GIS BASED MORPHOMETRIC ANALYSIS OF HINGLO RIVER BASIN, INDIA

Sourav Mukherjee[21] *& Pradhan Show*[22]

Abstract: *Morphometric analysis is an important technique to quantify the parameters of a drainage basin. Morphometric analysis helps to understand the stages of landscape development of a basin and its hydro-geomorphic character. In present study Hinglo River Basin of the states of Jharkhand and West Bengal was taken as study area. Various parameters of Hinglo river basin were analysed using ArcGis 10.2 software based on GIS method. Survey of India Toposheet (1:50,000) was used as base maps of the area. Study revealed that Hinglo Basin is a narrow elongated basin with low bifurcation ratio with moderate drainage density*

INTRODUCTION

In geomorphic studies drainage basin is considered as a basic unit of analysis. A drainage basin is a region of fluvial process, where the function of running water i.e. erosion, deposition brings about the distinct geomorphological characteristics of the basin (Sen, 1993).

The drainage basin analysis is important in many hydrological investigations like assessment of groundwater potential, groundwater management and environmental assessment. Hydrologists and geomorphologists have recognized that certain morphometric relations are very important in determining the run-off characteristics and geomorphic characteristics of drainage basin systems (Rama, 2014). Study of drainage basins and it subsequent quantification was first promoted by R. E. Horton (1934) in his " Stream Law " concept and at later period it was modified by A. N. Strahler (1950). After Horton and Strahler hydrologist and engineers like Schumm, Chorley, Chow, Morisowa and many others formulated empirical relations and laws regarding various aspects of a drainage basin.

The term 'morphometry' derived from two separate words: '*morpho'* means form and '*metriy*' means measurement. Thus the term morphometric analysis means measurement of form. Thus, morphometric analysis of a drainage basin includes

[21] Junior Research Fellow, Department of Geography, The University of Burdwan, Burdwan, W.B.-713104

[22] Assistant Professor, Department of Geography, Panchakot Mahavidyalaya, Purulia, W.B.

measurement of forms of a drainage basin that developed by fluvio- geomorphic processes. Morphometric analysis includes three important aspects of a drainage basin i.e.areal, linear and relief aspects. (Table No. 1)

Table No. 1 : Areal, relief and linear properties of a drainage basin.

Properties	Index
Areal	1. Areal Change 2. Shape Indices
Relief	1. Elevation 2. Ruggedness 3. Dissection 4. Slope 5. Distribution
Linear	1. Density 2. Texture 3. Frequency and Pattern

Source: (Sen, 1993)

It is not possible to measure each and every morphometric parameters of a drainage basin on ground, particularly for large areas. Fortunately geographic information system (GIS) techniques are capable of revealing morphometric characteristics of, for instance, a large-scale basin and can also aid in the comparison of varying lithology, relief, and other variables (Al-Saddy et al., 2016).The advantages of this GIS-based approach over the conventional methods are its ability to create, manipulate, store, display, analyse, and use spatial data much quicker and precisely (Singh et al., 2013).

The geographic and geomorphic characteristics of adrainage basin are important for hydrological investigations involving the assessment of groundwater potential etc.(Rai et al, 2017). Comparison of the morphometric parameters of sub-basins or sub watersheds of a river are necessary to assess the hydrological behaviour of each sub-basin and to predict the environmental impact on the main basin, whichin turn provides insights into hydrologic conditions necessary for developing watershed management strategies (Al-Saddy et. Al., 2016).

In present study Hinglo River Basin of West Bengal and Jharkhand States was selected for morphometric analysis and quantification of drainage basin parameters.

Objectives

The main objectives of the present study is

1. To analyze the quantitative aspects of Hinglo River Basin
2. To analyze the linear, areal and relief aspects of Hinglo River Basin.

Materials and Methods

To fulfill the objectives Geographical Information System (G.I.S) was applied as a research method for quantification of morphometric parameters of Hinglo river

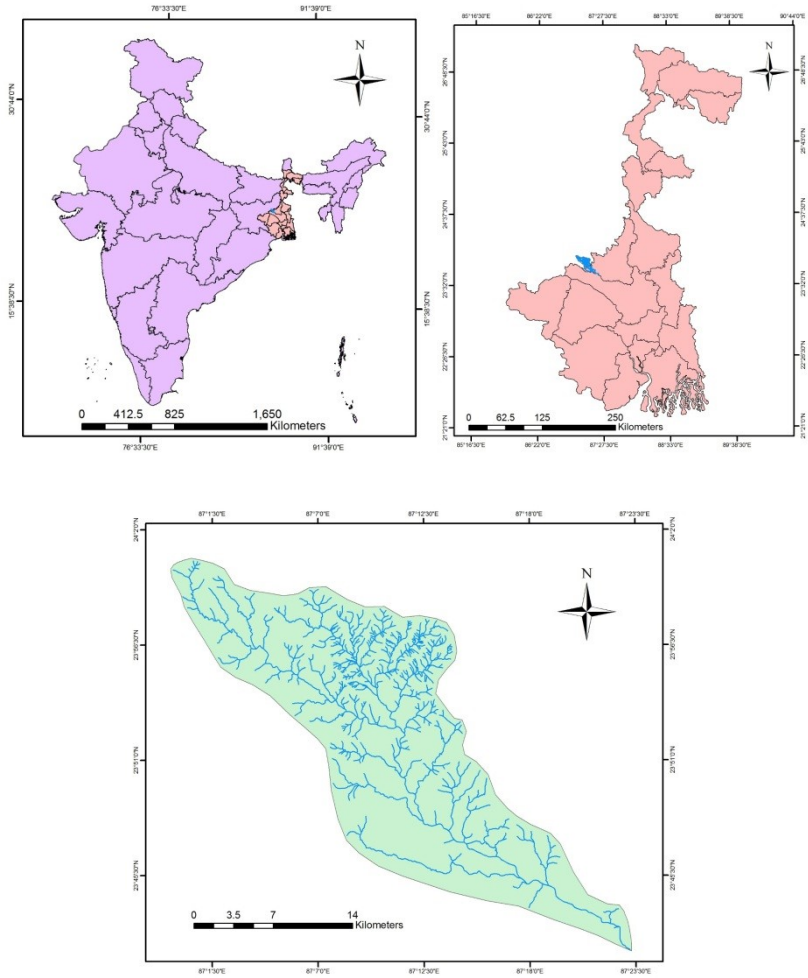
basin. Topographical sheets were used as basemap for delineation of Hinglo River Basin. Hinglo River basin was located in the survey of Toposheet No. 72L/16, 73I/13, 72P/4, 73M/1, 73M/5 and 73M/6 .Topographical sheets were initially scanned and georeferenced and converted to Universal Transverse Projection with World Geodetic System 1984 Datum using ArcGis 10.2 software. After georeferencing, mosaicing of toposheets were done to create basemap. Rivers from Topographical sheet were extracted using ArcGis 10.2 software. After digitization of rivers, basin area of Hinglo River also delineated. Stream ordering were done by Strahler (1950) method of stream ordering.Various morphometric parameters like stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, relief ratio, drainage density, stream frequency, form factor, Circularity ratio and elongation ratio were estimated using the mathematical formula given in Table No.2

Table No. 2: Morphometric Parameters of Hinglo River Basin

SL. No.	Parameters	Formula	Reference	Results
1.	Stream Order (u)	Hierarchical Rank	Strahler (1964)	5thOrder
2.	Stream Number	Total number of Stream of All orders	Strahler (1952)	366
3.	Stream Length	Length of the streams	Horton (1945)	531.53km
4.	Bifurcation Ratio (Rb)	$Rb = \frac{Nu}{Nu+1}$ Nu is number of segments of given order; and Nu + 1 is the number of segments of the next higher order	Schumm (1956)	3.35(Average)
5.	Length of Overland Flow (Lg)	$Lg = 1/Dd*2$ Where Dd is drainage density	Horton (1945)	0.45km/km^2
6.	Drainage Density (Dd)	$Dd = \frac{\Sigma Lu}{A}$ Where Lu is the Total length of stream of a basin and A is the area of the basin.	Horton (1932)	1.11 km/km^2
7.	Stream Frequency (Fs)	$Fs = \Sigma Nu/A$ Where Nu is total number of stream in a basin and A is the Area of the Basin	`Horton (1932)	0.77 /km^2
8.	Form Factor (Ff)	$Ff = \frac{A}{Lb^2}$ Where A is area of the basin and Lb^2 is Square of Basin Length	Horton (1945)	0.173
9.	Circularity Ratio (Rc)	$Rc = 4\pi A/P$ Where P' = basin perimeter; '4' is a constant value; and 'A' is the area of basin	Miller (1953)	0.41
10.	Elongation Ratio (Re)	$Re = D/Lb$ Where D is diameter of a circle with same basin perimeter and Lb is the maximum basin length	Schumm (1956)	0.738
11.	Lemniscate Method (Ls)	$K = Lb^{2/} 4A$ Where A is area of the basin and Lb2 is Square of maximum Basin Length	Chorley et,al (1957)	1.43

STUDY AREA

Hinglo River flows through the State of Jharkhand and West Bengal. It meets with Ajoy River near Palashdanga of Birbhum District of West Bengal. Extension of the basin is 23°42' 09" to 24° 00'04"N and 87°00'43" E to 87°22'44" E. Total area of Hinglo river basin is 478.144 Sq.Km. Total length of the river from source to mouth is 53 km. A dam was constructed on Hinglo River by Irrigation dept., Govt. of West Bengal in Sagarbhanga of Birbhum District in the year 1976. Hinglo



Map No. 1: Location of Hinglo River Basin

Basin originated from the fringe areas of Chotanagpur Plateau as a result most of its basin area belongs to hilly rugged terrain. Lower part of the basin situated in Rarh region.

GEOLOGY

The basement structure of the region is belongs to Achaean era. The rocks in the region belong to Archean to Triassic age found in the upper part of the basin. The

horizontal layering of Granitic and Gneissic complex is exposed as rocky surfaces at places. Gondwana system with coal bearing bed found in the lower part of the basin. Beside metamorphic rocks alternating layer of sand-silt-clay also found in the lower part of the basin. Lateritric formation is also found in the lower part of the river.

RESULT AND DISCUSSION:

Stream Order (u): Stream order is the hierarchical ordering of streams. Gravelius was the first person who in 1914 made the first attempt of stream ordering. However later R.E Horton (1945) and Strahler (1952) have modified the idea of stream ordering. In present study Strahler method of stream ordering was followed where the streams having no tributaries was considered as first order streams. Where two first order streams meet with each other they form a second order streams. Thus joining of two streams of same order formed stream of successive higher order. Hinglo river basin is a 5^{th} order river basin. The variation in order and size of the tributary basin is largely due to physiographic and structural conditions prevailing in this basin.

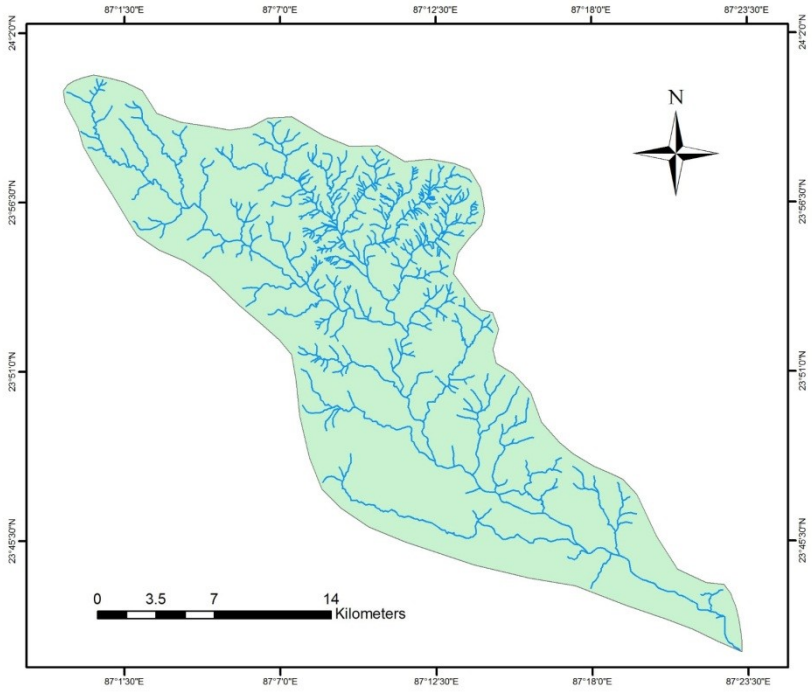
Stream Number: Stream Number is the total stream segment for each different stream order. Concept of stream number is formulated by R. E. Horton. According to R.E Horton, the number of stream segments of each order from an inverse geometric sequence with the order number. Number of stream segments decreases geometrically with increasing order. The number of streams of Hinglo River Basin of different orders was counted using ArcGIS 10.2 software. From Table no. 3 it is seen that number 1^{st} order streams is highest in Hinglo River Basin and stream segments for successive higher order decreases geometrically for higher order.

Table no. 3: Number of Stream segments for different orders of Hinglo River Basin

Stream Order	Stream Number
1	272
2	66
3	23
4	4
5	1

Bifurcation Ratio (Rb): The Bifurcation ratio is the ratio between the numbers of stream segments of any given order to the number of stream segments of the next successive order. The bifurcation ratio ranges in between 3 to 5 (Schumm, 1956). Bifurcation ratio depends on the geological and the lithological development of the drainage basin. Bifurcation ratio having>10 indicates the drainage basin developed over the easily erodible rocks. Bifurcation ratio for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} order stream is 4.06, 2.75, 4.6 and 2 respectively. Lower values of bifurcation ratio for 1^{st}, 2^{nd}, 3^{rd} and

4thorder streams indicate more structural control. Average bifurcation ratio for the basin is 3.35 and there is a strong control of geological structure on the drainage development of the basin.



Map No. 2: Hinglo River Basin

Length of Overland Flow (Lg): Length of Overland flow is the critical length of water flow on ground surface that need to be concentrate to form a channel.Normally, a higher value of length of overland flow represents low relief and whereas a low value of Length of overland flow is an indicative of high relief. For Hinglo river length of overland is flow is 0.45 km/km$^{2.}$ Value of the length of overland flow indicates that the basin has moderate to high relief and moderate slope.

Drainage Density (Dd): Drainage density (Dd) is the ratio between total length of the stream of all ordersof a drainage basin and the totalarea of that drainage basin. The idea of drainage density was first introduced by R. E Horton. Low drainage density indicates that the drainage basin is contained permeable subsurface where water easily infiltrateand number of streams is low whereas, high drainage density indicates the basin contained impermeable that most of the runoff was drained by surface streams. According to Horton (1945), value of the drainage density ranges from 0.93 km/km2 to 1.24km/km2 in the steep impervious area of the high precipitation regionand zero for the permeable basin with high infltration rate

(Biswas, 2016) Drainage density for Hinglo River Basin is 1.11 which indicates that Hinglo river flows over the terrain with weak subsurface material with moderate flow.

Stream Frequency (Fs): Stream frequency is the ratio between total numbers of streams of all order in a drainage basin to the total area of the basin. This concept was first given by R.E Horton. Stream frequency provides the idea of stages of landscape development. It is controlled by nature and amount of rainfall, nature of rock and soil permeability of the basin. Stream frequency for Hinglo River basin is 0.77/ km^2indiactesmoderate relief with moderate slope of Hinglo river basin.

Form Factor (Ff): Form factor is the ratio of the basin area to the square root of the basin length. The value of the form factor varies from 0 (highly elongated shape) to the unity, i.e., 1 (perfect circular shape). Thus the higher value of Form factor indicates oval shape or circular shape (Singh, 1993). For Hinglo River Basin Form Factor is 0.173, which means it is an elongated basin.

Circularity Ratio: The Circulatory ratio is the parameter which provides the idea of the shape of the drainage basin. Circulatory ratio is the ratio between basin areas to the area of the circle having the same basin parameter as the basin. Circular basins have a maximum efficiency for draining of run-off, whereas an elongated basin has the less ability. This information is helpful for forecasting of floods occurrences. Circularity ratio for Hinglo River Basin is 0.41 which means it is an elongated basin

Elongation Ratio: The elongation ratio provides the idea about shape or form of the drainage basin. Elongation Ratio is defined as the ratio of the diameter of the circle of the same area as the basin to the maximum basin length. This ratio ranges from 0 to 1.0 over a broad range of climatic and geological type. The lower the value (less than 1) the greater the elongated character of the basin and the value approaching unity will indicate oval or circular shape of the basin (Sen, 1993). *Elongation Ratio (0·738) value for Hinglo River Basin Indicate it is a narrow elongated Basin.*

Lemniscate Method (Ls): Lemniscate method is the comparison of a drainage basin with leminscate curve. It is based on the comparison of the basin with the lemniscate curve. The high value of K indicates elongated shape whereas low values associated with the circular shaped basins.The higher the value of K, more elongated in shape and vice versa (Mukherjee, 2014).Lemniscate value for Hinglo River Basin is 1.43 thus it is an elongated basin.

CONCLUSION

The low values of bifurcation ratios indicate that it is a structurally controlled basin. Low values of drainage densities indicate that the basin has moderate relief and moderate slope. Subsurface materials are permeable as a result drainage density and drainage frequency is low in the basin. Circularity ratio, form factor and elongation ratio indicates it is a narrow elongated basin. Thus there is low run-off generated in the basin.

References

1. Al-Saady, Y.I., Al-Suhail, Q.A., Al-Tawash, B.S. & Othman, A. A. (2016). Drainage network extraction and morphometric analysis using remote sensing and GIS mapping techniques (Lesser Zab River Basin, Iraq and Iran). Environ Earth Sci (2016) 75: 1243. https://doi.org/10.1007/s12665-016-6038-y.
2. Rama, V. A. (2014). Drainage basin analysis for characterization of 3rd order watersheds using Geographic Information System (GIS) and ASTER data. Journal of Geomatics. Vol 8 No. 2 October 2014.
3. Rai, P.K., Mohan, K., Mishra, S., Ahmad, A. & Mishra, N. V. (2017).A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India.Appl Water Sci (2017) 7: 217. https://doi.org/10.1007/s13201-014-0238-y.
4. Singh, S. (1998). Geomorpholohy. Prayag Pustak Bhavan. 20-A University Road, Allahabad-211002, India. Pp-355-384.
5. Sen, P.K. (1993). Geomorphological Analysis of Drainage Basins. The University of Burdwan. Burdwan-713104
6. Mukherjee, R. (2014). A quantitative analysis of the drainage characteristics of part of the son river basin.*Geo-Analyst.*
7. Biswas, S. S. (2016). Analysis of GIS Based Morphometric Parameters and Hydrological
   Changes in Parbati River Basin, Himachal Pradesh, India. J Geogr Nat Disast 2016, 6:2. http://dx.doi.org/10.4172/2167-0587.1000175.
8. Schumm S. A. (1956) The evolution of drainage system and slopes in badlands at Perth Amboy, New Jersey. Geological Sicence America Bull 67: 597-646.