Morphometric Analysis of Jiya Dhol River Basin

Luna Moin Das

North-Eastern Hill University, Shillong

Abstract: *Basin morphometry is an important means of understanding a drainage basin using mathematically derived parameters. In the present study basin morphometry has been analyzed under three broad aspects and they are the linear, areal and relief aspects. Within these aspects there are many parameters which are being determined by using mathematical formula on data derived from Toposheets of the study area. It is covering an area of 1094.93 sq. km. The drainage pattern of the upper section of the basin is trellis pattern and the lower section is anabranching. Floods are common phenomena of the lower section of this basin. This paper explains the role of basin morphometry specially the linear and relief aspect in providing condition for occurrence of flash floods in the lower section of Jiya Dhol River basin.*

Keywords: Basin Morphometry, Jiya Dhol River, Flood, GIS, Drainage Basin

1. Introduction

The study of river basin is very important in fluvial geography. Analysis of basin morphometry is an integral part in the study of river basin. River basin or drainage basin of a river is the whole area within which every single drop of water in the form of precipitation contributes to the flow of a particular master river. A drainage basin is bounded by drainage divide. A proper study of the basin morphometry helps a lot in the better understanding of the basin characteristic and this helps in better planning and management of the basin.

Larger section of the world's population resides in one or other river basin due to it conducive nature. It offers the basic platform for the development of humanity in the form of the vast fertile land. A better knowledge of the basin characteristic is necessary for the proper management of all section of the basin. All sort of research related to river and its basin need a proper study of the basin morphometry as it gives the first base for the study. Many studies have been done in different river basins of the world by various scholars because of diverging interest. The conventional methods of calculation basin morphometry (Horton, 1945; Smith, 1950; Schumm, 1956 and Strahler, 1957) are most commonly used. Along with these, the modern methods of Remote Sensing and GIS is also in much use these days throughout the world (Srivastava and Mitra, 1995; Nag, 1998; and Rao, *et al.* , 2010).

The major objectives of this paper are to find the basin morphometric parameters in Jiya Dhol River Basin of Brahmaputra Valley using Geographical Information System. This basin is one of the most flooded basins in the valley. This paper helps in understanding the role of basin morphometry in the occurrence of flood in the basin.

2. Study Area

The Jiya Dhol River is one of the north bank sub-tributaries of the Brahmaputra River that empties in Charikoria River. Basin of the Jiya Dhol River extends from 27˚15′ N to 27˚45′ N latitudes and 94˚15′ E to 94˚40′ E longitudes, covering an area of 1191.62 sq km, of which 38% (446.6 sq km) lies in Arunachal Pradesh and 62%

(746.6 sq km) in Assam (Fig. 1). The upper hilly part of the basin falls in the Outer Himalaya and the Siwaliks comprising of the Tertiary formations. While the middle part of the lies in the piedmont zone characterized by the presence of sand with admixture of cobbles and boulders, where as the lower reaches are characterized by alluvium. Climate of the basin is typically characterized by hot and humid conditions, representing oppressive climate, which is found all along the foothills and piedmont zone, i.e., junction between the Brahmaputra plains and the Himalaya Mountain. Summer rains occur in the pre-monsoon and monsoon seasons, while the winters are dry.
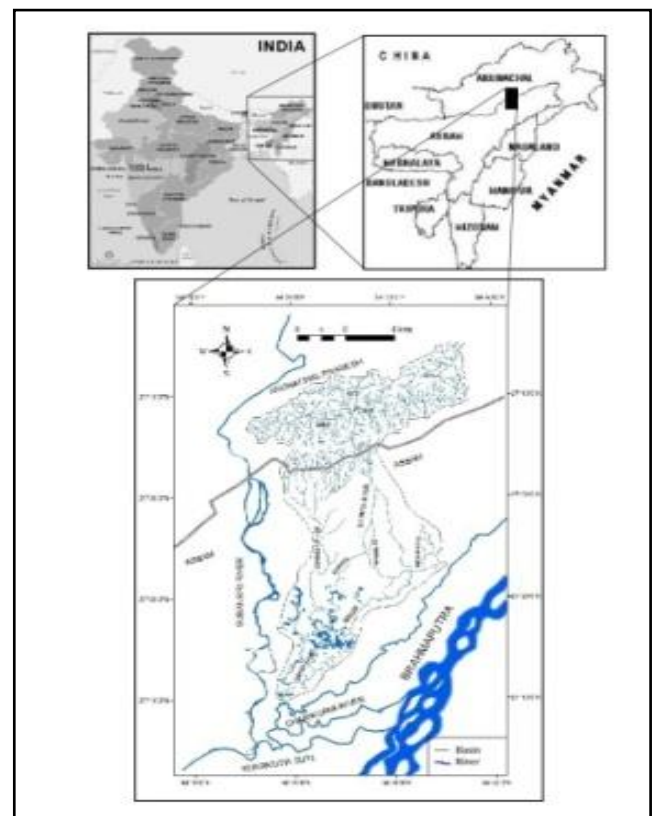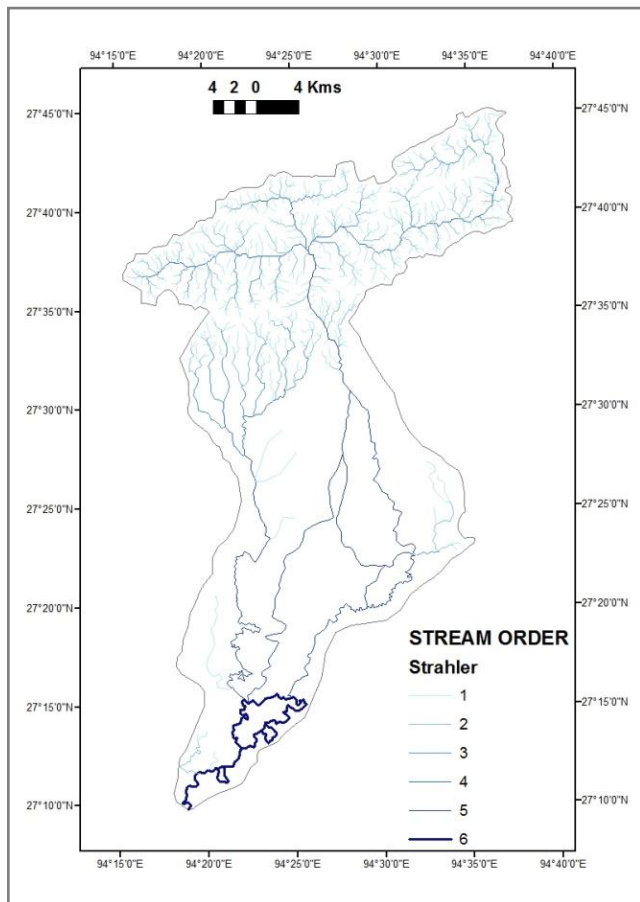
Figure 1: Jiya Dhol River Basin Figure 2. Stream Ordering (Strahler)

3. Material and Methodology

The most important data source for the morphometric analysis of Jiya Dhol River basin are the Survey of India Toposheets No. 83I/6, 83 I/7, 83 I/8 and 83 I/10 on 1:50,000 Scale and IRS LISS III Imagery. All of these are geometrically rectified and georeferenced in GIS Software (Arc GIS Verson 9.3). This is followed by digitization of the basin and the drainage networks in different layers. The stream ordering is done by using Strahler method. Various basin morphometric parameters under linear, areal and vertical aspects are calculated and interpreted.

4. Analysis

Basin morphometry is described within three different ambit or aspects and they are the linear aspect, areal aspect and the vertical aspects. Linear aspect includes stream order, bifurcation ratio, stream length and stream number. Areal aspect of the drainage basin includes drainage density, stream frequency, texture ratio, elongation ratio, circularity ratio and form factor ratio. Vertical aspect includes relief of the basin.

4.1 Linear aspect of the basin

Stream ordering is done on the basis of Strehler's method this method is also known as 'stream segment method' (Fig. 2). According to this method the smallest fingertip tributaries streams are designated as 1st order stream. Two

first order streams join together to form a 2nd order stream and similarly when two 2nd order streams joins together to form a 3rd order stream. In similar manner two lower order streams joins together to form a next higher order stream. This method is very commonly used in research purpose because joining of lower order streams to a higher order stream does not change the order of the higher streams. Thus, if new small order streams appear in due course of study, it does not affect the ordering of the higher order streams.

In the present study there are 1766 first order streams, 402 second order streams, 93 third order streams, 26 forth order streams, 4 fifth order streams and the highest order stream that is available in this basin is sixth order stream. The ordering of highest orders is very difficult in this river as after entering the plains of Assam the river Jiya Dhol splits up into many branches some of it joins the main river after a small distance but few joins other river which are lower in order. Further downward all joins together to as a single river. Two main branches are considered for ordering purpose as other as small in length. So, there are two sixth order streams. Since the sixth order stream that debouches to the plains of Assam from Arunachal is not joined by any other river of same order except by its anabranches it is considered as the highest order in the present basin.

Bifurcation ratio is the ratio of the number of streams of any order to the number of streams in the next higher order (Schumn, 1956). If the bifurcation ratio of a river network is low there is a higher chance of flooding. It can also show which part of the basin is more likely to flood. The most common bifurcation ratio is ranging between 3 to 5 is such a basin the geological structure do not distort the drainage pattern (Strahler, 1964) and it indicate that the drainage system characterized within homogeneous lithology. The lower course is subjected to more floods risk with lower value of bifurcation ratio. Otherwise, the average bifurcation ratio of the basin is 4.18 and so the whole drainage basin is homogeneous in lithology.

According to Horton (1945) *Stream Length Ratio* is defined as the ratio of the mean length of a given order to the mean stream length of the next lower order. It has important relationship with surface flow and discharge. The stream length ratio of the lower order streams shows the existence of the youth and mature stage where as the ratio between the 6th and the 5th order stream is lower as compared to the general trend and hence the basin is at an old stage of development in it lower section.

Stream Length (L_μ), is very significant in determining the hydrological features of the basin as it reveals the surface runoff characteristics. Areas with higher slope and fine texture have streams of relatively smaller lengths where as longer length of streams is generally characteristic of lower gradient. In general the total length of streams segments is maximum in first order streams and decreases as the stream order increases. The plot of the logarithm of stream length versus stream orders is an indicative of the characteristic of the basin lithology and topography. A linear pattern indicates homogenous lithology. From the

table it is clear that as the stream order increases the average stream length of respective order increase, thus the gradient of the streams decreases as the order increases. On the other hand the total length of the stream order from lower to higher order is decreasing till the 5th order but the total length of the 6th order stream increases and this is against the general rule. Horton's (1945) law of stream number states that the number of streams in each order forms an inverse geometrical sequence.

Length of Overland Flow (L_0) is described as the length of flow of water over the ground before it becomes concentrated in definite stream channel (Horton, 1945). The average length of the overland flow is approximately equal to the reciprocal of twice the drainage density. In the present basin the length of overland flow is 0.36 km. It is inversely related to the average slope of the basin.

Areal Aspect of the Basin

Areal aspect of the basin morphometry includes the horizontal characteristics of the drainage basin. Among the areal aspects the most important parameters are area of the basin, (A) and its perimeter (P). Area of the basin implies the total area confined within the basin. Basin perimeter is the total length of the boundary of the basin. The area of Jiya Dhol river basin is 1191.62 sq km and its perimeter is 241 km.

Drainage Density (D) is the average length of stream channels per unit area. It is an important indicator of the linear scale of landform element in stream eroded topography (Horton, 1932). It shows how closely the channels are spaced in a basin. In the present study the basin has a drainage density of 1.37 km of channel per unit square kilometer of area. Thus, the drainage density of the basin is moderate and it indicates the presence of moderate permeable subsoil in the basin. *Stream Frequency (F)* is the number of stream segments per unit area. It generally

has a positive relation with drainage density. Jiya Dhol river basin has a steam frequency of 1.92. Thus, it has low stream frequency. It has positive relation with the drainage density. *Drainage Texture (D_T)* is defined as the relative spacing of drainage lines and is a product of Drainage Frequency and Drainage Density. Course drainage texture is generally found in areas with low drainage density, medium in medium drainage density areas and ultra fine in high density regions (Strahler, 1964). This basin has a drainage texture of 2.63, which is a lower value, thus, the basin has course drainage texture. *Texture Ratio (R_T)* is the number of crenulations in the basin contour having the maximum number of crenulations divided by the basin perimeter (Smith, 1950). It is also the ratio total number of first order streams and the basin perimeter (Rao, *et al*, 2010). It also bears a strong relationship with drainage density. The texture ratio of the present basin is 7.35 and it indicates a moderate infiltration capacity and moderate relief of the terrain.

Elongation Ratio (R_E) is calculated by dividing the diameter of circle with the same area as the drainage basin by the maximum length of the basin (Schumn, 1956). It is an important index of analyzing shape of the basin. According to Strahler (1964), higher value of Elongation ration indicates very low relief. In the present basin the value of elongation ratio is 0.53, which is a lower value. Thus, it indicates high relief and elongated shape of the basin. *Circularity Ratio (R_C)* is defined as the ratio of basin area to the area of a circle with the same perimeter as that of the basin (Miller, 1953). Any value of circularity ratio near to unity indicates strongly circular shape of the basin and highly permeable homogeneous geological material. Its value for the present basin is 0.26 and thus, the basin is elongated in shape. *Form Factor Ratio (R_F)* is a dimensionless ratio of the basin area to the square of the basin length. Present basin has a Form Factor ration of 0.22 and it indicates elongated shape of the basin.

Table 1: Basin Morphometric Aspects

Linear Aspect

Stream order	No. of Streams	Bifurcation Ratio	Total Length in Kms	Average Length in Kms	Stream Length Ratio	Log of Total stream length	Log of No. of Streams
μ	N_u	Rb	L_u	$L_{u\,(Ave)}$	R_L	log L_u	log N_u
1st order	1766		887.4	0.5		2.95	3.25
2nd order	402	4.39	313.9	0.78	1.56	2.5	2.6
3rd order	93	4.32	155	1.67	2.14	2.19	1.97
4th order	26	3.57	105	4.04	2.41	2.02	1.41
5th order	4	6.5	64	16	3.96	1.81	0.6
6th order	2	2	109	54.5	3.41	2.04	0.3
Total	2293	Mean (Rb) **4.16**	1634.34				
Length of Overland Flow, L_0							**0.36**

Areal Aspect

Morphometric Parameters (Areal Aspects)	Symbols/Formula	Value
Area of the Basin (sq. kms)	A	1191.62
Perimeter of the basin (kms)	P	241
Drainage Density (km/sq. km)	$D=L/A$	1.37
Stream Frequency	$F=N/A$	1.92
Drainage Texture	$D_T=F \times D$	2.63
Texture ratio	$R_T=N_1/P$, where, N_1 is the no. of 1st Order Streams	7.33
Maximum Basin Length (kms)	L_B	73
Elongation Ratio	$R_E=2\sqrt{(A/\pi)}/L_B$	0.53
Circulation Ratio	$R_C=4\pi A/P^2$	0.26
Form Factor Ratio	$R_F=A/L_B^2$	0.22

Relief Aspect

Morphometric Parameters (Relief Aspects)	Symbol/Formula	Value
Basin Relief	$B=h-l$	1.4
Relative Relief	$R_h=B/P$	5.95
Relief Ratio	$R_h=B/L_b$	19.66
Ruggedness Number	$Rn=B \times D$	1.92

Relief Aspect of the Basin Morphometry

Relief aspect basically implies the vertical characteristics of the basin. These aspects are depended on the highest and the lowest point of the basin. The highest point (h) of the Jiya Dhol river basin is at an elevation of 1526 meters above the mean sea level and the lowest point (l) is at 91 meters above mean sea level. *Basin Relief* is the difference of elevation between the highest and the lowest points in the basin. This is the absolute relief of the basin. The basin relief of the present basin is 1435 meters or 1.435 km. The general basin relief is high for the studied basin. According to Melton (1957), *relative relief* is calculated by dividing basin relief by the parameter of the basin (in same units). This basin has a relative relief of 0.00595 and this is the relief that actually affects the flow of the river in the basin. The basin has a high relative relief and hence higher gradient. *Relief Ratio* is the ratio between basin relief and the maximum basin length. It is the measure of overall steepness of the basin and it is an indicator of the intensity of the erosional process operating on the slope of the basin (Schumn, 1957). The present basin has a high value of relief ratio and hence, the intensity of erosion in the basin is more. *Ruggedness Number,* is the product of the basin relief and drainage density. The ruggedness number of the basin is 1.92. The high value of ruggedness number, indicate higher erosional intensity in the basin.

5. Conclusion

The linear aspect of the basin morphometric parameters in the Jiya Dhol River basin suggest that the lower reach of the basin is in old stage of geomorphic development and has a higher risk of occurrence of flood. Whereas, the upper reach is in youth stage and has negligible risk of occurrence of flood. The areal aspect of morphometric parameters suggest the existence of moderately permeable subsoil, coarse drainage texture and elongated shape of the basin. The relief aspect of basin parameters suggest of high relief in the basin, high steepness of the slope and higher erosional intensity in the basin. The presence of anabranches in the lower section of the basin supports the higher gradient of the stream limited to the hilly upper section.

Thus, basin morphometric parameters of the Jiya Dhol river basin gives full support for the occurrence of flash flood in the basin, in the light that the streams of the basin are mostly fed by the rain water. The lower section of the basin is also subjected to higher siltation due to the higher erosional intensity in the hilly upper catchment.

Acknowledgement

Reference

[1] Horton, R.E. (1932). Drainage Basin Characteristics. *Transactions of American Geophysics Union,* 13, 350-361.

[2] Horton, R.E. (1945). Erosional Development of Streams and their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. *Bulletin of Geological Society of America*, 5, 275-370.

[3] Melton, M. A. (1957). An analysis of the relation among elements of climate, surface properties and geomorphology. Office of Navel Research Project, Technical Report 11, Department of Geology, Columbia University, New York.

[4] Melton, M.A. (1958). Correlation structure of morphometric properties of drainage system and their controlling agents. *Journal of Geology,* 66, 442-460.

[5] Miller, V.C. (1953). A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area. Verginia and Tennessee, Office of Navel Research Project, Technical Report 3, Department of Geology, Columbia University, New York.

[6] Nag, S.K. (1998). Morphometric Analysis using Remote Sensing Techniques in the Chaka Sub-Basin, Purulia district, West Bengal. *Journal of Indian Society of Remote Sensing*, 26(1and2), 69-76.

[7] Rao, K.N., Latha, P. S., Kumar, P. A. and Krishna, M.H. (2010). Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, India Using Spatial Information Technology. *International Journal of Geomatics and Geosciences*, 1(2), 179-187.

[8] Schumm, S. A. (1956). Evolution of Drainage and slopes in Badlands of Perth Ambay, New Jersey. *Bulletin of Geological Society of America*, 67, 567-646.

[9] Smith, K.G. (1950). Standards for Grading Texture of Erosional Topography. *American Journal of Science*, 248, 655-668.

[10] Srivastava, V.K. and Mitra, D. (1995). Study of Drainage Pattern of Ranigang Coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS II Imagery. *Journal of Indian Society of Remote Sensing*, 23, 225-235.

[11] Strahler, A. N. (1957). Quantitative Analysis of Watershed Geomorphology. *Transactions of American Geophysics Union*, 38, 913-920.

[12] Strahler, A. N. (1964). Quantitative Geomorphology of Drainage Basin and Channel Networks, In V.T. Chow (ed.). *Handbook of Applied Hydrology*.

Author Profile

Luna Moni Das, Doctoral Candidate, North-Eastern Hill University, Shillong, M.A., CSRD, Jawaharlal Nehru University (2009-11)