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RESEARCH ARTICLE

MORPHOMETRIC ANALYSIS OF THIRUMANIMUTTAR RIVER, TAMILNADU USING GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

Baseline morphometric information at a sub basin level is essential to develop an appropriate strategy for sustainable, socially acceptable, ecologically benign and economically viable development of a river basin. The present study was carried out in one of the less studied Thirumanimuttar river sub-basins of Cauvery river in the state of Tamilnadu, India. We used GIS and RS tools to study the morphometric characteristics of the basin. The seventh order main river is formed by several lower order streams forming a dentritic flow pattern. The mean bifurcation ratio is 3.61 indicating the basin is largely controlled by structure. The basin has medium drainage density of 0.996 per km^2 and is elongated in shape. The length of overland flow values of the basin is 0.502, indicating high relief. The study has strengthened in understanding the hydrological, geological and geomorphological characteristics of the Thirumanimuttar drainage basin.

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INTRODUCTION

The Thirumanimuttar is a sub basin of River Cauvery and is an important river for Salem and Namakkal districts to fulfill the domestic, agricultural and industrial needs. The demand for water has increased over the years, due to which the assessment of quantity and quality of water for its optimal utilization is necessitated. The morphometric parameters of a watershed are reflective of its hydrological response to a considerable extent and can be helpful in synthesizing its hydrological behavior. A quantitative morphometric characterization of a drainage basin is considered to be the most satisfactory method for the proper planning of watershed management because it enables us to understand the relationship between different aspects of the drainage pattern of the basin, and also to make a comparative evaluation of different drainage basins developed in various geologic and climatic regimes.

Study Area

The river Thirumanimuttar originates in the Shevaroy hills and Manjavadi Ghat at the altitudes of 1280m and 110m respectively from the North and North East of Salem town. The river course is almost 102km long towards South West and South from Salem town and to join River Cauvery at Kuduthurai near Paramathi Velur in Namakkal District. The Study area is located in Salem and Namakkal districts of Tamil Naduand it is represented in the Survey of India Topographic sheets Scale 1:50000 numbering 58I/1, 58I/2, 58I/3, 58I/4, 58I/5, 58I/6, 58I/7, 58I/8, 58E/7,58E/13 58E/14, 58E/15, 58E/16, Published in the year 1972.Area under study lies between North Latitudes 11□05′ and 11□50′ and East Longitudes 77□53′ and 78□20′.and an aerial extent of 2432 sq.km.

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MATERIALS AND METHODS

The study area is delineated from using drainages from toposheets of SOI, topographic maps no.58I/1, 58I/2, 58I/3, 58I/4, 58I/5, 58I/6, 58I/7, 58I/8, 58E/7,58E/13 58E/14, 58E/15, 58E/16, published in the year 1972. These were scanned, digitized and taken to GIS. The area under study lies between North Latitudes 11□05′ and 11□50′ and East Longitudes 77□53′ and 78□20′.The drainage network delineation was made from the Survey of India toposheet 1:50,000 scale. The slope and relief of the basin were examined using digital elevation model data (DEM) available at www.asterdem.com. The stream order, stream length, mean stream length, stream length ratio, bifurcation ratios, mean bifurcation ratio, relief ratio, drainage density, stream frequency, drainage texture, form factor, circulatory ratio and elongation ratio were estimated by using Arc GIS 9.3.1, and ERDAS IMAGINE 8.5 for the entire study.

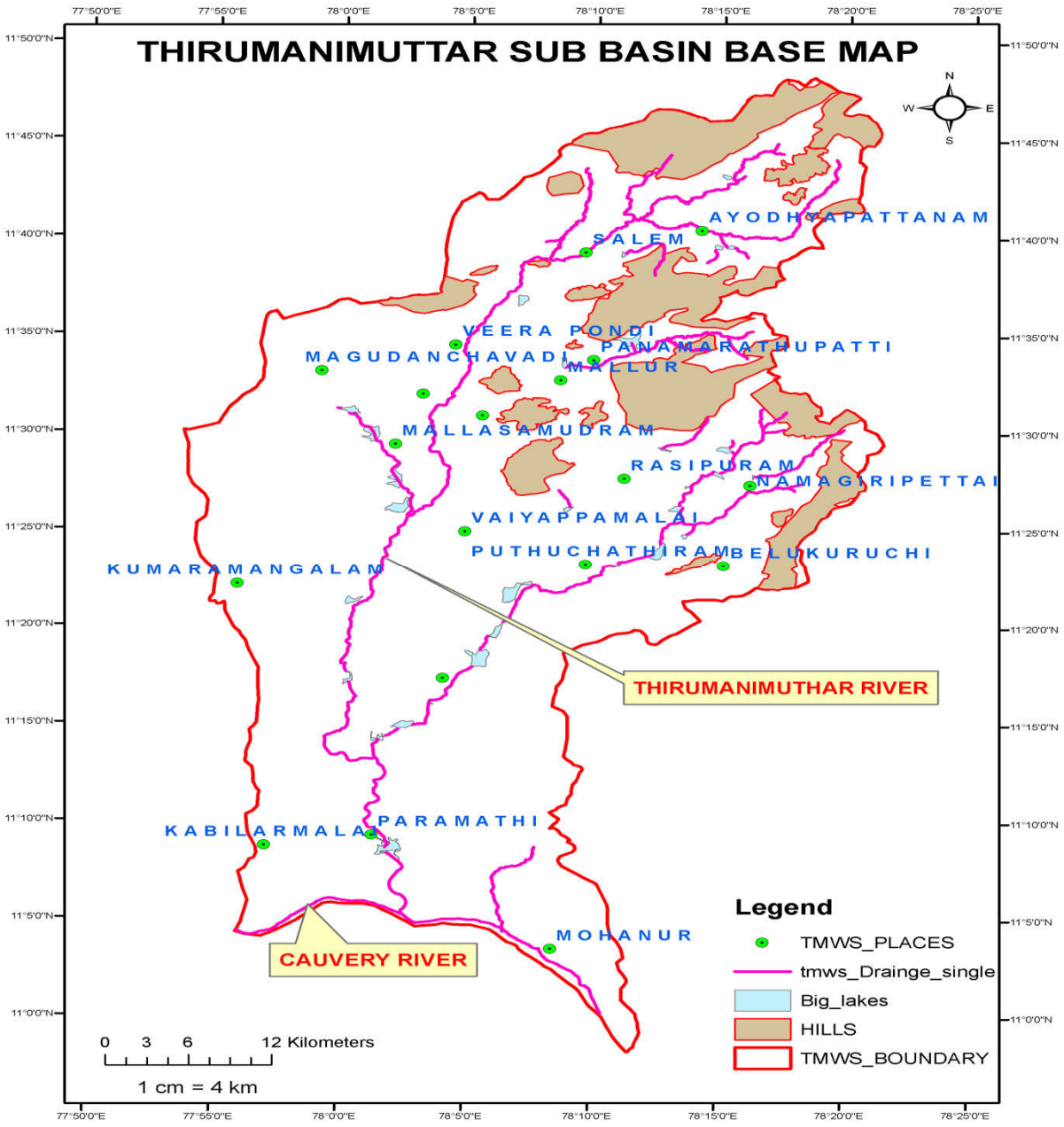
The measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landform provide the basis of the investigation of maps for a geomorphological survey. This

approach has recently been termed as Morphometry. The area, altitude, volume, slope, profile and texture of landforms comprise principal parameters of investigation. Dury (1952), Christian (1957) applied various methods for landform analysis, which could be classified in different ways and their results presented in the form of graphs, maps or statistical indices. The morphometric analysis of the Thirumanimuttar sub basin was carried out on the Survey of India topographical maps. No 58I/1, 58I/2, 58I/3, 58I/4, 58I/5, 58I/6, 58I/7, 58I/8, 58E/7,58E/13 58E/14, 58E/15, 58E/16 on the scale 1:50,000. The lengths of the streams; areas of the watershed were measured by using ArcGIS-9.3.1 software, and stream ordering has been generated using Strahler (1952) system. This was used here for linear, areal and relief aspect's assessment, i.e. Horton (1945) for stream ordering, stream number, stream length, stream length ratio, bifurcation ratio, length of overland flow, rho coefficient, form factor, & stream frequency; Strahler(1952) for a weighted mean bifurcation ratio, mean stream length, ruggedness number, & hypsometric analysis; Wolman (1964) for sinuosity index analysis; Mueller (1968). for channel & valley index. Schumm(1956) for basin area, length of the basin, elongation ratio, texture ratio, a relief ratio & constant of channel Hack (1957) for length area relation; Chorely (1957) for lemniscate's; Miller (1960) for a circularity ratio; Smith (1939) for drainage texture; Gravelius (1914) for a compactness coefficient; Melton (1957) for a fitness ratio, & drainage density; Smart (1967) for a wandering ratio; Black (1972) for watershed eccentricity; Faniran (1968) for drainage intensity; Wentworth (1930) for slope analysis, and Pareta (2004) for erosion analysis

Linear Aspects of the Channel System

The linear aspects of drainage network such as stream order (U), bifurcation ratio (Rb), stream length (Lu) results have been presented in the Table .1.

Stream Order (U): In the drainage basin analysis, the first step is to determine the stream orders. In the present study, the channel segment of the drainage basin has been ranked



according to Strahler‟s stream ordering system. According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first-order channels join, a channel segment of order 2 is formed and where two of order 2 joined, a segment of order 3 is formed, so on and so forth. The trunk stream through which all discharge of water and sediment passes is therefore, the stream segment of the highest order.

The study area is a 7th order drainage basin. The total number of 2578 streams were identified of which 1843 is 1st order streams; 539 are 2nd order; 148 are 3rd order, 36 in 4th order, 9 in 5th; 2 in 6th and one are indicating 7th order streams.

Stream Length (Lu): Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristic's streams of relatively smaller

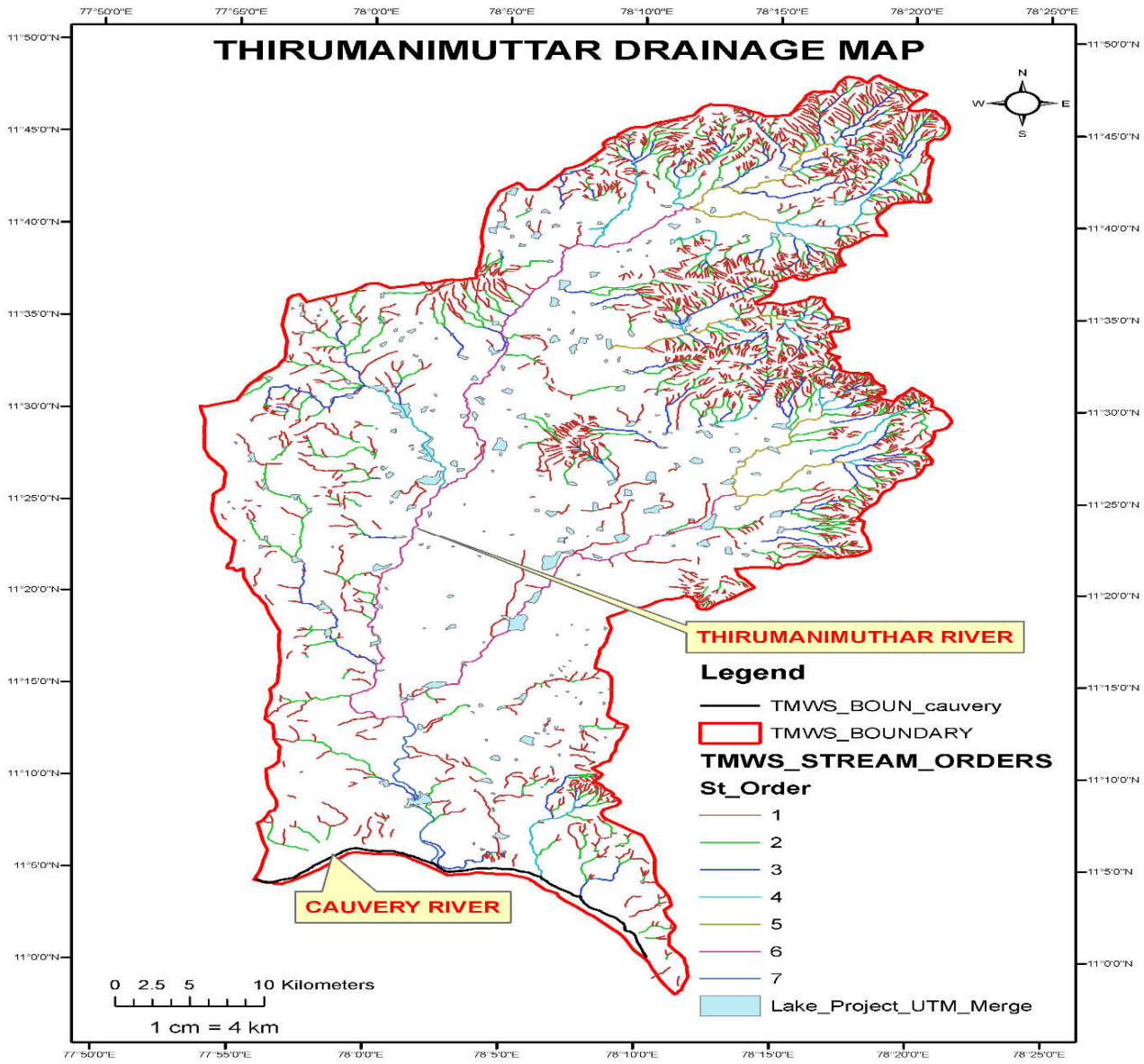


Table 1. Result of Morphometric Analysis

Morphometric Parameters	Results
Basin area(km2)	2432km2
Perimeter(km)	312km
Basin order	7
Basin Length(Lb) (km)	84km
Relief Ratio(Rh)	13.93
Basin Relief(Bb) (km)	1170km
Ruggedness Number(Rn)	1175
Mean Bifurcation Ratio(Rb)	3.61
Drainage Density(Dd) (km2)	0.996
Stream Frequency(Fs)(km2)	1.060
Texture Ratio (T) (km)	5.91
Form Factor(Rf)	0.344
Circularity Ratio(Rc)	0.314
Elongation Ratio(Re)	0.660
Length of overland flow(LG) (km)	0.502
Constant Channel Maintenance© (km)	1.004

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 number of streams of various orders in the basin is counted and their lengths from a mouth to drainage divide are measured with the help of GIS software. The order wise mean stream length in the study area for the first order is 1327.991kms, 560.380kms for second order, 297.945 kms for third order, 107.768 kms for fourth order, 60.747 for fifth order, 55.676kms for sixth order and 11.172kms for the trunk stream.

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.

Table 2. Result of Morphometric Analysis

Stream Order	Number of Stream	Bifurcation Ratio(Rb)	Stream Length(Lu) (km)	Stream Length Ratio (Rl)	Mean Stream Length(Lms)
1	1843	3.42	1327.991	2.37	0.720
2	539	3.64	560.380	1.88	1.013
3	148	4.11	297.945	2.76	2.013
4	36	4	107.768	1.77	2.749
5	9	4.5	60.747	1.09	6.749
6	2	2	55.676	4.98	27.838
7	1	0	11.172		11.172

Table 3. Stream analysis of Thirumanimuttar river basin

Stream Order	Number of streams Nu	Stream Number Cumu.	Total length of streams Lu (Km)	Stream Length Cumu. (Km)	Length Ratio	Mean stream length (Km)	Bifurcation Ratio	Mean Bifurcation Ratio
1	1843	1843	1327.991	1327.991	0.42	0.720	3.41	
2	539	2382	560.380	1888.371	0.53	1.039	3.64	
3	148	2530	297.945	2186.316	0.36	2.013	4.17	
4	36	2566	107.768	2294.084	0.56	2.993	4	
5	9	2575	60.747	2354.831	0.91	6.749	4.5	3.62
6	2	2577	55.676	2410.507	0.20	2.783	2	
7	1	2578	11.172	2421.679	-	1.117	-	

Mean Stream Length (Lsm)

The mean stream length of a channel is the characteristic size of drainage network componentsand its contributing basin surface. It is calculated by dividing the total stream length of order "u" by thenumber of a stream of segments in the order. The mean stream lengths of study area are 0.720, 1.039, 2.013, 2.99, 6.749, 27.838 and 11.172 from First-order stream to Seventh order stream.

Stream Length Ratio (RL)

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and having important relationship with surface flow and discharge. The ratio between orders in the study area differs from one order to another, which indicate slate youth to mature stage of geomorphic development.

Bifurcation Ratio (Rb)

The bifurcation ratio is the ratio of the number of stream segments of given order to the number of segments of next higher order (Horton 1945) considered the bifurcation ratio as an index of relief and dissection. It is well demonstrated that bifurcation ratio shows only a small variation in different regions on different environment except where powerful geological control dominates (Strahler 1957). The study area bifurcation ratio result shows that low in third order and high in second order ranges between 2 to 4.17 in which geology is reasonably homogeneous and no structural disturbances.

The maximum height of the Thirumanimuttar Riverbasin is 1280 m, and the lowest is 110m. Therefore, the relief of the basin is 1170 m. The basin length, relative relief and relief ratio of the area are given in Table 2.

ARIAL ASPECTASPECTS OF THE STUDY AREA

The aerial aspects include drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow.

DRAINAGE DENSITY (D_d)

Drainage density is the total length of all the streamsin the watershed to the area of watershed. It helps indetermining the permeability and porosity of thewatershed and an indicator of landform elements instream eroded topography. Drainage density means the ratio of area of drains to the area of catchment. if drainage density is more, that means, more drains are there to drain off the water from the catchment. Hence, there will be less storage of water. All that results in more runoff generation. More quantity of water will be drained off from the catchment. And the water will move more quickly. Low drainage densityleads to coarse drainage texture while high drainagedensity leads to find drainage texture. Low drainage density generally result in the area of highly resistant or permeable subsoil material and high drainage density is the resultant of weak orim permeable subsurface material. The result shows the value 0.996 per square kilometers in study are suggesting that the area has permeable subsurface strata and is a characteristic feature of coarse drainage, which generally shows values less than 5.0.

Stream Frequency (F_S)

Stream frequency or channel frequency (Fs) 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 1.06..

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 5.91, which fell within the coarse drainage texture.

According to Smith, 1950 the Drainage texture can be classified into four categories viz:

- Coarse drainage texture: < 4
- Intermediate drainage texture: 4 - 10
- Fine drainage texture: 10-15
- Ultra fine drainage texture: > 15

And the value obtained by using Smith method also reveals that the drainage basin falls in coarse drainage texture (the calculated value is 0.939).

Form Factor Ratio (R_f)

Quantitative expression of drainage basin outline form was made by Horton (1932) through a form factor ratio (R_f), which is the dimensionless ratio of basin area to the square of basin length. Basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998). The value of a form factor would always be less than 0.7854 (for a perfectly circular basin). Smaller the value of a form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. The form factor value of the basin is 0.344, which indicate a lower value of form factor and thus represent elongated in shape. The elongated basin with the low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin.

Circularity Ratio (Rc)

Miller (1953) defined a dimensionless circularity ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. He described the basin of the circularity ratios range 0.314 which indicated strongly elongated and highly permeable homogenous geologic materials. He described the basin of the circularity ratios range 0.4 to 0.5, which indicates strongly elongated and highly permeable homogenous geologic materials. The circularity ratio value (0.31) of the basin corroborates the Millers range which indicating that the basin is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition.

Elongation Ratio (Re)

Schumn (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. 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 Re values generally ranges between 0.6 and 1.0 over a wide variety of climate and geologic types. Values near to 1.0 are the characteristics of the region of very low relief, while values in the range of 0.6 - 0.8 usually occur in the areas of high relief and steep ground slope (Strahler 1964). These values are further categorized as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7). The Re value of study area is 0.66, which indicates the drainage basin is high relief and less elongated.

Length of Overland Flow (Lg)

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 result obtained for the study area was 0.502 km. The value of overland flow is higher in the semi-arid regions than in the humid and humid temperate regions, in addition to an 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). The low overland flow of Upper Jhelum basin clearly indicates that the catchment has a well-developed stream network and receives heavy rainfall as well.

Constant of Channel Maintenance

Constant of channel maintenance value for the present area is 1.004. 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.

Conclusion

The study of morphometric analysis of Thirumanimuttar using GIS retrieved that, Geographical Information System helps the researchers to analysis the drainage basin easily and accurately. The study of linear aspects of drainage basin result shows that, the basin has been formed in dendritic pattern with Seventh' order stream, plotting the logarithm of number of streams against stream's order shows a straight line which states the number of streams usually decreases as the stream order increases. The result of relief aspect shows the study area is high relief and high stream density, the result of areal aspect shows the texture of drainage falls within the intermediate drainage texture and the result of elongation ratio indicates the drainage basin is high relief and less elongated.

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