity, representing a mature stage of landscape evolution. The findings provide valuable insights into the basin's hydrological behaviour, erosion dynamics, and drainage efficiency, forming a robust scientific basis for hydrological modelling, soil and water conservation planning, and sustainable watershed management.

Furthermore, the applicability of these results can be significantly enhanced by integrating morphometric analysis with land use/land cover (LULC) data, soil characteristics, and rainfall patterns. Previous LULC studies conducted in Bagalkote District by Dr. Basavaraj Bagade and Anupama Dubey highlight the dominance of agricultural land use and limited vegetation cover, which directly influence runoff, infiltration, and erosion processes in the region. The integration of such datasets would enable more precise identification of erosion-prone zones, groundwater recharge areas, and priority regions for conservation interventions.Such an integrated and multidisciplinary approach would significantly enhance decision-making processes and contribute to the long-term sustainability and resilience of the watershed ecosystem.

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