*Int.J.Curr.Microbiol.App.Sci* (2018) *7*(9): 1245-1260

International Journal of Current Microbiology and Applied Sciences
*ISSN: 2319-7706* **Volume 7 Number 09 (2018)**
Journal homepage: http://www.ijcmas.com

**Original Research Article** https://doi.org/10.20546/ijcmas.2018.709.149

# Determination of the Geomorphologic Parameters of the Thuthapuzha River Basin in Central Kerala, India, Using GIS and Remote Sensing

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**Keywords**

GIS, Geomorphologic parameters, Thuthapuzha River basin

**Article Info**

***Accepted:***
08 August 2018
***Available Online:***
10 September 2018

**A B S T R A C T**

The morphometric analysis of the Thuthapuzha river basin using GIS gives a platform for deriving the geomorphological parameters. This Kerala river basin has dendritic type of drainage network with an elongated basin. The elongated basin is described by shape parameters such as form factor, shape factor, circulatory ratio, and elongation ratio. Lower stream frequency reveals that this basin has less structural disturbance as a result of high surface runoff and fast stream flow. Drainage texture is found to be 10.5 which reveals that the intensity of the stream network is finer indicating that the surface runoff is more. The average bifurcation ratio and stream frequency is found to be 1.83 and 2.4 respectively which describe the stream characteristics. The length of overland flow in the study area is 0.342 which shows that stream erosion is more predominant than sheet erosion in the catchment. The basin is having a ruggedness number of 3.402 which exhibits higher stream velocity, hence Thuthapuzha river basin is prone to soil erosion.

## Introduction

India is vast country with abundant natural resources. Land and water are the two most important natural resources. Rivers are primary sources for surface water. Due to the interaction between land and water, the flow characteristics will also change spatially and temporally along the flow path of water. The flow in river is primarily influenced by land surface features and rainfall. The surface features and processes associated with surface features can be better understood by the study called geomorphology (Worcester, 1948). The surface features include rivers, mountains, beaches, sand dunes etc. and these surface features influence the hydrologic response from the river basin. Since hydrologic response (discharge) is associated with surface features then, it can be better understood by the study of hydro-geomorphology (Scheidegger, 1976).

The analysis which is useful for the better understanding of geomorphology is done by geomorphometry and analysis is conducted to derive landform parameters (Pike *et al.*, 1995). The landform parameters also called as geomorphological parameters are derived from mathematical equation (Mark, 2004). Geomorphic parameters can be defined as the stream network, surrounding landscape and topography, which translate the input rainfall into runoff (Jarrar *et al.,* 2015). First step to derive geomorphological parameters is to compute the morphological parameters and then geomorphological parameters are derived by mathematical equations (Bhat *et al.,* 2015). Geomorphological parameter is attributes which have direct impact on floods, hydrologic regime, land use, soil erosion, and peak flow.

## Study area

The Thuthapuzha River basin located in the central part of Kerala, India has been selected for this study. Thuthapuzha is a tributary of Bharathapuzha river, one of India's medium rivers which is flowing towards west and reaches Arabian Sea at Ponnani. The total catchment area of the river basin is about 5,397 $km^2$ in which 1593 $km^2$ area lies in Tamil Nadu and remaining area lies in Kerala and the river flow is strongly influenced by south west monsoon. This river valley is the lifeline for water for almost one-eighth of Kerala's population residing in the districts of Malappuram, Thrissur, and Palakkad. Thuthapuzha River is one of the main tributary of Bharathapuzha which lies between $10^{\circ}$ $50^{1}$ to $11^{\circ}15^{1}$North latitude and $76^{\circ}$ $5^{1}$ to $76^{\circ}40^{1}$East longitude.

## Materials and Methods

First step to derive geomorphological parameters is to compute the morphological parameters and then geomorphological parameters are derived by mathematical equations. Computation of morphological parameters can be done from Digital elevation model (DEM) with the help of GIS software like ArcGIS. For the present study,Cartosat-1: DEM - Version-3R1 1 arc sec (~ 32 m) resolution was downloaded from ISRO, National Remote Sensing Centre's (NRSC), India Geo-platform Bhuvan website.

The morphometric parameters of sub basin such as the number of stream segments, stream order, drainage pattern, sub basin length, perimeter, and area were delineated from this DEM within the GIS environment. These parameters are further used in computing the geomorphological parameters such as drainage density, form factor, length of overland flow, circulatory ratio etc. using mathematical equations. The extraction of stream network and watershed parameters can be done under separate categories. The flow chart for the morphometric analysis in ArcGIS is given figure 1 and 3.

All measurement of morphometric parameters are obtained in the attribute table of the vector layer. The parameters required for deriving geomorphological parameters are number of streams of order u ($N_u$), stream length of order u ($N_l$), area of the basin (A), perimeter of the basin (P), main channel length (L), maximum elevation ($E_{max}$) and minimum elevation ($E_{min}$).

## Geomorphological parameters

Geomorphological parameters are landform equations which can be considered to reflect the surface roughness. In this study 14 parameters are identified and derived using morphometric analysis. All the parameters are categorized under four aspect: drainage network, basin geometry, drainage parameters, and relief parameters using defined mathematical equations. Drainage network parameters include bifurcation ratio, stream frequency, and stream length ratio.

Basin geometry include elongation ratio, circulatory ratio, shape factor, form factor etc. In the drainage texture category drainage density, drainage texture, infiltration number, length of overland flow, and constant of channel maintenance are considered. In case of the relief category basin relief, relief ratio, and ruggedness number are derived and each of these parameters are discussed below.

**Drainage network aspect**

The drainage network aspect includes parameters which influence the transport of water and sediments through a single outlet. The geomorphologic parameters related to Drainage network aspect are:

**Bifurcation ratio ($B_r$)**

The bifurcation ratio is calculated from the ratio of number of streams (Nu) in a given order to the number of streams (Nu+1) in the next higher order. The high variations of bifurcation ratio in the different types of land forms indicate the formation of stream segments by the continuous runoff forces on the geological structure

**Stream frequency ($S_f$)**

Stream frequency is the total number of stream segments with all orders per unit area. It is also called as channel frequency. Stream frequency indicates that the origin and development of stream in the sub-basin and that is directly depend on lithological characteristics

**Basin geometry**

Basin geometry involves the parameters which describe the shape of the river basin and it is two dimensional. The parameters are

**Form factor (F)**

Form factor is the important parameter which describes the shape of the basin and it is defined as the ratio of the area of sub-basin to the square of the main channel length (length of the basin). The value varies from 0 to 1. The lower value indicates that the river basin is elongated and higher value indicates that the basin is circular.

**Elongation ratio ($E_l$)**

It describes the shape parameter of the basin and this value indicates infiltration capacity along the stream flow path. Elongation ratio is the ratio of diameter of the circle having equal area to the sub-basin and the maximum length of the sub-basin. The value 0.9 to 0.8 indicates basin is circular, if it is 0.8 to 0.7 then it is oval and if it is less than 0.7 then basin is elongated.

**Shape factor(S)**

Shape factor is the ratio of square of the main channel length to basin area and describe the basin as circular, rectangular or triangular. This parameter has direct impact on the size of peak discharge and the time of concentration.

**Circulatory ratio ($C_r$)**

It represents shape characteristics of the sub basin. Circulatory ratio is defined as ratio of the area of sub-basin to the area of a circle having circumference equal to the perimeter of the sub-basin. It indicates the stage of dissection within the basin and mainly influenced by lithological characteristics of the basin. The low, medium and high values of the circulatory ratio are indications of the youth, mature and old stages of the life cycle of the tributary basins.

**Drainage parameters**

Drainage parameters include the frequency, density and intensity of the drainage network.

**Drainage density ($D_d$)**

Drainage density is defined as the ratio of total length of streams in all orders to the area of the basin. It describes the drainage characteristics of the basin. Drainage density identifies the distribution of stream segments, number of stream segments, climate, and topography.

**Drainage texture ($D_t$)**

Drainage texture is total number of stream segments of all orders per perimeter of that area and it is important parameter in the field of geomorphology which describe the spacing of drainage lines.

**Infiltration number ($I_n$)**

Infiltration number of the basin is defined as the product of drainage density and channel (stream) frequency. This parameter gives idea about infiltration characteristic of the river basin and higher values of infiltration number gives lower infiltration.

**Length of overland flow ($L_f$)**

Length of overland flow is half of the reciprocal of drainage density and it defines the length of flow path projected to the horizontal of the non-channel flow. It depends on the hydrologic and physiographic condition of the basin. It inversely related to slope hence higher value of length of overland flow indicates more of stream erosion.

**Constant of channel maintenance ($C_c$)**

Constant of channel maintenance is inverse of the drainage density and it is the property of landforms. It indicates the relative size of the landforms and higher value indicates least erodible and vice versa.

**Relief parameters**

Drainage network, and basin geometry are one and two dimension parameters but in case of relief parameters, it is the three dimension parameters. By measuring the elevation of each stream segment to the point where it joins the higher order stream and dividing the total by the number of streams of that order, it is possible to obtain the average elevation (vertical fall). The parameters involved with relief aspect are:

**Basin relief ($R_b$)**

Basin relief is defined as the elevation difference between highest elevations in the basin to the lowest elevation within the basin. More value of basin relief indicates lesser time to flow accumulation.

**Relief ratio ($R_r$)**

Relief ratio is defined as the ratio of maximum relief to main channel length (horizontal distance along the longest dimension of the sub-basin parallel to the principal drainage line). It describes steepness of relief in the basin.

**Ruggedness number ($R_n$)**

Ruggedness number is defined as the product of the maximum basin relief and drainage density. Since it depends on slope and drainage density, lower value of ruggedness number indicates lower stream flow velocity which implies less prone to soil erosion.

## Results and Discussion

**Morphometric evaluation of Thuthapuzha sub-basin**

The morphometric parameters were measured quantitatively. The morphometric data are obtained with the help of attribute data. From that attribute data basin having area of 1005 $Km^2$ with a perimeter of 240 Km. Length of the main channel is about 99.64 Km are obtained. The streams in the basin exhibits dendritic in nature which means the basin having many streams which are then joined which is called the tributaries of the river and this nature of drainage pattern develop where river channel follows slope of the terrain. The streams of different orders are shown in figure 3.

### Stream number ($N_u$) and stream order (U)

The stream order is defined as the origin of streams and the interconnections among them. It is useful to understand the stream shape, size, length, width and discharge amount of the streams. In this study, the stream order was classified according to Strahler's ordering system (Strahler 1964). Based on this ordering system, the sub-basin area having six orders of streams.

Small, narrow streams designated as first-order stream, the total number of which obtained from morphometric analysis is 1216. The second order streams in this sub basin are about 567. The sub-basin consists of six orders of streams with a total of 2414 stream segments in all orders. Out of these, the first stream order was found in larger numbers than the next hierarchical orders except sixth order, revealing that the terrain obviously had steep slope and short flow length in nature. The number of streams with order is given table 2

### Stream length ($S_L$)

The length of the stream in the sub-basin area was measured from the attribute data table of the stream order layer. Stream length is a direct indicative factor to measure the drainage density and the contributing area of runoff in the sub-basin. The total length of streams in all hierarchical order is 1469.52 Km. Among them, stream segments in the first order occupied a length of 778.29 Km and the second order about 334.79 Km. The stream lengths of all order are given in Table 2

### Length of the main channel (L)

The main channel is the longest drainage line from the outflow point to the upper limit of the catchment area. This has been measured from the flow length layer and the value is 99.64 Km.

### Slope of Thuthapuzha river basin

Slope is an important parameter to determine the morphometric characteristics of the catchment. This represents the topographical surface with its degree of inclination with respect to a horizontal plain surface. The slope range of this sub-basin is estimated from 0 to 67.52%. It is observed that the slope faces down in a southerly direction; however, the ridged structural hills in the northern parts consist multi-faceted slope directions. The spatial variation of consequent slope gradients has direct influences on the runoff and denudation activities in the sub-basin area. The slope map of Thuthapuzha River is shown in figure 4.

### Aspect map of Thuthapuzha river basin

Aspect refers to the horizontal direction to which a slope of the surface faces. The aspect of the surface can influence significantly the local climate. This is because of the interaction of the angle of the sun's rays with the slope surface. The output raster map shows the compass direction of the aspect with ranges from $0^0$ to $360^0$, in which the value $0^0$ is for true north and a $90^0$aspect is to the east, whereas $180^0$ is to the south and so on. The visual interpretation of the aspect map reveals that the western parts have noticed with easterly and north-easterly aspect. Moreover, the northern hilly terrain and eastern parts have found with westerly and south-westerly aspect, this west facing slope surface has strong effect on weathering, drainage network flow and distribution of natural vegetation.

Aspect map of Thuthapuzha river basin is shown in figure 5.

## Hill-shade

Hill-shade represents the 3D representation of surface and its just indication of mountain ridges and slopes. The map is generated up to azimuthal $315^0$ and altitude from $0^0$ to $90^0$. In this study the Hill-shade is obtained at a maximum azimuth of $254^0$. The Hill-shade of the Thuthapuzha river basin is shown in figure 6.

The parameters required for deriving geomorphological parameters are derived from morphometric parameters. The parameters are number of streams of order u ($N_u$), stream length of order u ($S_L$), area of the basin (A), perimeter of the basin (P), main channel length (L), maximum elevation ($E_{max}$) and minimum elevation ($E_{min}$) are used for computing geomorphological parameters.

## Geomorphologic parameter of thuthapuzha river basin

The geomorphological parameter of a basin or watershed are the parameter which represent the physical and morphological attribute that will contribute to the runoff. In this study 14 parameters are identified and derived using morphometric analysis. The entire river basin is divided into 19 Micro-watersheds as shown in figure 7 and among the 19 Micro-watersheds number 9 and 11 there is no streams present in the area and the area is also less than 1 $Km^2$. So except from these two Micro-watershed, geomorphologic parameters are derived for 17 Micro-watersheds. GIS software is used for deriving the parameters.

All the parameters are computed performed under four aspect: Drainage network, basin geometry, drainage and relief parameters using defined mathematical equations. All the parameters are discussed below

## Drainage network parameters

The Drainage network aspect includes parameters which transport water and sediments through single outlet. The geomorphologic parameters are

## Bifurcation ratio ($B_r$)

The bifurcation ratio was calculated from the ratio of number of streams ($N_u$) in a given order to the number of streams ($N_{u+1}$) in the next higher order and the value will varies from 0.66 to 2.78 for whole river basin with an average mean bifurcation ratio is 1.83. The higher ratio values have been calculated between the stream orders such as fourth and fifth order; second and third; first and second and the values are 2.78, 2.25 and 2.17 respectively. These lower values of bifurcation ratio indicate that continuous runoff characteristics with less structural disturbance and hence runoff is not affected by geological condition. Bifurcation ratio for Micro-watersheds ranges from 1.61 to 2.94.

## Channel frequency/stream frequency ($S_f$)

Stream frequency is given by the total number of stream segment of all orders per unit area. In the present study area, the stream frequency is obtained as 2.40 $Km/Km^2$. Lower value indicates stream frequency has fewer structural disturbances hence it causes a high rate of surface runoff and fast stream flow from the higher-order streams. This condition also takes place in the area where a large amount of sediment has been eroded from the weathered rocky surface. Stream frequency for Micro-watersheds ranges from 1.775 to 3.262.

## Basin geometry

Basin geometry involves the parameters which describe the shape of the river basin and it is two dimensional. The parameters are

**Fig.1** Flow chart for morphometric analysis

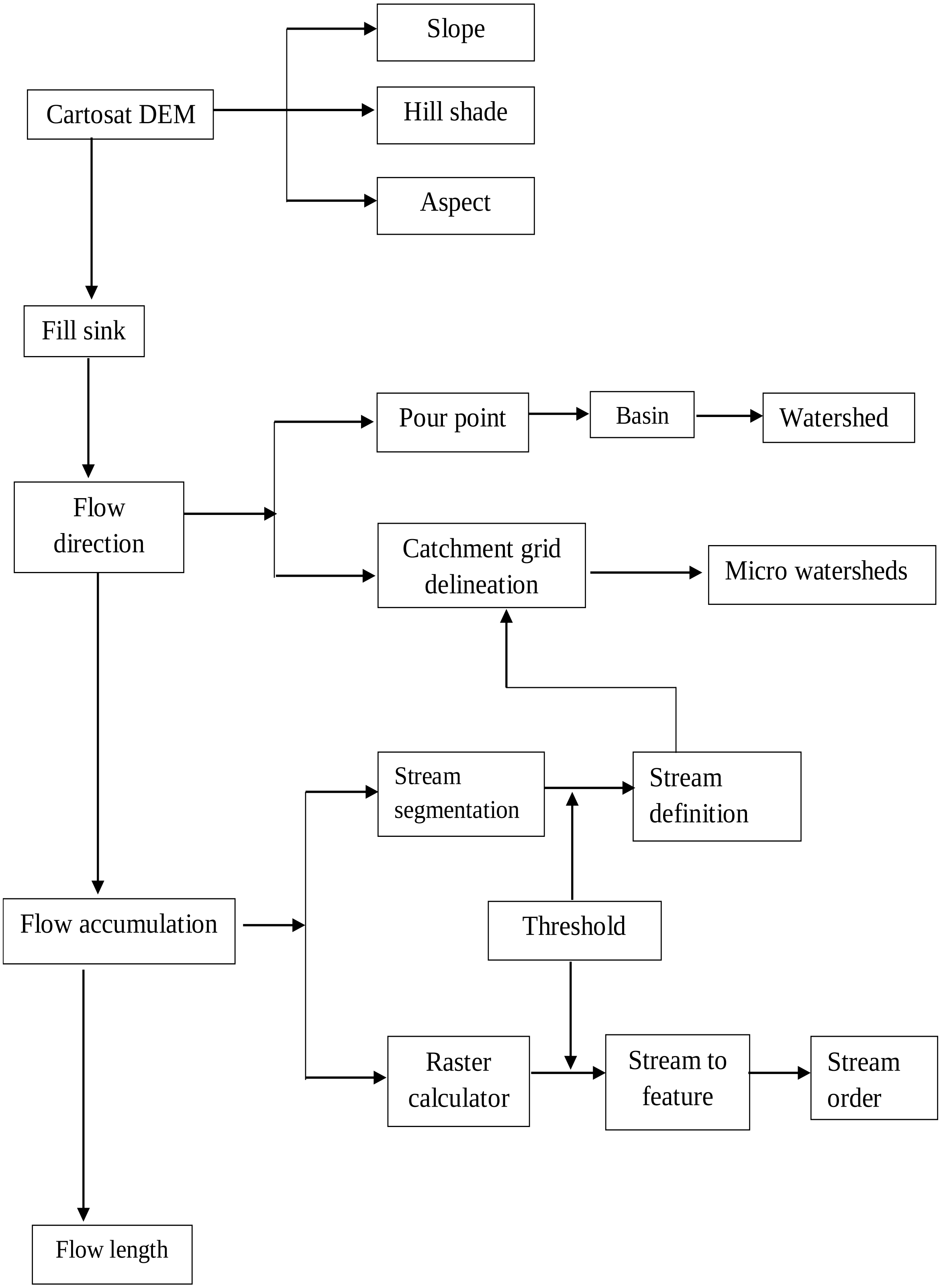

**Fig.2** DEM of Thuthapuzha river sub basin

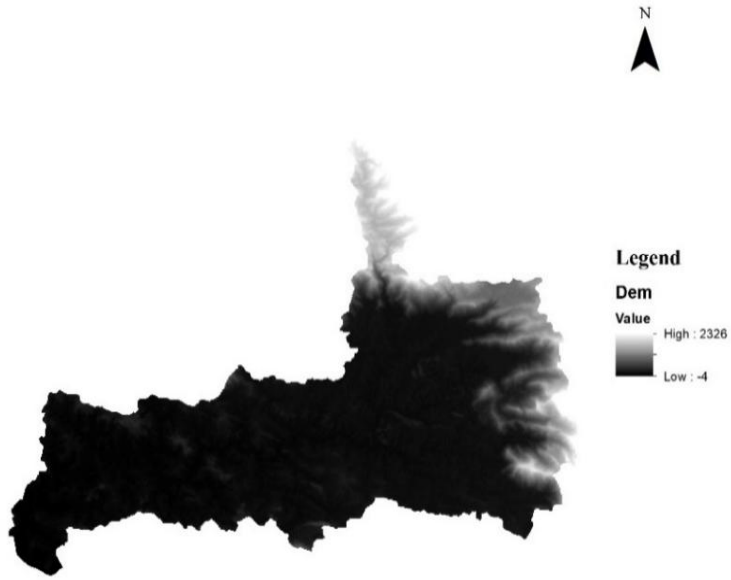


**Fig.3** Stream order map of the Thuthapuzha river basin

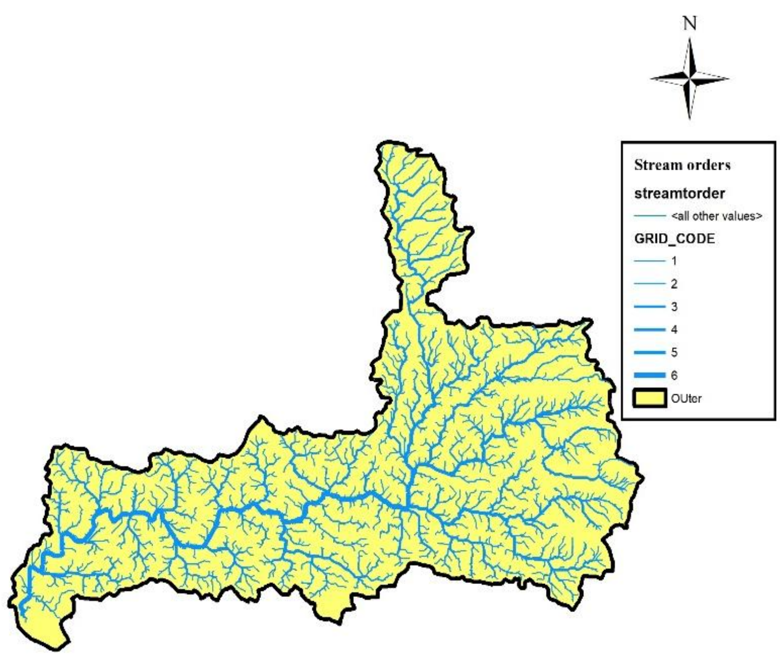

**Fig.4** Slope map of Thuthapuzha river basin

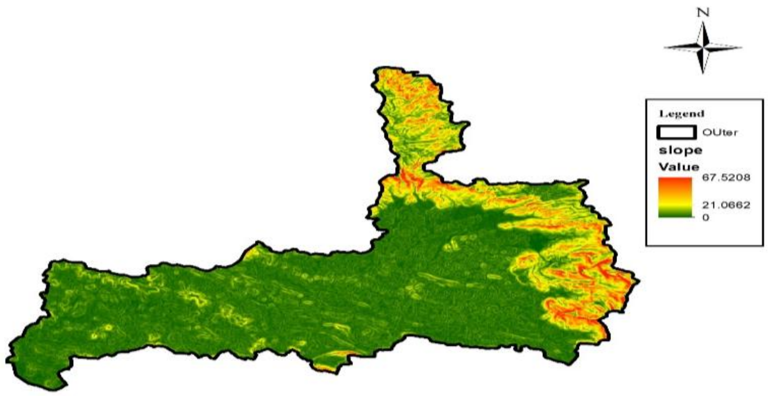


**Fig.5** Aspect map of Thuthapuzha river basin

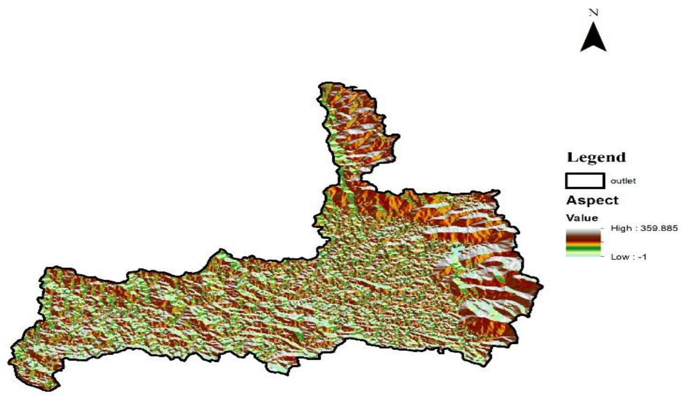


**Fig.6** Hill-shade map of the Thuthapuzha river basin

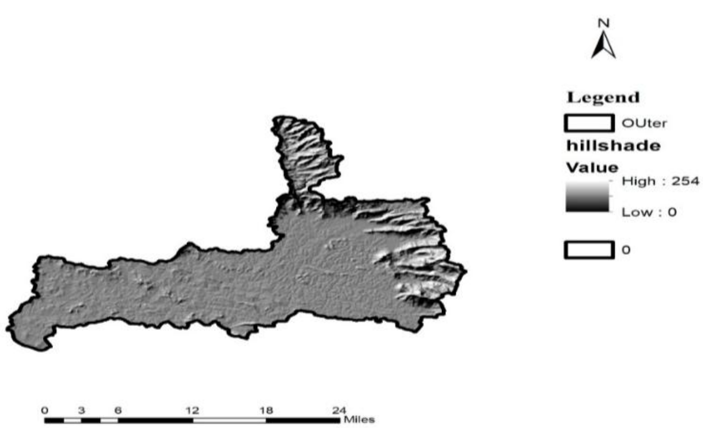

**Fig.7** Micro-watersheds map of the Thuthapuzha river basin

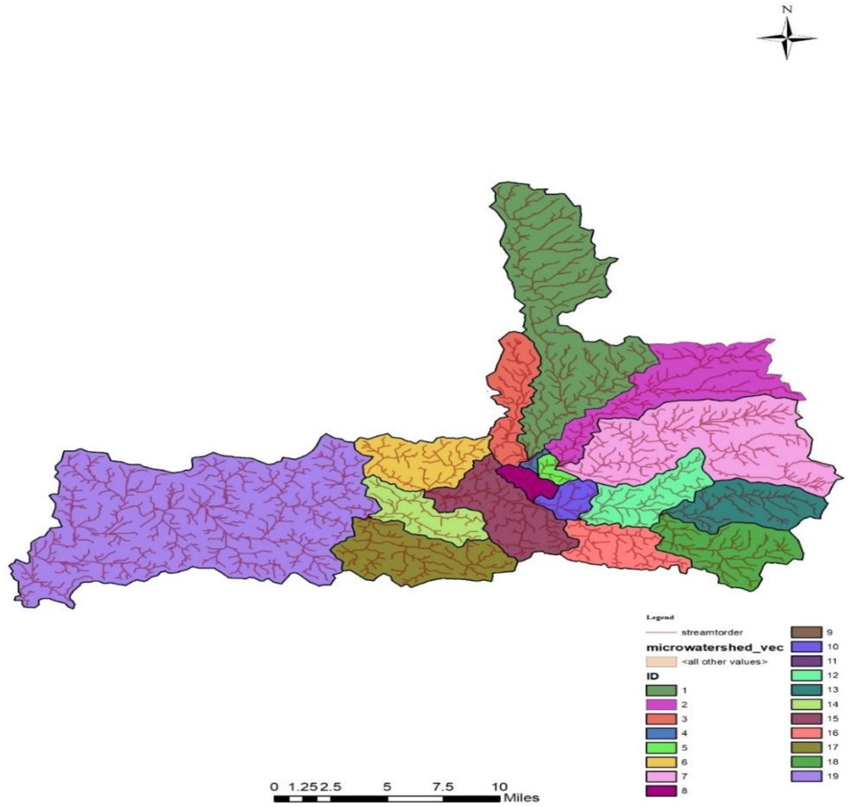


**Fig.8** Drainage density map of the Thuthapuzha river basin

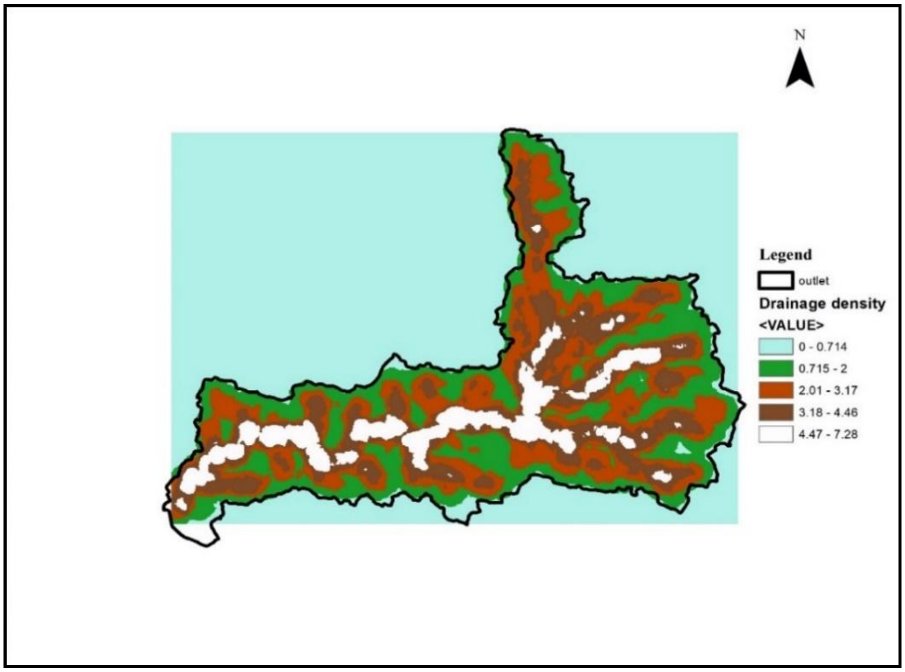

**Table.1** Mathematical formulae for computing geomorphological parameters

| Geomorphological parameter | Formula | Terms involved |
|---|---|---|
| Bifurcation ratio | $B_r = \frac{N_u}{N_{u+1}}$ | $N_u$=Number of streams of order u<br>$N_{u+1}$=Number of streams of order u+1 |
| Stream frequency | $S_f = \frac{N_u}{A}$ | $N_u$=Number of streams of order u<br>A = Area of the basin in $Km^2$ |
| Elongation ratio | $F = \frac{A}{L^2}$ | A = Area of the basin in $Km^2$<br>L=Main channel length in Km |
| Form factor | $E_l = \frac{1}{(L)}\sqrt{\frac{A}{\Pi}}$ | A = Area of the basin in $Km^2$<br>L=Main channel length in Km |
| Shape factor | $S = \frac{L^2}{A}$ | L=Main channel length in Km<br>A = Area of the basin in$Km^2$ |
| Circulatory ratio | $C_r = \frac{4\Pi A}{P^2}$ | A = Area of the basin in $Km^2$<br>P=Perimeter of the basin |
| Drainage density | $D_d = \frac{N_l}{A}$ | $N_l$ = Total Stream length of all order<br>A = Area of the basin in $Km^2$ |
| Drainage texture | $D_t = \frac{N_u}{P}$ | $N_u$=Number of streams of order u<br>P=Perimeter of the basin |
| Infiltration number | $(I_n) = D_d * S_f$ | $D_d$=Drainage density<br>$S_f$ =Stream frequency |
| Length of overland flow | $L_f = \frac{0.5}{D_d}$ | $D_d$=Drainage density |
| Constant of channel maintenance | $C_c = \frac{1}{D_d}$ | $D_d$=Drainage density |
| Basin relief | $R_b = E_{max} - E_{min}$ | $E_{max}$=maximum elevation<br>$E_{min}$ =minimum elevation |
| Relief ratio | $R_r = \frac{R_b}{L}$ | $R_b$=Basin relief<br>L=Main channel length in Km |
| Ruggedness number | $R_n = R_b * D_d$ | $R_b$=Basin relief<br>$D_d$=Drainage density |

**Table.4** The 14 parameters of 17 sub basins

| Column1 | Stream frequency | Bifurcation ratio | Elongation ratio | Form factor | Shape factor | Drainage density | Drainage texture | Circulatory ratio | Length of overland flow | Infiltration number | Basin relief(km) | Relief ratio | Ruggedness number | Constant of channel maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Micro1** | 2.174 | 2.4 | 0.1899 | 0.113 | 8.828 | 1.381 | 3.678 | 0.244 | 0.362 | 3.003 | 2.272 | 0.063 | 3.14 | 0.724 |
| **Micro2** | 2.35 | 1.71 | 0.192 | 0.115 | 8.669 | 1.369 | 2.79 | 0.24 | 0.365 | 3.218 | 1.139 | 0.045 | 1.56 | 0.73 |
| **Micro3** | 2.499 | 1.61 | 0.2 | 0.126 | 7.945 | 1.541 | 2.135 | 0.29 | 0.325 | 3.85 | 0.997 | 0.0629 | 1.536 | 0.649 |
| **Micro4** | 3.261 | 1.83 | 0.239 | 0.179 | 5.565 | 2.343 | 2.342 | 0.329 | 0.213 | 7.64 | 0.045 | 0.141 | 0.1455 | 0.427 |
| **Micro5** | 2.511 | 2.87 | 0.379 | 0.449 | 2.223 | 1.198 | 1.2 | 0.6 | 0.417 | 3.009 | 0.093 | 0.028 | 0.112 | 0.834 |
| **Micro6** | 2.403 | 1.69 | 0.369 | 0.429 | 2.331 | 1.404 | 3.032 | 0.511 | 0.356 | 3.375 | 0.14 | 0.0147 | 0.197 | 0.712 |
| **Micro7** | 2.294 | 1.77 | 0.192 | 0.116 | 8.644 | 1.384 | 4.532 | 0.4 | 0.361 | 3.175 | 2.001 | 0.062 | 2.77 | 0.722 |
| **Micro8** | 2.822 | 1.5 | 0.332 | 0.346 | 2.886 | 2.093 | 1.642 | 0.522 | 0.239 | 5.907 | 0.112 | 0.023 | 0.234 | 0.478 |
| **Micro10** | 1.775 | 1.91 | 0.284 | 0.253 | 3.95 | 1.376 | 1.333 | 0.629 | 0.363 | 2.442 | 0.123 | 0.018 | 0.169 | 0.727 |
| **Micro12** | 2.418 | 2.3 | 0.279 | 0.244 | 4.102 | 1.601 | 2.575 | 0.405 | 0.312 | 3.871 | 0.561 | 0.046 | 0.898 | 0.625 |
| **Micro13** | 2.548 | 2.94 | 0.225 | 0.2 | 5.008 | 1.458 | 3.322 | 0.528 | 0.343 | 3.715 | 1.647 | 0.116 | 2.402 | 0.686 |
| **Micro14** | 2.214 | 2.42 | 0.271 | 0.23 | 4.341 | 1.265 | 2.096 | 0.383 | 0.395 | 2.8 | 0.155 | 0.014 | 0.196 | 0.791 |
| **Micro15** | 2.092 | 2.63 | 0.448 | 0.628 | 1.593 | 1.3666 | 2.615 | 0.402 | 0.366 | 2.858 | 0.115 | 0.08 | 0.212 | 0.732 |
| **Micro16** | 2.476 | 2.59 | 0.254 | 0.203 | 4.931 | 1.364 | 2.387 | 0.309 | 0.367 | 3.38 | 0.094 | 0.008 | 0.128 | 0.733 |
| **Micro17** | 2.186 | 1.9 | 0.266 | 0.222 | 4.5 | 1.4 | 3.184 | 0.481 | 0.357 | 3.064 | 0.301 | 0.019 | 0.421 | 0.714 |
| **Micro18** | 2.122 | 1.71 | 0.254 | 0.203 | 4.927 | 1.52 | 2.823 | 0.491 | 0.329 | 3.226 | 1.12 | 0.075 | 1.073 | 0.658 |
| **Micro19** | 2.226 | 1.71 | 0.217 | 0.148 | 6.742 | 1.383 | 6.589 | 0.391 | 0.362 | 3.709 | 0.46 | 0.01 | 0.636 | 0.723 |

**Table.2** Number of streams with their order

| Stream order | Number of streams |
|---|---|
| **1** | 1231 |
| **2** | 567 |
| **3** | 252 |
| **4** | 192 |
| **5** | 69 |
| **6** | 103 |

**Table.3** Stream length with their orders

| Stream order | Stream length (Km) |
|---|---|
| **1** | 778.29 |
| **2** | 334.79 |
| **3** | 149.91 |
| **4** | 107.9 |
| **5** | 39.81 |
| **6** | 58.82 |

## Elongation ratio ($E_l$)

Elongation ratio is an important parameter which describes the shape of a sub-basin area. The elongated length (main channel length) of the study area is 99.64 Km and the computed elongation ratio is 0. 176. This lower value indicate that the sub-basin area is more elongated and it is characterized by a low infiltration capacity along the river flow path hence runoff will be more with higher relief. Elongation ratio for Micro-watershed is ranges from 0.189 to 0.448.

## Form factor (F)

Form factor is an important parameter to describe the shape of the catchment area. In this study area, the value of the form factor is obtained as 0.10. The lower value indicates that the sub basin has more elongated shape in nature with the characteristics of flatted peak flow for a longer duration. Such elongated sub basins are highly vulnerable to flood flows than circular-shaped catchment area. Out of 17 Micro-watersheds, the highest form factor is obtained from Micro-watershed 15 which is about 0.62.

## Shape factor(S)

The interpretation of similar to circulatory ratio, elongation ratio, form factor. It gives an idea about circular character of basin. Higher value of 9.87 indicates less circular more elongated which gives idea about basin is having shortest basin lag time. Shape factor for Micro-watershed is ranges from 1.593 to 8.828. The lowest value is obtained from Micro-watershed 15 is about 1.593 which indicates circular, hence this are Micro-watershed gives moderate to high peak flow with short duration.

## Circulatory ratio ($C_r$)

The circulatory ratio represents the shape characteristics of the catchment area. In this study area, the circulatory ratio is measured as 0.219. This value indicates the river basin is elongated and young stage of tributaries. The circulatory ratio for micro-watershed is ranges from 0.24 to 0.629. It is observed that almost all Micro-watershed exhibits elongated area with young stage to mature stage of tributaries.

### Drainage parameters

Drainage texture analysis includes the basin frequency, density and intensity of the drainage.

### Drainage density ($D_d$)

Drainage density is a ratio of the total length of all streams per basin area and higher value indicates degree of the rainfall removal from the basin. The spatial variation of drainage density is demarcated in a raster map format using ArcGIS software and it is shown in figure 8.

The average drainage density of Thuthupuzha River is obtained as 1.16 $Km/Km^2$. This is moderate value indicates to the availability of a large amount of precipitation on the slope terrain that results in moderate runoff and more surface drainage lines. Out of 17 Micro-watershed the highest value is obtained from Micro-watershed 4 and lowest from Micro-watershed 5 which is about 1.19. The drainage density map of Thuthapuzha river basin is shown in figure 8.

### Drainage texture ($D_t$)

Drainage texture is important parameter in the field of geomorphology which gives an idea about intensity of drainage characteristics. It measures closeness of the stream spacing. In the present study the drainage texture is obtained as 10.05 for whole river basin which indicates the river basin have very fine drainage texture. Out of 17 Micro-watershed, maximum number of Micro-watersheds comes under the category of coarse texture where drainage texture value is varies from 2 to 4. Highest drainage texture is obtained in Micro-watershed 19 which is about 6.589.

### Infiltration number ($I_n$)

Infiltration number is the product of stream frequency and drainage density which gives idea out the infiltration characteristics of the basin. Higher value indicates higher runoff, lower infiltration and vice versa. In this study, the infiltration number obtained as 3.508 which indicates moderate infiltration. Out of 17 Micro-watersheds, the highest infiltration number is obtained from the Micro-watershed 4 and Micro-watershed 8 which is 7.64 and 5.90 respectively.

### Length of overland flow ($L_f$)

The length of overland flow is defined as the length of flow path projected to the horizontal of the non-channel flow from a point on the adjacent stream channel. In the study area, the computed overland flow value is 0.342. This lower value indicates the Thuthupuzha river basin is under stream erosion is dominant than sheet erosion. Out of 17 Micro-watershed, only Micro-watershed 5 moderate stream erosion where it exhibits length of overland of about 0.417.

### Constant of channel maintenance ($C_c$)

It is inverse function of drainage density which gives idea about number of $Km^2$ required to develop stream of 1 Km. The computed value of constant of channel maintenance for the river basin is 0.684 and value indicates 0.684 unit area required to sustain unit length of stream in the basin with least erodibility. Out of 17 Micro-watershed, Micro-watershed 4 and Micro-watershed 8 gives constant of channel maintenance of about 0.427 and 0.478 respectively which indicates low erodible area whereas remaining all Micro-watershed comes under least erodible.

**Relief aspect**

Drainage network, and basin geometry are one and two dimension parameters but in case of relief parameters, it is the three dimension parameters. By measuring the elevation of each stream segment to the point where it joins the higher order stream and dividing the total by the number of streams of that order, it is possible to obtain the average elevation (vertical fall). The parameters involved relief are

**Basin relief ($R_b$)**

The relief of the sub-basin area varies at different reference points (peak of the hilly terrain) in the northern and eastern part. The maximum relief (basin relief) of the area is 2.330 Km. Computed higher value of basin relief indicates lesser time for flow accumulation hence runoff will be more.

Figure 8 gives basin relief in all Micro-watershed which indicates variation is more in case of relief parameters.

**Relief ratio ($R_r$)**

Relief ratio describes as the overall steepness of the river basin and this is a main indicator of the intensity of erosion process operating on the slope of the basin. Higher value indicates then area is located in hilly region, whereas lower value indicates basin is located in valley region. In this study area, the relief ratio is computed as 0.023 and. this lowest value of ratio indicates moderate relief and gentle slope. It is observed that relief ratio is higher in place where Hill-shades with highest relief ratio of 0.14 and lower in case Micro-watershed 16 which is about 0.008.

**Ruggedness number ($R_n$)**

Ruggedness is the product of basin relief and drainage density and its value obtained as 3.404 which is higher. This value indicates higher stream velocity because the relief parameters are higher which implies the Thuthapuzha river basin having high prone to soil erosion. The ruggedness value is ranges from 0.112 to 3.14 in case of 17 Micro-watershed. It is observed that highest ruggedness number is obtained from Micro-watershed which are present in Hill-shades.

Due to the long-time hydrologic and geological process, the interaction between these processes determines stream characteristics, landform, basin area, perimeter, and other morphometric parameter. It is observed that Thuthapuzha river basin has a dendritic type of drainage network an also basin having too much difference in relief. It is noticed that first order stream network has more number than second, third, fourth, fifth order streams. In case of sixth order streams, the number of streams is higher than fifth order streams which indicates that bifurcation ratio is less than one. This is obviously revealing that highest stream order origin nears to Hill-shade having long main channel length which describe the shape of the basin having elongated. The shape of basin is described by shape parameters such as form factor, shape factor, circulatory ratio, and elongation ratio. From all these parameters, the Thuthapuzha river basin exhibits elongated shape, lower order streams are young stage, flattened peak flow for longer duration, low infiltration along the flow path. Infiltration number also reveals that low to moderated infiltration. Drainage network parameters like low bifurcation and lower stream frequency reveal that basin has less disturbance by geological structure. Drainage texture revels that idea about the intensity stream network is finer which indicates surface runoff is maximum and erosion is intense.

The lower value of length of overland flow in study area reveals that stream erosion is dominant than sheet erosion. Hence stream bank erosion measures have to be taken for preventing erosion. From constant of channel maintenance, the basin exhibits moderate to low erodible area. High basin relief indicates the basin has lesser time for flow accumulation. From the ruggedness number it is observed that stream has higher velocity because of relief. Hence Thuthapuzha river basin has high prone to soil erosion.

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**How to cite this article:**

Chethan, B.J. and Vishnu, B. 2018. Determination of the Geomorphologic Parameters of the Thuthapuzha River Basin in Central Kerala, India, Using GIS and Remote Sensing. *Int.J.Curr.Microbiol.App.Sci.* 7(09): 1245-1260. doi: https://doi.org/10.20546/ijcmas.2018.709.149