Morphometric Analysis and Landuse Study of Gabharu River Basin using Remote Sensing and GIS

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Abstract: ***Geographical information system (GIS) has emerged as an efficient tool in delineation of drainage pattern. The present study deals mainly with the evaluation of morphometric parameters such as stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc),and form factor ratio (Rf) etc..The study area is located partly in West Kameng district of Arunachal Pradesh and partly in Sonitpur district of Assam,India. The SRTM DEM was collected for detailed study of the basin and then different thematic maps e.g. stream orders; drainage density, drainage frequency and relative relief have been prepared by using Arc GIS (9.3) software. Land use was investigated by the combined use of Remote sensing, GIS and also field survey. The study demonstrates that the integration of satellite remote sensing and GIS is an effective approach for analyzing the morphometric pattern and land uses study. This study would help in utilization of the resources for sustainable development of the basin.***

Keywords: Morphometry, LULC, GIS and Remote Sensing**.**

1. Introduction

Remote Sensing and GIS techniques are the proven efficient tools in the delineation, updating and morphometric analysis of drainage basin. Morphometry is an essential means in geomorphic analysis of an area. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). Drainage Network analysis was carried out at basin level using Spatial Analysis GIS System (ArcGIS. 9.3) to identify the influence of drainage morphometry on landforms, drainage, and land erosion characteristics. Morphometric analysis in this study is based on Linear, Relief and Areal aspects. Remote sensing plays a significant role in providing spatial information needed for computation of morphometric indices like stream order, stream length, bifurcation ratio, relief ratio, ruggedness ratio, drainage density, stream frequency, elongation ratio etc. The study demonstrates the fact that integrated Remote Sensing and GIS based approach is more appropriate and useful than conventional methods. It is felt that this study on morphometric parameters and Land use will play an important role in generating sustainable development planning.

2. Study Area

The present study area is located partly in the West Kameng district of Arunachal Pradesh and partly in the Sonitpur district of Assam. The area is geographically located between latitude 92024/1.43// and longitude 2702/45.86// and 92040/24.792// and 26037/29.30//. The Gabharu river originates from the west Kameng district of Arunachal Pradesh and flows down through the alluvial plains of Sonitpur district and finally meets the river Brahmaputra. The Gabharu basin has an area of 330.712 km^2.

3. Methodology

In the present study, morphometric analysis and priorization of basin is based on the integrated use of remote sensing and GIS technique. The digitization of drainage pattern is carried out using Arc GIS software. For stream ordering, Horton's law is followed by designating an un-branched stream as first order stream, when two first order streams join it is designated as second order. Two second order steams join together to form third order and so on. The number of streams of each order are counted and recorded. The drainage map along with basin boundaries is digitized as line coverage.

Morphometric parameters are computed using standard methods and formulae [1,2]. The values of morphometric parameters namely; stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio and compactness constant are calculated based on the formulae suggested by Horton [1], Miller (1953), Schumn (1956), Strahler [2] and Arc GIS software. Apart from the morphometry, a static study of the land use land cover distribution for Gabharu River basin has also been made. Manual classification method has been adopted in order to categorize the eleven LULC classes based on using Liss-IV satellite imagery.

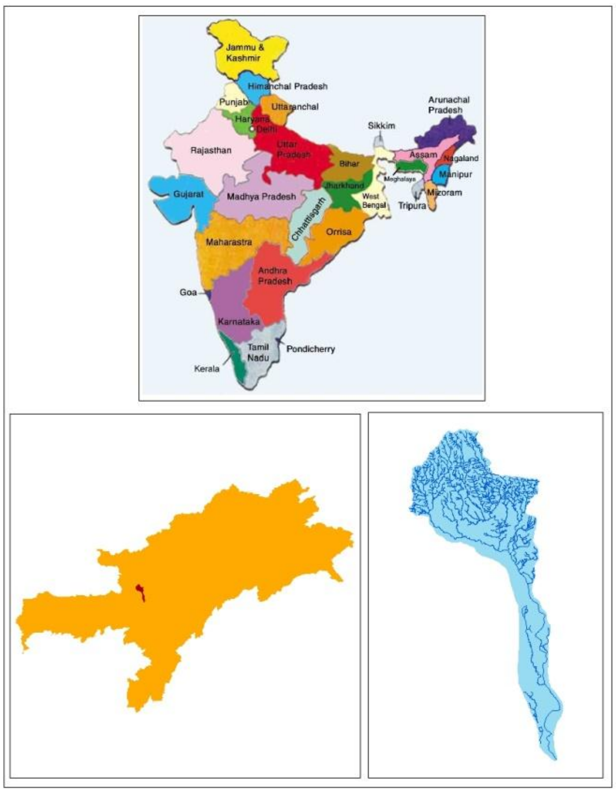

Figure 1: Location Map of Gabharu River Basin.

4. Result And Discussion

Morphometric analysis of basin

The following paragraphs describe the physical meaning of various morphometric parameters.

A. Linear Aspects

The linear aspects of morphometric analysis of basin include stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

B. Stream Order (U)

There are four different system of ordering streams that are available [Gravelius (1914), 1, 2 and Schideggar (1970)]. Strahler's system, which is a slightly modified of Hortons system, has been followed because of its simplicity, where the smallest, unbranched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the stream segment of highest order. It is found that Gabharu river is a 6th order basin. In all 615 streams were identified of which 480 are first order, 90 are second order, 31are third order, 9 are fourth order, 4 are fifth order and 1 in sixth order. Drainage patterns of stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control. The properties of the stream networks are very important to study basin characteristics [2].

C. Stream Length (Lu)

The stream length (Lu) has been computed based on the law proposed by Horton. Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. The stream of relatively smaller length is characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradient. Generally, the total length of stream segments is maximum in first order stream and decreases as stream order increases. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. The length of first order stream is 283.93Km, second order stream is 95.34 Km, third order stream is 71.7 Km, fourth order stream is 40.17 Km, fifth order stream is 23.2Km and sixth order stream is53.19Km. The change may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes (Singh 1997).The observation of stream order verifies the Horton's law of stream number i.e. the number of stream segment of each order forms an inverse geometric sequence with order number.

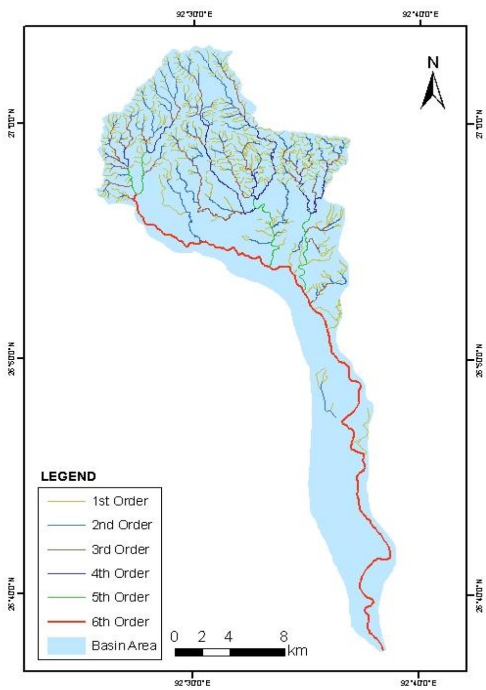

Figure 2: Stream Order of Gabharu basin.

D. *Mean Stream Length (Lsm)*

The mean stream length is a characteristic property related to the drainage network and its associated surfaces [2].The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of stream. The mean stream length of study area is 0.59for first order, 1.05 for second order, 2.31 for third order, 4.46 for fourth order, 5.8 for fifth order and 53.19 for sixth order. The mean stream length of stream increases with increase of the order.

E. Stream Length Ratio (RL)

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge [1]. The RL values between streams of different order in the basin reveal that there are variations in slope and topography.

F. Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumn 1956). Horton [1] considered the bifurcation ratio as an index of relief and dissections. Strahler [2] demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is not the same from one order to its next order. In the study area the mean Rb of the entire basin is 3.58. Usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern.

G. Relief Aspects

The relief aspects determined include relief ratio, relative relief and ruggedness number.

H. Relief Ratio (Rh)

The relief ratio, (Rh) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line [3]. The Rh normally increases with decreasing drainage area and size of watersheds of a given drainage basin (Gottschalk, 1964). Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin [3]. The value of Rh in basin is 36.13.

I. Relative Relief (Rbh)

This term was given by Melton (1957) which refers to the difference between the highest and lowest points in a particular area. In this study area it is obtained by visual analysis of the DEM prepared from SRTM data. The elevation varies from 57m to 1925m which represents the variation from near level to steep slope.

J. Ruggedness number (Rn)

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep [2]. The value of ruggedness number in present basin is 3060. The topographic ruggedness index (TRI) was developed by Riley, et al. (1999) to express the amount of elevation difference between adjacent cells of a DEM. Here the ruggedness map shows the least to highest rugged topography of Gabharu basin.

K. Aerial Aspects

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

L. Drainage density (Dd)

Horton (1932), introduced the drainage density (Dd) is an important indicator of the linear scale of land form elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of Km/Km2.The drainage density, indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. It has been observed from drainage density measurement made over a wide range of geologic and climatic type that a low drainage density is more likely to occur in region and highly resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture [2]. The drainage density (Dd) of study area is 1.7 Km/Km2 indicating clearly that the basin has permeable subsurface material, good vegetation cover and medium causing more infiltration of water and recharging groundwater aquifers. There exists a close relationship between drainage density and mean annual flood . So, the basin as a whole is less prone to flooding.

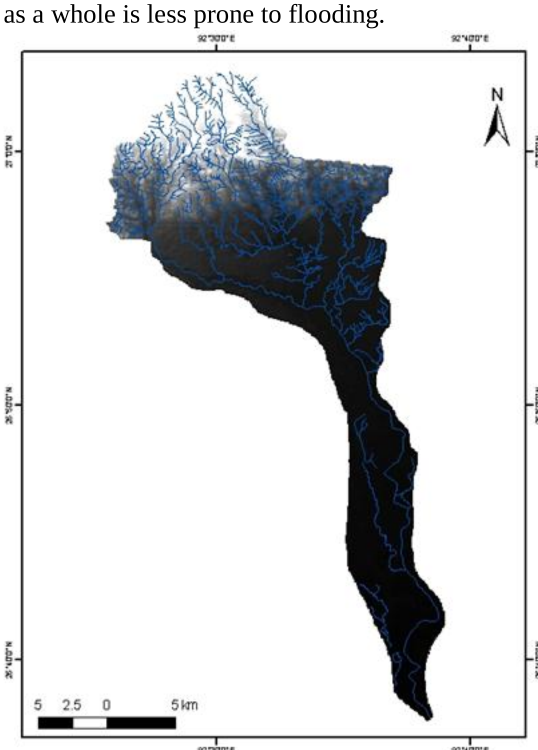

Figure 3: DEM of Gabharu basin.

M. Stream Frequency (Fs)

Stream frequency (Fs), is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density.

The stream frequency of Gabharu basin has been divided into 5 no of classes varying from very low to very high frequency class.

N. Texture Ratio (T)

Drainage texture ratio (T) is the total number of stream segments of all orders per perimeter of that area [1]. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. In the present study the texture ratio of the basin is 3.76 and categorized as moderate in the nature.

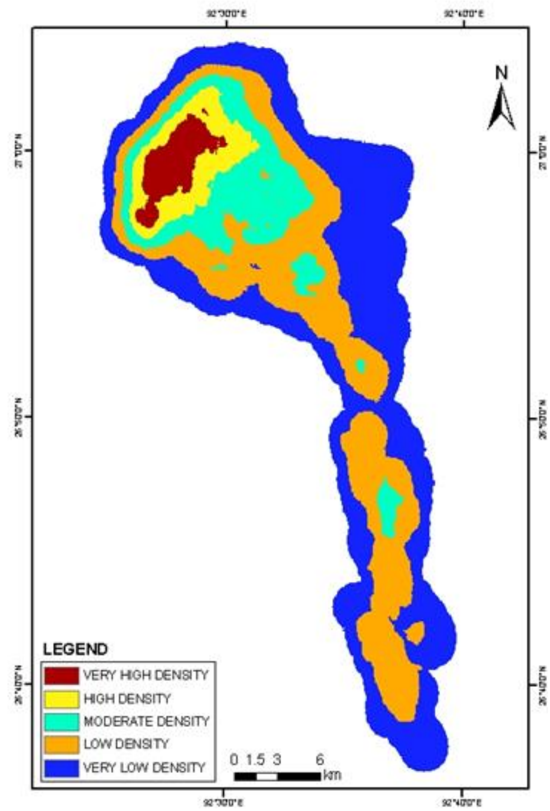

Figure 4: Drainage Density Map.

I. **TABLE 1:** MARGIN SPECIFICATIONS

Class Name	Values
Very low	3-42052.2
Low	42052.2-84101.4
Moderate	84101.4-126150.6
High	126150.6-168199.8
Very high	168199.8-210249

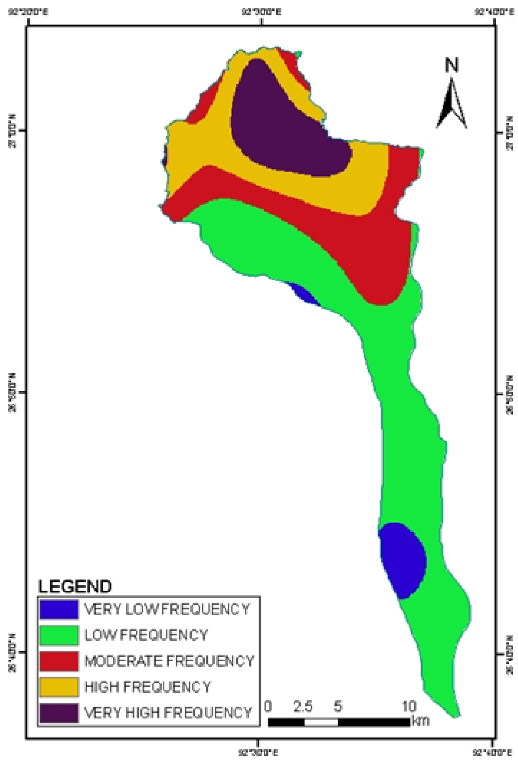

Figure 5: Drainage Frequency Map.

II. **TABLE 1I:** MARGIN SPECIFICATIONS

Class Name	Values
Very low	0-20
Low	20-40
Moderate	40-60
High	60-80
Very high	>80

O. Form Factor (Ff)

Form factor (Ff) is defined as the ratio of the basin area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area [1]. The form factor value should be always less than 0.7854 (the value corresponding to a perfectly circular basin). The smaller the value of the form factor, the more elongated will be the basin. Basins with high form factors experience larger peak flows of shorter duration, whereas elongated watersheds with low form factors experience lower peak flows of longer duration. The Ff value for study area is 0.13 indicating elongated basin with lower peak flows of longer duration than the average.

P. Circulatory Ratio (Rc)

Circularity Ratio is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin. It is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin. The Rc value of basin is 0.25 indicating the basin is characterized by moderate to low relief and drainage system seems to be less influenced by structural disturbances. The high value of circularity ratio shows the late maturity stage of topography.

Q. Elongation Ratio (Re)

Schumm [3] defined elongation ratio as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin.The elongation ratio of Gabharu basin is found to be 0.40.

R. Length of overland flow (Lg)

The Length of Overland Flow (Lg) is the length of water over the ground surface before it gets concentrated into definite stream channel [1]. Lg is one of the most important independent variables affecting hydrologic and physiographic development of drainage basins. The length of overland flow is approximately equal to the half of the reciprocal of drainage density. This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree. Lg of the study basin is 0.29.

S. Constant channel maintenance (C)

Schumm [3] used the inverse of drainage density as a property termed constant of stream maintenance C. This constant, in units of square feet per foot, has the dimension of length and therefore increases in magnitude as the scale of the land-form unit increases. Specifically, The constant C provides information of the number of square feet of watershed surface required to sustain one linear foot of stream. The value C of basin is 0.5.

5. Pattern of LULC

The static land use land cover distribution for Gabharu River basin as derived from the map is presented in the Table IV. The figures presented in table above represents the static area of each land use land cover category for the Gabharu basin. In this study, attempts have been made to map out the status of land use land cover of the basin using Liss-IV Satellite imagery (2014). This classified map depicts that there are 11 land cover/land use categories in the study area based on the NRSC LULC classes. The present study has brought to light that, more than half of the total area i.e. 178.64 sq.km is covered by Evergreen, Semi-evergreen forest, which is basically dense forest of Arunachal Pradesh. Rest of the basin is covered by Built-up and Agricultural land with 3.39% and 19.59% respectively, followed by Fallow land with 0.66% and Grass grazing-Semi Evergreen holds 1.2%. Apart from the main drainage, other Wetland/Water bodies holding 1.03% of the total basin area.

III. **TABLE 1II:** MORPHOMETRIC PARAMETER CALCULATIONS

Morphometric Parameters	*Formula/ Definition*	*References*
Stream order (U)	Hierarchical order	Strahler,1964
Stream Length (LU)	Length of the stream	Hortan, 1945
Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment.	Hortan, 1945
Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu-1=The total stream length of its next lower order.	Hortan, 1945
Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order	Schumn,1956
Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumn,1956
Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length	Schumn,1956
Ruggedness Number (Rn)	Rn=Bh×DdWhere,Bh = Basin relief, Dd=Drainage density	Schumn,1956
Drainage density (Dd)	D_d=L/A Where, L=Total length of stream, A= Area of basin.	Hortan, 1945
Stream frequency (Fs)	Fs=N/A Where, L=Total number of stream, A=Area of basin	Hortan, 1945
Texture ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin.	Hortan, 1945
Form factor (Rf)	Rf=A/(Lb)2 Where, A=Area of basin, Lb=Basin length	Hortan, 1945
Circulatory ratio (Rc)	Rc=4πA/P2Where A= Area of basin,π=3.14, P= Perimeter of basin.	Miller,1953
Elongation ratio	(Re) Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumn 1956
Length of overland flow	(Lg) Lg=1/2Dd Where, Drainage density	Hortan, 1945
Constant channel maintenance(C)	Lof=1/Dd Where, Dd= Drainage density	Hortan, 1945

IV. **TABLE 1V:** LULC CLASSIFICATION

LULC Class Name	*Area(sq.km)*	*Area(in %)*
Agriculture Plantation	5.01	1.51
Agriculture, Cropland	59.80	18.08
Agriculture, Fallow	2.17	0.66
Builtup,Urban	11.21	3.39
Forest,Deciduos	36.12	10.92
Forest,Scrub Forest	6.11	1.85
Forest/Evergreen,Semi Evergreen	178.64	54.02
Grass,Grazing	3.96	1.2
River	24.07	7.28
Wetland/Waterbodies, Inland Wetland	3.18	0.96
Wetland/Waterbodies, Reservoir/ Lakes/Ponds	0.44	0.13

6. Conclusion

Remote sensing and GIS techniques have proved to be efficient tools in drainage delineation and their updation. The study has been conducted with the high resolution satellite data and SRTM dem. The morphometric analyses of the Gabharu river basin was carried out through measurement of linear, areal and relief aspects of the watershed . The development of stream segments in the basin area is affected by rainfall. Dendritic drainage pattern is seen in the drainage basin indicating the homogeneity in texture and lack of structural control. The Drainage density of the basin reveals that the nature of subsurface strata is more or less permeable. The basin as a whole has course drainage density revealing the high infiltration capacity. Circularity ratio and Elongation ratio show the elongated shape of the basin and point out the low and delayed discharge of runoff and medium relief of the terrain. The morphometric analysis has proved that geomorphology has better influence on present landuse which is very clear in this study area. Being relatively flatter surface towards the southern part, most of the settlements and agricultural fields occur in this region. The present study shows that satellite remote sensing based morphometric and landuse mapping is very much effective for study of a River basin.

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