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GIS based morphometric analysis of gayathiripuzha river basin

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ABSTRACT

Rivers are playing a key Major role in development of an area. Examine the river morphometry is very crucial for sustainable development. By looking the history of development its shows that development occurred first on the river banks. on the other hand rivers are affeeted by the development of a region or nation. River play a key role in geomorphology of a region and river itself creates so many landforms. Changes in river directly affect the geomorphology of a region too. The present study deals with morphometric analysis of Gayathiripuzha River.

Key words : *Morphometric, Gayathiripuzha river basin*

Introduction

Drainage morphometry is a tool and technique to quantify the geometrical properties of drainage network in an area. Morphometric analysis of drainage channels provides guideline to understand their spatial arrangement, nature of climate, vegetation, local lithology, nature and rate of erosion, structural controls, infiltration capacity, ground water potential, terrain conditions like initial slope and the influence of tectonic activity if any in the landscape development. In fact, drainage morphometry is the technique of measurement and mathematical analysis of the configuration of the earth's surface shape and dimensions of its landforms (Clarke, 1966). Moreover, morphometry is an important aspect of characterization of watersheds (Starhler, 1964). Tectonic inferences can also be drawn at reasonable scale with the help of morphometric techniques. Similarly, effective management of natural resources can be done with the information gathered through morphometric techniques.

Study Area

Gayathiripuzha is one of the tributaries of Bharathapuzha. It's second largest among the Bharathapuzha tributary basins. Gayathiripuzha originates from Anaimalai hills and merges with Nila at Mayannur. Gayathiripuzha lies between 76°14'56.408"E 10°44'42.317"N TO 76°55'16.319"E 10°25'43.031"N. Gayathri River Basin, one among the major tributaries of river Bharathapuzha spread over 980.38 sqkm, 67 microwatersheds traversing the boundaries of 31 Grama panchayaths, 5 Block panchayaths and 2 districts was selected as the study area. Gayathri subwatershed is unique for the following reasons meriting its selection as study area. It is one among the two tributaries sustaining the life of River Bharathapuzha with its origin from portions of Western Ghats, south of Palakkad gap, catchment of four major reservoirs Mangalam, Pothundy, Meenkara and Chulliyar serving the irrigation requirements of the extensive paddy tracts of Alathur, Nenmara and Kollengode blocks of Palakkad district, still rich in its traditional farming

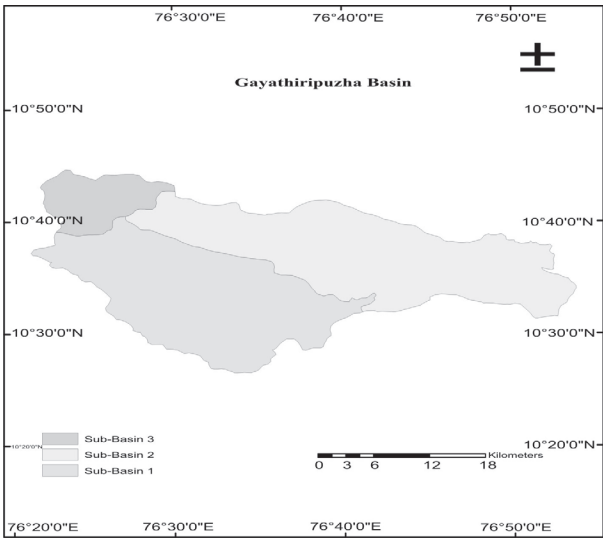

Fig. 1. Study Area

and water harvesting systems. The catchment as is the case elsewhere is facing serious threat of deterioration due to human intervention manifested by the fast disappearance of perenniality of surface and sub surface water resources.

Methodology

The map preparation process is done through georeferencing toposheets of study area by Arc Gis software. Then extracted contour, stream, spot height etc. By using quantitative techniques calculated Morphometry and sinuosity.

Morphometric Parameters

Linear Parameters

Morphometric Parameters	Formula	Source
Stream Order	Hierarchical Rank	Strahler (1964)
Stream Length (Lu)	Length of the stream	Horton (1945)
Mean Stream Length (Lsm)	Lsm =Lu/Nu Lu - Total stream length of order 'u' Nu – Total no.of stream segments of order 'u'	Horton (1945)
Stream Length Ratio (RL)	RL= Lu/Lu-1 Lu - Total stream length of order 'u' Lu-1 – The total stream length of its next lower order	Horton (1945)
Bifurcation Ratio (Rb)	Rb = Nu/Nu+1 Nu – Total no.of stream segments of order 'u' Nu+1 – no. of segments of the next higher order	Schumm (1956)

Areal Parameter

Morphometric Parameters	Formula	Source
Elongation Ratio (Re)	$Re = 2\sqrt{(A/\pi)}/L$ A- Area of the basin (km^2) π - Pie value – 3.14	Schumm (1956)

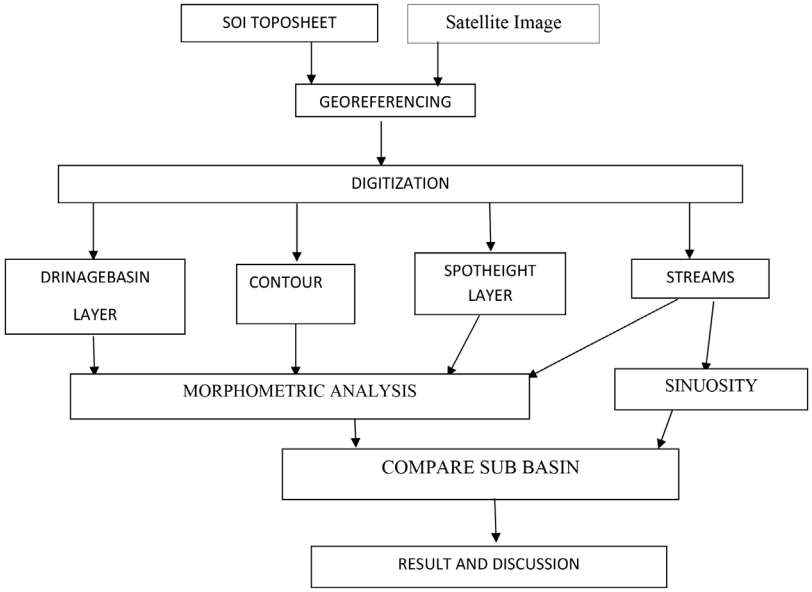

Fig. 2. Methodology

	L – Basin length	
Drainage Density (Dd) (km/km^2)	Dd = Lu/A Lu – Total stream length of all order A – Area of the Basin (km^2)	Horton (1932)
Drainage Texture (Rt)	Rt = Dd * Fs Dd – Drainage density Fs – Stream Frequency	Smith (1950)
Stream Frequency (Fs)	Fs = Nu/A Nu – Total no. of streams A – Basin area (km^2)	Horton (1932)
Form Factor (Ff)	Ff = A/L^2 A – Area of the basin (km^2) L – Basin length (km)	Horton (1932)
Circularity Ratio (Re)	Rc = 4 πA/P^2 Pi value is 3.14 A – area of the basin (km^2) P^2 – Square of the Perimeter (km)	Miller (1953)
Length of the overland flow (Lo)	Lo = 1/2DdDd – drainage density	Horton (1932)

Relief Parameter

Morphometric Parameters	Formula	Source
Basin Relief (R)	R= H-h R= Basin Relief H= Maximum elevation in meter H= Minimum elevation in meter	Hadley and Schumm (1961)
Relief Ratio (Rr)	Rr = R/LRr = Relief ratio R= Basin relief L = longest axis in kilometre	Schumm (1956)
Ruggedness number (Rn)	Rn = R*D Rn = Ruggedness number R = Basin relief Dd = Drainage density	Schumm (1956)

Results and Discussion

Basin Geometry

The sub-basin of Gayathiripuzha delineated for, morphometric analysis in the study area are depicted in Fig. 3.1 and the respective geometric parameters are presented in Table 3.2. The biggest sub-basin in the study area is BASIN 2 (483 sq.km) Which join with basin 3 and debouches into the Bharathapuzha River. The smallest sub-basin in the study area is Basin 3 which directly debouches into the Bharathapuzha River.

Linear Aspects

Stream Order (U)

Stream order is the index of size and scale of the drainage basin. An approximation of the stream flow can be deduced from stream order. In the sub-basins of Gayathiripuzha river basins, the highest order is 6 and 7 indicating the moderate size of the sub-basin. The highest stream order of biggest sub-basin is 6 But remaining sub-basins has 7 as highest stream order.

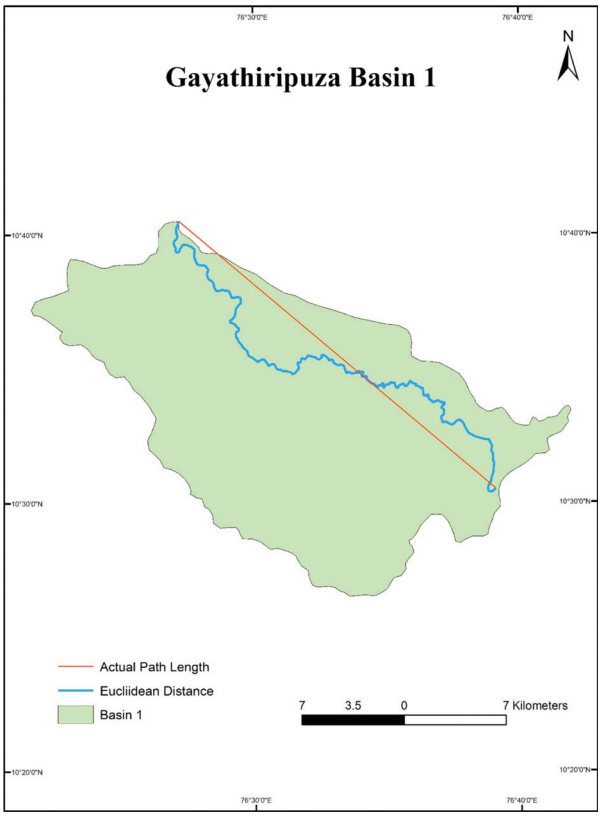

Fig. 3. Sinuosity of Gayathiripuzha Basin

Stream Number (Nu)

Total number of streams in the sub-basin in the respective stream order categories are presented in Table 3.3. Total number of streams in Gayathiripuzha river basin is 1951. More number of first order stream observed in the hilly regions of the study area indicates complex terrain and less permeable bedrock lithology. Large number of streams in the sub-basins indicate that the topography is rugged and the streams are intensively eroding their channels. Less number of streams in irrespective of its drainage area indicates a mature topography of its stream.

Bifurcation Ratio

The high bifurcation ratio (<5) for the higher order

Table 1. Morphometric Analysis and Results

	Basin 1	Basin 2	Basin 3
Mean Bifurcation Ratio (Rbm)	3.085223075	3.861597938	4.50277767
Area	440.837	483.777	95.2225
Drainage Density(D)	1.76390729	1.71197701	1.36126651
Stream Frequency (Fs)	2.06879187	1.90170264	1.24970464
Drainage Texture (Rt)	8.37934931	6.87629398	2.6195817
Circularity Ratio (Rc)	0.467410638	0.339443951	0.579561054
Length of Overland Flow (Lg)	0.28346161	0.292059997	0.367305003
Form Factor (Rf)	0.219316348	0.244287138	0.208512141
Elongation Ratio (Re)	0.5285677	0.5578474	0.5153838
Basin Relief (R)	1492	1598	187
Relief Ratio (Rh)	0.03327862	0.035909095	0.008750593
Ruggedness Number (Rn)	2.63	2.73	0.25

streams of the study area may be attributed to structural disturbances, which in turn, have distorted the drainage pattern. According to Agarwal (1998), if the bifurcation ratio (Rb) is low, the basin produces a sharp peak of discharge, and if Rb is high, the basin yields a low but extended peak flow. The distinguishing dissimilarity in the Rb values of various orders among the sub basins suggests the control of tectonic activities on drainage development. The bifurcation ratio of the sub-basin of the study area is found range from 2 to 6. The lower order of all the sub-basins have bifurcation ratio >3. This suggested that the basin is a highly dissected one and the upland zone of the basin is tectonically active as observed. High bifurcation ratio may also de due to the elongated shape of the basin (Strahler 1964; Zavoianu, 1985). The highest bifurcation ratio can be observed for the study area is 5.3 (Sub-basin 2). The high bifurcation ratio of the Gayathiripuzha Sub-Basin stream clearly indicates the factor of geological control on the drainage pattern.

Stream Length

Stream length is decreasing with increasing order of stream in most case but vary in the case of Sub-basin 1. The plot of logarithm of stream length versus the stream order is of linear relationship. Mean length is the average length of stream channel segments in a given stream order. It is dimensional properly reveal the characteristics size of components of a drainage network and its contributing basin surface. Mean stream length of a given order is generally greater than that of the immediately lower order and any deviation in it may be due to variation in the slope and topography which again reflects the tectonic activity. For the Sub-basin 1 mean length of the highest order stream is lower than that of immediately lower order indicating changes in stream gradient due to tectonic upliftment. Singh and Sing (1997) observed that an increasing trend in the stream length ratio from lower order to higher order indicating their mature geomorphic stages and if there is a change from one order to another order, it indicates their late youth stage of geomorphic development. Accordingly, from the study it is revealed that all Sub-basins are in late youth stage.

Length of Overland Flow (Lf)

It indicates the quantity of water required to exceed a threshold of erosion. The length of overland flow of Sub-basin of the study area ranges from 0.28 to 0.36. It indicates long flow path and comparatively gently sloping terrain of these Sub-basins, which

Table 2. Morphometric Analysis of Sub-Basin 1

Order	1	2	3	4	5	6	7
No. of order	677	170	46	12	4	2	1
Stream length (Lu)	426.722	145.6	84.667	71.127	26.692	7.9513	14.835
Mean stream length (Lsm)	0.63031	0.85646	1.8405	5.9272	6.6730	3.9756	14.835
Bifurcation Ratio (Rb)	3.9823	3.69565	3.8333	3	2	2	
Stream Length Ratio (RL)	2.9307	1.7196	1.1903	2.6647	3.3569	0.5359	

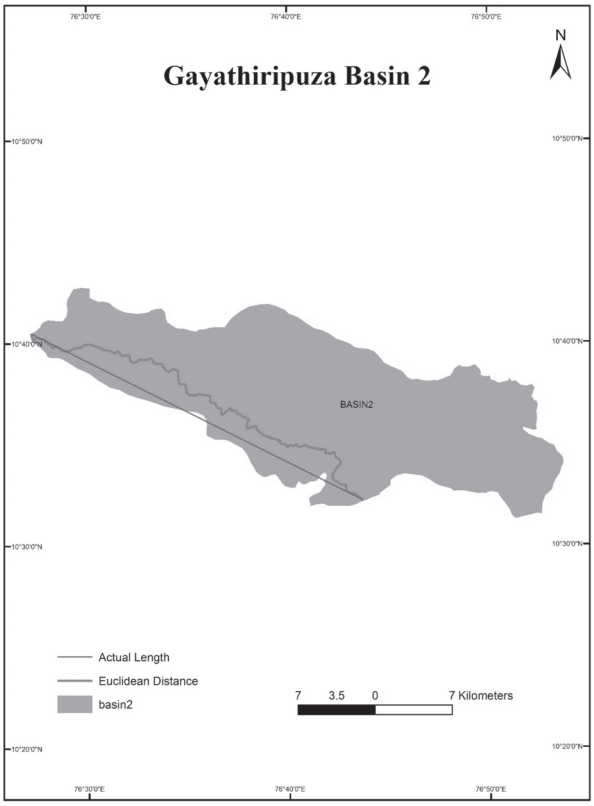

Fig. 4. Sinuosity of Gayathiripuzha Basin 2

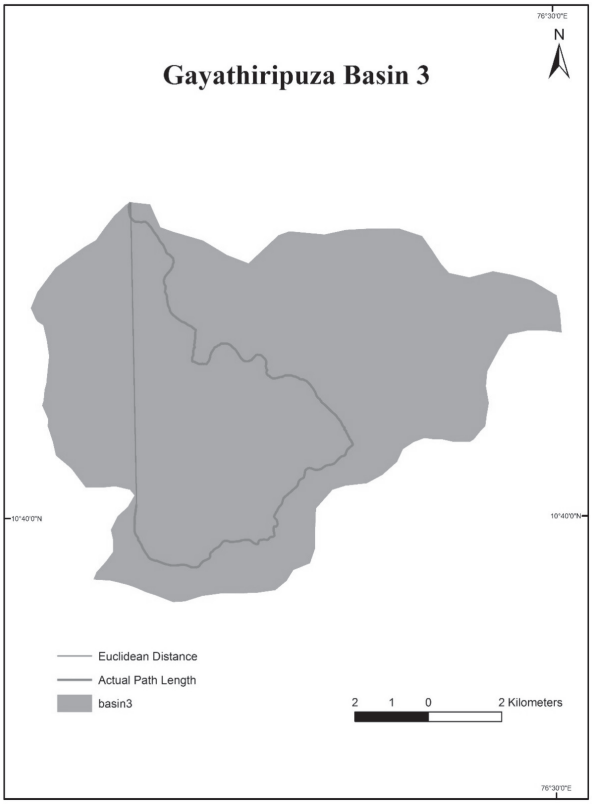

Fig. 5. Sinuosity of Gayathiripuzha Basin 3

facilitates more infiltration and less runoff.

Areal Aspects

Drainage Density

Drainage density of the Sub-basin of the study area varies from 1.36 to 1.76 In general, low drainage density is favored in the region of highly permeable subsoil materials, under dense vegetation cover and where relief is low. In the study area it's in moderate condition.

Stream Frequency

For the sub-basins of the study area, stream fre-

Table 3. Morphometric Analysis of Sub-Basin 2

Order	1	2	3	4	5	6
No. of order	666	194	48	9	2	1
Stream length (Lu)	411.754	195.9	99.9512	59.8297	46.5617	14.2185
Mean stream length (Lsm)	0.61825	1.00979	2.08232	6.64774	23.2809	14.2185
Bifurcation Ratio (Rb)	3.432989	4.041666	5.333333	4.5	2	
Stream Length Ratio (RL)	2.10185	1.95995	1.67059	1.28495	3.274726	

Table 4. Morphometric Analysis of Sub-Basin 3

Order	1	2	3	4	5	6	7
No. of order	89	24	5	Nil	Nil	Nil	1
Stream length (Lu)	66.9157	26.0512	23.4957	Nil	Nil	Nil	13.160
Mean stream length (Lsm)	0.75186	1.08547	4.69915	Nil	Nil	Nil	13.160
Bifurcation Ratio (Rb)	3.70833	4.8	5	Nil	Nil	Nil	
Stream Length Ratio (RL)	2.5686	1.10876	1.78530	Nil	Nil	Nil	

quency varies from 1.24 to 2.06. Low stream frequency observed in the study area reflecting, the gentle ground slope, and greater rock-permeability in those basins. It also shows the runoff is low and the infiltration is high. There is a positive correlation with drainage density and stream frequency of the Sub-basin in the study area suggesting an increase in number of streams with respect to increasing drainage density.

Circulatory Ratio

Strongly elongated drainage basins have a circulatory ratio between 0.40 to 0.50. The circulatory ratio of the Sub-basins in study area ranges from 0.33 to 0.57. These values show the basin are irregular and elongated with longer lag time and low peak flow.

Elongation Ratio

The Sub-basins of the study area shows elongation ratio ranging between 0.51 to 0.55. So, it indicates the area is moderately tectonically active.

Form Factor

The analysis showed that the form factor varies between 0.20 to 0.24. Which suggest that a narrow and elongated shape for the Sub-basin.

Drainage Texture

In the present study, it's observed the drainage texture range between 2 to 8. This shows that drainage texture is intermediate for Sub-basin1 and Sub-basin 2 but it's coarse for Sub-basin 3
Relief Aspect

Basin Relief

Basin relief is a significant factor for understanding denudation characteristics of the basins. Basin relief of the Sub-basin in study area ranges from 187 to 1598m. Among the Sub-basin of Gayathiripuzha river Sub-basin 2 has the highest basin Relief (1598m) and Sub-basin 3 has the lowest Basin-relief (187m)

Relief Ratio

It measures overall steepness of a drainage basin and is an indicator of the intensity of erosion process. Relief ratio of Sub-basins of the study area ranges from 0.008 to 0.033, which exhibits relief ratio <0.10 indicating that the area is occurring of gentle sloping small ridges and mounds in the catchment.

Sinuosity index

Sinuosity index is the ratio of stream length with the straight-line distance. Schumm (1983,1993) have demonstrated that much of the sinuosity variability of alluvial rivers reflects the variability of the valley slope, through experimental studies as well as field

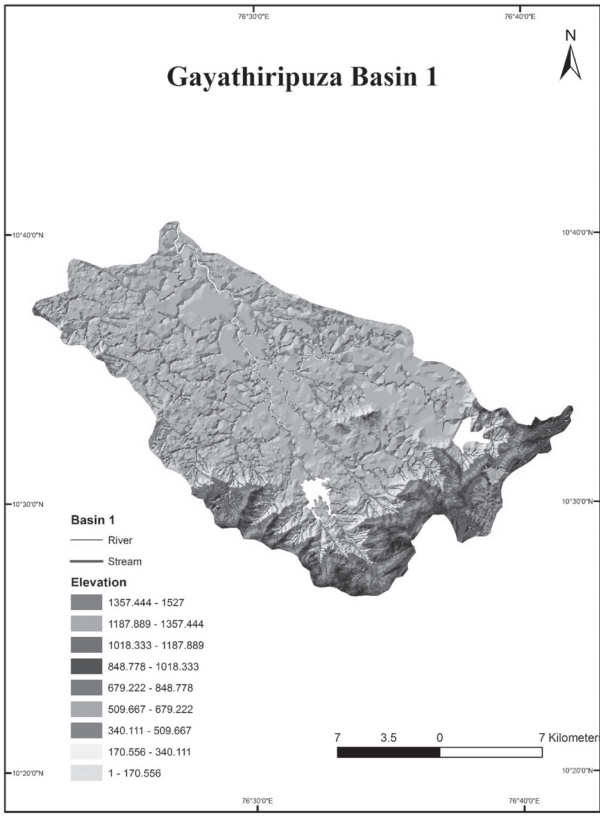

Fig. 6. TIN of Gayathiripuzha Basin 1

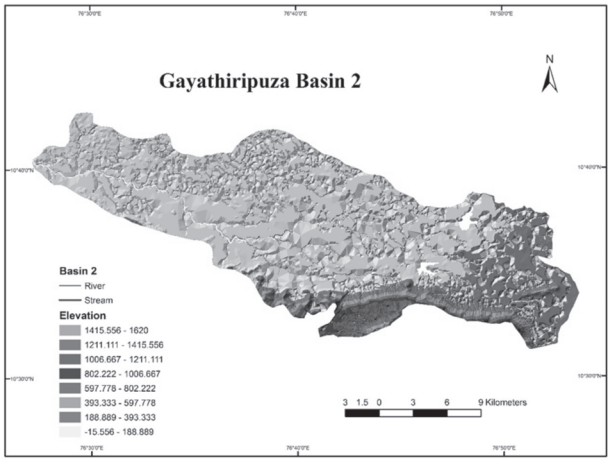

Fig. 7. TIN of Gayathiripuzha Basin 2

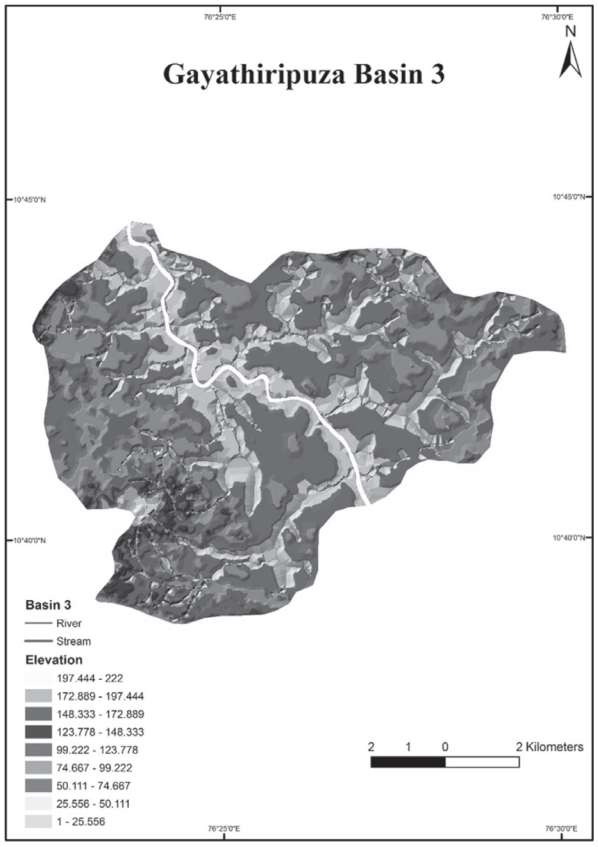

Fig. 8. TIN of Gayathiripuzha Basin 3

observations. Tectonic activities, local changes of sediment and water supply due to river junctions and changes in lithology are the main forces controlling the changes of valley floor slope (Shumm, 1986). Changes of valley slope controls the downstream changes of sinuosity.

Sinuosity

Basin 1- 1.5

Basin 2- 1.3

Basin 3- 2.5

Changes of valley slope controls the downstream changes of sinuosity. The Sub-basin of the study area has sinuosity ratio as 1.5, 1.3 and 2.5. In this study shows river has meandering form. But there is less chance to make ox-bow lake because the river is in late young stage.

Conclusion

Morphometric parameters of the basin have been computed and analyzed by using geoprocessing technique of ArcGIS and explore the relationship between the drainage morphometry, moderate and high relief, low run off and high infiltrations. Morphometric parameters were analyzed by measurement of linear, areal and relief aspects. Morphometry of Gayathiripuzha Basins is very different from other river basins in Kerala. The study area of Gayathiripuzha basins have well developed drainage system. Overall drainage pattern is dendritic in nature. But in some small area its look like parallel pattern. Drainage order also indicating moderate size of the Sub-basin, which having upto 6^{th} and 7^{th} order stream. Geology of the study area also effecting the drainage pattern and flow. The sinuosity index also putting light to this matter. Theoretically it's having the possibility to make meanders but in the case of gayathiripuzha basin is not possible. It's because geomorphologically Gayathiripuzha flowing through late youth stage and the length of the stream. The length of the stream is very low comparative with north Indian rivers. Only the first order stream area having high elevation, remaining area is characterized by gentle slope. Sub-basin 3 has the coarse drainage texture. It's the uniqueness of Bharathapuzha river in Kerala, which shows the sand content in the river beds. the basins are irregular and elongated with longer lag time and low peak flow. Runoff of the stream is low because of its gentle slope in nature, which make high infiltration. So overall Gayathiripuzha basins have some unique features and well-developed drainage pattern.

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