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Research Article

MORPHOMETRICAL ANALYSIS OF IMPHAL RIVER BASIN USING GIS

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ABSTRACT

GIS and image processing techniques were adopted to identify the morphological features and to analyse their properties. Various morphometric parameters like linear and aerial aspects of the river basin were determined and computed. The results indicated that the drainage area is 339 Km^2, perimeter 110.4 Km, basin length 38.99 Km, form factor 0.22, circulatory ratio 0.35, drainage texture 10.290, constant of channel maintenance 0.35. The stream frequency, drainage density, bifurcation ratio and length of overland flow are respectively 3.35 Km/Km^2, 2.84 Km/Km^2, 4.116 and 0.18 Km. The drainage density and circularity ratio value indicate that the basin has a gentle slope, low rainfall, strongly elongated and highly permeable bedrock. The relief ratio of the basin characterizes less resistant rocks.

Keywords: *Morphometrical, Configuration, Stream Order, GIS, Linear, Aerial, Relief*

INTRODUCTION

The development of morphometric techniques is a major advance in the quantitative description of the geometry of the drainage basins and its network. The morphometric parameters are useful in characterizing river basins and comparing their characteristics. For the first time it was proposed by Horton in 1945. The various morphometry parameters have been discussed. The morphometric analysis can be achieved through measurement of linear, aerial and relief aspects of basin and slope contributions (Nag and Chakraborty, 2003). Stream order, stream length, mean stream length, stream length ratio and bifurcation ratio are linear aspects. The relief measurements like relief ratio, basin length and total relief are the relief aspects. Different morphometric parameters like drainage density, texture ratio, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow are the aerial aspects.

Study Area

The study area (Figure 1) is situated at a distance of 18-45km north of Imphal city near National Highway No.39. It covers a total area of 339 Km^2 with the geographical position of 24.8757° to 25.2415°N and 93.79° to 94.0021°E. . The elevation of the area ranges from 800m to 2640m. Many tributaries join the Imphal River. The geological formations exposed in the present study area belong to the Disang Group, Barail Group and Recent Alluvium. The area is covered by Survey of India, toposheet no. 83G/16 and 83H/13 with 20m contours interval (Scale-1:50,000).

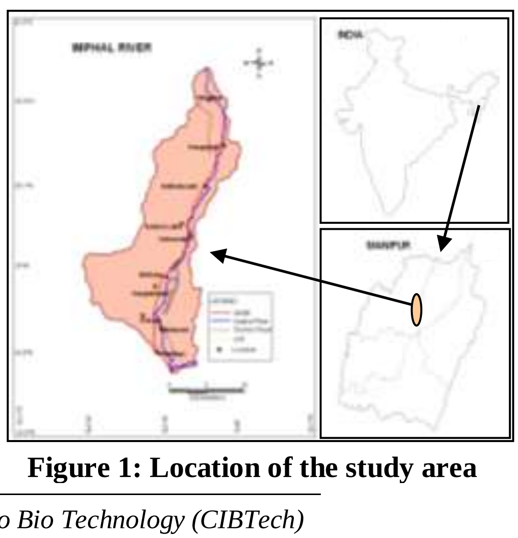

Figure 1: Location of the study area

MATERIALS AND METHODS

Methodology

To define the morphometric features of Imphal River catchment, the digital data covered by survey of India, toposheet no. 83G/16, 83H/13 and contours (with 20m interval at 1:50,000 scale) were obtained and were used in the analysis of digital data for this purpose. In the present study, the morphometric analysis has been carried out through measurement of linear, aerial and relief aspects of basin, using the mathematical formulae given in table 1.

Table 1: Formulae adopted for computation of morphometric parameters

05	Morphometric Parameters	Formula	Reference
1	Stream order	Hierarchical rank	Strahler (1964)
2	Stream length (L_u)	Length of the stream	Horton (1945)
3	Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$, Where, L_{sm}=Mean stream length L_u=Total stream length of order 'u' N_u=Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (R_L)	$R_L=L_u/L_u$-1, Where, R_L=Stream length ratio L_u=The total stream length of the order 'u' L_u-1=The total stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (R_b)	$R_b=N_u/N_u$+1, Where, R_b=Bifurcation ratio N_u=Total no. of stream segments of order 'u' N_u+1=No. of segments of the next higher order	Schumm (1956)
6	Mean bifurcation ratio (R_{bm})	R_{bm}=Average of bifurcation ratios of all orders	Strahler (1957)
7	Relief ratio (R_h)	$R_h=H/L_b$, Where, R_h=Relief ratio H=Total relief (Relative relief) of the basin (Km) L_b=Basin length	Schumm (1956)
8	Relative relief (R_{hp})	R_{hp}=H/P, where, R_{hp}= Relative relief H= Basin relief, P= Basin perimeter	Strahler (1958)
9	Drainage density (D)	$D=L_u/A$, Where, D=Drainage density L_u=Total stream length of all orders A=Area of the basin (Km^2)	Horton (1932)
10	Stream frequency (F_s)	$F_s=N_u/A$, Where, F_s=Stream frequency N_u= Total no. of streams of all orders A= Area of the basin (Km^2)	Horton (1932)
11	Drainage Texture (R_t)	$R_t=N_u/P$, Where, R_t=Drainage texture N_u=Total no. of streams of all orders P=Perimeter (Km)	Horton (1945)
12	Form factor (R_f)	$R_f=A/L_b^2$, Where, R_f=Form factor A=Area of the basin (Km^2) L_b^2=Square of basin length	Horton (1932)
13	Circulatory ratio (R_c)	$R_c=4*Pi*A/P^2$, Where, R_c=Circulatory ratio Pi='Pi' value i.e., 3.14, A=Area of the basin (Km^2) P^2=Square of the perimeter (Km^2)	Miller(1953)
14	Elongation ratio (R_e)	$R_e=2\sqrt{(A/Pi)}/Lb$, Where, R_e=Elongation ratio A=Area of the basin (Km^2), Pi='Pi' value i.e., 3.14 L_b=Basin length	Schumm (1956)
15	Length of overland flow (L_g)	$L_g=1/D*2$, Where, L_g=Length of overland flow D=Drainage density	Horton (1945)

RESULTS AND DISCUSSION

Linear Aspect

The linear aspects of drainage network such as stream order (N_u), bifurcation ratio (R_b) and stream length (L_u) results have been presented in Table 2.

Stream order: The stream classification system developed by Horton (1945) and complemented by B. Panov (1948) and Strahler (1952) has been adopted because, having a genetic basis, it allows comparative analysis of drainage basins. In the Strahler scheme for ordering the network, all the “fingertips” tributaries are designated as first order streams and where two of them join, they form a second order stream. Likewise, two second order streams join to form a third order stream and so on to the streams of fourth, fifth and higher order**.**

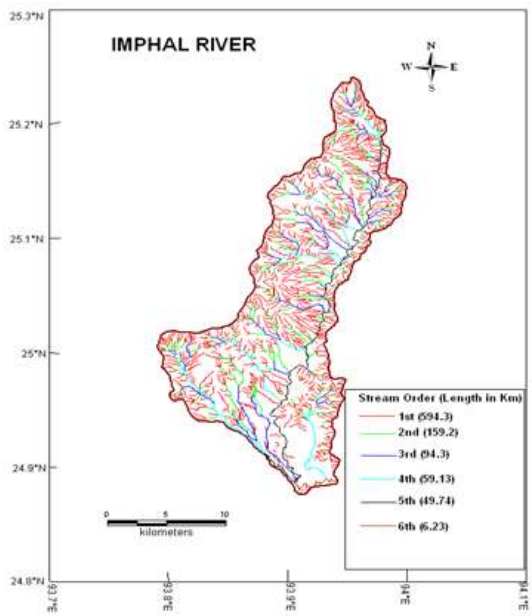

Figure 2: Stream network of Imphal River

Figure 2 illustrates the stream network of Imphal River. The stream orders vary from 1 to 6 and the total number of stream segments of all orders recorded was 1136. Orders of stream network indicated 879 of 1st orders, 196 of 2nd, 46 of 3rd, 12 of 4th, 2 of 5th, and 1 of 6th order streams. The number and length of stream segments of each order are given in table 2.

Horton (1945), Schumm (1956) and others discussed the relationship between stream order and factors composing a drainage basin. The most important results are as follows:

• As stream order increases, the number and the mean gradient of streams decrease in an inverse geometric ratio (figure 4).

• As stream order increases, the mean length of streams and the mean area of drainage basin increase. The shortest and the steepest streams have the smallest drainage basins.

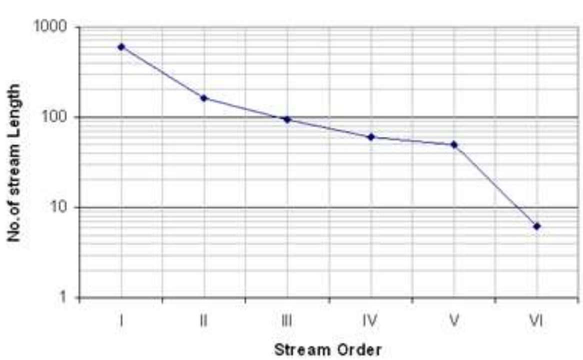

Figure 3: Regression of numbers of stream lengths versus stream order

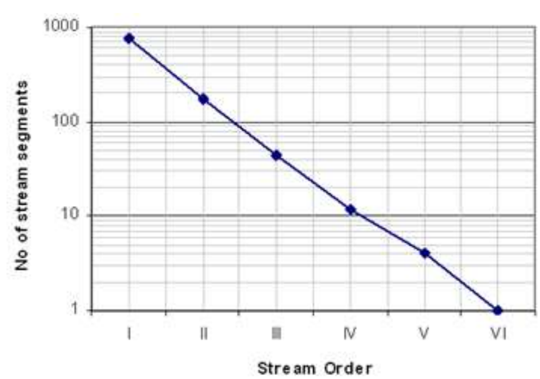

Figure 4: Regression of number of stream segments versus stream order

Bifurcation Ratio (R_b): The term bifurcation ratio (R_b) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order (Schumm, 1956). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment dominates. The mean bifurcation ratio value is 4.12 for the study area (Table 2) which indicates that the geological structures are less disturbing the drainage pattern.

Table 2: Linear aspects of the drainage network of the study area

River Basin	Stream Order	Number of streams N_u	Total length of streams in Km L_u	Log N_u	Log L_u
Imphal River	I	879	594.3	2.944	2.774
	II	196	159.2	2.292	2.202
	III	46	94.3	1.663	1.974
	IV	12	59.1	1.079	1.772
	V	2	49.7	0.301	1.696
	VI	1	6.3	0	0.780

Bifurcation Ratio R_b					Mean bifurcation ratio
1st order/ 2nd order	2nd order/ 3rd order	3rd order/ 4th order	4th order/ 5th order	5th order/ 6th order	
4.485	4.261	3.833	6.000	2.000	4.116

Stream Length (L_u): Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. The streams of relatively smaller lengths are characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The numbers of streams of various orders in the basin are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. Plot of the logarithm of stream length versus stream order (Figure 3) showed the linear pattern which indicates the homogenous rock material subjected to weathering-erosion characteristics of the basin. Deviation from its general behavior indicates that the terrain is characterized by variation in lithology and topography.

Areal Aspects of the Drainage Basin

Area of a basin (A) and perimeter (P) are the important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. The aerial aspects of the drainage basin such as drainage density (D), stream frequency (F_s), texture ratio (T), elongation ratio (R_e), circularity ratio (R_c) and form factor ratio (R_f) were calculated and results have been given in Table 3.

Drainage Density (D): Horton (1932) introduced that the drainage density (D) is an important indicator of the linear scale of landform elements in stream-eroded topography. Drainage densities can range from less than 5 Km/Km^2 when slopes are gentle, rainfall low, and bedrock permeable (e.g. sandstones), to much larger values of more than 500 Km/Km^2 in upland areas where rocks are impermeable, slopes are steep, and rainfall totals are high (Huggett, 2003). The drainage density (D) of the study area is 2.84 Km/Km^2. In the present study, the density falls less than 5 Km/Km^2, which indicates that the area has a gentle slope, low rainfall and permeable bedrock.

Table 3: Aerial aspects of the study area

Sl.No.	Morphometric Parameters	Result
1	Drainage density	2.84 Km/Km^2
2	Form factor	0.22
3	Stream frequency	3.35
4	Length of overland flow	0.18 Km
5	River length	58.49 Km
6	Drainage area	339 Km^2
7	Drainage perimeter	110.4 Km
8	Compactness factor	1.69
9	Circulatory ratio	0.35
10	Elongation ratio	0.53
11	Drainage texture	10.290
12	Constant of channel maintenance	0.35

Stream Frequency (F_s): Stream frequency or channel frequency (F_s) is the total number of stream segments of all orders per unit area (Horton, 1932). 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 value of the basin is 3.35.

Texture Ratio (T): Texture ratio (T) is an important factor in the drainage morphometric analysis which depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. In the present study the texture ratio of the basin is 10.290 which falls within the fine drainage texture.

Drainage texture can be classified into four categories viz:

i) Coarse drainage texture : < 4

ii) Intermediate drainage texture : 4 - 10

iii) Fine drainage texture : 10-15

iv) Ultra fine drainage texture : > 15

Elongation Ratio: Elongation ratio 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 elongation ratio varies from 1.275 when the basin shape is a circle, to 1.128 when it is a square, and decreases in proportion to increasing elongation, reaching a minimum of approximately 0.200. The results of the present study indicated a value of 0.53 which indicate increase in elongation of the basin.

Circularity Ratio: Miller (1953) defined a dimensionless circularity ratio (R_c) as the ratio of basin area to the area of circle having the same perimeter as the basin. Circulatory ratio of the present study area is 0.35. The ratio is equal to unity when the basin shape is a perfect circle, decreasing to 0.785 when the basin is a square, and continues to decrease to the extent to which the basin becomes elongated, Miller (1953).

Form Factor Ratio: The form factor will be comparatively higher, if the basin is wider. Consequently, much narrower basins have low form factor values. The low form factor is indicated in the elongated basin and high form factor is indicated in the wider basin (Gregory & Walling, 1985). The calculated value of form factor for the catchment is 0.22. Sparse to dense vegetation along with some current jhumming, gentle to moderately steep slope and low to high relief characterize the low value of form factor. Form factors greater than unity are considered as anomaly in the basin shape. The value indicates narrow and elongated basin.

Constant of channel maintenance: Constant of channel maintenance value for the present area is 0.35. The low value of channel maintenance is characterized by gentle slope, moderate to high relief and moderate to dense forest cover whereas the high value of channel maintenance is characterized by the gentle slope, high relief and dense forest cover.

Length of overland flow: Length of overland flow is referred to as the distance of flow of the precipitated water, over the land surface to reach the stream. The results obtained for Imphal River was 0.18 km. The

Research Article

overland flow is higher in the semi arid regions than in the humid and humid temperate regions, in addition absence of vegetation cover in the semi arid regions is primarily responsible for lower infiltration rates and for the generation of higher surface flow (Kale & Gupta, 2001).

Compactness factor: Compactness factor of the basin is used to express the basin shape. This coefficient is equal to unity when the basin shape is a perfect circle, increasing to 1.128 in the case of a square, and may exceed 3 for a very elongated basin (Luchisheva, 1950). The compactness factor for the catchment is 1.69.

Relief Aspects of the Study Area

Basin relief is an important factor in understanding the denudational characteristics (the denudational landforms are formed as a result of active processes of weathering, mass wasting and erosion caused by different exogenetic geomorphic agents such as water, glaciers, wind etc., the landforms formed by the agents of denudation are identified as pediments, pediplains etc.,) of the basin. Relief is the difference between the maximum and minimum elevations in the basin. The maximum height of the Imphal River basin is 2640 m and the lowest is 800 m. Therefore, the relief of the basin is 1840 m. The basin length, relative relief and relief ratio of the area are given in table 4.

Table 4: Relief aspects of the study area

Sl.No.	Morphometric Parameters	Result
1	Basin length	38.99Km
2	Relative relief	0.0167
3	Relief ratio	0.0472

Relief ratio: According to Schumm (1963), the relief ratio is the dimensionless height-length ratio equal to the tangent of the angle formed by two planes intersecting at the mouth of the basin, one representing the horizontal, the other passing through the highest point of the basin. The relief ratio is calculated by using the following formula: Relief ratio = H – h/L where H = highest elevation in the basin, h = lowest elevation in the basin and L = longest axis of the basin. The relief ratio of the Imphal River basin is 0.0472. Generally, the relief ratios of the basin are low which are characteristic features of less resistant rocks of the area (Sudheer 1986; Sreedevi 1999).

Basin length (L): Basin length (L) has been given different meanings by different workers (Schumm 1956; Gregory and Walling 1973; Gardiner 1975 and Cannon 1976). According to Gregory and Walling (1973), the Basin Length (L) is the longest length of the basin, from the catchment to the point of confluence. The length of the Imphal River basin is 38.99 Km.

Conclusions

The present study is the outcome of the visual interpretation of Topographic Map 83G/16 and 83H/13 with 20m contours interval (Scale-1:50,000). The analysis of the morphometrical features of the catchment using GIS indicates size, shape, slope of the catchment and distribution of stream network within the catchment. Bifurcation ratio, stream length and stream order of basin indicate that the basin is sixth order basin with geological structures less disturbing the drainage pattern and the terrain characterized by variation in lithology and topography. The study of stream network also suggests that with the increase in stream order, the number of streams and length of streams decreases. Drainage density, texture ratio, circulatory ratio and elongation ratio show that the area has a gentle slope, low rainfall, permeable bedrock, fine drainage texture and narrow and elongated basin. The low value of relief ratios of the basin characterizes less resistant rocks indicating erosional processes in the area.

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REFERENCES

Cannon JP (1976). Generation of explicit parameters for a quantitative geomorphic study of the Mill Creek Drainage Basin. *Oklahoma Geology Notes* **36**(1) 13–17.

Gardiner V (1975). *Drainage Basin Morphometry* (British Geom Group, Tech Bull) **14** 48.

Gregory KJ and Walling DE (1973). *Drainage Basin Form and Process: A Geomorphological Approach* (Arnold, London).

Gregory KJ and Walling DE (1985). *Drainage Basin Form and Process: A Geomorphological Approach* 47, 54.

Hack J (1957). Studies of longitudinal stream profiles in Virginia and Maryland: U.S. Geological Survey Professional Paper, 294-B.

Horton RE (1932). Drainage basin characteristics. *Transactions, American Geophysical Union* **13** 350361.

Horton RE (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America* **5** 275370.

Kale, Vishwas S and Gupta Avijit (2001). *Introduction to Geomorphology* 84, 85, 86.

Luchisheva AA (1950). Practical Hydrology. Gidrometeoizdat, Leningrad. (In Russian).

Miller VC (1953). A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Vorginia and Tennessee; Project NR 389042, Tech. Rept. 3., Columbia University, Department of Geology, ONR, Geography Branch, New York.

Nag SK and Chakraborty S (2003). Influence of Rock Types and Structures in the Development of Drainage Network in Hard Rock Area. *Journal of the Indian Society of Remote Sensing* **31**(1) 25-35.

Richard JH (2003). *Fundamentals of Geomorphology* (Routledge Fundamentals Physical Geography).

Schumm SA (1956). Evaluation of drainage systems and slopes in badlands at Perth Amboy, New Jersy. *Bulletin of the Geological Society of America* **67** 597646.

Schumm SA (1963). Sinuosity of alluvial rivers on the great plains. *Bulletin of the Geological Society of America* **74** 1089–1100

Sreedevi PD (1999). Assessment and management of groundwater resources of Pageru River basin, Cuddapah district, Andhra Pradesh, India. Unpublished Ph.D. Thesis, Sri Venkateswara University, Tirupati.

Strahler AN (1952). Dynamic basis of geomorphology. *Geological Society of America Bulletin* **63** 923-938.

Strahler AN (1957). Quantitative analysis of watershed geomorphology. *Transactions, American Geophysical Union* **38** 913920.

Strahler AN (1964). Quantitative geomorphology of drainage basins and channel networks. In: *Handbook of Applied Hydrology*, edited by Chow VT (McGraw Hill Book Company, New York) 4II,

Sudheer AS (1986). Hydrogeology of the Upper Araniar River basin, Chittor district, Andhra Predesh, India. Unpublished Ph.D. Thesis, Sri Venkateswara University, Tirupati.

Zavoianu I (1985). Morphometry of drainage basins. Institute of Geography, Bucharest.