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MORPHOMETRIC ANALYSIS OF PAGLA RIVER BASIN, EASTERN INDIA USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Geography

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ABSTRACT

A Morphometric analysis of Pagla river basin has been carried out using Geographical Information System (GIS). Morphometric parameters have been evaluated from four perspectives : drainage network, basin geometry, drainage texture and relief characteristics. The Pagla river basin covers an area of 562.10 sq.km. The study area has been designated as a fifth order basin and lower order streams mostly dominate the basin with drainage density value of 0.98 km/sq.km. The elongation ratio of the basin is 0.49 which indicates that the study area is elongated with low relief and gentle slope. The results of this study provide information on drainage morphometry that can help to understand the hydrogeomorphological character of the basin.

KEYWORDS

Morphometric analysis, Hydrogeomorphology, Geographical Information System (GIS)

INTRODUCTION :

The term morphometry can be defined as the measurement of the shape, or geometry, of any natural form - be it plant, animal or relief features (Strahler, 1969). From geomorphological point of view, morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth surface and the shape and dimension of its landforms (Clarke, 1966, pp. - 235). Morphometry analysis of a river basin provides a quantitative description of the drainage system, which is an important aspect of the characterization of basin (Strahler, 1964). It is important in any Hydrogeomorphology investigation like assessment of ground water potential, ground water management, basin management and geo environmental assessment. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the tributaries etc. (Rastogi et al., 1976). R.E. Horton pioneered the hydrologic and hydromorphometric analysis of basin and provided a rational and systematic place (Brinson, 1993). Later he was followed by Smith (1950), Miller (1953), Schumm (1956), Strahler (1964), Mueller (1968) and so on. In India, morphometric studies of various drainage basins have been carried out by Rastogi and Sharma (1976), Nautiyal (1994), Nag and Chakraborty (2003), Magesh et al. (2013), Das and Gupta (2014), Pande (2014) and so forth. In the present study an attempt has been made to find out morphometric characteristics of Pagla river basin using Geographical Information System (GIS).

STUDY AREA :

Pagla is a right bank tributary of river Bhagirathi. It lies between 24º 20' N. to 24º 32'N. latitudes and 87º 31' E. to 88º 4' E. longitudes. The total length of the river is nearly 100 km and it covers an area of 562.10 sq. km. Elevation of the basin ranges between 229 m to 20 m. The average annual rainfall in the study area is 1583.45 mm which occurs mostly during monsoon season. Almost every year during monsoon period water logging becomes a serious environmental problem in the lower part of the Pagla river basin.

DATA SOURCE AND METHODOLOGY :

For carrying out morphometric analysis, drainage and contour map of the study area have been prepared based on Survey of India (SOI) toposheets (72P/11, 72P/15, 72P/14, 78D/2 and 78D/3) on 1 : 50000 scale with sufficient ground truth by using Arc GIS 10 software. Morphometric parameters have been evaluated from four perspectives : drainage network, basin geometry, drainage texture, and relief characteristics. All stream segments have been hierarchically ranked according to Strahler stream ordering method. The stream number of various orders have been counted, while the stream length, basin length, basin area and perimeter of the basin have been measured with the help of Arc GIS 10 software. The attributes have been assigned to create the digital database for drainage and contour layers of the river basin.

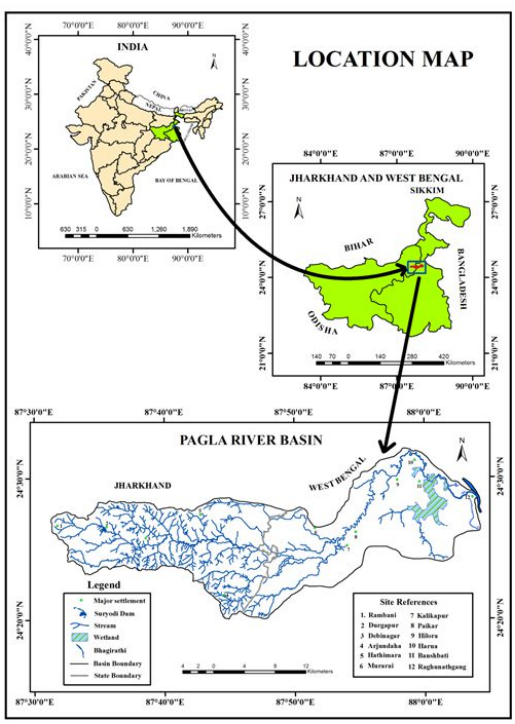


Figure 1 : Location map of the study area

RESULT AND DISCUSSION :

In the following section the various morphometric parameters of Pagla river basin have been discussed under four aspects : Drainage Network, Basin Geometry, Drainage Texture and Relief Characte ristics.

Table 1 : Methodology and computed result of morphometric parameters related to Drainage Network

Aspect	SL. No.	Morphometric Parameters	Methods	Reference	Computed Value
Drainage	1	Stream Order	Hierarchical ranking of streams	Strahler, 1964	1 to 5
	2	Stream Number (Nu)	Number of stream segments in each order	Horton, 1945	496
	3	Orderwise stream Length (Lu)	Length of all stream segments of a given order	Horton, 1945	551.28 km.

NETWORK	4	Mean Stream Length (Lū)	Lū = (Lu/Nu) Where, Lu = Total stream length of order u Nu = Number of stream of order u	Strahler, 1964	0.59 - 82.17 km.
	5	Stream Length Ratio (RL)	RL = Lu/ Lu+1 Where, Lu = Total stream length Lu+1 = Length in next lower order	Horton, 1945	1.85 - 12.28
	6	Weighted Mean Bifurcation Ratio (Rbw)	$Rb_1 \times n_1 + Rb_2 \times n_2 + \cdots + Rb_n \times n_n / n_1 + n_2 \ldots n_n$	Strahler, 1957	4.13

DRAINAGE NETWORK :

Segmentation and hierarchical ordering of streams is necessary to address the hydrogeomorphic character of a drainage basin. Based on the Strahler (1964) scheme of stream ordering the Pagla river basin has been designated as a 5th order basin having 562.10 sq.km. of area. In the present study, 496 stream segments have been recognised out of which 75.81 % (376) is 1st order, 18.35 % (91) is 2nd order, 4.64 % (23) is 3rd order, 1 % (5) is 4th order and 0.20 % (1) comprises 5th order stream. It is apparent from the above discussion that the total number of streams gradually decreases as the stream order increases (Figure - 2). The total stream length is 551.28 km. and the 1st order streams constitute 40.23 % of the total stream length. Mean stream length (Lsm) is the ratio between the total stream length and the number of streams of a given order. The Lsm values for the Pagla river basin vary from 0.59 to 82.17 km. There is a positive relationship between stream order and mean stream length of the Pagla basin (Figure - 3). The stream length ratio (RL) for the study area vary widely from 1.85 to 12.28 and are strongly dependent on the topography and the slope. In the study area weighted mean bifurcation ratio ranges between 3.32 to 5.07. High Rbw value indicates structural control on the development of drainage network.

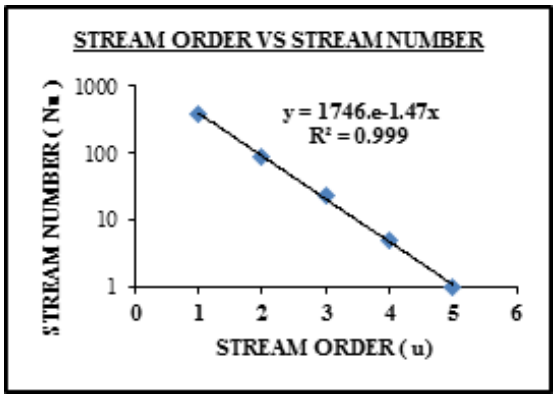


Figure 2 : Relationship between Stream order and Stream Number

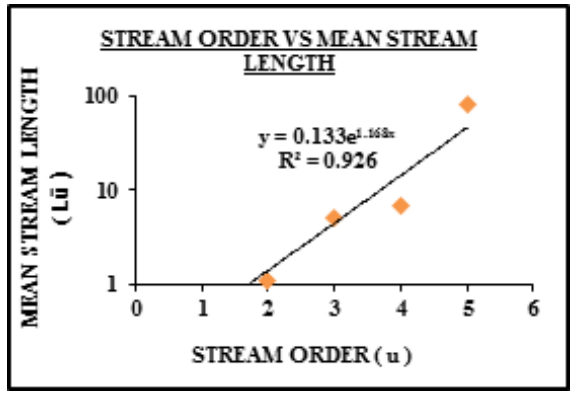


Figure 3 : Relationship between Stream order and Mean stream Length

Table 2 : Methodology and computed result of morphometric parameters related to Basin Geometry

Aspect	SL. No.	Morphometric Parameters	Methods	Reference	Computed Value
BASIN GEOMETRY	1	Basin Area (A)	Plane area within the perimeter along the drainage basin	----------	562.10 Sq.Km.
	2	Basin Length (Lb)	Longest length of the basin from source to mouth	----------	55.01 km.
	3	Basin Perimeter (P)	Total length of water divide	----------	149.60 km.
	4	Form factor (Rf)	$Rf=A/Lb^2$ Where, A = Area of the basin, Lb^2 = Square of the basin length	Horton, 1932	0.19
	5	Elongation Ratio (Re)	$Re= 1.128\sqrt{A}/Lb$, Where, A = Area of the basin, Lb = Basin length	Schumn, 1956	0.49
	6	Circularity Ratio (Rc)	$Rc=4\times\pi\times A/P^2$ where, $\prod = 3.14$, A = Area of the basin, P = Perimeter	Miller, 1953	0.32

BASIN GEOMETRY :

The Pagla river basin covers an area of 562.10 sq.km. and has a perimeter of 149.60 km. According to Gregory and Walling (1973) basin length (L) is the longest length of the basin from the catchment to the point of confluence. The length of the basin is 55.01 km. The shape of a watershed is controlled by geological structure, lithology, relief and climate, and varies from narrow elongated forms to circular or semi circular forms. The shape mainly governs the rate at which water is supplied to the main channel (Fenta et al., 2016). In the present study, three parameters namely form factor (Ff), elongation ratio (Re) and circularity ratio (Rc) have been used for characterizing watershed shape, which is an important parameter from hydrological perspective. Horton (1932) defined form factor (Ff) as the ratio of the basin area and square root of the basin length. Pagla river basin is an elongated basin with lower peak flows of longer duration due to lower Ff value (0.19). Elongation ratio (Re) is defined as the ratio of diameter of a circle having the same area as the basin and maximum basin length (Schumm, 1956). The Re value of Pagla river basin is 0.49 which indicates that the basin is elongated with low relief and gentle slope. Miller (1953) defined circularity ratio (Rc) as the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the basin. The circularity ratio of the Pagla river basin is 0.32 which indicates that overall the basin has elongated shape.

Table 3 : Methodology and computed result of morphometric parameters related to Drainage Texture

Aspect	SL. No.	Morphometric Parameters	Methods	Reference	Computed Value
Drainage Texture	1	Stream Frequency (Fs)	Fs = Nu/A, where, Nu = Total number of streams of all orders, A = Area of the basin	Horton, 1945	0.88
	2	Drainage Density (Dd)	Dd = Lu/A, where, Lu = Total stream length of all orders, A = Area of the basin	Horton, 1945	0.98
	3	Drainage Texture (Dt)	Dt = Nu/P, where, Nu = Total number of stream segments of all orders, P = Basin perimeter	Horton, 1945	3.32
	4	Infiltration Number (In)	In=Df×Dd where, Df = Drainage density, Df = Drainage frequency	Faniran, 1968	0.86
	5	Length of Overland Flow (Lof)	Lof=1/2×Dd where, Dd = Drainage density	Horton, 1945	0.49
	6	Constant of channel Maintenance (CCM)	CCM = 1 / Dd, where, Dd = Drainage density	Schumn, 1956	1.02 sq.km.

DRAINAGE TEXTURE :

According to Horton (1945), stream frequency (Fs) is defined as the ratio of the number of stream segments of all the orders in the basin to the total area of the basin. The stream frequency for the Pagla river basin is 0.88 / sq.km. that shows high permeable lithology and low relief of the basin. Drainage density (Dd) is defined as the total stream length in a given basin to the total area of the basin (Strahler, 1964). The Dd of the Pagla river basin is 0.98 km / sq. km. which indicates that the study area has a weak or permeable sub surface material with low relief. Drainage texture (Dt) is the total number of stream segment of all orders per perimeter of that area (Horton, 1945). The Dt value of Pagla basin is 3.32. Infiltration number plays a dominant role in observing the infiltration characteristics of the basin. It is inversely proportional to the infiltration capacity of the basin i.e. greater the value lesser the infiltration capacity and greater the surface run off potentiality and vice verse. The infiltration number of the study area is 0.86. and length of overland flow (Lof) is 0.49 km which indicates moderate surface runoff. Constant of channel maintenance (CCM) is the number of sq. foot of watershed surface is needed to sustain one linear foot of channel or it may be in metric measurement. In the present work 1.02 sq. km. / km. of basin area is needed to support 1 km of channel.

Table 4 : Methodology and computed result of morphometric parameters related to Relief Characteristics

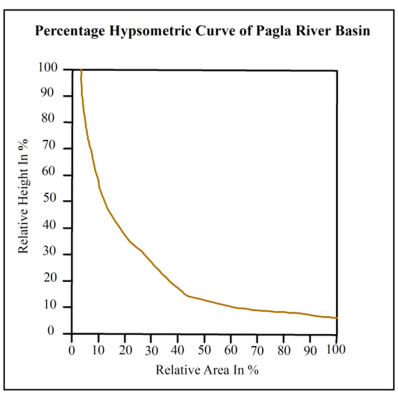
Aspect	SL. No.	Morphometric Parameters	Methods	Reference	Computed Value
RELIEF CHARACTERISTICS	1	Absolute Relief / Maximum Relef (Rmax)	The maximum elevation in a watershed	----------	229
	2	Minimum Relief (Rmin)	The minimum elevation in a watershed	----------	20
	3	Basin Relief (Bh) / Total Relief (H)	H = Rmax-Rmin, Where, Rmax = Maximum elevation Rmin = Minimum elevation	Schumm, 1956	209
	4	Relief Ratio (Rh)	where, Bh = Basin relief Lb = Maximum length	Schumm, 1956	0.0038
	5	Dissection Index (Di)	Di = Relative relief / Absolute relief	Dov, Nir, 1957	0.91
	6	Ruggedness Index (Ri)	Ri=Relative relief×Drainage density/100	Chorley, 1972	0.21

Relief Characteristics :

Maximum and minimum height of the basin is 229 m and 20 m respectively. Basin relief (Bh) or total relief (H) of the basin is defined as the difference in elevation between the highest and lowest points on the basin (Schumm, 1956). In the present study basin relief (Bh) of the Pagla river watershed is 209 m. The relief ratio (Rh) of the entire basin is 0.0038 that shows extremely low lying character of the basin. Similarly the basin has low dissection (0.91) and ruggedness indices (0.21). The low ruggedness value of the basin implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density (Pareta, 2011).

Hypsometric Analysis :

The Percentage Hypsometric Curve has been used for the present study. Hypsometric Integral (HI) and Erosional Integral (EI) of the Pagla river basin are 0.32 and 0.68 respectively which indicates that Pagla river is in the late mature stage of geomorphic evolution.



CONCLUSION :

The present study has proved that GIS is an effective tool for computation and analysis of various morphometric parameters and helps to understand various hydrogeomorphic characters like nature of the bed rock, infiltration capacity, Surface runoff and so on. The Pagla river basin has been designated as a 5th order basin. The basin is dominated by lower order streams and the total stream length is maximum in first order streams. Pagla river basin is an elongated basin with low relief and gentle slope due to the lower elongation ratio (0.49). Low value of stream frequency and drainage density indicates presence of impermeable rock in the drainage basin. Low ruggedness index indicates less soil erosion. The study also reveals that the Pagla river is in the late mature stage of geomorphic evolution.

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