Morphometric Analysis of Lower Bhavani River Basin, Using Geographical Information System

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Abstract

The morphometric parameters of the basin can deal with areal, linear and relief features and is noteworthy in tending to the hydrological characteristics. Present study deals with several morphometric parameters, like stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), and form factor ratio (Rf) etc and its relation to hydrological characteristics in Lower Bhavani River basin. The GIS based approach expresses the Lower Bhavani River basin is sixth order drainage basin. The computed Lower Bhavani River basin area is 2243 sq.km with the 323.9 km as perimeter. The absolute relief of the study area is 1600m, ruggedness number is 60.93, basin relief is 53.45km, bifurcation ratio number is 4.23 and the relief ration is 0.77. Altogether 1595 streams were recognized of which 1240 are the first order, 273 are the second order, 62 are the third order, 16 are the fourth order, 3 are the fifth order and 1 has a place with the 6th order. Drainage pattern is dendritic to subdendritic type. The drainage pattern demonstrates the terrain is of homogeneity in nature and bifurcation ratio exhibit absence of structural and tectonic control. The length of stream segment is maximum in case of first order stream and reduces as the stream order increases with the exception of the 6th order; as it joins the Bhavani river so the length is more than the fifth order and expresses flatter terrain in 1st order and slopy nature in higher order region. Drainage density (Dd) of the study area is 1.14km/km2 indicates higher infiltration and denser vegetation.

Key Words: Morphometry, Drainage basin, DEM, RS and GIS.

1. Introduction

The Morphometric investigation is the quantitative assessment of qualities of landform unit present on the earth surface. The morphometric analysis of watershed gives quantitative description of the drainage basin, which is of great importance on the hydrological analysis.

Hence, study on morphometric characteristics of a river basin is essential to understand the hydrological behaviour in general and soil erosion and runoff in particular. The major parameter; stream length, number of streams and basin length is derived from drainage layer. The estimations of morphometric parameters like stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio and compactness constant are dependent on the formulae proposed by Horton (1945), Miller (1953), Schumn (1956), Strahler (1964), Nookaratm (2005). Morphometric analysis of drainage system is a prerequisite to any hydrological study. GIS and Remote sensing techniques play an important role in drainage delineation and their updation. Also this technique is useful in assessing the terrain variation and morphometric parameters of a drainage basin. Morphometric analysis of the Lower Bhavani River basin, based on several drainage parameters derived from remote sensing data and determined with GIS tools includes measurement of linear, aerial and relief aspects.

2. Study Area

The Bhavani river originates from Nilgiri hills of Western Ghats and is long (217km) Perennial River fed mostly by the southwest monsoon and also supplemented by the northeast monsoon. Bhavani River is one of the important longest tributary of Cauvery River. Lower Bhavani River Basin extends between 11.24^0 N and 11.72^0 N Latitudes and 77.00^0 E and 77.68^0 E Longitudes with the total geographical area of 2243 sq km (fig 1). The average annual rainfall of the basin is 618 mm, highest temperatures are recorded during the months of April and May with maximum 40°C. Altitude of the study area ranges from 158m as lowest 1668m as highest. It drains an area of 0.62 million hectares spread over Tamil Nadu (87%), Kerala (9%), and Karnataka (4%).

3. Methodology

In this study watershed boundary as well as drainage were extracted from Survey of India toposheets of 58E/2, 58E/3, 58E/6, 58E/7, 58E/10 AND 58E.11 and from SRTM Digital elevation model (DEM) data. Arc GIS 10.1 has been used in preparation of streams and topographic maps. The parameters like stream length, perimeter and area of the river basin were determined with the help of Arc GIS 10.1. The methodology adopted for the present study as shown in the form of flow chart (fig 2). The formulae adopted for determining the linear, areal and relief based morphometric parameters of the Lower Bhavani river basin are given in table 1.

4. Result and Discussion

The key parameters to execute the morphometric analysis of watershed include the area, perimeter, basin length, and total relief of watershed. These parameters are indicative for the analysis of linear, relief and areal aspects of the basin. The morphometric analysis describes the basin processes and to compare basin characteristics and also supplements to understand the history of the drainage basin.

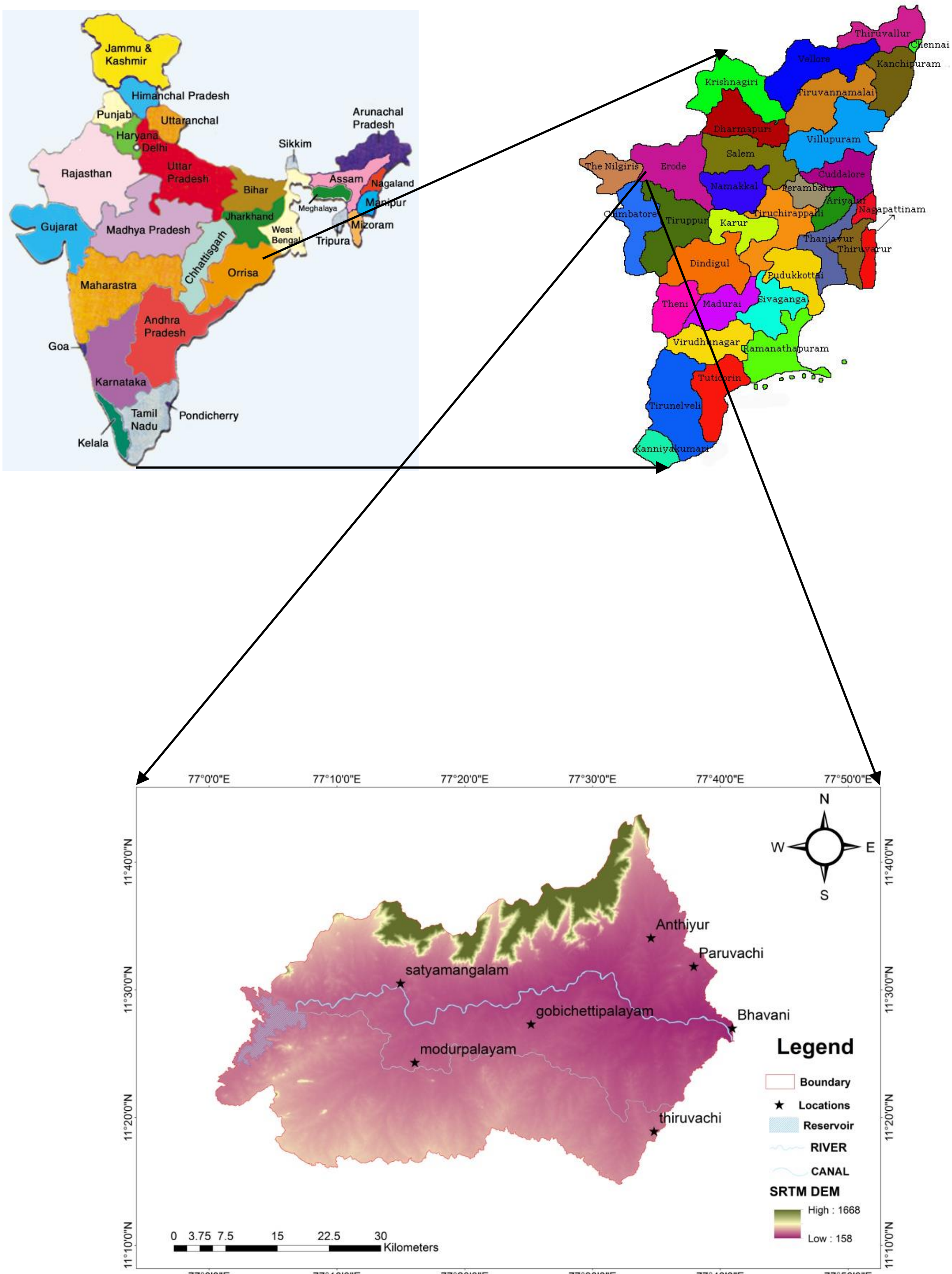

Figure 1 Location map of Lower Bhavani River Basin

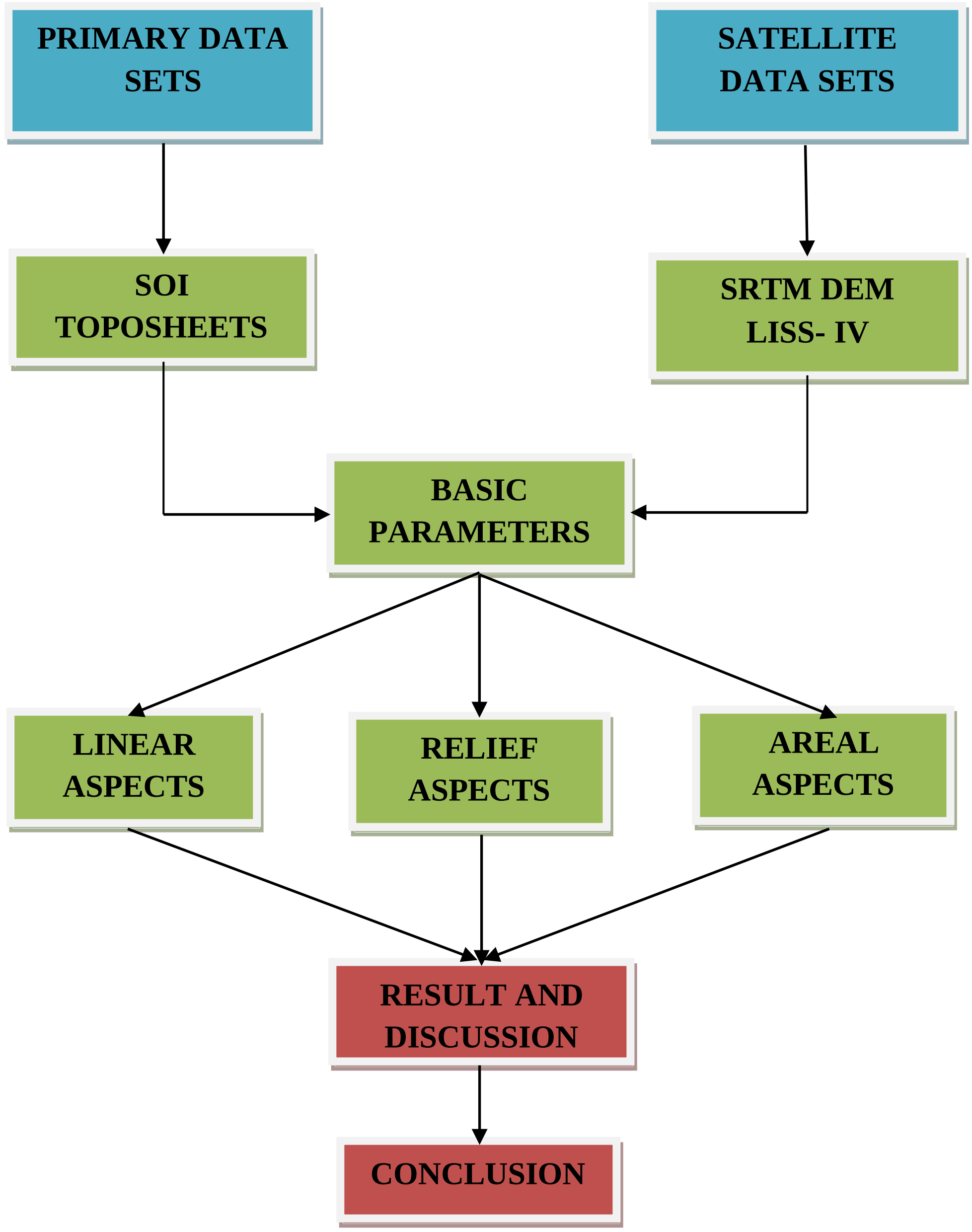

Figure 2 Flowchart showing the methodology used in the present study

Table 1 Method of Calculating Morphometric Parameters of Drainage basin

	MORPHOMETRIC PARAMETERS	FORMULA	REFERENCES
LINEAR ASPECTS	Stream order (U)	Hierarchical order	Strahler,1964
	Stream Length (LU)	Length of the stream	Hortan, 1945
	Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment	Hortan, 1945

	Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order	Schumn,1956
	Mean bifurcation ratio (Rbm)	Rbm = average of bifurcation ratios of all order	Strahler (1957)
RELIEF ASPECTS	Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumn,1956
	Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length	Schumn,1956
	Absolute relief (Ar)	Ar = Maximum elevation point	
	Dissection index (DI)	DI = Rr / Ar (max)	
	Ruggedness Number (Rn)	Rn=Bh×Dd Where,Bh= Basin relief, Dd=Drainage density	Schumn,1956
AREAL ASPECTS	Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin.	Hortan, 1945
	Stream frequency (Fs)	Fs=N/A Where, L=Total number of stream, A=Area of basin	Hortan, 1945
	Drainage texture (Dt)	T=N1/P Where, N1=Total number of all order stream, P=Perimeter of basin.	Hortan, 1945
	Elongation ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumn 1956
	Circulatory ratio (Rc)	Rc=4πA/P2Where A= Area of basin,π=3.14, P= Perimeter of basin.	Miller,1953
	Form factor (Rf)	Rf=A/(Lb)2 Where, A=Area of basin, Lb=Basin length	Hortan, 1945

4.1 Linear Aspects:

The linear aspects include stream order, stream length, mean stream length and bifurcation ratio. The linear parameters of the Lower Bhavani River basin are given in table 2.

A) **Stream Order (U)**

Stream order is one of the essential techniques used to portray the parts of a watershed. The drainage network transport water and the sediment of a basin through a solitary outlet, which is marked as the maximum order of the basin and conventionally the highest order stream available in the basin considered as the order of the basin. Stream ordering characterizes streams in connection to tributaries, drainage area, total length and period of water. The total number of stream segments present in each order is known as stream number (Nu). Strahler's system has been followed to designate the stream segments, because of its simplicity, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. The trunk stream is the stream segment of highest order, lower Bhavani River is of 6th order. In the Bhavani basin 1595 streams were identified of which 1240 are first order, 273 are second order, 62 are third order, 16 are fourth order, 3 are fifth order, and 1 is sixth order. The total number of stream segments is decrease as the stream order increases in the basins and exhibits dendritic to subdendritic drainage pattern (fig 3).

B) Stream Length (Lu)

Stream length (Lu) is a standout amongst the most significant hydrological features of the basin as it uncovers surface runoff characteristics. For the most part, the total length of stream segments is greatest in first-order stream and declines as stream order increases. In the Lower Bhavani River basin the total length of the first-order stream is 1310.779km, second order stream is 683.3112km, third order is 324.75km, the fourth order is 162.04km, the fifth order is 26.75km and 6th order is 65.65km. As 6th order stream joins the Bhavani River so the length is higher than fifth order. In the lower Bhavani basin it is observed that the order increases length decreases as similar to that of number of stream segments. The longer length of 1st order streams shows flatter terrain and minimum length of higher order signifies longer slopes. The maximum length of 1st order and minimum length of 5th order river, indicates the terrain consist of high relief, moderately steep slope with homogeneous weathering and erosion.

C) Mean Stream Length (Lsm)

The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of stream. It is directly corresponding to the size and geography of the basin. The mean stream length of the first order is 1.05km, second order stream is 2.50km, third order stream is 5.23km, fourth order stream is 10.13km, and fifth order stream is 8.92km and 6th order stream is 65.65km. It is also observed that the increase of the order the mean stream length is also increases.

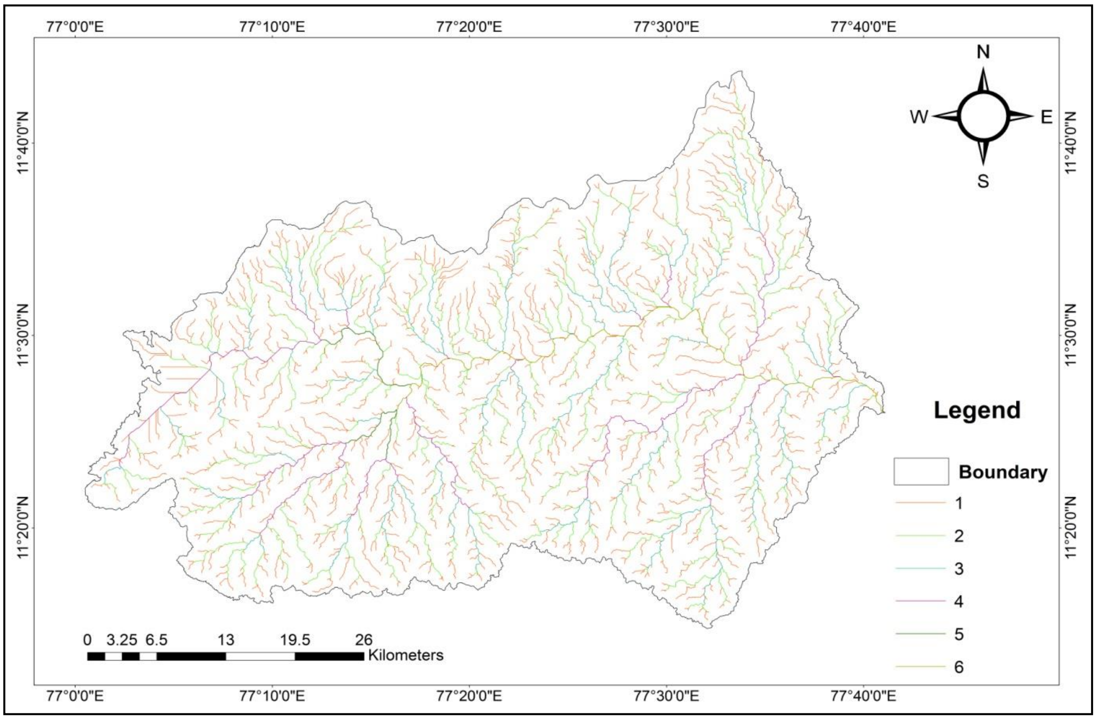

Figure 3: Stream order in raster and vector map of the study area

D) Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumn, 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. In the lower Bhavani river basin, Rb fluctuates from 3 to 5.3. Strahler essentially denoted that geographical structures don't influence drainage pattern for bifurcation ratio is in the middle of 3.0 to 5.0. The range of Rb in Lower Bhavani River basin indicates lesser influence of structural control and significant influence of lithology.

E) Mean Bifurcation Ratio (Rbm)

The mean bifurcation ratio (Rbm) is defined as the average of bifurcation ratios of all order and it is 4.23 in the Lower Bhavani River basin.

Table 2 Linear parameters of Lower Bhavani River Basin

STREAM ORDER	STREAM NUMBER	STREAM LENGTH	MEAN STREAM LENGTH	BIFURCATION RATIO
1	1240	1310.779	1.06	
2	273	683.3112	2.5	4.54
3	62	324.7553	5.23	4.4
4	16	162.0421	10.13	3.87
5	3	26.75493	8.92	5.33
6	1	65.65	65.65	3

4.2 Relief Aspects

The relief aspects include basin relief, relief ratio, relative relief and ruggedness number.

A) Basin Relief (Bh)

Basin relief is defined as the vertical distance between the lowest and highest points of basin. Basin relief of the lower Bhavani river basin is 53.45km.

B) Relief Ratio (Rh)

Relief ratio (Rh) is characterized as the proportion of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). Relief ratio estimates the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1956). The relief ratio of the study area is ascertained as 0.77.

C) Absolute Relief (Ar)

Absolute relief is defined as the maximum elevation point in a river basin. The absolute relief of lower Bhavani river basin is 1600m.

D) Dissection Index (Di)

Dissection index is defined as the ratio of relative relief to maximum absolute relief, and the Dissection index of the lower Bhavani river basin is 1.06.

E) Ruggedness Number

Ruggedness number is defined as the product of maximum relief and drainage density where both parameters are in same unit. It is a dimensionless number. The value of ruggedness number of present study area is 60.93.

4.3 Areal Aspects

A) Basin Length (Lb)

Schumm (1956) characterized the basin length as the longest measurement of the basin parallel to the principal drainage line. According to Schumm (1956) Basin length of the study area is 69.50km.

B) Basin Area

The region of the watershed is another essential parameter as like that of basin length. Schumm (1956) set up an intriguing connection between the total watershed areas and the total stream lengths, which are supported by the contributing regions. The lower Bhavani river basin area computed by Arc GIS expresses that the basin area is 2243 sqkm.

C) Basin Perimeter

Basin perimeter is the external limit of the watershed that enclosed its area. It might be utilized as an indicator of watershed size and shape, and the perimeter of the lower Bhavani river basin is 323.9km.

D) Drainage Density (Dd)

Drainage density is one of the sensitive parameter which provides the link between the forms attributes of the basin and the processes operating along stream course (Gregory and Welling, 1973). Drainage density is defined as the ratio of total stream length in a given basin area to the total area of the basin which is expressed in km/km^2 (fig 4). Drainage density measurement is useful in measuring landscape direction and runoff potential. Drainage density is correlative with basin relief, geology and density of vegetation. High drainage density shows impermeable subsurface material with sparse vegetation and high relief. Low drainage density exhibits high infiltration and few channels are carry the runoff and is prone to erosion with dense vegetation. High drainage density identifies with fine drainage texture whereas low drainage density leads to coarse drainage texture. The drainage density of study area is 1.14km/km^2 indicating low drainage densities, and indicates highly permeable subsoil and dense vegetation cover.

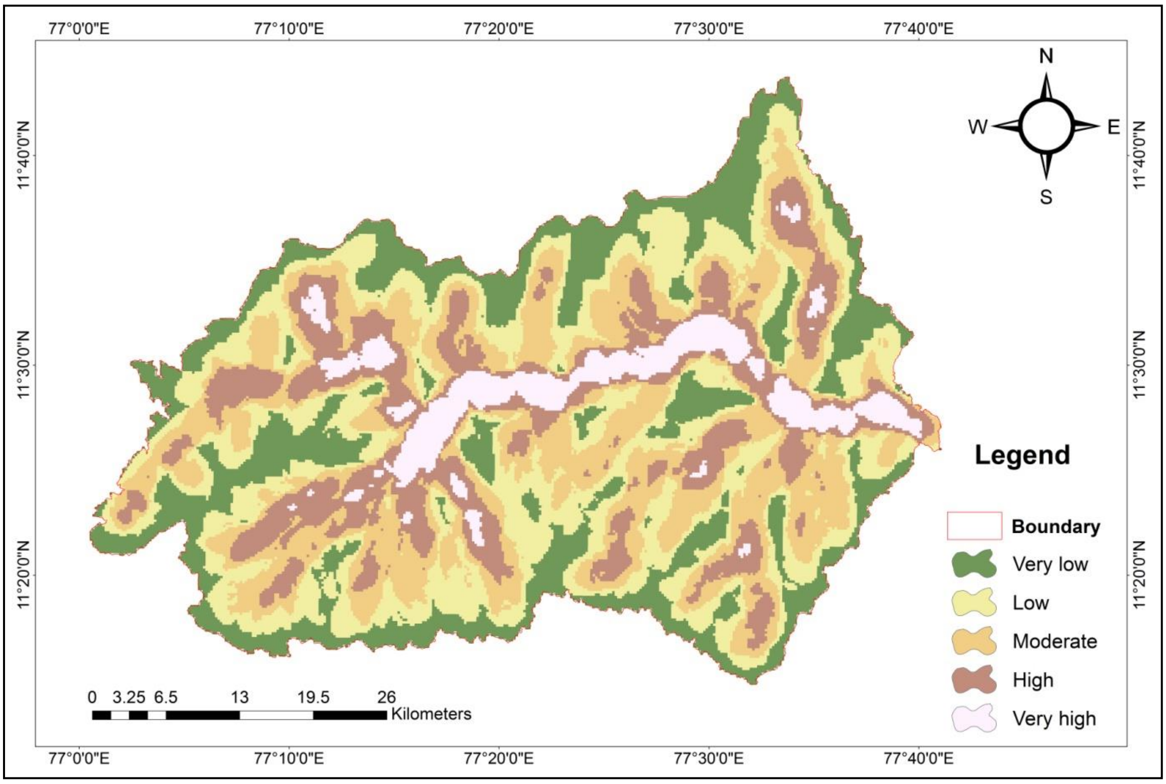

Figure 4: Drainage density map of the study area

E) Stream Frequency (Sf)

Stream frequency is characterized as the sum of all stream segments of all orders per unit area (Horton, 1932). It relies on basin lithology and reflects the texture of the drainage network. Reddy et al. (2004) expressed that low values of stream frequency (Sf) show the presence of a permeable subsurface material and low relief. Stream frequency of study area is 0.71km/km2. Stream frequency shows positive relationship with drainage density demonstrating an expansion in stream population regarding expanding in drainage density. Stream frequency is directly proportional to runoff.

F) Drainage Texture

Drainage texture ratio (T) is defined as the total number of stream segments of all orders per perimeter of that area (Horton, 1945). It depends upon climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. In the present study drainage texture of the basin is 4.92 and forms as moderate texture and leads to moderate erosion in the Lower Bhavani River basin.

G) Elongation Ratio (Re)

As indicated by Schumm elongation ratio (Re) characterized as the proportion of the diameter the basin to the maximum extreme basin length of a similar area. Elongation ratio plays a vital role in computation of basin shape. The Re value differs from 0 (fit as a fiddle) to unity i.e. 1.0 (in the circular shape). In this manner higher the elongation ratio more circular shape of the basin and vice-versa. Those regions where Re value near 1.0 incorporates low relief region. Furthermore, those regions near 0.6 to 0.8 usually associated with high relief and steep ground slope. The range of elongation ratio and its corresponding basin shape is given in table 3.

Table 3 Ranges of Elongation ratio

Elongation Ratio	Shape of Basin
<0.7	Elongated
0.7-0.8	Less elongated
0.8-0.9	Oval
>0.9	Circular

Elongation ratio of study area is 0.75 indicates that the Lower Bhavani River basin area is less elongated. Elongation ratio value is directly proportional to infiltration capacity and indirectly proportional to runoff and bifurcation ratio. The lowest value of elongation ratio in the lower Bhavani river basin indicates high relief, steep slope.

H) Circulatory Ratio (Rc)

The circularity ratio is characterized by Miller (1953), as the proportion of the region of the basin to the area of the circle having indistinguishable boundary from the basin perimeter. Circularity ratio value varies from 0 (in line) to 1 (in a circle). The Rc value of study area is 0.26, which is less than 1 indicates that the lower Bhavani river basin is not circular in shape and comprises moderately permeable heterogeneous geologic material.

I) Form Factor (Ff)

The form factor is characterized as the proportion of the basin area to the square of the basin length and is demonstrating the shape of the basin. The form factor value of the study area is 0.46. Smaller value of form factor is (< 0.7854) indicates that the lower Bhavani river basin is of elongated basin. Also, it express that the study area shows low peak flow for longer duration.

5. Conclusion

Stream order of the basin indicates that the basin is of sixth order basin with dendritic to a sub-dendritic type of drainage pattern and bifurcation ratio, length ratio indicates that the basin behaves as homogeneous weathering in nature and there is no structural or tectonic control. It is also noticed that there is a diminishing in stream frequency as the stream order increases and vice versa, which is characteristic feature of drainage with dendritic to sub- dendritic nature. The elongation ratio of the study area is 0.75 and circulatory ratio is 0.26. The less elongated nature of the Lower Bhavani River basin indicates higher relief with steep slope nature. On the other hand the circulatory ratio expresses, the Lower Bhavani River basin is not circular in shape and comprises moderately permeable heterogeneous lithology.

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