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MORPHOMETRIC ANALYSIS OF BURHIGANG AND SADHARU RIVER BASIN WITH THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM (GIS)

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Abstract

The morphometric analysis of drainage basins and channel networks is crucial for understanding the geo-hydrological nature of the area, reflecting the prevailing climate, geology, geomorphology, and structural antecedents of the catchment area (Rao et al., 2009). Geographical Information System (GIS) offers an effective tool for image processing, identification of morphological features, and analyzing basin properties. This study aims to evaluate morphometric parameters such as stream order (N_u), stream length (L_u), bifurcation ratio (R_b), drainage density (D_d), stream frequency (F_s), etc., of the Burhigang and Sadharu basins, two adjoining basins situated in the newly created Biswanath district of Assam, including a small part in Arunachal Pradesh. The basins are located between 26°57'17.10" N and 26°38'10.75" N latitudes and 93°06'32.85" E and 93°16'42.25" E longitudes.The GIS-based morphometric analyses reveal that both Burhigang and Sadharu are 4th order basins covering 160.68 km² and 74.91 km² area, respectively. Utilizing SRTM data rectified with topographic data of 1:50000 scales obtained from the Survey of India toposheet, this paper presents an analysis of morphometric parameters using digital analysis and standard formulae suggested by Horton (1932, 1945), Miller (1953), Schumm (1956), and Strahler (1964).

Keywords: Burhigang, Sadharu, River Basin, Morphometric Analysis, Geographic Information System.

1. INTRODUCTION

Morphometry, as a field, involves the measurement and mathematical analysis of the earth's surface configuration, including the shape and dimensions of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). This analysis encompasses various aspects such as linear, areal, relief, gradient of channel network, and contributing ground slope of the basin (Nautiyal, 1994; Nag and Chakraborty, 2003; Magesh et al., 2012). It is widely recognized that drainage basin morphology reflects the geological and geomorphological processes that have occurred over time (Horton, 1945; Strahler, 1952, 1964; Shreve, 1969; Evans, 1972; Chorley et al., 1984; Merritts and Vincent, 1989; Ohmori, 1993; Oguchi, 1997; Burrough and McDonnell, 1998; Hurtrez et al., 1999). Understanding drainage morphometry is crucial for comprehending landform processes, physical properties of soil, and erosional characteristics river basin.

Remote Sensing and Geographic Information System (GIS) techniques have proven to be efficient tools for delineating, updating, and conducting morphometric analysis of drainage basins. GIS facilitates image processing, identification of morphological features, and analysis of basin properties. This paper focuses on the morphometric analysis of two adjoining river basins, the Burhigang and the Sadharu, located in the Biswanath district of Assam, utilizing GIS-based techniques. The study aims to provide insights into the hydrological behavior of the basin, which can be valuable for understanding various aspects of basin dynamics.

Several previous studies have utilized similar methodologies for morphometric analysis in different geographical settings. For example, Ramu et al. (2013) conducted a morphometric analysis of the Tungabhadra drainage basin based on secondary sources such as SRTM data. Rao et al. (2009) demonstrated the dynamic equilibrium achieved through interactions between matter and energy to understand the geo-hydrological characteristics of drainage basins. Similarly, Somashekar and Ravikumar (2011) carried out quantitative morphometric analysis for the Hesaraghatta watershed and its sub-watersheds in Bangalore. Tamma Rao et al. (2012) utilized RS and GIS techniques to evaluate morphometric parameters of sub-watersheds in the West Godavari district. Waikar et al. (2014) and Rai et al. (2014) conducted GIS-based morphometric studies of drainage basins using ArcGIS software and SRTM data.

In this study, we aim to analyze the morphometric characteristics of two adjoining river basins under similar physiographic conditions, namely the Burhigang and Sadharu basins, using GIS techniques.

2. OBJECTIVES

The basic aim of the study is to attain the following objectives:-

i) To apply Geographic Information System (GIS) for the morphometric analysis of the Burhigang and the Sadharu River.

ii) To find out the morphometric variables of the Burhigang and the Sadharu basin with the help of digital analysis and standard formulae.

3. METHODOLOGY

The morphometric analysis of the Burhigang and Sadharu basins in this study is conducted through an integrated approach utilizing SRTM data and GIS techniques. The SRTM data is geometrically rectified to align with Survey of India (SOI) topographical maps at a scale of 1:50,000. The digitization of drainage patterns is performed using ArcGIS 10.4 software.

Strahler's method is employed for stream ordering, and the resulting drainage map, along with basin boundaries, is digitized as line coverage with unique identifiers assigned to each stream order. Morphometric parameters pertaining to linear and shape characteristics are computed using standard methods and formulas derived from previous research (Horton, 1932, 1945; Strahler, 1964).

Fundamental parameters such as stream length, area, perimeter, number of streams, and basin length are derived from the drainage layer. Using the formulas suggested by Horton (1945), Miller (1953), Schumn (1956), Strahler (1964), and Nookaratm (2005), the values of various morphometric parameters i.e. stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio, and compactness constant are calculated.

4. STUDY AREA

The study area for this research is primarily situated within the newly formed Biswanath district, which was previously part of the Sonitpur district in Assam, India. Both the Burhigang and Sadharu rivers originate from the foothills of Arunachal Pradesh, thereby extending the study area into a small portion of the neighboring

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state. The Burhigang and Sadharu basins encompass an area of 160.68 km^2 and 74.91 km^2 respectively.

The climate of the region is characterized as humid with subtropical monsoon features. The average annual rainfall in the area exceeds 200 cm, while the average temperature ranges from 29°C during the summer months to 18°C during the winter season. Geographically, the Burhigang and Sadharu basins are situated between latitudes $26^0\ 57^/\ 17.10^{//}$ N and $26^0\ 38^/\ 10.75^{//}$ N, and longitudes $93^0\ 06^/\ 32.85^{//}$ E and $93^0\ 16^/\ 42.25^{//}$ E.

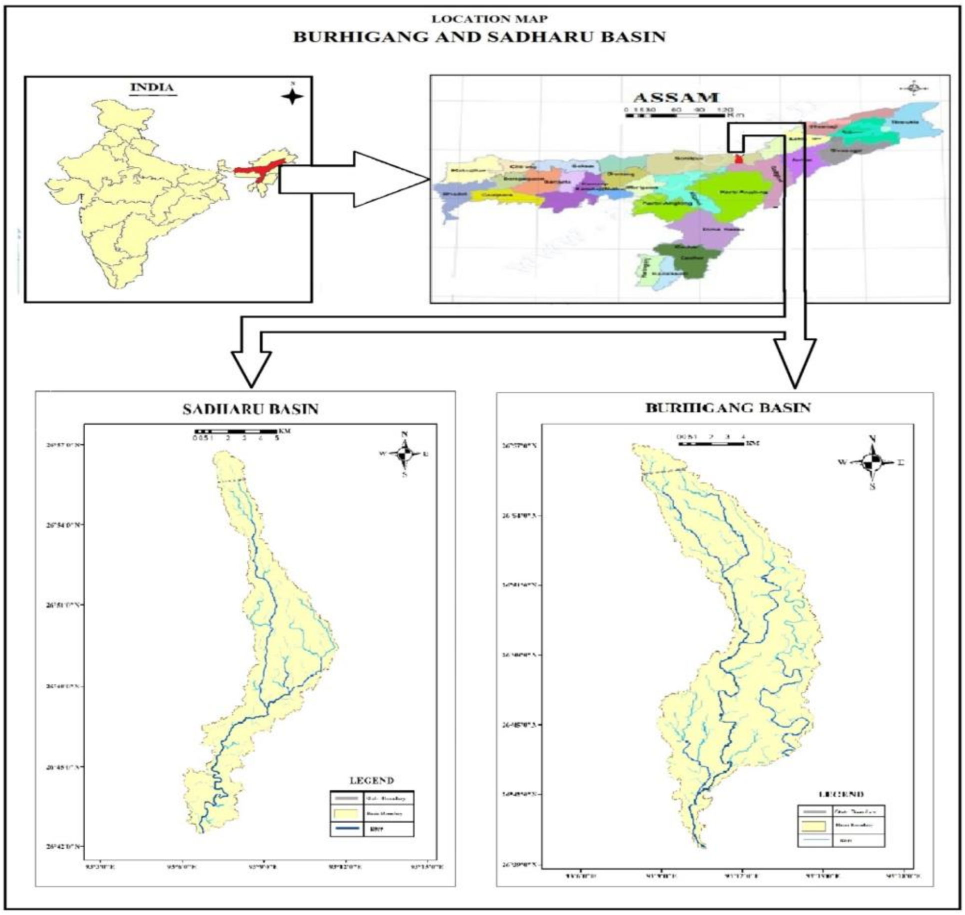

Figure 1: Location Map of Burhigang and Sadharu Basin

5. MORPHOMETRIC ANALYSIS

5.1 Linear Aspects:

The linear aspects include stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

5.1.1 Stream Order (U) and Stream Number (N_u):

Strahler's (1952) method of stream ordering has been used to find out the stream orders of the Burhigang and Sadharu River. It is a slightly modified version of Horton's(1945) original, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2ndorder give a 3rd order and so on. It is found that both the Burhigang and the Sadharu river tributaries are of 4th order. In all 156 streams were identified in Burhigang basin of which 129 are first order, 21 are second order, 5 are third order, and 1 in fourth order. On the other hand Sadharu Basin has fewer streams with 78 first order steams, 14 second order, 3 3rd order and 1 fourth order streams.

5.1.2 Bifurcation Ratio (R_b):

Bifurcation ratio (R_b) is defined as the ratio of the number of stream segments of a given stream order to the number of stream segments of the next higher order (Schumn 1956). It is observed that Bifurcation Ratio is on higher side for both the Burhigang and the Sadharu basin.In the Burhigang basin R_b varies from 6.14 to 5; the mean R_b of the entire basin is 5.11.The same for Sadharu basin varies between 5.57 and 3 with a mean of 4.41.

5.1.3 Stream Length (L_u):

The stream length (L_u) is a significant hydrological feature of the basin to study surface runoff characteristics and is computed based on the law proposed by Horton. The numbers of streams are of various orders of Burhigang and Sadharu Basins are counted and their lengths from mouth to drainage divide are measured with the help of ArcGIS software. In Burhigang basin the length of first order stream is 86.46 Km, second order stream is 38.75 Km, third order stream is 53.35 Km, and fourth order stream is 31.26 Km; while in Sadharu Basin the stream lengths counts 65.99 Km in first order, 26.47 Km in second order, 21.85 Km in third order and 17.99 km in fourth order.

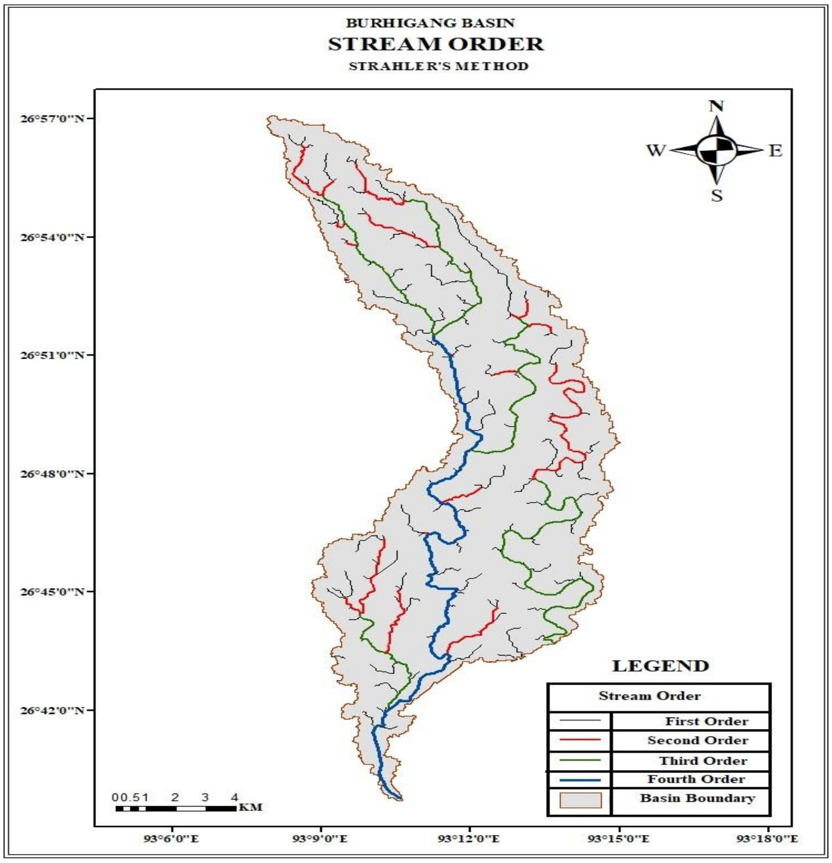

Figure 2: Stream Order of Burhigang Basin

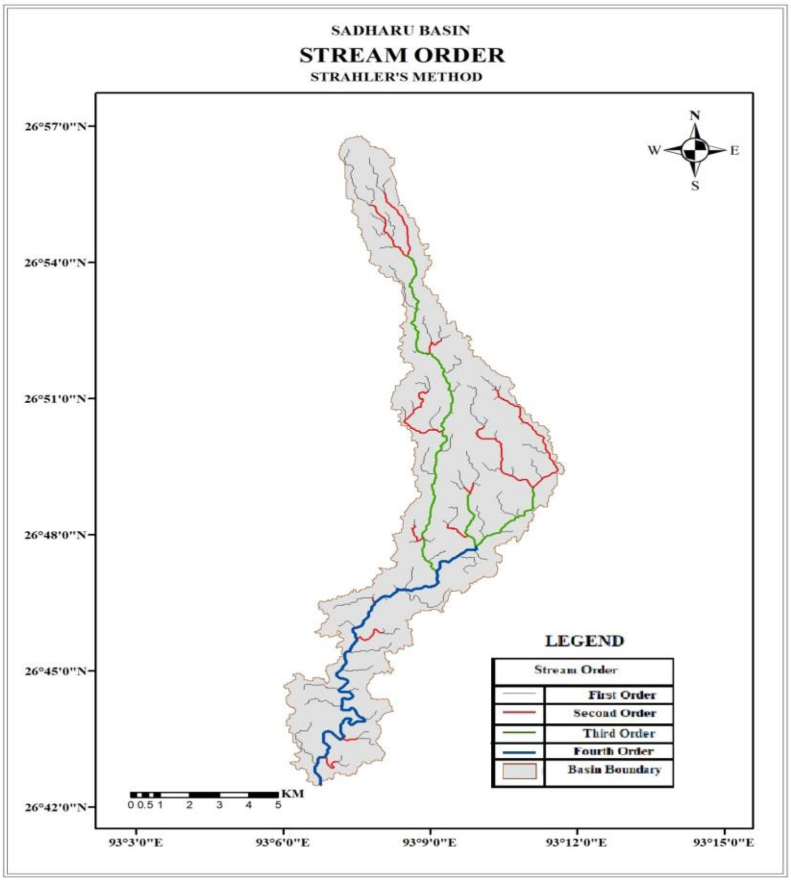

Figure 3: Stream Order of Sadharu Basin

5.1.4 Mean Stream Length (L_{sm}):

The mean stream length is one of the important characteristic property of drainage network and its associated surfaces (Strahler, 1964).The mean stream length (L_{sm}) has been computed by dividing the total stream length of a particular stream order by the number of stream segments of that order. The mean stream length of Burhigang basin is 0.67 Km for first order, 1.85 Km for second order, 10.67 Km for third order, and 31.27Km for fourth order. In Sadharu basin mean stream length of tributaries stands 0.85 Km for first order, 1.89 Km for second order, 7.28 Km for third order, and 17.99 Km for fourth order.

5.1.5 Stream Length Ratio (R_l):

The stream length ratio can be defined as the ratio of the mean stream length of a given stream order to that of the next lower order and has a significant relationship with surface flow and discharge (Horton, 1945). The stream length ratios of Burhigang basin calculated as 2.93, 5.78 and 2.75 respectively for fourth, third and second order. For Sadharu basin the values of stream length ratios for fourth, third and second order are respectively 2.47, 3.85 and 2.24.

5.2 Relief Aspects:

The relief aspects of a river basin include relief ratio, relative relief and ruggedness number.

5.2.1 Relief Ratio (R_h):

The relief ratio, (R_h) is defined as the ratio of maximum relief a drainage to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). The R_h normally increase with decreasing drainage area and size of watersheds of a given drainage basin (Gottschalk, 1964).Relief ratio of a drainage basin measures the overall steepness of the basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1956). The value of R_h in Burhigang basin is 0.95 and that of Sadharu basin is 0.73.

5.2.2 Slope:

Slope analysis is one of the most important parameter in geomorphological studies for watershed development and morphometric analysis. The slope elements, in turn, are controlled by the climatomorphogenic processes in areas having rock of varying resistance (Magesh et al. 2011; Gayen et al. 2013). A slope map of the study area is calculated based on SRTM data using the spatialanalysis tool in ARC GIS-10.4. Slope grid is identified as ‘‘the maximum rate of change in value from each cell to its neighbors’’ (Burrough 1986). The degree of slope in Burhigang Basin varies from $0^0$to $31.30^0$and that of Sadharu Basin varies from $0^0$to 38.75^0. The slope map of Burhigang and Sadharu basin is shown in the following Figures.

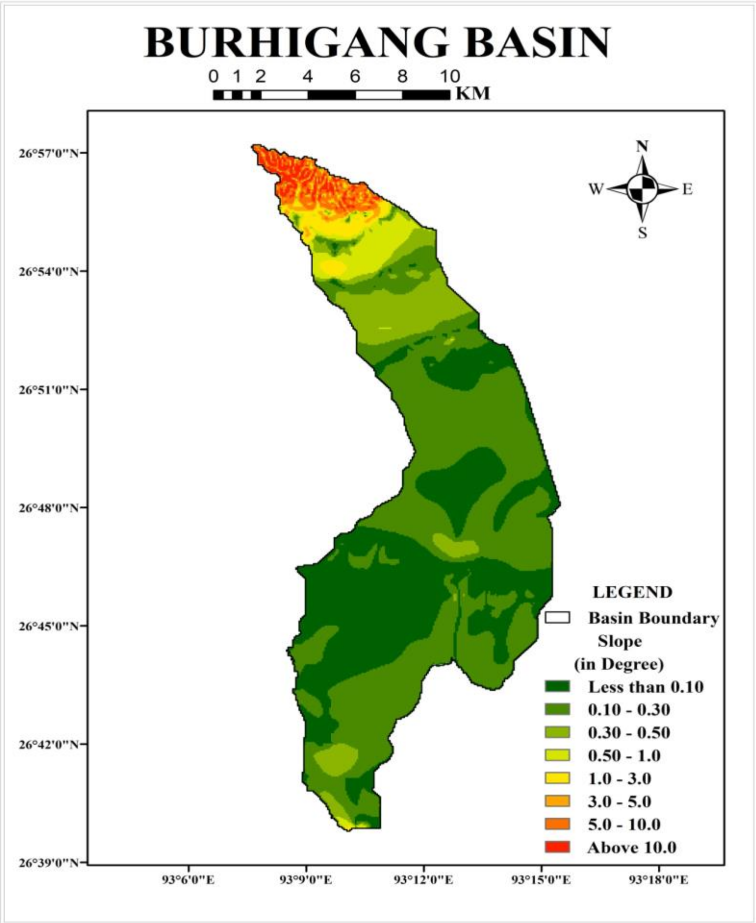

Figure 4: Slope Map of Burhigang Basin

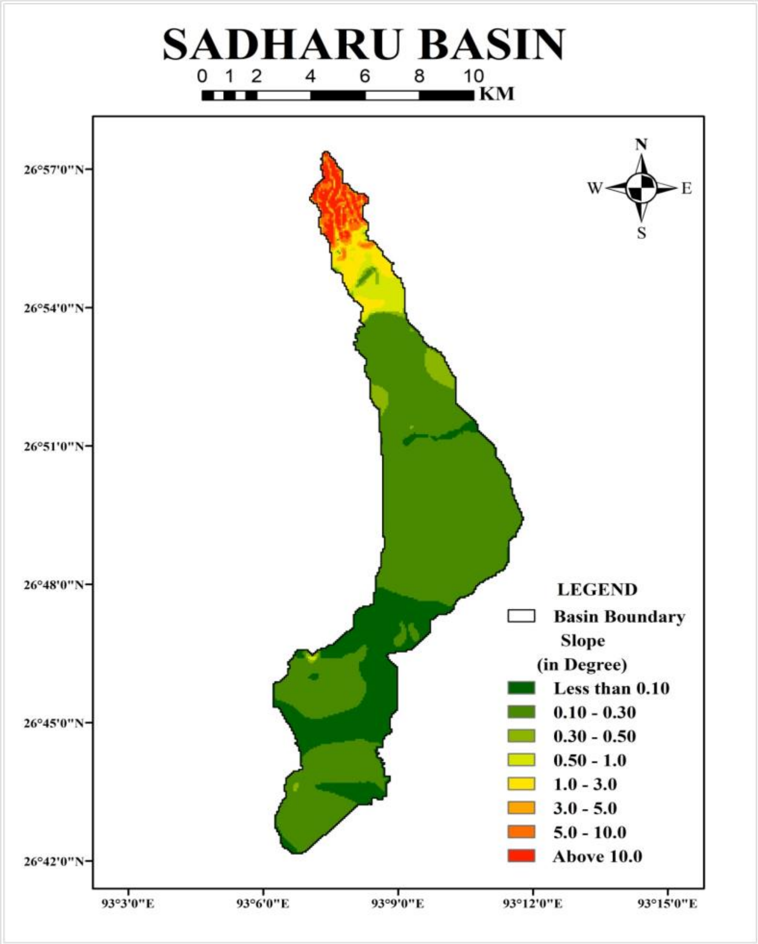

Figure 5: Slope Map of Sadharu Basin

5.2.3 Ruggedness number (R_n):

Basin Ruggedness number is express as the product of maximum basin relief (B_h) and drainage density (D_d) of the river basin where both parameters are in the same unit. The calculated value of ruggedness number in Burhigang basin is 45.46 and it is in Sadharu basin is 37.06 (Schumm, 1956).

5.3 Aerial Aspects:

It deals with the total area of horizontal plane contributing overland flow to the channel segment of a given order and includes all tributaries of lower than that particular order.It comprises of drainage density, drainage texture, stream frequency, form factor, circularity ratio, and elongation ratio.

5.3.1 Drainage density (D_d):

Drainage density (D_d) indicates the linear scale of land form elements in stream eroded topography and was introduced by Horton (1932). It is the ratio of the cumulative length of channel segments of all orders within a basin to the total area of the basin, which is expressed in terms of Km/Km^2.The drainage density (D_d) of Burhigang is 1.33 Km/Km^2 and Sadharu Basin is 1.77 Km/Km^2indicating moderate drainage densities. The Moderate drainage density of both the basins is an indicator of highly permeable subsoil and vegetative cover within the basin area (Nag, 1998).

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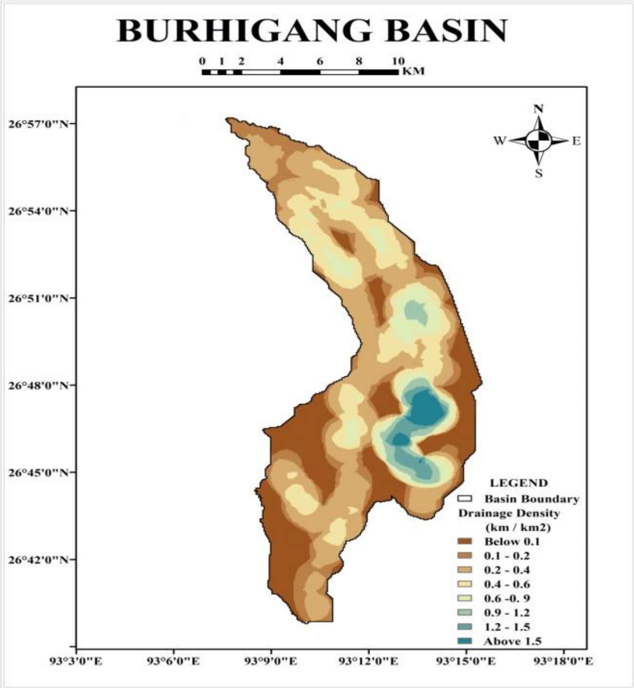

Figure 6: Drainage Density Mp of Burhigang Basin

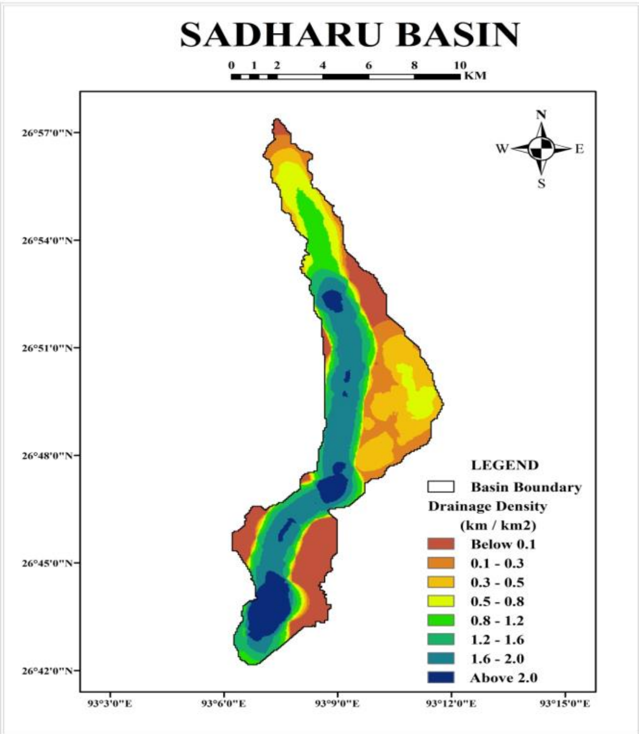

Figure 7: Drainage Density Map of Sadharu Basin

5.3.2 Stream Frequency (F_S):

Stream frequency (F_S), is of a river basin is the total number of stream segments of all orders per unit area. It shows positive correlation with drainage density in both the watersheds indicating an increase in number of streams with the increase in drainage

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density. The F_s for the Burhigang basin is 0.97 and for the Sadharu basin is 1.28 (Horton, 1932).

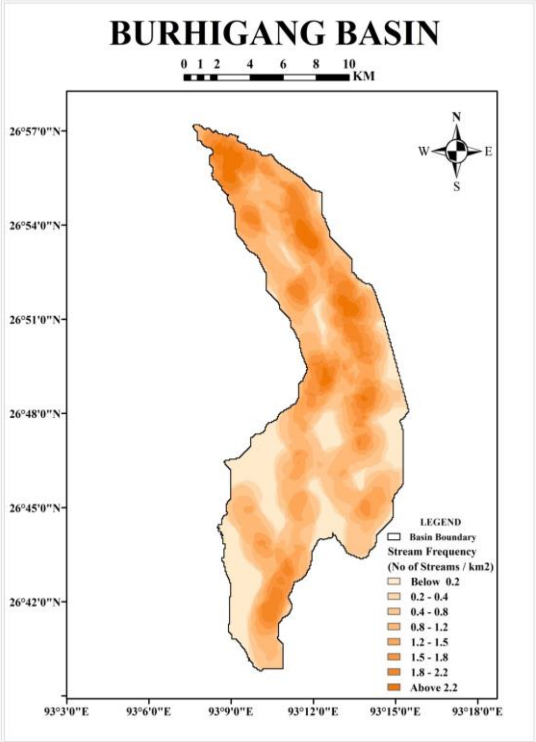

Figure 8: Stream Frequency of Burhigang Basin

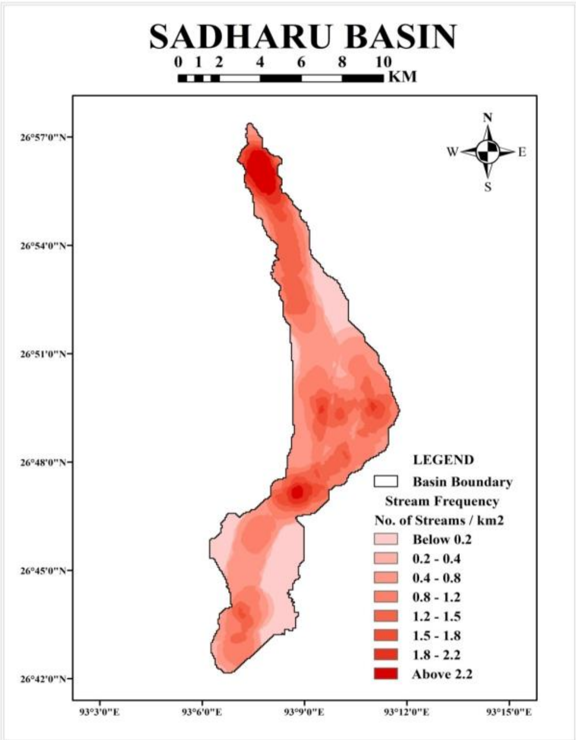

Figure 9: Stream Frequency Map of Sadharu Basin

5.3.3 Texture Ratio (T):

Drainage texture ratio (T) is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). In the present study the texture ratio of Burhigang and Sadharu basin are0.96 and 0.71 respectively.

5.3.4 Form Factor (R_f):

Form factor (R_f) is defined as the ratio of the total area of drainage basin to the square of the length of the basin. This factor indicates the flow intensity of a basin of a defined area (Horton, 1945). The standard value of form factor is 0.7854 which corresponds a perfectly circular basin. The lower the value of the form factor than the standard value 0.7854, the more elongated will be the drainage basin. The R_f value for Burhigang Basin is 0.090 and for Sadharu Basin is 0.124, suggesting extremely elongated basin shape for both the basins.

5.3.5 Circulatory Ratio (R_c):

Circularity Ratio is the ratio of the area of a drainage basin to the area of circle which has the same circumference as the perimeter of that drainage basin (Miller, 1953). The R_c value of Burhigang basin is 0.112 and the same of Sadharu basin is 0.078. It indicates that both the Burhigang and Sadharu basins are almost elongated andare characterized by low relief variations.

5.3.6 Elongation Ratio (R_e):

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle with the same area as that of the drainage basin and the maximum basin length. The R_e values in the study area is 0.17 for Burhigang Basin and 0.20 for Sadharu basin indicating extremely elongated shape the two basins.

Table 1: Method of Calculating Morphometric Perimeters of Burhigang and Sadharu Basin

Morphometric Parameters		Formula/Definition	Results		References
			Burhigang	Saharu	
LINEAR	Stream order (U)	Hierarchical order	First Order	First Order	Strahler ,1964
			Second Order	Second Order	
			Third Order	Third Order	
			Fourth Order	Fourth Order	
	Stream Number (N_u)	Numerical value	1st : 129	1st : 78	Strahler ,1964
			2nd : 21	2nd : 14	
			3rd : 5	3rd : 3	
			4th : 1	4th : 1	
	Bifurcation Ratio (R_b)	$R_b = N_u / N_{u+1}$ N_u= Stream Number of given order N_{u+1}= Stream Number of next higher order	R_{b1}: 6.14	R_{b1}: 5.57	Schumn,1956
			R_{b2}: 4.2	R_{b2}: 4.67	
			R_{b3}: 5	R_{b3}: 3	
	Stream Length (L_U)	Length of the stream in (Km)	1st : 86.46	1st : 65.99	Horton, 1945
			2nd: 38. 75	2nd : 26.47	
			3rd : 53.35	3rd : 21.85	
			4th : 31.26	4th : 17.99	
	Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$ L_u= Stream Length (Km) N_u= Stream Number	1st : 0.67	1st : 0.87	Horton, 1945
			2nd : 1.85	2nd : 1.89	
			3rd : 10.67	3rd : 7.28	

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			4^{th} : 31.27	4^{th} : 17.99	
	Stream length ratio (R_l)	$R_L = L_u / L_{u-1}$ L_u= Stream length of given order (u) L_{u-1}= Stream length of next lower order.	R_{l4}: 2.93	R_{l4}: 2.47	Horton, 1945
			R_{l3}:5.78	R_{l3}: 3.85	
			R_{l2}: 2.75	R_{l2}: 2.23	
RELIEF	Basin relief (B_h)	Vertical distance between the lowest and highest points of basin (Km)	34.18	20.94	Schumn,1956
	Relief Ratio (R_h)	$R_h = B_h / L_b$ B_h=Basin relief L_b=Basin length	0.95	0.73	Schumn,1956
	Ruggedness Number (R_n)	$R_n = B_h \times D_d$ B_h= Basin relief (Km) D_d=Drainage Density (Km^2/Km)	45.45	37.06	Schumn,1956
AERIAL	Drainage density (D_d)	D_d =L/A L=Total Stream length (Km) A= Area of basin (Km^2)	1.33	1.77	Horton, 1945
	Stream frequency (F_s)	F_s=N/A N= Total number of streams A= Basin Area (Km^2)	0.97	1.28	Horton, 1945
	Texture ratio (T)	$T=N_1/P$ N_1=Total number of first order stream P= Basin Perimeter (Km)	0.96	0.71	Horton, 1945
	Form factor (R_f)	R_f=A/(Lb)2 A= Basin Area (Km^2) L_b=Basin length (Km)	0.124	0.090	Horton, 1945
	Circulatory ratio (R_c)	$R_c = 4\pi A/P^2$ A= Basin Area (Km^2) π=3.14 P= Basin Perimeter (Km)	0.112	0.078	Miller,1953
	Elongation ratio (R_e)	$R_e = \sqrt{(A/\pi)}/L_b$ A= Basin Area (Km^2) π=3.14 L_b=Basin length (Km)	0.20	0.17	Schumn 1956

6. CONCLUSION

Geographic Information System and Remote sensing techniques have proved itself to be one of the most accurate and efficient tool in drainage delineation and their updation. Bifurcation ratio, length ratio and stream order of basin indicates that both the Burhigang and the Sadharu Basin are fourth order basins with irregular type of drainage pattern. Relief ratio, Ruggedness number and visual interpretation of DEM of study area indicate moderate to low relief of the two basins. Drainage density, texture ratio, circulatory ratio and elongation ratio shows that texture of region is moderate and shape of both the basinsextremly elongated. The formulae used for evaluating morphometric parameter and Results of this analysis are tabulated in Table 1.

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