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Fluvial Geo-Morphometry of AIE River Basin using RS and GIS

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Abstract:
The River AIE has a lot of influence on the River bank localities as the flood it carries is flash flood and due to flash flood a lot of damage has been afforded by the localites. A study was conducted to learn the watershed condition to get a better view for the condition that the people are facing every year. From the study a brief idea could be made after delineating the watershed area and determining the data one after another and the data was processed by calculating with the mathematical formula given by various researchers. After calculation, it was found that the watershed is elongated and the slope of most of hill is steep. Due to elongated watershed the water is coming out through a common channel and due to steep the surface water reach the base quickly and thus the water accumulated becomes higher and flows down the channel with high velocity and discharge and as it reach the plain areas it tends move along the direction of velocity and cause destruction.

Keywords: Delineation, DEM, Morphometry, Watershed.

I. INTRODUCTION

The Aie River which is known as Mao River at its source at Sarpang district of Bhutan is a Himalayan River which runs through steep slopes and flows through the State of Assam, India and falls on the River mighty Brahmaputra at Jogighopa, Bongaigaon, Assam. Many sub-tributaries from the extreme corners of the district joins together to form a single channel and runs through the Gelephu. Aie River is mainly comprises of the district boundary of Sarpang district. The River during the period of monsoon turns into flashy River due to steep slopes at the upstream of Indo-Bhutan border. Geo-environmental characteristics that are influencing geomorphic processes and landforms in the study area of the Aie River have been discussed below.

II. LITERATURE REVIEW

[1] ***Nongkynrih et al., (2011)*** analyzed morphometry of the Manas River basin using earth observation data and Geographical Information System by numerically or mathematically quantifying the different aspects of the drainage basin, the morphometric parameters used in analysis were Linear, Areal and Relief aspects of the basin. The watershed area of Manas basin was 31,480.00 sq.km *(Nongkynrih et al., 2011).* The drainage basin was of 8th order, which indicates dendritic drainage pattern. Drainage density was 0.78 per sq.km, which indicates medium drainage density. Length of the overland flow was 0.64, indicating its young topography. Bifurcation Ratio was between (3.0 - 5.0), indicates distortion by geological structures. 1st order segment was the most, which indicates the basin is subjected to erosion. Mean Stream Length=1.28-43.78, which indicates change in topographic elevation & slope. Elongation Ratio=1.47, which indicates shape is elongated. Slope of the basin is plain at the Southern parts and Very steep at the Northern parts. Low Relief to Moderately relief at the plains and High Relief at the Hilly portion.

[2] ***Misra et al., (2018)*** has performed morphometric analysis of the Champabati watershed using earth observation data and Geographical Information System by numerically or mathematically quantifying the different aspects of the drainage basin, the morphometric parameters used in analysis were Linear, Areal and Relief aspects of the basin. The watershed area of Champabati watershed is 1256.695sq.km. The drainage basin is of 5th order. Drainage density =0.77 per sq.km, which indicates very course drainage density. Length of the overland flow= 0.42. Bifurcation Ratio=3.94, which indicates distortion by geological structures. 1st order segment are the most, which indicates the basin is subjected to erosion. Elongation Ratio=0.529, which indicates elongated in shape with moderate to low relief. Slope of the basin is plain at the Southern parts and Very steep at the Northern parts.

[3] ***Thakuriah et al., (2012)*** have evaluated morphometric parameters of the Diyung River which is flowing over the Barail Hill range of southern part of Dima Hasau District to join Kopili River of the Brahmaputra plain in Nagaon District, Assam through earth observation data and Geographical Information System by numerically or mathematically quantifying the different aspects of the drainage basin, the morphometric parameters used in analysis were Linear, Areal and Relief aspects of the basin. The watershed area of Diyung River is 3,882.737 sq.km. The drainage basin is of 7th order. Drainage density was between (0.00 - 4.00) per sq.km, which indicates very low to high drainage density. Bifurcation Ratio was between (3.00 - 5.12), which indicates distortion by geological structures. 1st order segment are the most, which indicates the basin is subjected to erosion. Elongation Ratio was (0.35 - 0.83), which indicates elongated in shape with moderate to low relief. Form factors for the study of the watersheds (0.30 - 0.50) indicating that basin is more or less circular basin.

III. MATERIALS AND METHODOLOGY

The area where the spatial-temporal analysis was performed covers both Indo-Bhutan areas, where the source is at Sub-Himalayan Mountains of Bhutan and the sink is at Assam, India. The Indian counterpart is adversely affected by flash flood. The location map of the exact area is shown Figure.1.

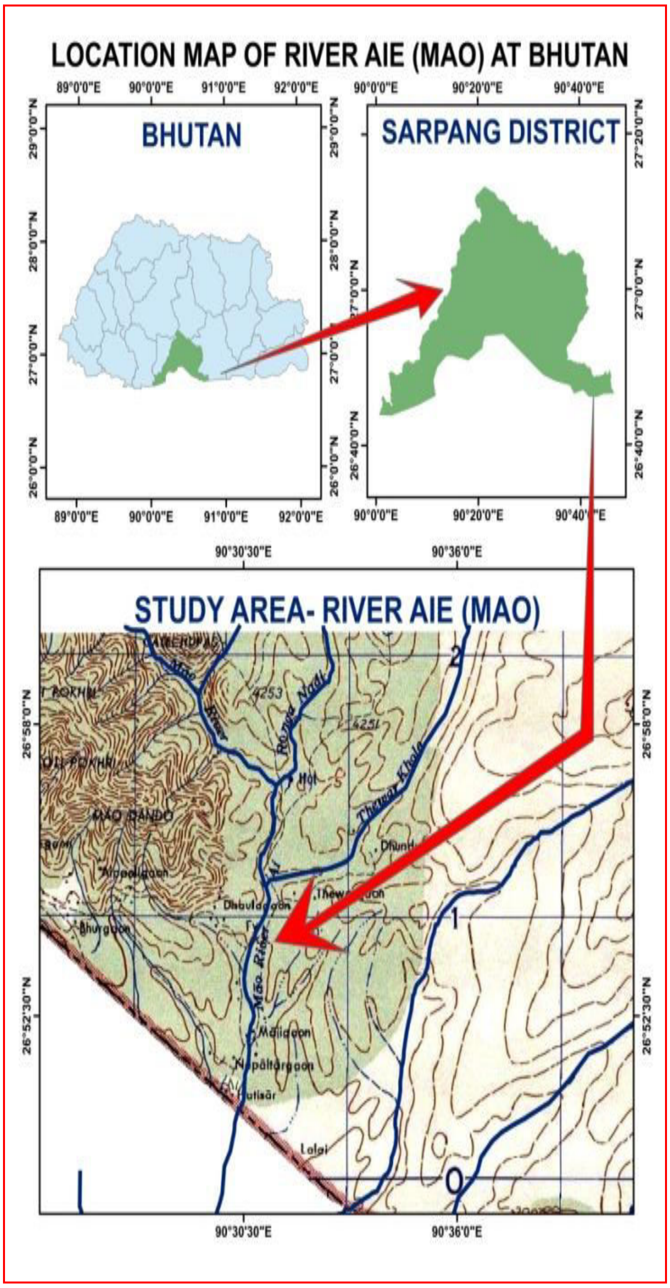

Figure.1. Location map

The River AIE, which originates from the Sub-Himalayan range of Bhutan (27°00'19"N 90°15'32"E), which is known as River MAO in Bhutan, travels 51.00 Kilometer towards the south eastern direction and heads south ward in between the hill locks to reach out to the India –Bhutan border through Gelephu city of Sarpang district at Hatichar (26°51'14"N 90°30'04"E) in the state of Assam. The Remote Sensing data used is ASTER GLOBAL DEM (1 ARC Second, 90 meter resolution). The software used is ArcGIS 9.2 for Image processing & geospatial analysis. Morphometry is the process of analysing the different aspects of a drainage basin numerically or mathematically to determine the condition of watershed present in the hills/mountains. It is very important to determine the geographic analysis of the watershed, as the data are real time data taken through various powerful satellites which shows the type, size and shape of the earth surface from the atmosphere using the radiation emitted by the sensors which may be active or passive. The watershed was delineated step by step as shown in Figure.2 and Figure.3 shows the DEM used, to extract the maximum precised data taken by various satellites from the atmosphere and which were processed using Arc-GIS software. The output is shown in Figure.4.

Figure.2. Step by Step Procedure for Delineation of the Watershed

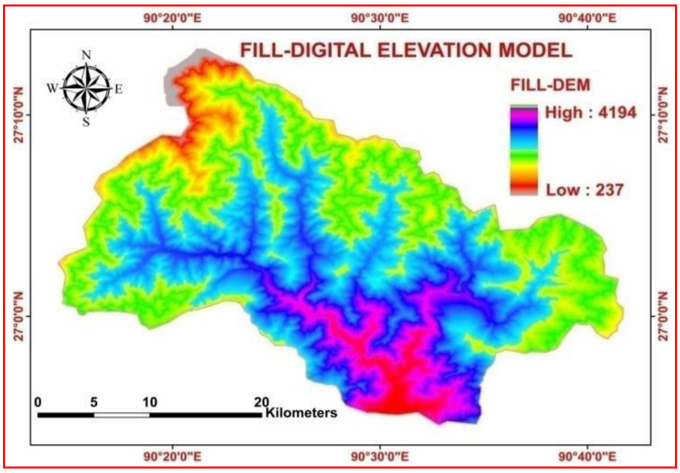

Figure.3. Filled DEM of the Watershed

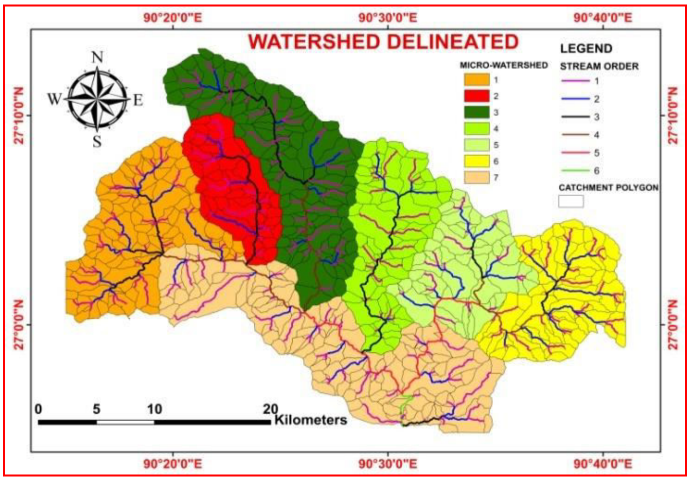

Figure.4. Delineated Watershed

IV. RESULTS AND DISCUSSION

The morphometric parameters of the watershed was computed and summarized according to 1-D (Linear Aspect), 2-D (Areal Aspect) and 3-D (Relief Aspect).

Sl. No.	Parameters	Formulae	References
1	Stream Order(U)	Hierarchical rank	Strahler(1964)
2	Stream Length(Lu)	Length of the stream	Horton(1945)
3	Mean Stream Length (Lsm)	Lsm=Lu/Nu	Strahler(1964)
4	Stream Length Ratio(RL)	RL=Lu/Lu-1	Horton(1945)
5	Bifurcation Ratio(Rb)	Rb=Nu/Nu+1	Schumm(1956)
6	Mean Bifurcation Ratio(Rbm)	Rbm=average of bifurcation ratio so fall order	Strahler(1957)
7	Drainage density(Dd)	Dd=Lu/A	Horton(1945)
8	Drainage texture(T)	T=DdxFs	Smith(1950)
9	Stream Frequency(Fs)	Fs=Nu/A	Horton(1945)
10	Elongation ratio(Re)	$Re=D/L=1.128A^{1/2}/L$	Schumm(1956)
11	Circularity ratio(Rc)	$Rc=4\pi A/P^2$	Strahler1964
12	Form factor(Ff)	$Ff=A/L^2$	Horton(1945)
13	Length of over land flow(Lg)	Lg=1/D*2	Horton(1945)
14	Relief	R=H-h	Hadley and Schumm(1961)
15	Relief Ratio	Rr=R/L	Schumm(1963)

Figure.4. Formulae for Morphometric Analysis

A. LINEAR ASPECTS

Linear aspects of the basins are closely linked with the channel patterns of the drainage network where in the topological characteristics of the stream segments in terms of open links of the network system are analyzed. The morphometric investigations of linear parameters of the basin includes:-

i. STREAM ORDER

The designation of stream order is the first step in morphometric analysis of a drainage basin. Herein, the number of streams gradually decreases with increase in stream order**.** From the analysis there were 284 1st order, 111 2nd order, 91 3rd order, 40 4th order, 4 5th order and 1 6th order streams.

ii. STREAM LENGTH

Stream length is one of the most important hydrological features of the basin indicate the variation of surface runoff behaviors. Longer lengths of streams are generally indicative of flatter gradients. The stream length is higher for the first order and decreases as the stream order increases. The stream length has been computed based on the law proposed by Horton, with the help of GIS software. In the present work, results show that the total length of stream is more in case of first order stream sand decreases with the increase in the stream order. The overall length of 531 streams of water shed is 532.04 km. The lengths of first order, second order and third order, forth order, fifth order and sixth order streams are 256.60 km, 126.64 km, 77.96 Km,39.11 Km, 27.46 Km and 4.27 km respectively.

iii. STREAM NUMBER

The order wise total number of stream segment is known as the stream number. Higher the stream number indicates lesser permeability and infiltration. It leads to inference that several stream usually upsurges in geometric progression as stream order increases. The results of study area reveal that the number of streams in the first-order is 256.60 and accounts for 48.32% of all segments. The number of streams in second-order is 111 and accounts for 20.90% while the number of streams in third order is 91 and accounts for 17.13% while the number of streams in forth order is 7.53% while the number of streams in fifth order is 0.75% and only 1 in the sixth order which contributes an account for 0.18%. As per Horton's laws the stream number decreases in geometric progression as the stream order increases.

iv. MEAN STREAM LENGTH

Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its contributing watershed surfaces. It's directly proportional to the size and topography of drainage basin. It is obtained by dividing the total length of stream of an order by total number of segments in the same order. The mean stream length of any given order is greater than that of lower order in all watersheds. The mean length of the study area is 0.903Km for first order, 1.140 Km for second order, 0.856 Km for the Third order, 0.977 Km for the forth order, 6.866 Km for the fifth order, 4.273 Km for the sixth order respectively. Overall Mean stream length is 2.5 Km.

v. BIFURCATION RATIO

Bifurcation ratio is closely related to the branching pattern of a drainage network. It is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Nu+1) considered the bifurcation ratio as an index of relief and dissection. The bifurcation ratio is dimension less property indicates the degree of integration prevailing between streams of various orders in drainage basin and generally ranges from 3.0 to 5.0. In the study bifurcation ratio varies from 1.2 to10 and mean of bifurcation ratio for entire basin was 4.01 which is in between the range of 3.0 to 5.0 i.e., structurally stable and permeable.

B. AREAL ASPECTS

Areal aspects of a watershed of given order is defined as the total area projected upon a horizontal plane contributing over land flow to the channel segment of the given order and includes all tributaries of lower order. Area and perimeter of a basin are the important parameters in quantitative geomorphology. The area of the basin is defined as the total area projected upon a horizontal plane. Perimeter is length of the boundary of the basin. Areal aspects of the drainage basin such as drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio, shape factor, compactness coefficient were calculated.

i. DRAINAGE AREA

The fundamental unit of virtually all watershed and fluvial investigations is the drainage area. An individual drainage basin is a finite area whose runoff is channeled through a single outlet. It is enclosed within the boundary of the watershed divide. A drainage divide is simply a line on either side of which water flows to different streams. Drainage area measures the average drainage area of streams in each order; it increases exponentially with increasing order. The drainage area of the study area was found to be 788.86 sq.km.

ii. DRAINAGE DENSITY

It is a measure of the total length of the stream segment of all order per unit area. The drainage density indirectly indicates the ground water potential of an area, due to its relation with surface runoff and permeability. Slope gradient and relative relief are the main morphological factor of drainage density. Higher the range of drainage density faster the runoff will be and it also suggests that the value vary between 0.55 and 2.09 km/km^2 in a humid region with an average of 1.03 km/km^2. Low drainage density generally result in the area of highly resistant or permeable sub soil material and high drainage density is the resultant of weak or impermeable sub surface material. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The drainage density of the study area is 0.67 km/km2 which indicate that the basin has permeable drainage.

iii. CIRCULARITY RATIO

The circularity ratio is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin. Circularity ratio is dimensionless and expresses the degree of circularity of the basin depends on stream flow in the watershed. It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate and slope of the basin. It is a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of circularity ratio indicate the young, mature, and old stages of the life cycle of the tributary watershed. Circularity ratio value for the study area was obtained as 0.46 and it indicated the basin is strongly elongated and highly permeable.

iv. FORM FACTOR

Form factor is a dimensionless ratio of watershed area to the square of the length of the watershed. This factor indicates the flow intensity of a basin of a defined area. The form factor values vary from 0 (in highly elongated shape) to 1 (in perfect circular shape). Value greater than 0.78 indicated the perfectly circular basin, smaller values suggest the elongated form of basin. The value of form factor for the study is 0.23 indicating that basin is elongated.

v. ELONGATION RATIO

The elongation ratio is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. The values elongation ratio are grouped into three class namely circular (>0.9), Oval (0.9 - 0.8), and less elongated (0.8 - 0.7) and elongated (<0.7). A circular basin is more efficient in the discharge of runoff than an elongated basin. The elongation ratio of the study area is 0.55 < 0.7 which indicates that the water shed is elongated in nature.

vi. LENGTH OF OVERLAND FLOW

It is the length of water over the ground before it gets concentrated into definite streams channels. It is approximately equals to half of reciprocal of drainage density. This factor depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion. Higher the values of Length of overland flow lower will be the relief and vice versa. The value of length of overland flow in watershed is 0.75 means gentle slopes and long flow paths, more infiltration, and reduced runoff.

C. RELIEF ASPECTS

Relief aspects of drainage basin relate to the three dimensional features of the basin involving area, volume and altitude of vertical dimension of landforms where in different morphometric methods are used to analyze terrain characteristics.

i. RELATIVE RELIEF

Watershed relief is the difference in elevation between the lowest and the highest point of the watershed. Relief is an important factor in understanding the denudational characteristics of the basin and plays a significant role in land forms development, drainage development, surface and subsurface water flow, permeability and erosional properties of the terrain. The high relief value indicates high gravity of water flow, low permeable and high runoff conditions. The difference in elevation between the remotest point and discharge point is obtained from the available contour map. The highest elevation of watershed was 4194.00 m above mean Sea level and the lowest relief was 237.00 m above mean Sea level. The overall relief, H calculated for the watershed was 3957.00 m. Relative relief = 2.69, i.e., low relative relief.

ii. AVERAGE SLOPE

Slope is defined as the angular inclination of terrain between hill-tops and valley bottoms. Slopes are significant morphometric attributes in the study of landforms of drainage basin. Slope angle in degree of the drainage basin are tabulated and classified into convenient slope categories viz., (i) level slope = 0 –15, (ii) gentle slope = 15 – 25, (iii) moderate slope = 25 – 35, (v) steep slope = 35 – 45, and (vi) very steep slope = above 45. This is prepared for the study of spatial variations of average slope within the basin which is shown in Figure 5.20.

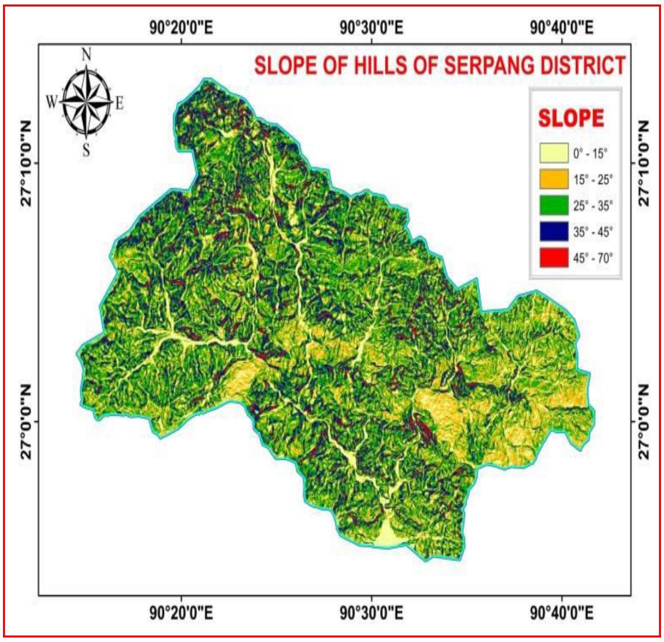

Figure.5.20:- Slope map of the Watershed

The numerical analysis of the watershed is presented in Table.1. (a),(b),(c).

Table.1. (a), (b), (c)-Geomorphic Analysis of the Watershed

Order No	No. of Streams	Stream Length	Mean Stream Length	Stream Length Ratio	Mean Stream Length	Bifurcation Ratio	Mean Bifurcation Ratio	Stream Frequency	Drainage Texture
u	N_u	L_u	$L_{sm}=L_u/N_u$	$R_l=L_u/L_{u-1}$		$R_b=N_u/N_{u+1}$		$F_s=N_u/A$	$T_t=N_u/P$
1	284.00	256.60	0.903	1.262	2.5	2.558	4.01	0.36	1.93
2	111.00	126.64	1.140	0.750		1.219		0.14	0.756
3	91.00	77.96	0.856	1.141		2.275		0.11	0.1714
4	40.00	39.11	0.977	7.023		10		0.05	0.075
5	4.00	27.46	6.866	0.622		4		0.0005	5.970
6	1.00	4.27	4.273	-		-		0.0001	0.4
	531.00	532.04	2.503	Table. (a).					

Area in sq.km, A	Perimeter in km, P	Basin Length, L_b Km	Total Length Km	Total Streams	Drainage Density, D
788.86	146.75	58.00	532.04	531.00	0.67
Mean Stream Length	Relative Relief	Form Factor	Circulatory Ratio	Elongation Ratio	Length of Overland Flow, L_g
2.5	26.96	0.23	0.0855	0.55	0.75

Table. (b).

	Altitude	Difference
HIGH	4194.00 m	3957.00 m
LOW	237.00 m	

Table. (c).

V. CONCLUSION

Quantitative analysis of morphometric parameters of the watershed is found to be very useful in the drainage basin evaluation, water conservation and natural resource management at micro level. Morphometric analysis of the study area is characterized by dendritic type drainage basin. Lower order streams dominate the basin with highest stream order being sixth order. Higher mean bifurcation ratio of the study area indicates a strong structural control on the drainage pattern of watershed. The value of form factor and circulator ratio and elongation ratio indicates the watershed is elongated in shape having low runoff. Further, the study concludes that (DEM) data coupled with GIS technique is a competent tool to analyze the morphometric parameters for water resource management at micro level of any terrain by planners and decision makers to develop strategy for sustainable watershed development programs.

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