MORPHOMETRIC ANALYSIS OF JIYA DHOL BASIN IN GIS FRAMEWORK.

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Abstract- The study of river basin is very important in fluvial geography. Analysis of basin morphometric is an integral part in the study of river basin. Basin morphometry is a means of numerically analyzing or mathematically quantifying different aspects of a drainage basin. Basin morphometry is an important means of understanding a drainage basin using mathematically derived parameters. In the present study, morphometric analysis of the drainage basin has been carried using earth observation data and geographical information system (GIS) techniques. Basin morphometry has been generally analyzed under three broad aspects and they are the linear, areal and relief aspects. These aspects of morphometric analysis have been studied extensively by generating DEM of the basin and formulating them in Arc GIS and compute various physical properties of the basin. In the present study, the Jiya Dhol river basin which is one of the north bank tributaries of river Brahmputra in Assam has been selected for morphometric analysis.

Key Words-Morphometric Analysis, Arc GIS,DEM, Linear, Areal and Relief aspects.

1. INTRODUCTION

1.1 GENERAL

India, with a vast area of 329 million hectare, has diverse geographic and climatic conditions which result in uneven distribution of rainfall over the country. Most of the rainfall takes place during monsoon season and the rest of the year remains dry. The large variation of rainfall, which is the main source of water in the rivers, results in large variation of flow in rivers. Due to large variation of flows, the alluvial rivers of the country such as Ganga and Brahmaputra, have large variation in their behavior during the lean season and flood season. While during the lean season, the shoals in the low water channels cause problems in navigation, during flood season, deep channels swing laterally and erode the banks posing threat of serious damage to valuable property, lines of communication, towns and villages. The northern plain has been formed by the interplay of three major rivers systems, namely- the Indus, the Ganga and the Brahmaputra along with their tributaries. The Brahmaputra marks the eastern most boundary of the Himalayas. Beyond the Dihang gorge, the Himalayas bend sharply to the south and spread along the eastern boundary of India. They are known as the Purvachal or the eastern hills and mountains. These hills running through the north-eastern states are mostly composed of strong sandstones which are sedimentary rocks. Covered with dense forests, they mostly run as parallel ranges and valleys. The Purvachal comprises the Patkai hills, the Naga hills, Manipur hills and Mizo hills.

1.2 QUANTITATIVE ANALYSIS OF MORPHOMETRIC PARAMETERS

The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Geology, relief, and climate are the key determinants of running water ecosystems functioning at the basin scale (Frissel et al., 1986). Morphometric descriptors represent relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa 2006) and enable an enhanced understanding of the geological and geomorphic history of a drainage basin (Strahler 1964). A watershed is an ideal unit for management of natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper 2008). The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams, etc. (Chorley 1969, Gregory and Walling 1973). Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics. It has of great significance in understanding the hydrologic scenario of an area, because a strong mutual relationship exists between morphological variables and hydrological characteristics.

1.3 OBJECTIVES OF THE STUDY

The objective of the present study has been sum up as follows

1. To find the basin morphometric parameters in Jiya Dhol River Basin of Brahmaputra Valley using Geographical Information System.

2. To generate various thematic maps.

2. STUDY AREA.

The Jiya Dhol River is one of the north bank sub- tributaries of the Brahmaputra River. This river originates from the lower Himalayan belt and cut crosses twice the easterly oriented Siwalik ranges and has been carrying very high sediment load which are deposited on the Brahmaputra plains after debouching from the hills. After passing through a narrow gorge in Arunachal Pradesh, the river enters the plains of Assam in Dhemaji district where it flows in braided channels. The river is known as 'Kumotiya' from the Railway line to the Gogamukh – Ghilamara P.W.D. road wherefrom it is known as the river 'Sampara'. The river finally debouches into the river Brahmaputra near Selamukh. The Jiya Dhal river formed a fan deposit and exhibit extensive shifting of its channels. Basin of the Jiya Dhol basin extends from 27°25′45´´ N to 27°44′15" N latitudes and 94°15′ E to 94°37′30´´ E longitudes, covering an area of 437 sq km, of which 18% (79 sq km) lies in Arunachal Pradesh and 82% (357 sq km) in Assam. 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. The River used to meet the Brahmaputra at a place near Selamukh (27.08°N, 94.31°E) before abandoning of the Kherkutiya Sutiby

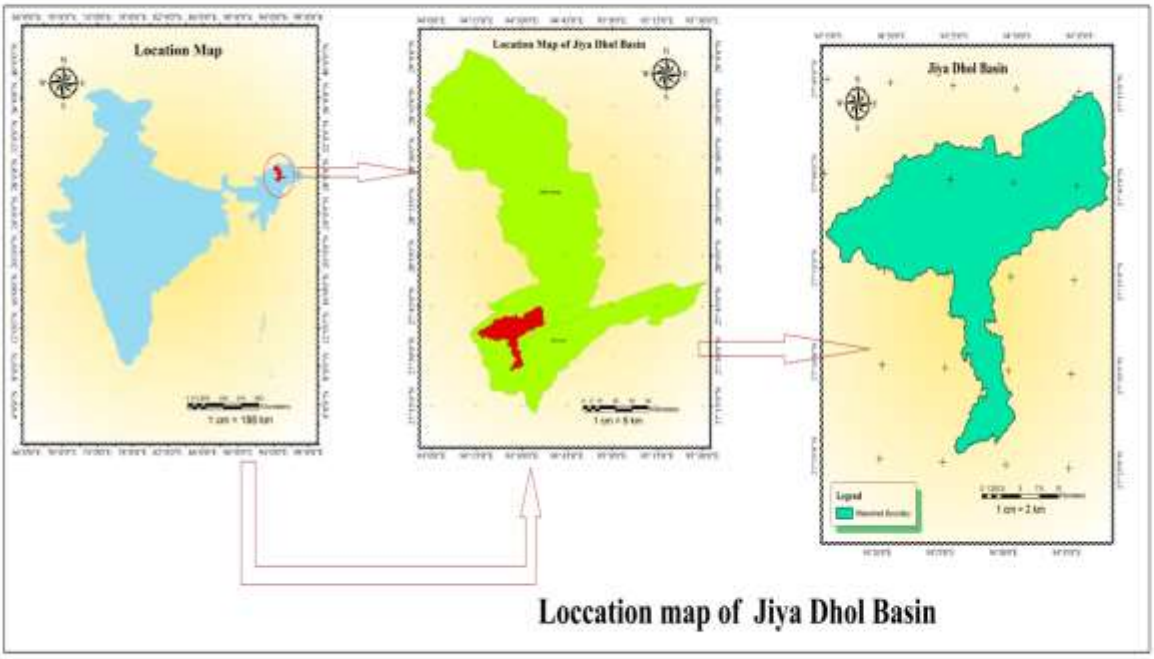

Fig 1: location map of Jiya Dhol River Basin

Brahmaputra. Three rivers namely Siri, Sido and Sika meet at a place called Trimukh (27 °37´56´´N, 94°25´15´´E) in Arunachal Pradesh and the downstream part from this location is called Jiya dhal. The river enters Assam at a place called Jia dhal Mukh (27.58°N, 94.45°E). Hence, the three tributaries contribute most of the runoff and sediment to the Jiya Dhol river. The name Jiya dhal derived from the words "Jiya" and "Dhal" meaning "alive" and "flash flood" respectively, as the river has great tendency of generating flash-flood during monsoonal rain. After crossing a gorge near Jiyadholmukh, it debouches on to the Brahmaputra plains, where the course of the river becomes very broad. In the plains, the river is divided in to several branches which rejoin again downstream. The most important branches of the Jiya Dhol, which are well known for causing floods, are Kumatia and Samorajan. At present, a considerable amount of the runoff of Jiya Dhol is carried by the Samorajan river, while the Kumatia receives water from the Jiya Dhol during the monsoon only. Along the southern slope of the foothill many small streams combine together and flow further south in the name of No Noi or Dihingia River. It empties into Smarajan and it is the most important tributary of Jiya Dhol in the plains of Assam. The Kumatia branch of the river meets other small tributaries. On the other hand, Samarajan on entering Ghilamara is called as Sampara. After flowing further down Sampara rejoins the Kumatia branch and retain the name Sampara. Ultimately, it meets Charikoria after crossing many swamps and wetlands.

3. MATERIALS AND METHODOLOGY.

The main objective of morphometric analysis is to find out the drainage characteristic to explain the overall evaluation of the basin and prepare different thematic maps. Morphometric analysis comprises of a series of sequential steps. Toposheets for Jiya Dhol basin is not available as the area falls under restricted zone of Assam and Arunachal Pradesh. The present study is mainly concerned to evaluate morphometric characteristics of the river basin at sub watershed level in order to assess the prioritization of Jiya Dhol basin on the basis of erodibility with geospatial techniques. To do the same DEM data (30 m resolution) ASTER is used in GIS environment.

Drainage network is delineated by using the Arcmap 10.1 using the DEM of ASTER. The various morphometric parameters are evaluated for the Jiya Dhol basin. The morphometric parameters were divided in three categories: basic parameter, derived parameters and shaper parameters. Area, Perimeters, Basin Length, Stream Order, Stream Length, Maximum and Minimum Heights and slope come under first categories. Those of the second categories are Bifurcation Ratio, Stream Length Ratio, Stream Frequency, Drainage Density, Drainage Texture, Basin Relief and Relief Ratio are calculated with the help of standard formulae. The Shape parameters are Elongation Ratio, Circularity Index and Form Factor. The drainage network of the basin was analyzed as per Horton laws and the stream ordering was made after Strahler.

4. MORPHOMETRIC PARAMETERS.

4.1 Area (A)

The rate of runoff of any drainage basin depends on its area and physiography. The drainage basin area is a dimensional parameter and it is denoted by A. The drainage basin is instrumental in governing the rate at which water is supplied to the main stream as it proceeds to the outlet. Area of basin of a particular order is defined as the total area projected upon a horizontal plane, contributing overland flow to the channel segment of a given order including all the tributaries of the lower order.

4.2 Perimeter (P)

Length boundary of a basin is known as the perimeter of the basin and it is denoted by P. The factors that are dependent on the basin parameter are elongation ratio and circulatory ratio. Earlier, the perimeter was measured with chartometer (i.e., a map measurer). Perimeters of different sub-watersheds were derived from GIS software that automatically gives the perimeter of each polygon.

4.3 Stream Order (U)

The designation of stream orders is the first step in drainage basin analysis. It is based on hierarchic ranking of streams proposed by (Strahler, 1964). The first order streams have no tributaries. The second order streams have only first order streams as tributaries. Similarly, third order streams have first and second order streams as tributaries and so on.

4.4 Stream Number (N_u)

Number of streams is described as total counts of stream segments of different order separately and is inversely proportional to the stream order. Stream number is denoted by N_u.

4.5 Total stream length (L_u)

Stream length is one of the most significant variables of a drainage basin characterizing runoff and basin features. It is an indicative of chronological developments of stream segments. Smaller length of stream segments are prominent in hilly areas with larger slopes where as longer streams are generally indicative of flat areas with lesser slope.

4.6 Mean stream length (L_{um})

Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its contributing watershed surfaces (Strahler, 1964). It is obtained by dividing the total length of stream of an order by total number of segments in the order.

4.7 Stream Length Ratio (R)

Horton (1945, p.291) states that the length ratio is the ratio of the mean (Lu) of segments of order (So) to mean length of segments of the next lower order (Lu-1), which tends to be constant throughout the successive orders of a basin.

$$R = L_u / L_{u-1}$$

4.8 Bifurcation ratio (R_b)

Bifurcation ratio related to the branching pattern of the drainage network. The bifurcation ratio is the ratio of the number of streams in lower order (N_u) to the next higher order (N_{u+1}).
Bifurcation ratio is supposed to be controlled by drainage density, stream entrance angles, lithological characteristics, basin shape, basin area etc. (Singh 1998).

$$R_b = N_u / N_{u+1}$$

4.9 Basin Length (L_b)

It is the distance between the remotest point of the basin to the outlet. As the basin length increases, the peak discharge decreases. It is given by the formula (Nookaratnam et al 2005).

$$L_b = 1.312A^{0.568}$$

4.10 Length of Overland Flow (L_o)

Horton (1945) used the term to refer to the length of the run of the rainwater on the ground surface before it is localized into definite channels. Since, this length of overland flow, at an average, is about half the distance between the stream channels, Horton, for the sake of convenience, had taken it to be roughly equal to half the reciprocal of the drainage density.

$$L_0 = 1/2D_d$$

4.11 Form Factor (R_f)

According to Horton (1932), form factor may be defined as the ratio of basin area to square of the basin length. Smaller the value of form factor, more elongated will be the watershed.

$$R_f = A / L_b^2$$

4.12 Elongation Ratio (R_e)

According to Schumm (1965, p. 612), elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Strahler states that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types.

$$R_e = \frac{2}{L_b}\sqrt{\frac{A}{\pi}}$$

4.13 Circulatory ratio (R_c)

The circulatory ratio is influenced by the length and frequency of stream. The circulatory ratio is similar measure as elongation ratio, originally define by (Miller, 1953), as the ratio of the area of the basin to the area of the circle having equivalent circumference as the basin perimeter and is denoted by the (R_c) and is given by **$R_c = (1.128 \times A^{0.5})$**

4.14 Drainage density (D_d)

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. It is equal to the reciprocal of the constant of channel maintenance and equal to the reciprocal of two times the length of overland flow. The unit of drainage density is km/km^2 and denoted by Dd

$$D_d = \frac{N_u}{A}$$

4.16 Drainage frequency (D_f)

Drainage frequency may be expressed by relating the number of stream segments to the area drained. In other words, Stream frequency is the total number of stream segments in a watershed divided by the area of the watershed. Horton, 1932) introduced stream frequency or channel frequency as number of stream segments per unit area and is given by $D_f = \frac{N_u}{A}$

4.17 Drainage Texture (T)

Drainage texture means that the relative spacing of drainage lines. Drainage texture is on the underlying lithology, infiltration capacity and relief aspect of the terrain. Drainage texture is denoted by T and it is the total number of stream segments of all orders per perimeter of that area (Horton, 1945).

$$T = \frac{N_u}{P}$$

4.18 Compactness coefficient (C_c)

Compactness coefficient of a watershed is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed. $C_c = 0.2821 \frac{P^{0.5}}{A}$

4.19 Constant of Channel maintenance (C_m)

Schumm (1956) used the inverse of drainage density or the constant of channel maintenance as a property of landforms. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957). It is given by

$$C_m = 1/D_d$$

4.20 Relief Ratio (R_h)

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm, 1956) $R_b = H/L_b$

4.21 Relative Relief (R_f)

The maximum basin relief was obtained from the highest point on the watershed perimeter to the mouth of the stream. Using the basin relief, a relief ratio was computed as suggested by Schumm by dividing it with computed length of basin.
$R_f = (H) / P$

4.22 Ruggedness number (R_n)

Strahler (1958) defined ruggedness number as a dimensionless number, as a product of total relief (H) and drainage density (D_d) in the same unit. $R_n = D_d \times H$

5. RESULTS AND DISCUSSION

A thematic map is a type of map specifically designed to show a particular theme connected with a specific geographic area. A thematic map is a map that focuses on a specific theme or subject area. Thematic maps emphasize spatial variation of one or a small number of geographic distributions. The result of various thematic maps such as DEM, drainage basin map, slope map, flow direction, flow accumulation is prepared using GIS software. The thematic maps for main watershed are given below.

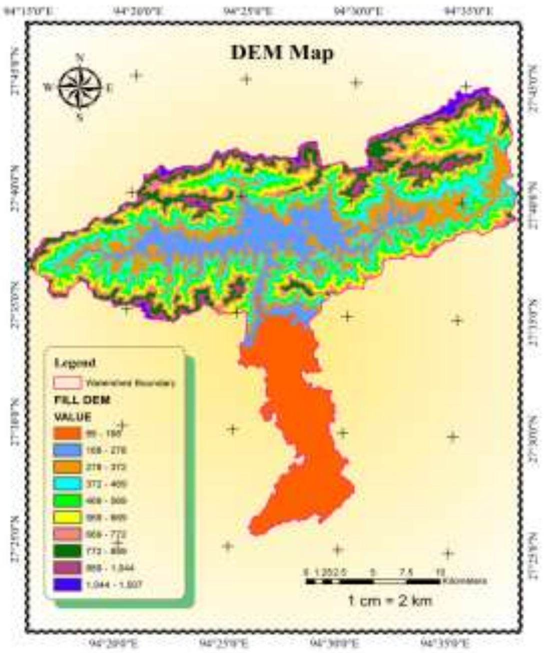

Fig:2 DEM map

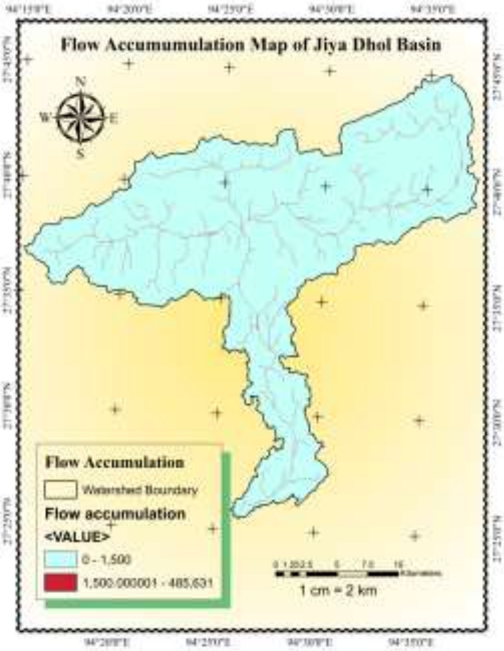

Fig 3 : Flow Accumulation Map.

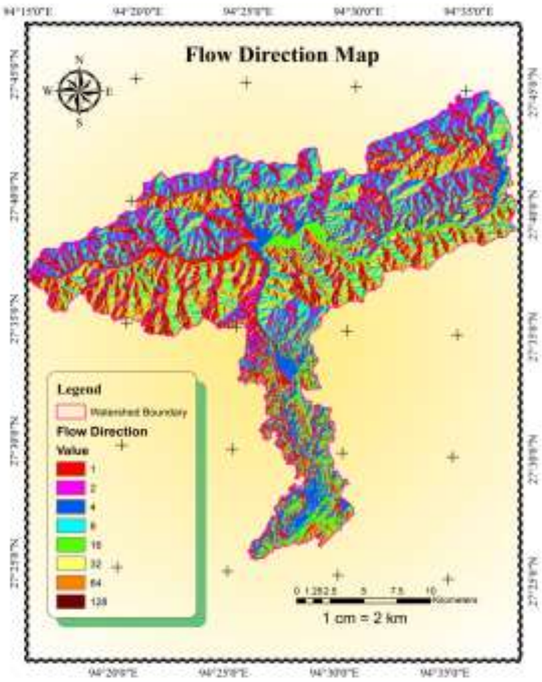

Fig 4: Flow direction Map.

Fig 5: Drainage Map of Jiya Dhol Basin.

Fig 6: Slope Map

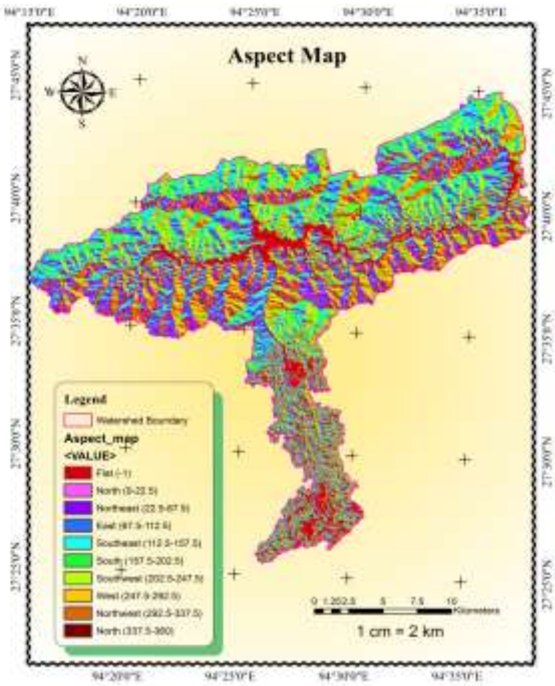

Fig.7: Aspect Map.

Table 1: Slopes of the basin

Slope Classes	Slope Range	Description
A.	0% - 5%	Nearly level
B.	6% - 12%	Very Gentle Slope
C.	13% - 18%	Gentle slope
D.	19% - 24%	Moderate Sloping
E.	25% - 29%	Storongly Sloping
F	30% - 35%	Moderately Steep
G	36% - 41%	Steep
H	42% - 49%	Very Step
I	>50%	Highly Steep

5.1 Estimation of morphometric paramters.

The morphometric analysis of the parameters, namely area of the basin and perimeter of the basin are obtained from the sofware ArcGIS 10.1 and other parameters such as srtream order, stream length, drainage density, relief ratio, bifurcation ratio, elongation ratio, drainage frequency, basin length, drainage texture, ruggedness number, constant of channel maintenance, form factor, stream length ratio, circulatory ratio etc are calculated using various mathematical formulae from the topographic maps derived from ASTER DEM in GIS software.

Table 2: Drainage analysis of the Basin

Stream order	No. of Streams (Nu)	Length of Streams (km) (Lu)
1	99	177.915839
2	21	61.966062
3	2	46.700792
4	1	30.08839
	Total = 123	**Total =316.671083**

Table 3: Evaluation of morphometric parameters and their significance

Sl No	Morphometric parameters	Unit	Results	Significance
1	Area , A	Sq Km	437.00	Larger the area, smaller is the runoff and vice versa.
2	Basin Perimeter, P	Km	174.20	Elongation ratio and circulatory ratio depends upon basin perimeter.
3	Basin Length, Lb	Km	41.47	As the basin length increases, the peak discharge decreases.
4	Total no of Streams, Nu	Nos	123	Higher value means high drainage frequency.
5	Total stream length, Lu	Km	316.67	Small value signifies hilly area, large value signifies flat area.
6	Drainage Density, Dd	Km/ SqKm	0.72	Small value depicts relatively flat area and permeable underlying strata.
7	Constant of Channel maintenance, Cm		1.38	Low value indicates rocky impermeable underlying strata.
8	Total Relief, H	Km	1.42	Increases with increase in elevation difference between source and outlet of the stream
9	Length of Overland Flow, Lo	Km	0.69	Independent variable which greatly affect the quantity of water required to exceed a certain threshold of erosion. This factor relates inversely to the average slope of the channel.
10	Drainage Frequency, Df		0.28	It mainly depends on topographical features and drainage network of the area. Lower values of stream frequency indicate lower volume of surface runoff. Higher stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief condition and low infiltration capacity.
11	Drainage Texture, T	Unit/ Km	0.71	Very course drainage texture (value<2)
12	Form Factor, Rf		0.25	Smaller value signifies elongated watershed and longer time of concentration, low peak flows of longer duration
13	Bifurcation Ratio, Rb		5.74	Bifurcation ratio is lower in alluvial region as compared to the hilly areas. Relatively high value signifies hilly terrain and the river is prone to flooding during rainy season.
14	Stream Length Ratio, R		0.5821	

15	Elongation Ratio, Re		0.321	Smaller value means elongated watershed. indicates more elongation and more prone to erosion and sediment load with less infiltration capacity
16	Circulatory Ratio, Rc		0.181	Smaller value means elongated watershed. Lower value of circulatory ratio indicates less circular shape of a basin, slower discharge and possibility of erosion is less.
17	Relief Ratio, Rh		0.034	It is an indicator of intensity of erosion processes and sediment delivery rate of the basin. While lower values indicate the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope.
18	Relative Relief, Rr		0.01	Increase with increase in total relief
19	Ruggedness Number, Rn		1.03	Smaller value indicates relatively flat area of the basin and low drainage density & less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density. (Paretha and Paretha 2011).

6. CONCLUSION

From the present morphometric analysis of Jiya Dhol basin following points can be high lighted.

1. The values of form factor, circulatory ratio and elongation ratio of the study area show that the basin is very elongated and thus has a low peak flow of longer duration. Consequently, the flood flow of this type of basin is very difficult to manage than a circular basin.
2. Drainage density (D_d) of the study area is 0.72 km/km^2.Thus, in this study , the drainage denssity falls less than 5 km/km^2 which indicated that the area has a gentle slope and permeable bedrock.
3. The relief ratio and relative relative relief of the basin is low, which is a characteristic feature of e presence of less resistant rocks. Low relief ratios also indicate that the recharge capabilities of the basin are low and chances of ground water potential is poor.
4. The bifurcation ratio of the basin is relatively high. The high value of Rb for sub-watershed indicates high runoff, low recharge and mature topography. This high value indicates that the study area is relatively prone to flooding. The high R_b value indicates relatively more structural disturbance in the basin.
5. The value of drainage texture is 0.71 for the basin which is an indication the basin has a very coarse texture.
6. The present study is valuable for erosion control, watershed management, land and water resouces planning and future prospective related to runoff study.

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