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AN ANALYSIS OF MORPHOMETRIC AND HYPSOMETRIC CHARACTERISTICS OF THIRUMANIMUTHAR BASIN IN TAMIL NADU USING GIS.

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Abstract
The present study has been conducted to analysis the morphometric and hypsometric characteristics of Thirumanimuthar basin. The topographical variation data is necessary for the study of any basin, so the SRTM elevation contours have been downloaded as secondary data from the official website and it was used as a base for elevation model of the basin. The morphometric characters were identified using the calculation of linear, aerial and relief aspects of the basin, while hypsometric characteristics found using hypsometric integral and curve.

Keywords: *Morphometry, Hypsometry, Basin, Stream orders.*

INTRODUCTION

The measurement of morphometry appears to be increasing importance. It is equally fundamental to all science studying the forms of the natural world (Ion Zavoianu, 1985). Basin morphometry is a means of numerically analyzing various aspects of drainage channel and its characteristics that can be measured for comparison (Nag and Lahiri, 2011). Morphometric studies in the field of hydrology were first initiated by Horton and Strahler in 1940 and 1950 (Liaqat et al., 2011). The numerical analysis of basin includes the linear, aerial and relief aspects, which can be used to immense utility in river basin evaluation, basin prioritization for soil and water conservation, and natural resources management at micro level (Kanth and Hassan, 2012).

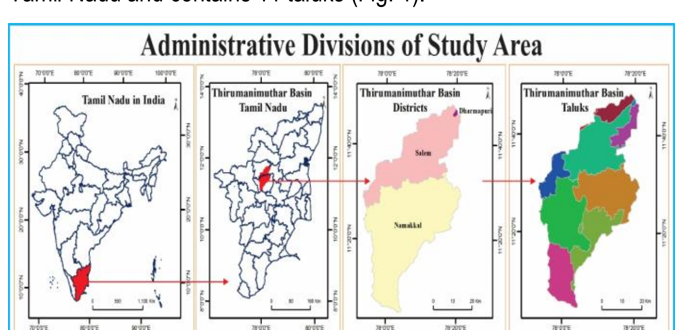
The principle of the hypsometric curve was established in 1854 by Carl Koritska, who showed that relief should be divided into horizontal sections which can be assimilated to frustums of cones with the same base and height (Ion Zavoianu, 1985). Hypsometry refers to a frequency distribution of elevations and the hypsometric curve represents a fraction of the basin area below a given height, usually reported in non-dimensional terms by normalizing the elevations relative to the total elevation range in the area of interest (Ramu and Mahalingam, 2012). The hypsometric integral is an area under the normalized curve, which by definition must lie in the range 0 to 1 (Harrison et al., 1983).

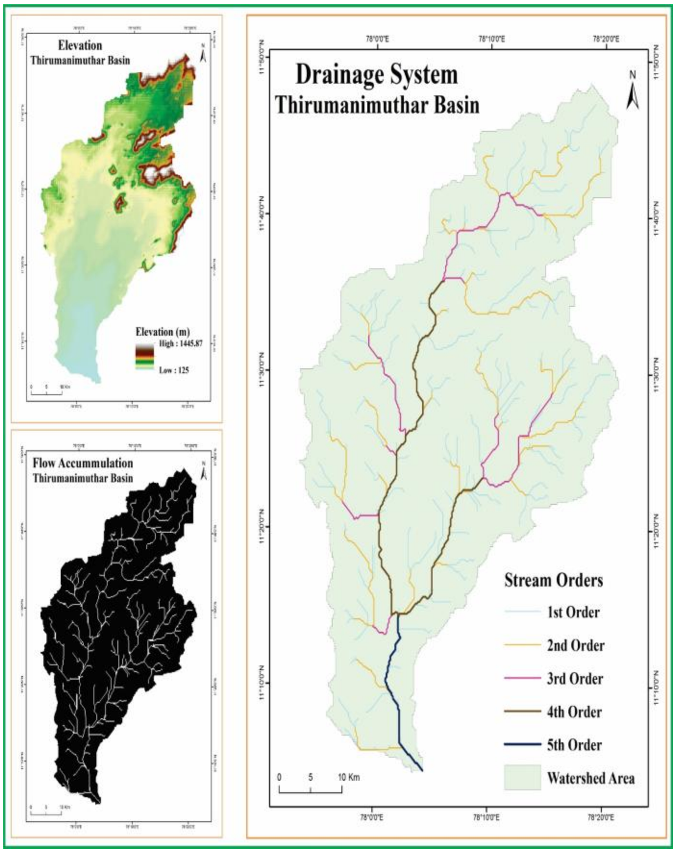
Before the invention of computers and GIS technology, the basin characteristics were found through the topographic maps using conventional methods (Christopher et al., 2010), but these were found to be time consuming and difficult, particularly for large areas. Recently, Satellite Remote Sensing with its synoptic view coupled with GIS has evolved as unique tool for quantitative description of watershed / drainage basins (Chakraborty D, Dutta D and Chandrasekharan H, 2002). The development of sophisticated spatial analysis tools in GIS made several researchers to adopt it for the study of basin characteristic (Javed A, Khanday M Y, and Ahmed R, 2009).

As the detailed study of basin is necessary for the development of a region. The present study concentrated on the Thirumanimuthar basin in the Tamil Nadu for the identification of morphometric and hypsometric characteristics, that can be helpful for the development activities of the basin in the future. The Thirumanimuthar is one of the tributaries of river Cauvery, that flows from Northeastern direction to Southwestern direction (Vijayakumar N, 2014). The anthropogenic disturbance on the nature had been witnessed in the basin recently (Vijayakumar N, et al., 2015) retrieved that, shrub land, deciduous forests, agriculture, fallow, water bodies and plantation were converted into built up between the year 1992 and 2010. The study conducted by the Central Pollution Control Board, India 2015, states that, the stretch of the river between Salem and Papparapatti is polluted that is not complying with water quality criteria. The river once served as a major source for groundwater recharge in Salem and Namakkal districts. However, due to encroachment of waterways and pollution, it is one of the most polluted rivers in the State of Tamil Nadu (Saravanan, 2015) Hence the result of present study will be helpful for the understanding of the basin characters and its management activities.

STUDY AREA

The area of basin can be delineated manually from the topographical map by connecting the high elevated points on the region (USDA), as well as the remotely sensed elevation data (SRTM, ASTER, CartoSAT) also can be used to delineated the basin area using GIS (Dwivedi, 2011; Rudraiah m, et al., 2008), which would reduce the time as well as man power. The present study has been used SRTM elevation data to delineate the area of Thirumanimuthar basin using ArcGIS spatial tools. The total area covered by basin is 2186.72 Km^2, that spreads over three districts of Tamil Nadu and contains 11 taluks (Fig: 1).





The study area is bounded by many wavy hills and undulated terrain characterised with archean rocks (Vijayakumar N, et al., 2015). The elevation of study area ranges between 1446 meters to 125 meters, by looking at the prepared digital elevation model of the basin, it is clear that, Northeastern part of basin is having higher elevation while southern part is having lower elevation and the elevation degrease gently from the Northeast to south. The average annual rainfall is about 852 mm (Thirunavukkarasu A, et al., 2015).

METHODOLOGY

The study is fully based on the secondary source that collected from concern department and from the authorized websites. The elevation data is the base for the delineation of basin as well as for the identification of streams in it. Therefore, the SRTM contours elevation data of the basin has been downloaded from www.opendem.com. Further the downloaded contours have been used to prepare the digital elevation model of basin, from which morphometric and hypsometric characteristics of basin have been calculated. The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin and slope contribution (Rudraiah m, et al., 2008), the formulas used for the analysis of each characteristic of basin given in table 1. The hypsometric analysis is carried out through the hypsometric curve and hypsometric integral. To identify the hypsometric properties of basin, the tool called Hypsometry developed by Jerry Davis has been used in ArcGIS environment.

RESULTS AND DISCUSSION

LINEAR ASPECTS

The linear aspects of drainage basin's morphometric are stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

Stream Order

There are several methods have been suggested for the classification of stream orders, notably, Gravelius, 1914; Horton, 1945; Panov, 1948; Strahler, 1952; Leopold and Miller, 1956; Schumm, 1956; Rzhanitsyn, 1960; Hirsch, 1962; and Shrew, 1966, have proposed different methods and each method of classification has merits and demerits in one or other manner (Ion Zavoianu, 1985). Among the several methods Strahler's (1952) method has been accepted widely and applied for several regions in the world (Ion Zavoianu, 1985). Therefore the study also followed Strahler's method for the classification of streams, Strahler defines, the stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, the intersection of two second-order links will create a third-order link, and so on. The intersection of two links of different orders, however, will not result in an increase in order (ESRI 10.3 help).

The classification streams in the basin retrieved that, the basin consists of totally 203 streams among which 160 is belong to 1^{st} order, 32 is 2^{nd} order, 8 is 3^{rd} order, 2 is 4^{th} order and 1 is 5^{th} order. The irregular branching in all directions with the tributaries joining the streams at all angles in the basin confirms that, the drainage pattern of Thirumanimuthar is dendritic (Emilie R. Zernitz, 1932).

Stream Length

Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics (Christopher, et al., 2010). Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases (Chitra C, et al., 2011). The length of streams in each order has been calculated using the GIS. The calculation shows that, the length of total streams in the basin is 807.90 km, among which 422.90 km is belong to 1^{st} order, 200.74 km is 2^{nd} order, 87.43 km is 3^{rd} order, 74.90 km is 4^{th} order and 21.94 is 5^{th} order.

Mean Stream Length

The mean stream length of a channel is the characteristic size of drainage network components and its contributing basin surface. It is calculated by dividing the total stream length of order "u" by the number of stream of segments in the order (Ramu, et al., 2013). Basins with relatively smaller lengths specifies the larger slopes and finer textures and the longer lengths of streams are generally indicative of flatter gradients (Doad A P, et al., 2012). The mean stream length of each orders gives the clear idea than the total stream length of each orders to identify the structural process in the basin. The result shows that, the mean stream length of 1^{st} order is 2.64 km, 2^{nd} is 6.27 km, 3^{rd} is 10.93 km, 4^{th} is 37.45 km and 5^{th} is 21.94 km. The smaller the stream length is being presented in lower stream orders, that indicates the areas are belongs to larger slopes and finer textures, while longer the stream length is being presented in higher stream orders, that indicates the areas are belong to flatter gradients.

Stream Length Ratio

Horton (1945) proposed the factor length ratio, which is the ratio of the mean length of a stream if any given order to the mean length of a stream of the next lower order, based on the fact that mean length of a stream of any given order is always greater than the mean length of a stream of the next lower order (Sethupathi A S, et al., 2011). The stream length ratio of present study is 0.47 for 2^{nd} order, 0.44 for 3^{rd} order, 0.86 for 4^{th} order and 0.29 for 5^{th} order. The variation of stream length ratio between stream orders represents the late youth to mature stage of geomorphic development (Liaqat et al., 2011).

Bifurcation Ratio

The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumn, 1956). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment except where the powerful geological control dominates (Sethupathi A S, et al., 2011). The differences in bifurcation ratio values can be attributed to geological and lithological development of the drainage basin. Higher bifurcation ratio values indicate for a strong structural control in the drainage pattern, whereas the lower values indicate that the sub-basins are less affected by the structural disturbances (Strahler, 1964). The analysis result of bifurcation ratio of basin represents the value of 5 for 1st order, 4 for 2nd and 3rd order, 2 for 4th order. From this is clear that, the lower stream order areas are having strong structural control than higher stream order areas.

RELIEF ASPECT

The relief aspects are determined by relief ratio, and ruggedness number.

Relief Ratio

Difference in the elevation between the highest point of a basin (on the main divide) and the lowest point on the valley floor is known as the total relief of the river basin (Mahadevaswamy G, et al., 2011). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by Schumm who found that sediments loose per unit area is closely correlated with relief ratios (Pareta and Pareta, 2011). The relief ratio normally decreases with the increasing area and size of sub-basin of a given drainage basin (Gottschalk, 1964). The relief ratio of Thirumanimuthar is 13.84.

Ruggedness Number

The ruggedness number is calculated by multiplying the basin relief with the density of drainage, where both parameters are in same unit. The ruggedness values indicate the slope steepness and its length (Sarmah and Tiwari, 2012). High values of ruggedness number occurs when both variables are large, when slope is not only steep but long as well (Strahler, 1958). The present studies ruggedness value is 0.49, that indicates the gentle slope.

AERIAL ASPECT

The aerial aspects of basin are including drainage density, drainage texture, stream frequency, circularity ratio, elongation ratio and length of overland flow.

Drainage Density

It is a measure of the length of stream per unit in the basin, it is significant point in the linear scale of landform elements in stream-eroded topography and does not change regularly with orders within the basin (Lakshmamma, et al., 2011). Horton has introduced drainage density as an expression to indicate the closeness of spacing of channels (Panhalkar S S, et al., 2012). The significance of drainage density is recognized as a factor determining the time travel by water (Schumm, 1956). The drainage density of Thirumanimuthar is 0.37 km^2.

Stream Frequency

Horton introduced stream frequency as the number of stream segments per unit area. It is obtained by dividing the total number of streams of all orders by the total drainage basin area, stream frequency is related to permeability, infiltration capacity and relief of a basin (Chitra C, et al., 2011). Hopefully, it is possible to have basins of same drainage density differing stream frequency and basins of the same stream frequency differing in drainage density (Das A, et al., 2012). The stream frequency of present study is 0.09 per square km. The value of stream frequency for the basin exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density.

Texture Ratio

The texture ratio is dependent on the underlying lithology, infiltration capacity and relief aspect of the terrain (Zende A M and Nagrajan R, 2011). Texture ratio can be considered as indices of erosion intensity (Morgan, 1986). High values of texture ratio indicate high runoff and erosion potential of the basin area (Chakraborty D, Dutta D and Chandrasekharan H, 2002). The present study's texture ratio is 0.47, which is an average value. This average value clearly indicates a moderate runoff from the area.

Circulatory Ratio

Circularity ratio is the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate and slope of the basin (Javed A, Khanday M Y, and Ahmed R, 2009). It is a significant ratio, which indicates the dendritic stage of a basin. Its low, medium and high values are indicative of the youth, mature and old stages of the life cycle of the tributary basins (Sreedevi P D, et al., 2004). The circularity ratio of Thirumanimuthar is 0.24, that indicates youth stages of the life cycle of the tributary basins.

Elongation Ratio

Elongation ratio represents how close a basin to a rectangular shape (Koshak N and Dawod G, 2011). It is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. It is a very significant index in the analysis of the basin shape which helps to give idea about the hydrological character of a drainage basin (Nongkynrih and Husain, 2011). Values near to 1.0 are typical of regions of very low relief whereas the values 0.6 to 0.8 are usually associated with the high relief and steep ground slope (Strahler, 1964). These value can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9 to 0.8), (c) elongated (<0.7) (Jasrotia A S, Kumar A, Aasim M, 2012). The elongation ratio of Thirumanimuthar basin is 0.24 and it clearly states that, the basin is having elongated shape.

Length of Overland Flow

Measurements and statistical analysis of stream's overland flow length is most commonly used attributes (Nag S K and Lahiri A, 2011). The length of overland flow approximately equals to half of reciprocal of drainage density (Horton, 1945). It is the length of water over the ground before it gets concentrated into definite stream channels. This factor basically relates inversely to the average slope of the channel and is quite synonymous with the length of the sheet flow to the large degree (Rudraiah m, et al., 2008). The length of overland flow approximately equal to the half of the reciprocal of drainage density. This factor basically relates inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree (Dwivedi, 2011). Generally higher value of length of overland flow is indicative of low relief and whereas low value of length of overland flow is an indicative of high relief (Kanth and Hassan, 2012). The length of overland flow of Thirumanimuthar basin is 0.18, the result states that, the basin lies on high relief.

Constant Channel Maintenance

The constant indicates the number of Kms^2 of basin surface required to develop and sustain a channel 1 Km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957). Channel maintenance constant of the watershed is 2.71 Kms^2/Km.

Hypsometry Integral

The hypsometric integral value is between 0 to 1, it gives a hypsometric integral which is defined as the proportion lying below the curve to the total square graph, if the result value is between 0.6 and 1.0; it indicates the youthful state of dissection; if the result value is between 0.35 and 0.60, it indicates a maturedly dissected landform; and if the result is less than 0.35, then it indicates an equilibrium or old state of dissection (Ramu and Mahalingam, 2012). The calculated integral value for Thirumanimuthar shows the value of 0.12, it indicates an equilibrium or old state of dissection.

Hypsometry Curve

The hypsometric curve of a catchment represents the relative area below (or above) a given altitude (Strahler, 1952). The hypsometric curve has been termed the drainage basin relief graph and it is an important indicator of watershed conditions (Sharma S K et al., 2013). A hypsometric curve is essentially a graph that shows the proportion of land area that exists at various elevations by plotting relative area against relative height. These curves have been used to infer the stage of development of the drainage network also it is a powerful tool to differentiate between tectonically active and inactive areas (Keller and Pinter,1996). The curve is created by plotting the proportion of total basin height against the proportion of total basin area. Convex hypsometric curves characterize young slightly eroded regions; 'S' shaped curves characterize moderately eroded regions; concave curves point to old, highly eroded regions (Sarpa G, Toprak V and Duzgun S, 2001). The result of Thirumanimuthar hypsometric curve represents (fig:) the basin belongs to old stage.

CONCLUSION

The present study conducted to analysis the morphometric and hypsometric properties of Thirumanimuthar basin in Tamil Nadu. The morphometric analysis has done using linear, aerial and relief characteristics of the basin. The result of morphometric analysis retrieved that, 5^{th} order id the higher stream order of the basin and the number streams in each decrease while the stream order increasing. The structure of stream shows it is a dendritic pattern. The stream length calculation depicts, lower stream order areas belong to larger slopes and finer textures, while higher stream orders belong to the areas are flatter gradients. The bifurcation ratio represents the lower stream order areas are having strong structural control than higher stream order areas. The ruggedness value indicates the basin is gentle slope. The elongated ration result represents that; the basin's shape is elongated. The length of overland flow depicts the basin lies on high relief. The value of hypsometric integral depicts the basin is in equilibrium or old state of dissection and the hypsometric curve denotes the basin belongs to old stage. The result of this study would be helpful to understand the nature of basin and also it can be used as an input parameter for the future development activities in the Thirumanimuthar basin.

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Table: 2a Results of Morphometric Analysis

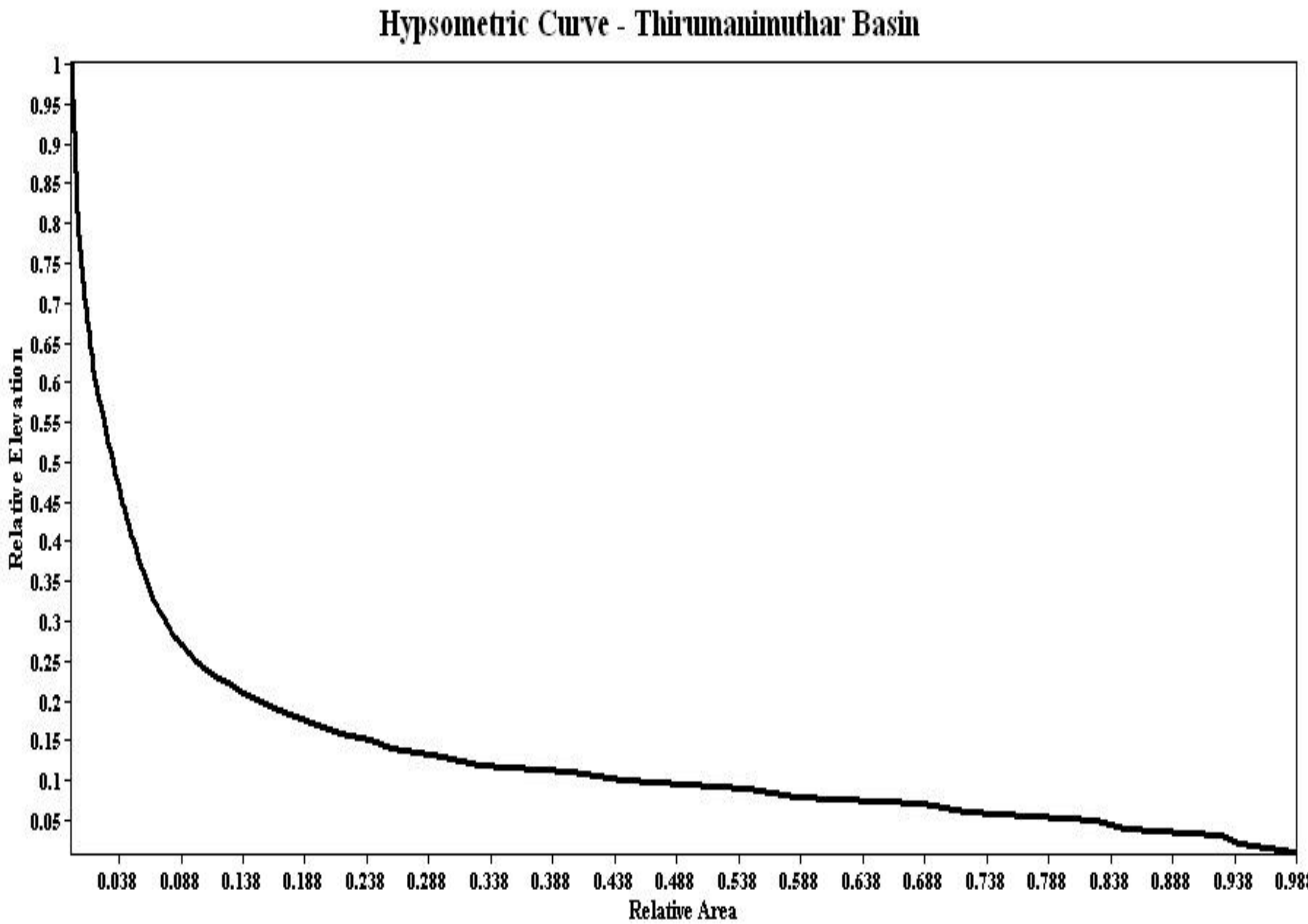
Stream Order	Number of Streams	Length of Streams (Km)	Bifurcation Ratio	Mean stream length	Stream length ratio
1st	160	422.90	5	2.64	-
2nd	32	200.74	4	6.27	0.47
3rd	8	87.43	4	10.93	0.44
4th	2	74.90	2	37.45	0.86
5th	1	21.94	-	21.94	0.29

Table:1 Methods of Calculating Morphometric parameters of Drainage basin

	Morphometric Parameters	Methods	References
LINEAR	Stream order (U)	Hierarchical order	Strahler, 1964
	Stream length (L_u)	Length of the stream	Horton, 1945
	Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$ where, L_u=Stream length of order 'U', N_u=Total number of stream segments of order 'U'	Horton, 1945
	Stream length ratio (R_L)	$R_L=L_u/L_{u-1}$; where L_u=Total stream length of order 'U', L_{u-1}=Stream length of next lower order.	Horton, 1945
	Bifurcation ratio (R_b)	$R_b = N_u/ N_{u+1}$; where, N_u=Total number of stream segment of order'u'; N_{u+1}=Number of segment of next higher order	Schumn,1956
RELIEF	Basin relief (B_h)	Vertical distance between the lowest and highest points of watershed.	Schumn, 1956
	Relief ratio (R_h)	$R_h=B_h/L_b$; Where, B_h=Basin relief;L_b=Basin length	Schumn, 1956
	Ruggedness number (R_n)	$R_n= B_h \times D_d$ Where, B_h =Basin relief; D_d=Drainage density	Schumn, 1956
ARIAL	Drainage density (D_d)	D_d = L/A where, L=Total length of streams;A=Area of watershed	Horton, 1945
	Stream frequency (F_s)	F_s = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1945
	Texture ratio (T)	T = N1/P where,N1=Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor (R_f)	$R_f=A/(L_b)$ 2;where, A=Area of watershed, L_b=Basin length	Horton, 1932
	Circulatory ratio (R_c)	R_c=4πA/P2 ;where, A=Area of watershed, π=3.14, P=Perimeter of watershed	Miller, 1953
	Elongation ratio (R_e)	$R_e=2\sqrt{(A/\pi)}/L_b$;where, A=Area of watershed, π=3.14, L_b=Basin length	Schumn,1956
	Length of overland flow (L_g)	$L_g = 1/2D_d$ where,D_d=Drainage density	Horton, 1945
	Constant channel maintenance (C)	Lof = $1/D_d$ where, D_d=Drainage density	Horton, 1945

Table: 2b Results of Morphometric Analysis

Basin relief (m)	1320.87
Relief ratio	13.84
Ruggedness number	0.49
Basin Length (Km)	95.46
Area of Watershed (Km2)	2186.72
Perimeter of Basin (Km)	338
Total Length of Streams (Km)	807.90
Total Number of Streams	203
Drainage Density (Km2)	0.37
Stream frequency (Per Km2)	0.09
Texture ratio	0.47
Circulatory ratio	0.24
Elongation ratio	0.28
Length of overland flow	0.18
Constant channel maintenance	2.71
Dissection index	0.91


Hypsometric Curve - Thirumanimuthar Basin
Relative Elevation
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.038
0.088
0.138
0.188
0.238
0.288
0.338
0.388
0.438
0.488
0.538
0.588
0.638
0.688
0.738
0.788
0.838
0.888
0.938
0.988
Relative Area