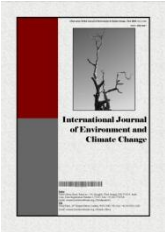

International Journal of Environment and Climate Change

12(10): 524-539, 2022; Article no.IJECC.87218
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Morphometric Analysis of Nanjannad Hill Watershed in South India using Geographical Information System

Gangannagari Karthik [a*], K. Nagarajan [a], S. Manivannan [b], Balaji Kannan [a] and M. R. Duraisamy [c]

[a] *Department of Soil & Water Conservation Engineering, Tamil Nadu Agricultural University, Coimbatore, India.*
[b] *ICAR-Indian Institute of Soil & Water Conservation, Research Centre, Udhagamandalam, 643 004, Tamil Nadu, India.*
[c] *Department of Physical Sciences and Information Technology, TNAU, Coimbatore, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1030827

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87218

Original Research Article

Received 14 March 2022
Accepted 17 May 2022
Published 18 May 2022

ABSTRACT

Watershed is a natural geohydrological unit that allows surface runoff to a particular point or outlet, Morphometric analysis plays a vital role in the proper planning and development of the watershed. Morphometric analysis of the Nanjannad watershed is carried out using integrated approach of remote sensing and GIS techniques. The present study attempted to determine the morphometric characteristics of Nanjannad watershed of Ooty, Tamil Nadu. Geographical information system (GIS) is used to evaluate linear, areal and relief aspects of morphometric parameters. The drainage area of the watershed is 434 ha, the watershed is a Fourth-order drainage basin, and the lower order streams are mostly dominating in the watershed. Physiography, rainfall and lithology of the location control the stream orders. The development of stream segments in the watershed area is affected by rain, slope of the watershed varies from 0 to 87%. The mean R_b of the entire watershed is 4.38, indicating that geological structures do not influence the drainage pattern much.

[φ]*Masters student;*
[#]*Professor;*
[†]*Principal Scientist;*
**Corresponding author: E-mail: karthikreddyjinnaram@gmail.com;*

The whole watershed elongation ratio is 0.67 showing the majority of the area has Moderate relief and a steep slope, Relief ratio values implies that the discharge of the Nanjannad watershed is high and groundwater potential is meager, the moderate value of drainage density, stream frequency and drainage intensity, indicates that runoff is more likely to cause water logging. This work can be used as input to evaluate hydrology and water resources and will be helpful for integrated watershed planning.

Keywords: Drainage pattern; geographical information system; integrated watershed planning; morphometric analysis; stream frequency.

1. INTRODUCTION

"A watershed is a physical entity defined as the area drained by a stream in such a way that all flow originating in the watershed area is discharged to a single outlet. Watershed geospatial application improves the accuracy and speed of watershed planning. Remote sensing and geographic information systems aid in creating a watershed database, which is extremely useful for performing spatial analysis. Remote sensing data can provide a quick overview of a large area at once, which is extremely useful in drainage morphometry analysis. The mean bifurcation ratio value indicates that structural disturbances and geological features do not affect the watershed. A permeable subsurface creates the watershed, and runoff is moderate, as evidenced by the low drainage density, stream frequency, and infiltration numbers. The low drainage density indicates that the size is appropriate for constructing water collection facilities in streams" [1].

"Morphometric analysis of the Pavagada watershed revealed that the drainage pattern varying from dendritic to sub dendritic drainage pattern, stream orders ranging from the fourth to the fifth order, drainage density values in the watershed ranges from 1.55 to 2.16 km/km^2 indicating that the drainage is very coarse to coarse in the watershed, relief ratio lies between 0.006 and 0.021 and average bifurcation ratio ranging from 3.24 to 4.88" [2]. "K-J watershed worked out morphometric analysis revealed that the drainage density of the watershed area is 3.05 km^{-1} indicating impermeable surface materials, drainage texture of the watershed falls into the fine texture category (>8), elongation ratio and circularity ratio of the watershed are 0.62 and 0.03 respectively indicating that the K-J Watershed is less elongated with dendritic stage and steep slope" [3].

Morphometric parameters in the watershed are useful function for proper visualization of all the watershed parameters and its impact on the watershed, morphometric parameters are also useful for estimation of runoff using hydrological models, prioritization of watersheds and also for preparing proper strategies for watershed management [4]. Most of the watersheds are ungauged and some of them are difficult to access, so proper study of morphometric analysis of the watershed becomes more important [5]. "Morphometric analysis of the watersheds utilizing remote sensing and Geographical Information System have been used by many researchers over the world" [6,7,8,9].

Development of a watershed is very important for proper planning and efficient use of resources in a watershed. Integrated use of remote sensing and GIS techniques can be used in soil erosion assessment and computation of hydrological behavior in a watershed. Hydrological runoff estimation of the watershed is used for the design of the soil and water management structures and flood analysis. Forests and trees are a significant water source for the surrounding regions and are an integral aspect of the Nilgiris hilly environment. Despite the fact that the Nilgiris receives more rainfall with greater intensity, wildlife and vegetation in forest regions endure severe water shortages throughout the summer [10]. Hill watersheds are more prone to soil erosion due to heavy steep slopes, so watershed morphometric analysis of all the parameters is required and analysing each morphometric parameter helps to know the problems of the watershed [11].

Nanjannad hill watershed is facing a severe soil erosion problem, high runoff in the watershed is causing soil erosion. Morphometric analysis provides better understanding of the watershed such that proper watershed management planning can be done. So, estimation of morphometric parameters is helpful for implementing proper soil and water conservation measures. Aim of the present study is to find

Morphometric analysis of Nanjannad hill watershed using GIS and Remote sensing and to analyze each morphometric parameter and describe the conditions of the watershed it includes estimation of Linear aspects, Areal aspects, Relief aspects and extraction of DEM map, Slope map and Drainage map of Nanjannad watershed.

This research will be useful for upcoming researchers for the design of rainwater harvesting structures and water management strategies of the Nanjannad watershed.

2. MATERIALS AND METHODS

2.1 Study Area

In the present study, Nanjannad watershed of Ooty is taken for morphometric analysis. The various characteristics and details of the study areas are mentioned in the following section 11˚20' 0" N to 11˚22' 30" N latitude and 76˚37'30" E to 76˚40'0" E longitude as shown in Fig. 1. Ooty is located in the Nilgiris hill ranges. The climate in the study area of high elevation results in low temperatures. The day temperature in the Nilgiris district ranges from 22.1°C in the summer to 5.1°C in the winter. At times, the night time temperature drops below 0°C. Summer begins in early March, with the hottest months being April and May. The weather begins to cool slowly around the middle of June, and by January, the mean daily maximum temperature has dropped to 5.1°C. The Nilgiris hill ranges are located in the fragile Western Ghats environment, with elevations ranging from 300 m to 2636 m above mean sea level. The majority of the Nilgiris is covered by forest (56%) followed by plantation crops (20%) such as tea and coffee, and the remaining areas are covered by vegetables. The total annual rainfall is 1204 mm in which, 54 per cent is distributed over four months, from June to September. The remainder is distributed between January to May and October to December [12].

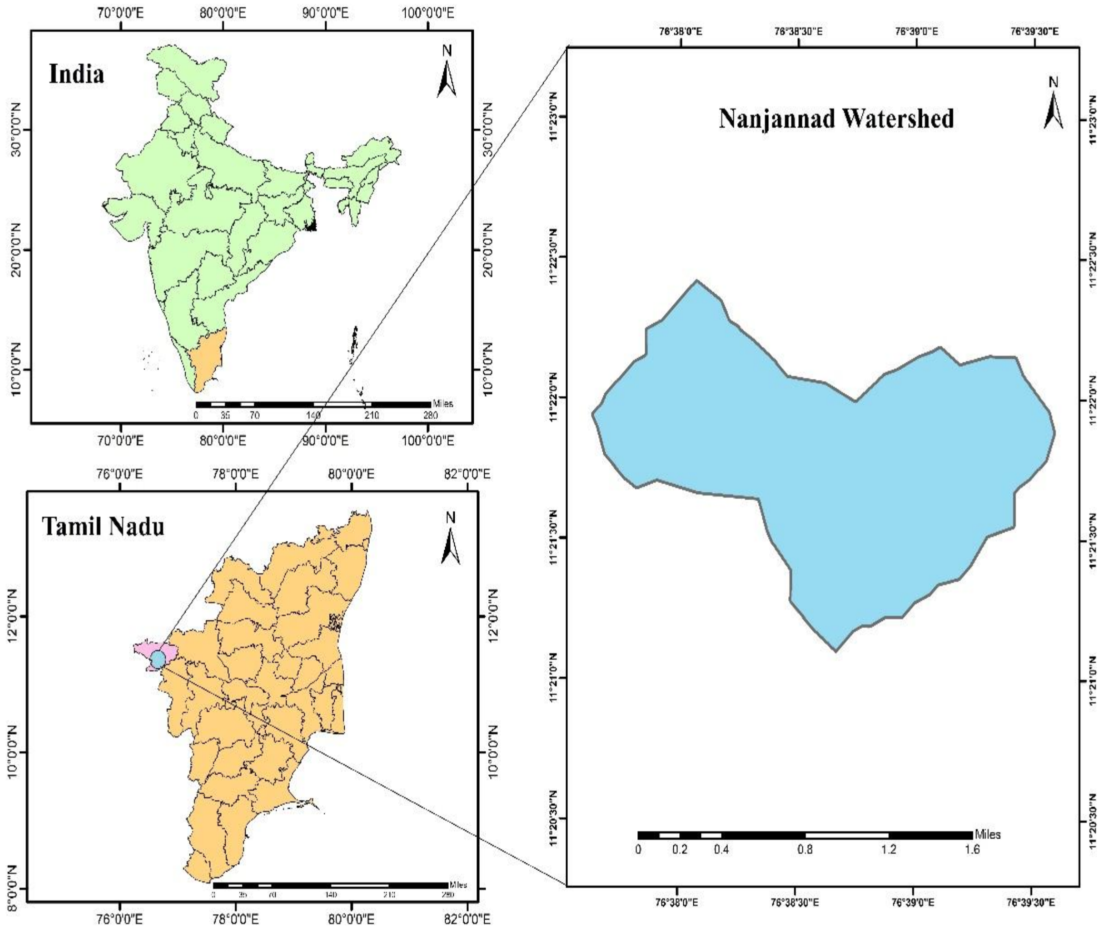

Fig. 1. Nanjannad Watershed map

2.2 Soil and Geomorphology

The type of soil influences the soil moisture content and the quantity of silt washed down in water harvesting structures and hillsides. Different soils present in the watershed are lateritic soil, red sandy soil, red loam, black soil, Alluvial and Colluvial soil. Small patches of red sandy soil and red loams are found. Black soils are formed in the valleys where waterlogging is widespread during the monsoon season. Alluvial soils are found along the valleys and major water courses [10].

2.3 Land use

Forests plays an important role in the Nilgiris mountainous ecosystem, supplying water to the surrounding areas. Land use has an impact on runoff, infiltration rates, as well as the different types of vegetation cover. Land use and land cover analysis in the Nanjannad watershed revealed that Vegetation is dominating in the watershed area as shown in Table.1, with shrubs and hill tops. Due to steep slopes and inadequate land use patterns, water erosion is a severe problem in the watershed area. Agriculture practices range from the valley floor to the hilltop, with a broad range of cropping systems and management practices. The main crops cultivated in this watershed area are potato, carrot, cauliflower, cabbage, beetroot and radish [13].

Table 1. Land use pattern in Nanjannad watershed

S. No	Land use pattern	Percentage (%)
1	Forest	35.4
2	Water bodies	18.2
3	Vegetation	37.3
4	Barren land	9.1

2.4 Geographic Information System (GIS)

Cartosat DEM file was downloaded from Bhuvan Portal and Ground data of the watershed is collected, ArcGIS 10.3 software is used to delineate watershed areas using Digital Elevation Model and prepare various thematic maps to extract the watershed characteristics required for the morphometric analysis of watershed. The area undertaken for the study has been done the morphometric parameters determined by using GIS technique. The area of interest lies in UTM zone 43-N having datum WGS 1984. The DEM shape map for the watershed is delineated and extracted as shown in the Fig. 2.

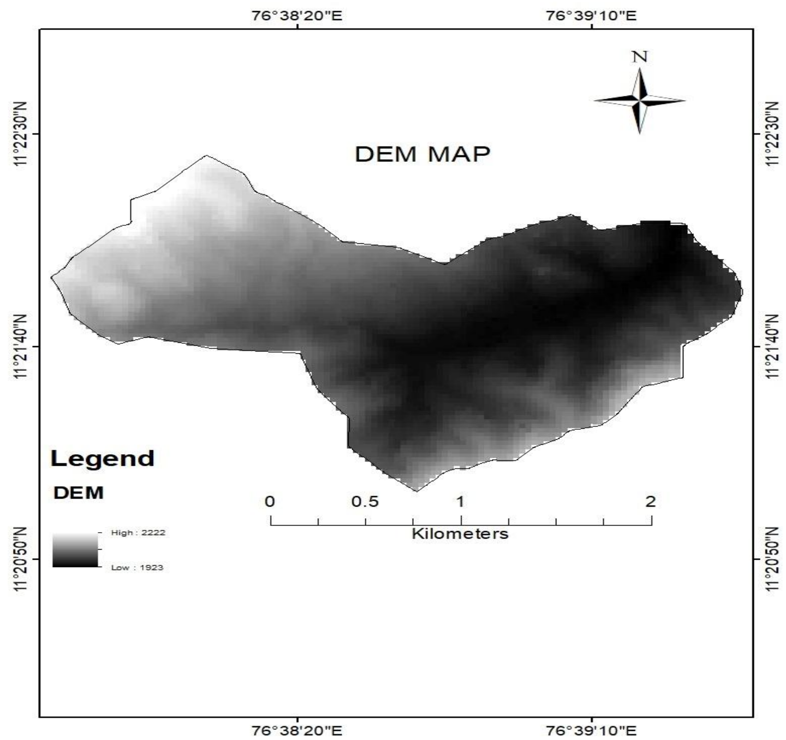

Fig. 2. Digital elevation model (DEM) of Nanjannad Watershed

3. RESULTS AND DISCUSSION

The morphometric parameters of Nanjannad watershed have been studied in detail and it was found that the total drainage area is 434 ha. The drainage pattern of watershed is dendritic to sub dendritic in existence and is influenced by area general topography and drainage map produced from the hydrology analysis as shown in Fig. 3. The drainage pattern indicates the influence of slope and lithology, dendritic patterns are the most common in drainage watershed composed of relatively homogenous rock with not having control over underlying soil structure. Mean slope of a watershed will be helpful to predict erodibility [14]. Higher the value of slopes, soil erosion will be more, keeping other things as constant. The slope ranged between 0 and 87 %. Maximum slope in the Nanjannad watershed is 87% with average slope of 34.6 %. The watershed slope map is shown in Fig. 4. The main cause for erosion is the most part of the area is under steep slopes in the watershed. All the parameters are correlated with the previous data in linear, aerial and relief aspects of the Nanjannad watershed.

3.1 Linear Aspects

Linear aspects of the watershed explain about the streams and it network in the watershed, the linear aspects of the Nanjannad watershed are discussed and tabulated the linear aspects in Table.2 and Table.3, this linear aspect gives the preliminary information from which the other areal and relief aspects are connected..

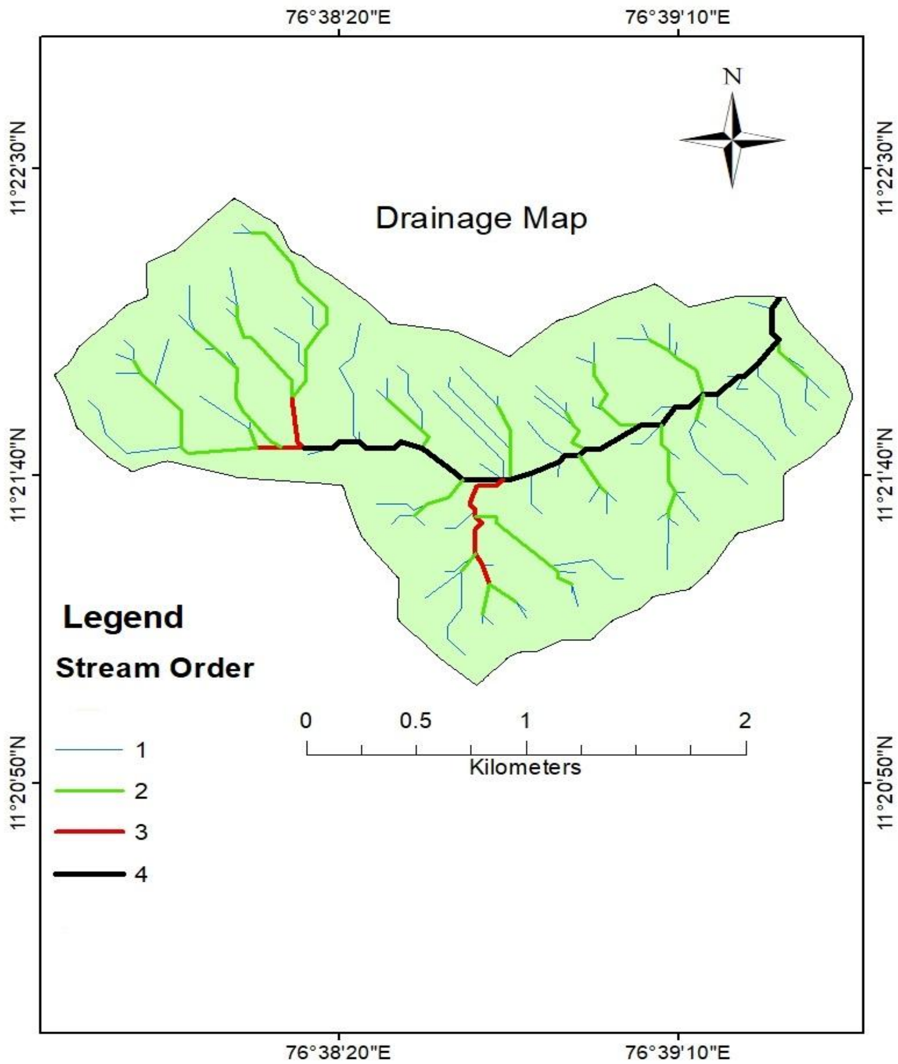

Fig. 3. Stream order map

3.1.1 Stream order (S_u)

The designation of streams orders is initial step of watershed drainage analysis. Higher the stream order, indicates that the watershed area is larger. In study area, the orders of streams are 1st order, 2nd order, 3rd order and 4th order so, the watershed is designated as 4th order watershed. The law of stream number [15] and the law of stream length [16] were done by the stream network of the Nanjannad watershed. Similar result obtained as 4th order basin obtained by the Partha pratim and Jyothiprava [17].

3.1.2 Stream number (N_u)

Stream number in the watershed explains the number of stream segments present in an order. According to Horton law, any order's stream order and stream number are geometrically inversely connected. The following are stream numbers in various orders in the watershed: Number of first order streams are of 78, the second order streams of 18, the third order streams of 4, and the fourth order stream has a value of 1 (Table.2). More first-order streams indicate a significant runoff load on down streams [20].

3.1.3 Stream length (L_u)

The stream length of the Nanjannad watershed under various orders were computed with the use of attribute table Using GIS. The number of different stream orders in a watershed and their lengths measured, and stream length decreases as stream order increases. The watershed of rising order used to be maintained via geometrical similarities [21]. We calculated the value using Horton's law, which is 24.6 kilometers (Table 2). The overall length of the streams increases in the first order and decreases in the subsequent orders.

3.1.4 Mean stream length (L_{um})

Mean stream length of the watershed is dimensionless property that reveals the typical size of drainage network and the watershed surfaces. The mean stream length of a watershed is computed by dividing total stream length of a specific order to that of total number of streams of that particular order. The Lum can reveal the surface area of the watershed that contributes to the drainage network [21]. The mean stream length of Nanjannad watershed varied from 169 m to 2718 m. The average value of mean stream length for the watershed is 243.5 m (Table. 2). The L_{um} of any of the stream order in a watershed is more than of the lower order stream and less than that of the higher order stream. The size and topography of the watershed govern the value of Lum, which varies between watersheds [20].

3.1.5 Stream length ratio (L_{ur})

The stream length ratio is the ratio of the average length segment of any order to the average length segment of the next lower order, which remains constant in a watershed for successive orders [15]. In the present watershed, stream length ratios were 2.4-9.4 (Table. 2) and these values will indicate dependency on both slope and topography. Similar observations are noted in Welmal watershed as varying from 3.4- 11.8 by Nasir Gabi tukara et al, 2021 [22].

3.1.6 Bifurcation ratio (R_b)

The bifurcation ratio is the ratio of the number of streams in any order to that of number of streams in the next higher order [15]. Bifurcation ratio is a dimensionless property. Except for the powerful geological structure, the bifurcation ratio varies only slightly across regions [21], in the Nanjannad watershed bifurcation ratio ranges between 4.0-12.8 (Table.3), the bifurcation ratio value indicating that the geological structures do not influence the drainage pattern.

3.1.7 Weighted mean bifurcation ratio (R_{bwm})

The weighted mean bifurcation ratio is computed by multiplying the bifurcation ratio of a pair order by the total number of streams in the ratio [21]. The Rbwm is the mean of all the sum of the values. The value of R_{bwm} in the research area was 4.38 (Table.3). The watershed mean bifurcation ratio indicates that there is negligible influence of geological features on the drainage network, due to the variation in geology and lithology in the watershed, the R_{bwn} ratio is not the same for all orders.

3.1.8 Length of main channel (Cl)

The length of the main channel is the distance from the outlet to the channel head along a subjectively defined main channel, or more objectively, the length of the longest flow path to the drainage divide. The computed main channel length by using ArcGIS-9.3 software, which was

4.09 km (Table. 3), channel length will specify how the channel is flowing through the watershed, as the length is less compared to other watersheds but the slope is very high, due to the steep slopes the runoff and discharge at the outlet are high.

3.1.9 Length of the basin (L_b)

The length of the basin is the longest dimension which is parallel in the direction to the main drainage line [18]. It is the length of the line from mouth of a watershed to the point on the perimeter that is farthest from the outlet. The Nanjannad watershed had a basin length of 3.01 km (Table.3), this length indicating that the watershed having a varying length as the amount of flow will be dependent on the length of the watershed.

3.2 Areal Aspects

Areal aspects of the watershed are two-dimensional properties and this explains about the study of the watershed, which include the description of arrangement of the areal elements and obtaining the relationship between them, the areal aspects are found out and they are arranged in the order and tabulated in Table.4.

3.2.1 Watershed area (A)

The drainage area, also known as the watershed area, this is the most important watershed characteristic for the hydrologic analysis. It represents the amount of water that is to be generated by a rainfall and watershed area is critical in determining the drainage network. Total watershed area and total stream length are proportional to one another [18], this is influenced by the areas that contribute to it. Area in Nanjannad watershed was calculated using ArcGIS software and which was found as 434 ha (Table.4), the watershed area is locating in hilly terrain and it is a hill watershed.

3.2.2 Watershed perimeter (P)

The watershed perimeter is the outer boundary of the watershed that encloses its area. The watershed perimeter can be defined as the length of the ridge line that separates the watershed. It also indicates the size and shape of watershed. The basin perimeter is calculated by using ArcGIS-9.3 software, and the value was 9.94 km (Table.4).

3.2.3 Length area relation (L_{ar})

This relationship was used for a greater number of watersheds in the United States; stream length and watershed area are related to a power function, which is: L_{ar} = 1.4 * A * 0.6 [23]. Using this relationship, estimated length of the Nanjannad watershed to be 3.62 km (Table.4), which is exactly the same as the length obtained using the GIS technique.

3.2.4 Lemniscate's (k)

The Lemniscate's value of a watershed is used to determine slope of watershed. The formula is k = L_b^2 / 4 * A, where, L_b is length of watershed (km) and A is area of watershed (km^2) [24]. The Lemniscate (k) value for the watershed was 2.10 (Table.4), indicating that the maximum inception area is made up of a high number of higher-order streams.

3.2.5 Form factor (F_f)

The form factor is important in explaining the drainage basin flow property. The form factor is determined by dividing the watershed area by the square of the watershed length [16]. The form factor value for the perfectly shaped circular watershed is 0.754 (Table.4). However, the value of all natural watersheds will be less than that. The watershed will get increasingly extended as the form factor value drops. The longer the shape, the smaller the form factor. Low runoff will generate over a long period of time, whereas rounded shape watersheds with a high value of form factor experience high runoff over a short period of time and are highly sensitive to flood. The form factor in the current watershed is 0.48, indicating the watershed is moderately elongated and high runoff, similar kind of value i.e., 0.44 is obtained by the ravi basin of Chamba district in Himachal Pradesh by Kuldeep Pareta indicating the watershed is elongated and facing high runoff problem in the basin area [31].

3.2.6 Elongation ratio (Re)

The elongation ratio is the ratio of the diameter of a circle the same size as the drainage basin to the maximum basin length [18]. A circular basin discharges runoff more efficiently than an elongated basin. Elongation ratio values ranges from 0.6 to 1.0 across a variety of climate and lithology conditions. The lowest watershed ratio values imply steep slope and high relief, whereas the highest ratio values suggest plain land with

Table 2. Stream order, number of streams, stream length, stream length ratio and bifurcation ratios in Nanjannad watershed

S_u	N_u	L_u(m)	L_{um}(m)	L_{ur}	L_{ur-r}	L_{ur}*L_{ur-r}	L_{uwm}	R_b	N_{u-r}	R_b*N_{u-r}	R_{bwm}
1	78	13220.3	169.5				2.42				4.38
2	18	7499.6	416.6	2.46	96	235.99		4.3	96	416	
3	4	1156.4	289.1	0.69	22	15.27		4.5	118	531	
4	1	2718.1	2718.1	9.40	5	47.01		4.0	27	108	
Total	101	24594.5	243.5		123	298.26		12.8	241	1055	

S_u: Stream order, N_u: Number of streams, L_u: Stream length, L_{um}: Mean stream length, L_{ur}: Stream length ratio, L_{ur-r}: Stream length used in the ratio, R_b: Bifurcation ratios, L_{uwm}: Weighted mean stream length ratio, N_{u-r}: Number of streams used in the ratio, R_{bwm}: Weighted mean bifurcation ratio

Table 3. Linear morphometric parameters of Nanjannad watershed

Sl. No.	Morphometric parameter	Method/ Formula	Reference	Result
1	Main channel length (Cl)	GIS analysis	Length	4.09 km
2	Basin length (L_b)	GIS analysis	Schumm (1956) [18]	3.01 km
3	Length from watershed Centre to mouth (L_{cm})	GIS analysis	Black (1972) [19]	2.04 km
4	Weighted mean stream length ratio (L_{uwm})	GIS analysis	Ratio	2.42
5	Weighted mean bifurcation ratios (R_{bwm})	GIS analysis	Ratio	4.38

Table 4. Areal morphometric parameters of Nanjannad watershed

Sl. No.	Morphometric parameter	Method/Formula	Reference	Result
1	Mean basin width (W_b)	$Wb= A/L_b$	Horton (1932) [16]	1.43 Km
2	Basin area(A)	Gis analysis	Schumm (1956) [18]	434 ha
3	Basin perimeter(P)	Gis analysis	Schumm (1956) [18]	9.94 km
4	Relative perimeter (P_r)	P_r=A/P	Schumm (1956) [18]	0.43
5	Length area relation (L_{ar})	L_{ar}=1.4*A*0.6	Hack (1957) [23]	3.62
6	Lemniscate(k)	$K=Lb^2/A$	Chorley (1957) [24]	2.10
7	Form factor ratio (F_f)	$F_f= A/Lb^2$	Horton (1932) [16]	0.48
8	Shape factor ratio (R_s)	$S_f=L_b^2/A$	Horton (1945) [15]	2.10
9	Elongation ratio (Re)	$R_e= 2/ L_b*(A/\pi)^{0.5}$	Schumm (1956) [18]	0.67
10	Texture ratio (R_t)	R_t=N1/P	Schumm (1956) [18]	7.84
11	Circularity Ratio (R_{cn})	R_{cn}=A/P	Strahler (1957) [25]	0.43
12	Circularity Ratio (R_c)	R_c=12.57*(A/2P)	Miller (1953) [26]	0.55
13	Drainage texture (D_t)	$D_t=N_u/P$	Horton (1945) [15]	10.15
14	Compactness coefficient (C_c)	$C_c=0.2841*P/A^{0.5}$	Magnesh (2011) [27]	1.36
15	Fitness ratio (R_f)	R_f= Cl / P	Melton (1957) [28]	0.41
16	Wandering ratio (R_w)	$Rw = Cl/L_b$	Smart and Surkan (1967) [29]	1.36
17	Stream frequency (F_s)	$F_s = N_u/A$	Horton (1932) [16]	23.47
18	Drainage density (D_d)	$D_d = L_u/A$	Horton (1932) [16]	5.71 km/ km^2
19	Constant for channel maintenance	Unit A/ Unit L	Schumm (1956) [18]	0.18 Km^2/ km
20	Drainage intensity (D_i)	$D_i = F_s / D_d$	Faniran (1968) [30]	4.11
21	Infiltration number (I_f)	$I_f = F_s*D_d$	Faniran (1968) [30]	133.99
22	Length of overland flow (L_g)	$L_g = A/2*L_u$	Horton (1945) [15]	0.09 km

low relief and low slope. The elongation ratio in our current study was 0.67 (Table.4), this reveals that the major portion of the area has moderate relief and steep sloped, similar value of 0.67 was obtained by the Aiyar basin in the taminadu by Wilson [32].

3.2.7 Texture ratio (R_t)

Texture ratio is a key factor in drainage morphometric analysis because it is affected by infiltration capacity and terrain relief. Texture ratio is computed by dividing total number of first-order streams by the watershed perimeter (R_t = N1 / P). The calculated value is 7.84 (Table.4). This value indicating to be very high, implying very coarse texture, and reveals that watershed have high rainfall, a medium infiltration rate, and a high relief.

3.2.8 Circulatory ratio (R_c)

The watershed circularity ratio (R_c) is area of a circle with the same circumference as the watershed perimeter. Circulatory ratio is a vital indicator that is affected by the watershed climate, geological structure, slope, stream frequency, drainage density, and relief. circulatory ratio value ranges from 0 to 1, defining the minimum to maximum circulatory shape. R_c values of high, medium, and low indicate the old, mature, and young stages of the watershed's life cycle, respectively. The circulatory ratio of watershed ranges from 0 to 0.4, which indicates highly elongated and permeable homogeneous geologic materials [26]. The circulatory ratio in this watershed is 0.43 (Table.4), indicating a slightly elongated watershed with high runoff discharge and highly permeable subsoil, similar value i.e., 0.48 obtained by the Naliganahalli watershed explained as high runoff susceptible area by Srinivasa vittala [33].

3.2.9 Drainage texture (D_t)

Drainage texture is calculated as the ratio of sum of total number of streams of all the orders to that of perimeter of watershed. The drainage texture value is influenced by the vegetation, rock, climate, and soil type, as well as infiltration capacity, relief, and development stage. The drainage texture of a watershed is classified into five classes such as very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8), very fine (>8). In the Nanjannad watershed, the overall value of drainage texture was 10.15 (Table.4). This value implies that the watershed has moderate drainage texture. Similar kind of result was observed by Partha Prathim and Jyotiprava Dash ,2018 [17] for Katra watershed of Odhisa.

3.2.10 Compactness coefficient (C_c)

The compactness coefficient is calculated as the ratio of the watershed perimeter to the circumference of a circle which has equal area to the drainage basin. This is unaffected by the size of the watershed and is only affected by the slope. It is the deviation of the watershed shape from a circular watershed. C_c=1 denotes that the basin behaves entirely as a circular basin. C_c>1 indicates that the watershed is deviating from its circular shape. The compactness coefficient in this watershed is 1.89 (Table.4), this value indicates that the basin is deviated from the circular shape and this means it can be used easily for proper grazing.

3.2.11 Fitness ratio (R_f)

Fitness ratio is the proportion of main channel length to the watershed perimeter [28]. This value is used to indicate the topographic fitness of watershed. The fitness ratio in the watershed is 0.41 (Table.4), this value indicating that the watershed is topographically fit.

3.2.12 Wandering ratio (R_w)

The wandering ratio (R_w) is the proportion of the mainline length to the valley length [29]. The valley length is the straight-line distance from the watershed outlet to the ridge farthest point. The Wandering Ratio in watershed is 1.36 (Table.4).

3.2.13 Centre of gravity of the watershed (G_c)

Center of gravity of watershed is the center point on the watershed [34]. The center of gravity of the watershed was found out by using ArcGIS-9.3 software. In Nanjannad watershed the center of gravity is at 11˚21'40" N latitude and 76˚38'20" E longitude. Center of gravity provides the analysis of center point elevation in the watershed, how the flow is at central stage of the watershed.

3.2.14 Stream frequency (F_s)

The stream frequency of a watershed is defined as the total number of stream segments of all the orders present in a unit area [16]. The relief, permeability and infiltration capacity of the watershed have an influence on stream frequency (F_s). The drainage density, the initial resistivity of the rock, and the amount of rainfall also play a role. The Stream Frequency of our watershed is 23.47 (Table.4). This value implies that increase in the stream population is linked to that of the drainage density.

3.2.15 Drainage density (D_d)

Drainage density is an important landform parameter that represents the density or closeness of the stream network and allows for a quantitative measurement of potential runoff and dissected landscape [35]. Drainage density expresses that the ratio of total length of the stream regardless of stream order to the watershed per unit area. It is an expression for the dissection and analysis of landforms, even though a function of climate lithology and relief of that area. It can be used as indirect indicator to explain those variables and morphogenesis of landforms. The Spatial Analyst Tool in ArcGIS-9.3 is used to calculate drainage density. The drainage density in this study area was 5.71 km/km^2 (Table.4), indicating coarse drainage and permeable subsurface strata [21]. Rajiv Chopra, 2005 [36] found a similar type of finding for the Bhagra phungotri watershed in Punjab, where he found a D_d value of 5.84 km/km^2 indicating the coarse drainage in the watershed.

3.2.16 Constant of channel maintenance (C)

Constant of channel maintenance is defined as the inverse of Drainage density and this is a significant aspect of landform. It specifies the number of units of watershed surface that must support one unit of channel [18]. This is primarily determined by the permeability, rock type, climate regime, vegetation cover, and relief, as well as the duration of erosion. The 'C' value refers to the relative size of landform components in a river basin and has a specific genetic significance [25]. The Constant of Channel Maintenance in this Nanjannad watershed area is 0.18 km^2/km (Table.4).

3.2.17 Drainage intensity (D_i)

The drainage intensity is defined as the ratio of the basin's stream frequency (S_f) to its drainage density (D_d). In this study area, the Drainage Intensity was 4.11 (Table.4). This moderate value of drainage density indicates runoff is more likely to cause water logging.

3.2.18 Infiltration number (I_f)

The infiltration number of a watershed is defined as the product of Drainage density (D_d) and Stream Frequency (S_f) and the infiltration number obtained describes about the infiltration characteristics of the watershed [37]. It is inversely proportional to the infiltration capacity of the watershed. Lower infiltration and higher runoff are associated with a higher infiltration number. The Infiltration Number in the Nanjannad watershed was 133.99 (Table.4). This value indicates lower infiltration and high runoff in the watershed area.

3.2.19 Length of overland flow (L_g)

The length of overland flow is described as length of the flow path which is projected to horizontal, non-channel flow from one point on the stream divide to another point on the neighbouring stream channel [15]. The greater the average slope of the channel, the shorter the length of overland flow. This factor is exactly the same as that of the length of sheet flow. The Length of overland flow is scaled to fit the scale of the first order drainage watershed and is roughly equal to one-half the inverse of the Drainage intensity. In the present watershed the Length of Overland Flow was 0.09 km (Table.4). This value indicating that the length of overland flow is high. Similar value is obtained i.e 0.09 by the gyan in Kangshabati watershed [38].

3.3 Relief Aspects

Relief aspects are related to the estimation of three-dimensional properties of the watershed, the three-dimensional properties involve the area, volume and altitude of the landforms, the relief aspects are found out and the inference for the result is discussed and the values are tabulated in Table.5 and the slope of the watershed is major aspects which will be useful in estimation of the gradient ratio is found out using hydrology analysis as shown in Fig. 4.

3.3.1 Relief ratio (R_r)

The relief of watershed is computed as the difference in elevation between the highest elevation point and lowest elevation point on the watershed. The elevations in the watershed are used as a key indicator of a drainage system. The Relief ratio is defined as the ratio of total relief to the longest flow length of the watershed parallel to the main stream [18] and it is also proportional to the Length of the overland flow and time to peak. The steepness of the watershed impact on the watershed erosion intensity. Relief ratios typically increase as drainage area and decrease size. In the present watershed the relief ratio was 0.08 (Table.5). Similar values obtained in some watersheds as the result obtained is lower than the result i.e., 0.12 obtained by Rabindra Tiwari N *et al.,* 2021 [41] at Deonar river basin but higher than the result i.e., 0.04 obtained by Parta pratim and Jyotiprava, 2018 [17] at Katra watershed of Odisha.

3.3.2 Relative relief (R_{rp})

Relative relief is defined as the maximum relief of the watershed, this is obtained from highest point in the watershed perimeter to the point to stream mouth. The difference of highest and lowest elevation points in watershed is referred to as relative relief. Digital elevation model can provide a sense of relative relief for any watershed. The relative velocity of vertical tectonic movements can be calculated using relative relief. Relative relief is used to investigate active tectonic structures, identify paleo surfaces, estimate seismic activity, and investigate the interaction of endo and exogenic processes of orogenesis [42]. The relative relief of the watershed in our study was 259 m (Table.5), this value indicating that the relative relief is high and the watershed is more prone to soil erosion in the watershed region.

3.3.3 Ruggedness number (R_n)

Ruggedness number is defined as the product of two parameters i.e., relative relief and drainage density [39]. The ruggedness number denotes the terrain structure and also indicates that the area is susceptible to soil erosion. The ruggedness number computed for Nanjannad watershed is 1.48 (Table. 5). These results indicate that the Nanjannad watershed is extremely with high relief and with high stream density. Similar result is obtained i.e., 1.42 which is slightly lower that of the result obtained by Binoy kumar et al, 2021 [21] for a Chite Lui watershed.

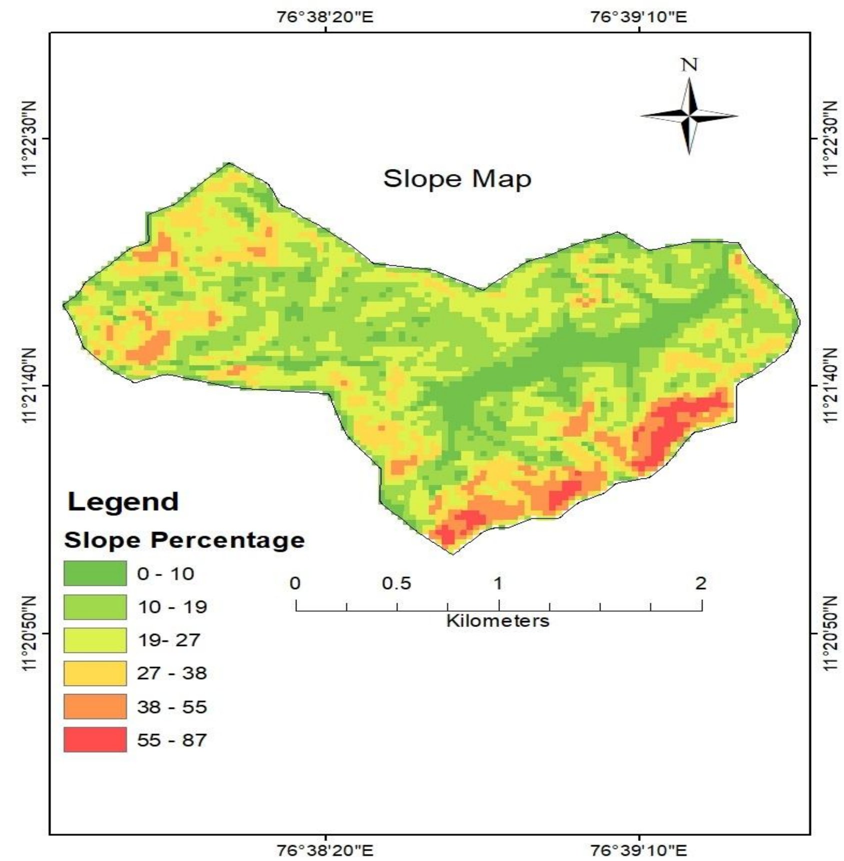

Fig. 4. Slope map

Table 5. Relief related morphometric parameters of Nanjannad watershed

Sl. No.	Morphometric parameters	Method/ Formula	Reference	Quantitative data
1	Height of basin mouth(z)	GIS analysis/ DEM	height	1928 m
2	Maximum height of the basin(Z)	GIS analysis/ DEM	height	2187 m
3	Relative relief (H)	H=Z-z	Strahler (1952) [39]	259 m
4	Relief ratio (R_{hl})	R_{hl}=H/L_b	Schumm (1956) [18]	0.08
5	Relative Relief ratio (R_{hp})	R_{hp}=H*100/P	Melton (1957) [28]	2.60
6	Gradient ratio (R_g)	R_g= (Z-z)/ Lb	Sreedevi et al.,[40]	86.22
8	Ruggedness number (R_n)	R_n=D_d*H/100	Melton (1965) [35]	1.48

3.3.4 Gradient ratio (R_g)

Gradient ratio is a measure of channel slope that allows for the calculation of runoff volume. The gradient ratio is defined as the slope steepness of its vertical intervals reduced to unity. The Gradient ratio is used to calculate the tangent of the watershed angle of slope. The Gradient ratio in a channel slope parameter used in the calculation of runoff volume [40]. The Gradient ratio in the watershed is 86.22 (Table.5). This value indicates that the Nanjannad watershed has high steepness and slope variation.

4. CONCLUSION

GIS has been shown to be a useful tool in watershed morphometric analysis. Based on the drainage orders present in Nanjannad watershed, this has been classified as Fourth order drainage watershed. Lower order streams predominate in the watershed. The morphometric analysis of the watershed drainage networks reveals a dendritic to sub-dendritic drainage pattern, all the results are correlated and intermediate GPS points are taken in the watershed which are cross checked with results have the exact values which showed the accuracy in the measurement of morphometric analysis of Nanjannad watershed, the linear, areal and relief parameters are corelated and it has seen a positive correlation of the watershed parameters.

The variation in stream length ratio is influenced by slope and topography of the watershed. The bifurcation ratio in the Nanjannad watershed indicates that geology has little influence on the drainage network. The frequency of streams and the drainage density have a positive correlation, indicating that there will be increase in stream population with respect to the increase of the drainage density of the watershed. The drainage density is very coarse to coarse textured, and the subsurface soil are permeable. With the moderate value of drainage density, stream frequency, and drainage intensity, runoff is more likely to cause water logging. Relief ratio values implies that the discharge of the Nanjannad watershed is high and groundwater potential is meager. This research is so much useful for design of rainwater harvesting structures of the Nanjannad watershed and also to design better water use strategies for watershed management.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

The author would like to thank V. Kasthuri Thilagam for providing help in the research work, ICAR-Indian Institute of Soil & Water Conservation, Research Centre, Udhagamandalam, 643 004, Tamil Nadu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Roy SK, Chowdhury MA, Talukdar S, Billah MM, Banik AC, Mallick J.

Comparisons of watershed delineation of river network representation and morphometric analysis in karnaphuli river basin, Chittagong, Bangladesh: a study with different digital elevation model (DEM); 2022.

2. Srinivasa Vittala S, Govindaiah S, Honne Gowda H. Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing. 2004;32(4):351-362.
3. Kumar S, Chaudhary BS. GIS applications in morphometric analysis of Koshalya-Jhajhara watershed in northwestern India. Journal of the Geological Society of India. 2016;88(5):585-592.
4. Choudhari PP, Nigam GK, Singh SK, Thakur S. Morphometric based prioritization of watershed for groundwater potential of Mula river basin, Maharashtra, India. Geology, Ecology, and Landscapes. 2018;2(4):256-267.
5. Khare D, Mondal A, Mishra PK, Kundu S, Meena PK. Morphometric analysis for prioritization using remote sensing and GIS techniques in a hilly catchment in the state of Uttarakhand, India. Indian Journal of Science and Technology. 2014;7(10):1650-1662.
6. Malik A, Kumar A, Kandpal H. Morphometric analysis and prioritization of sub-watersheds in a hilly watershed using weighted sum approach. Arabian Journal of Geosciences. 2019;12(4): 1-12.
7. López-Pérez A, Fernández-Reynoso DS. Watershed prioritization using morphometric analysis and vegetation index: A case study of Huehuetan river sub-basin, Mexico. Arabian Journal of Geosciences. 2021;14(18):1-21.
8. Mangan P, Haq MA, Baral P. Morphometric analysis of watershed using remote sensing and GIS—a case study of Nanganji River Basin in Tamil Nadu, India. Arabian Journal of Geosciences. 2019;12(6):1-14.
9. Prabhakar AK, Singh KK, Lohani AK, Chandniha SK. Study of Champua watershed for management of resources by using morphometric analysis and satellite imagery. Applied Water Science. 2019;9(5):1-16.
10. Manivannan S, Kannan B, PS Khola O, Kasthuri Thilagam V. Geospatial Technology Based Water Management Action Plan for South Forest Division of Nilgiris, Tamil Nadu; 2021.
11. Sujatha ER, Selvakumar R, Rajasimman B. Watershed prioritization of Palar sub-watershed based on the morphometric and land use analysis. Journal of Mountain Science. 2014;11(4): 906-916.
12. Govindaraj D, Senthikumar N, Periyasamy SS. Altitudinal gradients and species richness: A study on diversity of orthoptera in Nilgiris Shola Forests and Grasslands. Records of the Zoological Survey of India. 2022;121(4):465-472.
13. Saravanan S, Jennifer JJ, Singh L, Thiyagarajan S, Sankaralingam S. Impact of land-use change on soil erosion in the Coonoor Watershed, Nilgiris Mountain Range, Tamil Nadu, India. Arabian Journal of Geosciences. 2021;14(5):1-15.
14. Wentworth CK. A simplified method of determining the average slope of land surfaces. American Journal of Science. 1930;20(117):184-194.
15. Horton RE. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geological Society of America Bulletin. 1945;56(3): 275-370.
16. Horton RE. Drainage-basin characteristics. Transactions, American geophysical union. 1932;13(1):350-361.
17. Adhikary PP, Dash CJ. Morphometric analysis of Katra watershed of Eastern Ghats: A GIS approach; 2018.
18. Schumm SA. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological society of America bulletin. 1956;67(5):597-646.
19. Black PE. Hydrograph responses to geomorphic model watershed characteristics and precipitation variables. Journal of hydrology. 1972;17(4):309-329.
20. Schumm SA. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological society of America bulletin. 1956;67(5):597-646.
21. Barman BK, Rao CUB, Rao KS, Patel A, Kushwaha K, Singh SK. Geomorphic Analysis, Morphometric-based Prioritization and Tectonic Implications in

Chite Lui River, Northeast India. Journal of the Geological Society of India. 2021;97(4):385-395.

22. Tukura NG, Akalu MM, Hussein M, Befekadu A. Morphometric analysis and sub-watershed prioritization of Welmal watershed, Ganale-Dawa River Basin, Ethiopia: implications for sediment erosion. Journal of Sedimentary Environments. 2021;6(1):121-130.
23. Hack JT. Studies of longitudinal stream profiles in Virginia and Maryland. US Government Printing Office. 1957; 294.
24. Chorley RJ. Illustrating the laws of morphometry. Geological Magazine. 1957; 94(2):140-150.
25. Strahler AN. Quantitative analysis of watershed geomorphology. Eos, Transactions American Geophysical Union. 1957;38(6):913-920.
26. Miller VC. A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area Virginia and Tennessee. Columbia Univ New York; 1953.
27. Magesh NS, Chandrasekar N, Soundranayagam JP. Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu, India: a GIS approach. Environmental Earth Sciences. 2011;64(2):373-381.
28. Melton MA. An analysis of the relations among elements of climate, surface properties, and geomorphology. Columbia Univ New York; 1957.
29. Smart JS, Surkan AJ. The relation between mainstream length and area in drainage basins. Water Resources Research. 1967;3(4):963-974.
30. Faniran A. The index of drainage intensity: a provisional new drainage factor. Aust J Sci. 1968;31(9):326-330.
31. Pareta K, Pareta U. Integrated watershed modeling and characterization using GIS and remote sensing techniques. Indian Journal of Engineering. 2012;1(1): 81-91.
32. Wilson JJ, Ch N. Morphometric analysis of major sub-watersheds in Aiyar & Karai Pottanar Basin, Central Tamil Nadu, India using remote sensing & GIS techniques. Bonfring International Journal of Industrial Engineering and Management Science, 2(Special Issue Special Issue on Geospatial Technology Development in Natural Resource and Disaster Management). 2012;08-15.
33. Srinivasa Vittala S, Govindaiah S, Honne Gowda H. Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing. 2004;32(4):351-362.
34. Mishra SS, Nagarajan R. Morphometric analysis and prioritization of sub-watersheds using GIS and remote sensing techniques: A case study of Odisha, India. International Journal of Geomatics and Geosciences. 2010;1(3):501.
35. Melton MA. The geomorphic and paleoclimatic significance of alluvial deposits in southern Arizona. The Journal of Geology. 1965;73(1):1-38.
36. Chopra R, Dhiman RD, Sharma PK. Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing. 2005;33(4):531-539.
37. Umrikar BN. Morphometric analysis of Andhale watershed, Taluka Mulshi, District Pune, India. Applied Water Science. 2017;7(5):2231 -2243.
38. Gayen S, Bhunia GS, Shit PK. Morphometric analysis of Kangshabati-Darkeswar Interfluves area in West Bengal, India using ASTER DEM and GIS techniques. J Geol Geosci. 2013;2(4): 1-10.
39. Strahler AN. Hypsometric (area-altitude) analysis of erosional topography. Geological society of America bulletin. 1952;63(11):1117-1142.
40. Sreedevi PD, Subrahmanyam K, Ahmed S. The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. Environmental Geology. 2005; 47(3):412-420.
41. Tiwari RN, Kushwaha VK. Watershed Prioritization Based on Morphometric Parameters and PCA Technique: A Case Study of Deonar River Sub Basin, Sidhi Area, Madhya Pradesh, India. Journal of the Geological Society of India. 2021; 97(4):396-404.

42. Anand AK, Pradhan SP. Assessment of active tectonics from geomorphic indices and morphometric parameters in part of Ganga basin. Journal of Mountain Science. 2019;16(8):1943-1961.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87218