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GIS BASED MORPHOMETRIC ANALYSIS OF SUB-BASINS OF GABHARU RIVER BASIN, NORTH-EAST, INDIA

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ABSTRACT

Basin morphometric analysiswas undertaken tocharacterize the different aspects of the Gabharudrainage basin. In the present study, morphometric analysis of the5th order sub-basins of Gabharu river basin has been carried out using geographical information system (GIS) techniques. The morphometric parameters considered for analysis includes the linear, areal and relief aspects of the basin. The Gabharu river basin covers an area of 330.712 sq km and is a 6th order drainage basin. The mean bifurcation ratios of the sub-basins indicate highly dissected elongated drainage basins. Thebivariate analysis of the different aspects are in accordance with the established Laws on morphometry. The study revealed dominant fluvial and structural influence on the development of the basin.

INTRODUCTION

Morphometric analysis of watershed or drainage basin is concerned with quantitative evaluation of fluvial landforms which make up a substantial part of the earth's surface. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth'ssurface and of the shape and dimension of its landforms (Clarke, 1966).The use of GIS techniques in morphometric analysis have emerged as powerful tools in recent years. In the present study, morphometric parameters have been extracted and analyzed using GIS techniques for understanding the topographical characteristics of the Gabharu river sub- basins.

STUDY AREA

The Gabharu river basin, a sixth order basin, is a tributary basin of the Brahmaputra lying on the northern side of the Brahmaputra. It lies partly in the West Kameng district of Arunachal Pradesh and partly in the Sonitpur district of Assam (Fig.1). It is constituted of four fifth order sub-basins (Fig.2) and has an area of 330.712 km^2. Originating from the west Kameng district of Arunachal Pradesh, the Gabharuriver flows down for about 52 km along a NNW-SSE course through the alluvial plains of Sonitpur district before meeting the Brahmaputra near Gabharumukh. The present study is based on Survey of India (SOI) topographic maps- 83A/8, 83A/12, 83B/5, 83B/9 and 83B/10 of 1971 on 1:50,000 scale. Geologically the area is constituted of the Siwaliks in the upper catchment. The Quaternaries occupy the lower part consisting of mainly unconsolidated sediments which can be subdivided into older and younger alluvium. There are also the presence of granite inselbergs in the south near the Brahmaputra. The inselbergs comprise feldspathic gneisses and gneissic. granite rocks

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DATABASE AND METHODOLOGY

These topographic maps were rectified/referenced geographically and mosaiced and the entire study area was delineated in GIS environment with the help of Arc-GIS software assigning Universal Transverse Mercator (UTM), World Geodetic System (WGS dating from 1984 and last revised in 2004) and 46N Zone Projection System. Digitization of the drainage basin was carried out in GIS environment using Arc GIS 9.3 software. The attributes were assigned to create the digital data base for drainage layer of the basin

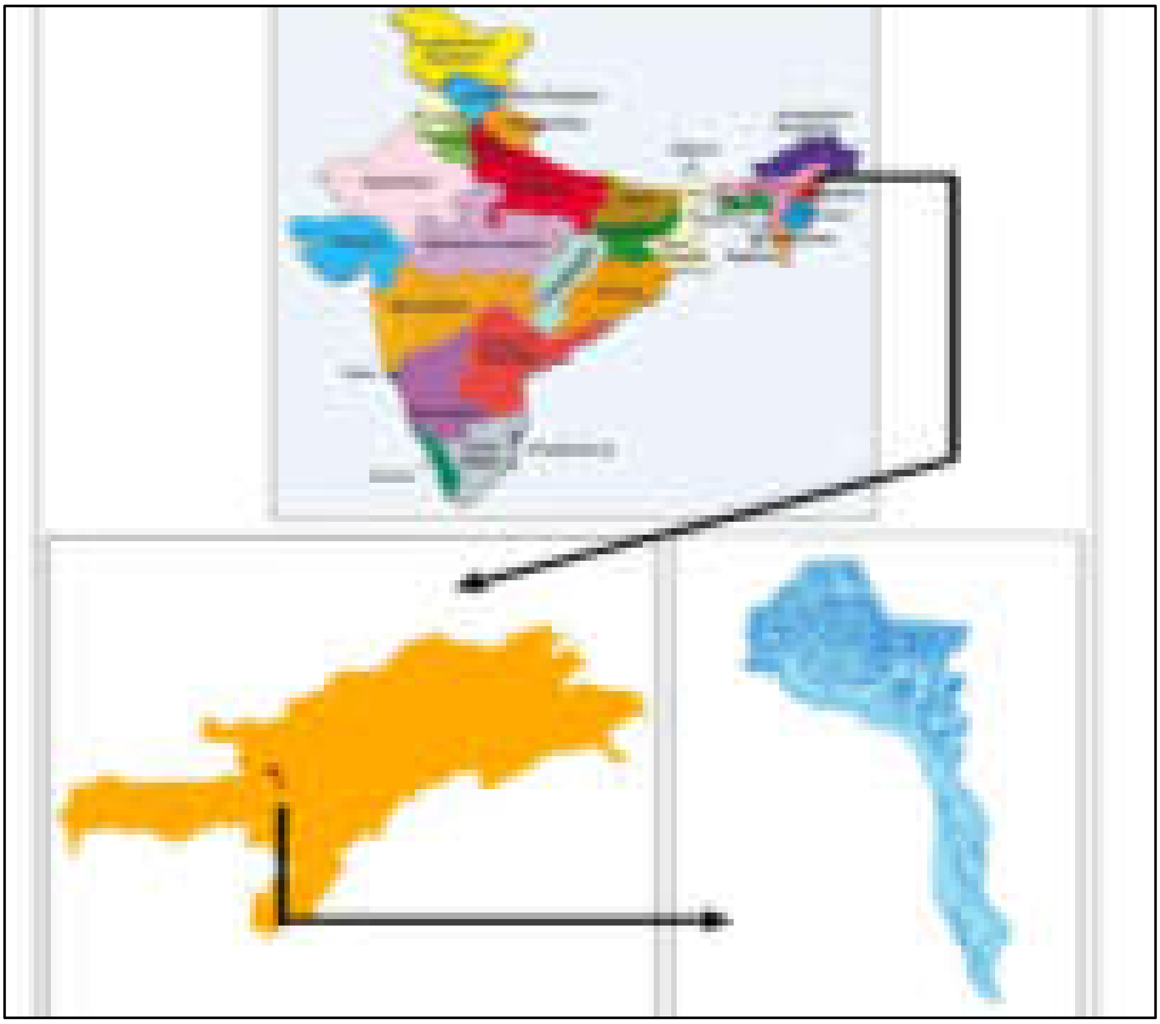

Figure 1. Location of Gabharu river basin

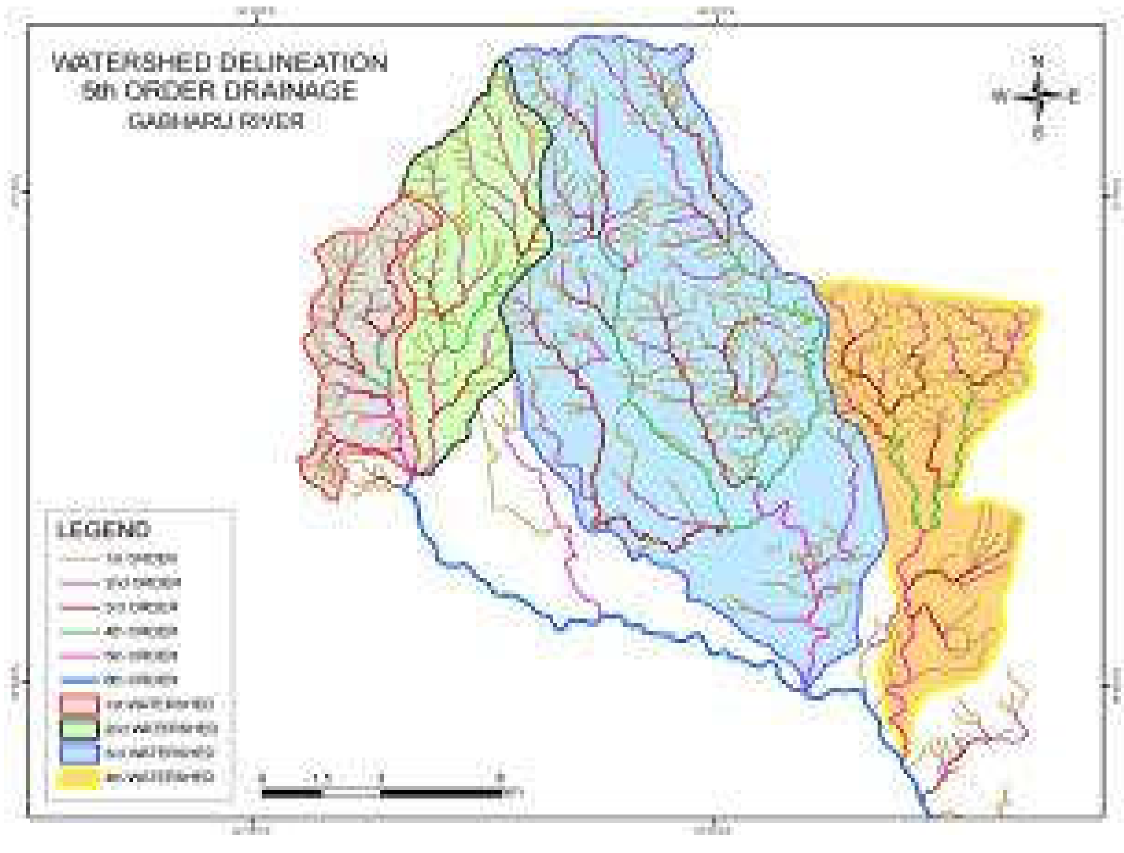

Fig 2: 5th order sub-basins of Gabharu basin

Table1. Results of parameters of morphometric analysis of the sub-basins

Stream order	Sub-Basin 1		Sub-basin 2		Sub-basin 3		Sub-basin 4	
	Stream No	Bifurcation Ratio (Rb)	Stream No	Bifurcation Ratio (Rb)	Stream No	Bifurcation Ratio (Rb)	Strea m No	Bifurcation Ratio (Rb)
First	52	3.25	66	7.33	235	6.18	94	4.94
Second	16	2.66	9	1.8	38	3.8	19	2.37
Third	6	3	5	2.5	10	3.33	8	4
Fourth	2	2	2	2	3	3	2	2
Fifth	1		1		1		1	
Mean Bifurcation ratio		2.72		3.40		4.07		3.32

Stream order	Sub-Basin 1			Sub-basin 2			Sub-basin 3			Sub-basin 4		
	Stream Length	Mean Stream Length	Stream Length Ratio	Stream Length	Mean Stream Length	Stream Length Ratio	Stream Length	Mean Stream Length	Stream Length Ratio	Stream Length	Mean Stream Length	Stream Length Ratio
First	25.55	0.49		30.88	0.46		125.70	0.53		55.08	0.58	
Second	6.08	0.38	0.23	16.68	1.85	0.54	46.25	1.21	0.36	15.57	0.81	0.28
Third	11.67	1.94	1.91	7.09	1.41	0.42	35.02	3.50	0.75	14.36	1.79	0.92
Fourth	2.41	1.2	0.20	4.38	2.19	0.61	23.56	7.85	0.67	9.82	4.91	0.68
Fifth	2.64	2.64	1.09	4.05	4.05	0.92	8.06	8.06	0.34	8.45	8.45	0.86

Sub-Basin No	Area	Maximum Basin Length	Basin Perimeter	Elongation Ratio	Circularity Ratio	Form Factor
Sub-Basin I	15.56	8.07	23.60	0.52	0.35	0.24
Sub-Basin II	24.48	11.13	26.95	0.48	0.42	0.19
Sub-Basin III	96.77	18.10	48.02	0.60	0.52	0.29
Sub-Basin IV	37.66	12.39	34.79	0.54	0.39	0.24

Sub-Basin No	Drainage Density	Stream Frequency	Infiltration Number	Texture Ratio	Length of Overland Flow
Sub-Basin I	3.10	4.94	15.31	2.20	0.16
Sub-Basin II	2.57	3.39	8.71	2.44	0.19
Sub-Basin III	2.46	2.96	7.28	4.89	0.20
Sub-Basin IV	2.74	3.29	9.01	2.70	0.18

Sub-Basin No	Max. Basin Relief	Relief Ratio	Ruggedness Number
Sub-Basin I	1180	146.22	3658
Sub-Basin II	1580	141.95	4060.6
Sub-Basin III	1760	97.23	4329.6
Sub-Basin IV	640	51.65	1753.6

MORPHOMETRIC ANALYSIS

In the present study morphometric analysis has been carried out with the help of remote sensing technique and the results of different parameters and drainage characteristics of the basin are briefly discussed. The parameters of Morphometric analysis have been classified under: Linear aspects, Areal aspects and Relief aspects. The results of morphometric analysis are given in Table1. The morphometric parameters studied are as follows-

LINEAR ASPECTS

STREAM ORDER

In the present study, Strahler's system of ordering of Streams, has been followed where the smallest, unbranched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channel segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. The trunk stream is the stream segment of highest order. It is found that Gabharuriver is a 6th order basin. In this study we have considered the 5th order sub-basins of Gabharu river basin. There are in total four 5th order sub-basins and the number of first, second, third and fourth order streams of the sub-basins varies considerably.

STREAM NUMBER (Nu)

Stream number is the number of streams of any order (Strahler, 1964). Horton's (1945) law states that the 'number of stream segments of each order forms an inverse geometric sequence with order number". In the present study it is observed that the number of streams gradually decreases as the ordering of the streams increases. The geometric relationship between Stream order and Stream Number is graphically shown in Fig:3.

STREAM LENGTH (Lu)

Stream length is the length of streams of any order (Horton, 1945). Stream length is measured from the farthest drainage divide to the mouth of a river. Usually, the total length of stream segments is highest in first order streams, and it decreases as the stream order increases in the present case. This brings out strong assumption that the basin is subjected to erosion and also that some areas of the basin are characterized by variation in lithology and topography (Singh and Singh, 1997; Vittala et al., 2004 and Chopra et al., 2005).

BIFURCATION RATIO (Rb)

Bifurcation ratio is the ratio of number of streams of order (N_u) to that of the next higher order (N_{u+1}) (Horton,1945). Higher value of bifurcation ratio indicates more complexity and degree of dissection of a drainage basin.

STREAM LENGTH RATIO (RL)

Stream length ratio is the ratio of mean stream length of streams of order 'u' (L_u) to that of the next lower order (L_{u-1}), (Horton, 1945). Stream length ratio, according to Horton (1945), has an important relationship with surface flow and discharge. It indicates if there is a major change in the hydrological characteristics of the underlying rock surface in the areas of consecutive stream orders (Pakhmode et al. 2003). Stream length ratio between the streams of different order in each sub-basin of the study area is variable.

AREAL ASPECTS

STREAM FREQUENCY (F_S)

The stream frequency is the ratio of stream number of all orders in a basin to the area of the basin (Horton,1932). The stream frequency values in the study area shows a positive correlation with the drainage density values.

DRAINAGE DENSITY (D_d)

Drainage density is the ratio of stream length of all orders in a basin to the area of the basin (Horton, 1932). Drainage density is an important indicator of the linear scale of landform element in stream eroded topography (Horton, 1932). It is a measure of fluvial dissection and is influenced by numerous which factors, among resistance to erosion of rocks, infiltration capacity of the land and climatic conditions rank high (Vestappen, 1983). Drainage density measures basin efficiency in removing excess precipitation inputs. High flood-prone regions are characterized by high drainage density values. The low values in the study area (2.46 to 3.10) suggests low run-off generation capabilities and high permeability.

INFILTRATION NUMBER (I_f)

Infiltration number is the product of stream frequency and drainage density (Faniran, 1968). It is a parameter which gives an idea of the infiltration characteristics of a basin. Higher value indicates lower infiltration capacity and consequent high surface run-off and vice versa. Infiltration number of the study area ranges from7.28 to 15.31 indicating good infiltrationcapacity.

TEXTURE RATIO (Rt)

Texture ratio is the ratio of total number of first order streams to that of the perimeter of the basin (Horton, 1945). According to Smith (1950), texture values are classified as <2 (very coarse), 2-4(coarse), 4-6 (moderate), 6-8 (fine) and >8 (very fine). In the study area sub-basin I,II and IV show coarse texture and sub-basin III show moderate texture.

FORM FACTOR (Rf)

The form factor is the ratio of basin area to square of the basin length and is a quantitative expression of drainage basin outline (Horton, 1932). The form factor value varies from 0 in highly elongated basin to 1 for perfectly circular basin. The form factor values of the study area suggests elongated shape of the sub-basins.

CIRCULARITY RATIO (Rc)

Circularity ratio is expressed as, $Rc=4\pi A/P^2$,where A= Area of basin, π=3.14, P= Perimeter of basin. It is defined as the ratio of the basin area to the area of a circle having the same circumference perimeter as the basin, which is dimensionless and expresses the degree of circularity of the basin. The values of circularity ratio in the study area suggests that the sub-basins are elongated in shape.

ELONGATION RATIO (Re)

Elongation ratio is defined as, $R_e = 2\sqrt{(A/\pi)}/Lb$; where, A is the basin area and Lb is the basin lengthSchumm (1956). .Elongation ratio is expressed as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin (Schumm,1956). The elongation ratio values in the study area suggests elongated shape of the sub-basins.

LENGTH OF OVERLAND FLOW (Lg)

Length of overland flow is expressed as, Lg=1/2Dd where, D is Drainage density (Hortan, 1945). The length of overland flow is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton,1945).The length of overland flow approximately equals to half of reciprocal of drainage density. This factor is inversely related to the average slope of the channel. The values of Lg ranges from 0.16 to 0.20 indicating steep slope of the sub-basins.

RELIEF ASPECTS

BASIN RELIEF (R) AND RELIEF RATIO (R_r)

Basin relief is the difference in elevation between the highest and lowest points of a a basin (Hadley & Schumm, 1961). Basin relief controls the stream gradient and, therefore, influences floods patterns and the amount of sediment that can be transported (Hadley and Schumm, 1961). The relief ratio is the ratio of basin relief to basin length. Relief ratio is directly proportional to surface run-off and flood activity. In the study area, both the basin relief and relief ratio (Table:2) are towards the higher side, both being important parameters suggesting steep slopes and faster run-off. However, the indications given by the other parameters strongly suggest lower run-off. This contradiction can be explained in terms of lithology.

RUGGEDNESS NUMBER

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit(Schumn, 1956)) An extreme high value of ruggedness number occurs when both variables are large and slope is steep (Strahler, 1956).

DISCUSSIONAND CONCLUSION

The morphometric analysis has been carried out through linear, areal and relief aspects of basins. The morphometric parameters such as bifurcation ratio, stream length ratio, stream frequency, drainage density, infiltration number, elongation ratio, basin relief and relief ratio were extracted.

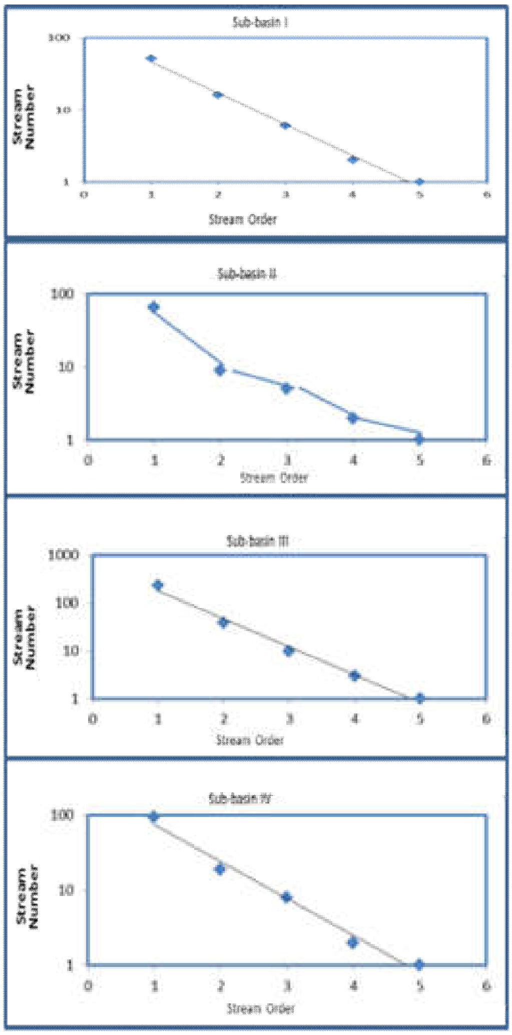

Fig3: Semi-log plots of Stream order vs Stream number

The stream order basinsvs stream number relation has been found to be inverse thus validating the Horton's Law of inverse relationship. The bifurcation ratios with respect to the first and second order streams are quite high indicating the influence of structure on the elongated shape of the sub-basins. Such high Rb values also indicate highly dissected topography. The stream order vs stream length reveals an inverse relation whereas, the same for stream order vs mean stream length exhibits a direct positive relation. These also testifies the validity of Horton' Law for stream length in these sub-basins.
The basin shape parameters such as elongation ratio, form factor and circularity ratios indicate elongated nature of the sub-basins. The drainage density and stream frequency values are low to moderate implying reasonable infiltration. This is indicated by low infiltration number values because low infiltration number implies high infiltration capacity. The length of overland flow values are moderate. Low to moderate Dd values must have been accompanied by a higher Lg values. This can be explained by reasonably high infiltration which must have prevented appreciable overland flow.

High values of the relief parameters in this lithologically homogeneous terrain are suggestive of tectonic uplift. It can thus be concluded that in the present study area structural influence has dominated in the evolution of the river basin apart from fluvial influence. The present study indicates that GIS proves to be an efficient tool for delineation and analysis of a drainage basin.

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