# MORPHOMETRIC ANALYSIS OF PALAR RIVER BASIN, Kancheepuram District, Tamil Nadu, India


## Abstract

The study concludes that capturing the response of the hydrological pattern of the watershed might be accomplished by the analysis of morphological parameters with the use of a geographic information system (GIS). Additionally, it has been noted that the most efficient, quick, and precise method for morphometric study of a basin is emerging from remote sensing satellite data. This method is proven to be useful for extracting river basins and their stream networks using ASTER (DEM) and remote sensing satellite data. An effective tool for morphometric study and assessment of the linear, slope, areal, and relief aspects of morphometric parameters is geoprocessing methods. The combined results have identified the basin's topographical conditions and even its most recent developmental circumstances. Additionally, the structure of the area will alter. Therefore, in order to properly plan and manage the development of both the water resources development plan and the land resource development plan, it is necessary to analyse high level characteristics of drainage and environment. The area that is presently part of the Kancheepuram district was formerly part of the Chengalpattu district. The Kancheepuram and Tiruvallur district was formed in 1997 by dividing the previous Chengalpattu district. Tamil Nadu has the district of Kancheepuram. Rani Pet and Tiruvannamali district, in the west, and Tiruvallur district, in the north, border it. Chengalpattu district lies in the east. Kancheepuram is one of the states of Tamil Nadu's 38 districts. Geographically, the district is 4,43,210 hectares large. Calculated morphometric characteristics include stream order, length, bifurcation ratio, drainage density, frequency of streams, form factor, circulatory ratio, etc. The development of the drainage system is influenced by the lithology and has been influenced by the study of all morphometric parameters in GIS. The erosional development of the land caused by the streams has advanced well beyond maturity. The design of rainwater collecting, and watershed management can benefit greatly from this research.



## Keywords

Drainage morphometry – Palar River basin – Watershed management – DEM – GIS

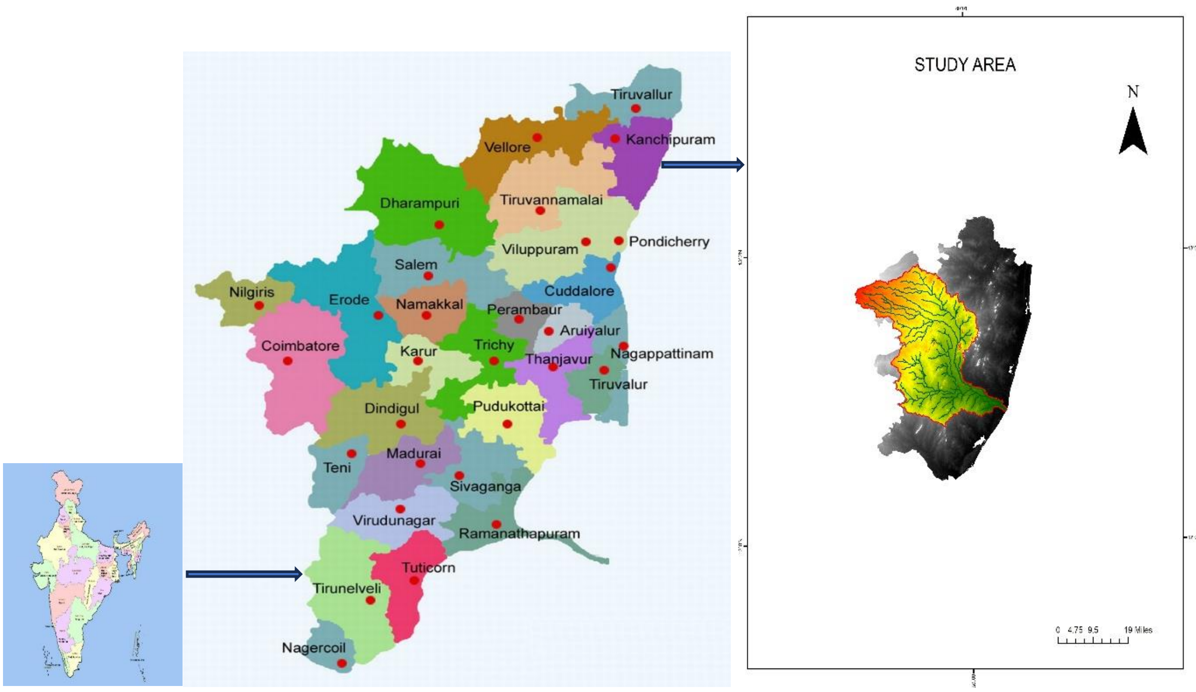

## Introduction

Morphometry refers to the measurement and mathematical study of the physical characteristics of the Earth's surface ae well as the size, shape, and arrangement of its landforms. Numerous factors, including the geology, structural elements, geomorphology, soil, and vegetation of the area through which it runs, have an impact on the evolution of drainage systems across both space and time. An essential part of describing basins is their morphology, and morphometric study of river basins gives a quantitative description of the drainage system. It is crucial in all hydrological investigations, including those that evaluate the potential for groundwater, manage groundwater, manage basins, and analyse the environment. The physiographic features of a drainage basin, such as its size, shape, slope, drainage density and length of the contributories, etc., are connected to a variety of hydrological phenomena. Drainage gives a fundamental understanding of the drainage basins or watershed's starting gradient, variation in rock resistance, structural control, and geological and geomorphologic history. Analysis of various drainage parameters, including stream ordering, basin area and perimeter measurement, drainage channel length, drainage density (Dd), bifurcation ratio (Rb), length of the stream, stream density, stream network number, circularity ratio (Rc), elongation ratio (Re), form factor (Ff) , length of overland flow (Lg), length area relation (Lar), compactness coefficient (Cc), constant channel maintenance, stream frequency, texture ratio, mean stream length is necessary for the evaluation of morphometric parameters. In addition, the quantitative evaluation of the drainage system is a crucial watershed attribute. The satellite pictures from the remote sensing technology are highly helpful in the study of drainage basin morphometry because they give a synoptic view of a wide area and are a practical way for morphometric analysis. Most of the issues with land and water resources planning and management may be solved using the rapidly developing spatial information technology, remote sensing, GIS, and GPS, as opposed to traditional techniques of data processing. To determine morphometric characteristics in a GIS setting, such as drainage basin area, drainage density, drainage order, relief, and network diameter, a Digital Elevation Model (DEM) of the area was created. The drainage region may be easily identified and distinguished using a combination of hydrological and spatial analysis, remote sensing satellite data, and a GIS environment. For hydrological research including the evaluation of groundwater potential, etc., the geographic and geomorphic features of a drainage basin are significant. The current research area shows how remote sensing and GIS techniques are used to determine the various morphometric characteristics of the Palar River Basin in the Kancheepuram districts.

## Study area

Kancheepuram is one of the states of Tamil Nadu's 38 districts. The area that is presently part of the Kancheepuram district was formerly part of the Chengalpattu district. The Kancheepuram and Tiruvallur district was formed in 1997 by dividing the previous Chengalpattu district. Its latitude and longitude are 12° 14′ 00″ to 13° 02′ 00″ N and 79° 31′ 30″ to 80° 15′ 30″ E, respectively. The district covers a total area of 4,43,210 hectares. The northeast and southwest monsoons are the greatest, contributing 54% and 36% of the total annual rainfall, respectively. One of the largest ephemeral rivers in southern peninsular India is the Palar River. The river has been dammed for irrigation purposes, especially throughout Tamil Nadu's portion of its course. Numerous studies on the Palar River basin have been conducted to comprehend its channel avulsion, drainage system, flood occurrences in the Palar basin, etc. However, considering the neotectonics activity in the drainage pattern and their geometric configurations, the drainage systems of this region have received little attention. Using SRTM data, the research area's river basin border and stream network are identified. Using WGS 1948 UTM Zone 43N, the extracted basin and stream network is projected to the local projection.

Figure 1: Study Area



## Methodology

For the purpose of developing strategies for soil and water conservation, the current work is based on a morphometric analysis of the Palar River Basin. DEM data (30 m resolution) was used to analyse the morphometric conditions. ArcGIS 10.3 software aids in the delineation of the Palar River Basin. GIS software automatically gathers direct measurements of geometric properties, such as the length and number of streams, the length and perimeter of the basin. Area, perimeter, stream order, length, number, bifurcation ratio, drainage density, frequency, drainage texture, length of basin, form factor, circulatory ratio, and elongation ratio, among other morphometric characteristics. Every morphometric attribute is considered as a separate parameter and given knowledge-based weighting by considering how it affects soil erosion. A rank has been assigned to each parameter based on the morphometric analysis. Aerial aspect has minimal weighting for high values whereas linear aspect has a strong weighting for high values. The parameters of the drainage basin aid in evaluating and comprehending the linked slope and relief qualities. The basin with the lowest compound weight has been given priority once the compound parameter values have been determined. Three main categories-high priority, moderate priority, and bad priority- have been established for the ultimate priority categorization. The high priority emphasises the necessity for a reclamation process and an action plan for managing floods and conserving soil and water.

Table 1: Morphometric Analysis of Palar River Basin- a comparative characteristics

| Morphometric parameters | Formula & definition | Reference |
|---|---|---|
| Area of basin (A) | Plan area of the watershed (km^2) | Horton 1945 |
| Bifurcation ratio (Rb) | Rb = Nu / Nu + 1<br>Where Nu = number of stream segments present in the given order<br>Nu + 1 = number of segments of the next higher order | Schumn 1956 |
| Stream density (Dd) | Dd = Stream length/Basin area | Horton 1945 |
| Circulatory ratio (Rc) | Rc = 4 π × A / P2<br>Where A = area of the basin<br>π = 3.14<br>P = perimeter of the basin | Miller 1953 |
| Compactness Coefficient (Cc) | Cc = 0.2821P/A^0.5<br>Where P = basin perimeter<br>A = area of the basin | Gravelius 1914 |
| Constant channel maintenance (C) | Lof = 1/ Dd<br>Where Dd = drainage density | Horton 1945 |
| Drainage density (Dd) | Dd = L/A<br>where L = total length of stream<br>A = area of the basin | Horton 1945 |
| Elongation ration (Re) | Re =√ (A/ π)/Lb<br>Where A = area of basin<br>π = 3.14<br>Lb = basin length | Schumn 1956 |
| Form factor (Ff) | Ff = A/(Lb)2<br>Where A = area of basin<br>Lb = basin length | Horton 1945 |
| Length of overland flow (Lg) | Lg = 1/2Dd<br>Where Dd = drainage density | Horton 1945 |
| Length Area Relation (Lar) | Lar = 1.4*A0.6 | Hack 1957 |

| | | |
|---|---|---|
| Mean stream length (Lsm) | Lsm = Lu/Nu<br>Where Lu = mean stream length of a given order (km)<br>Nu = number of stream segments | Horton 1945 |
| Perimeter of basin (P) | Perimeter of watershed (km) | Horton 1945 |
| Stream frequency (Fs) | Fs = N/A<br>Where L = total number of streams<br>A = area of basin | Horton 1945 |
| Stream length (LU) | Length of the stream | Horton 1945 |
| Stream number (Nu) | Nu = Total number of stream segments of order u | Strahler 1964 |
| Stream order (U) | Hierarchical order | Strahler 1964 |
| Texture ratio (T) | T = N1/P where N1 = total number of first order-stream<br>P = perimeter of basin | Horton 1945 |

## Morphometric Analysis

The findings of the morphometric analysis performed in the current study are briefly explained and analysed, along with the integration of remote sensing and GIS methodologies. Basin and stream network geometries are connected to the movement of water and sediment across basins through the study of basin morphometry. The length, shape, and relief of a drainage basin determine the rate at which water is discharged from the basin. The size of the drainage basin influences the quantity of water output. By using the mathematical formulas provided in Table, the morphometric analysis is performed with respect to the parameters such as Area of the basin, Length of the stream, Stream order, Stream density, Perimeter of the basin, Stream network number, Drainage density, Circularity ratio, Elongation ratio, Form factor, Length of overland flow, Length area relation, Compactness coefficient, Constant channel maintenance, Stream frequency, Texture ratio, Bifurcation ratio, Mean stream length.

## Result and discussion

The findings of the examination of the morphometric characteristics of the Palar River Basin are shown below. The research area is 1904.43 km^2 in size. The overall geography of the area causes the dendritic drainage pattern, which is sloped.

## Area of the Basin (A)

Like the course of the stream drainage, the size of the river basin is an essential factor. The contributing areas correspond an intriguing relationship that Horton (1945) found between the total basin areas and the total stream lengths. ArcGIS 10.3 software is used to calculate the basin area, which is 1904.43 km^2 in Table.

Figure 2: Area of basin

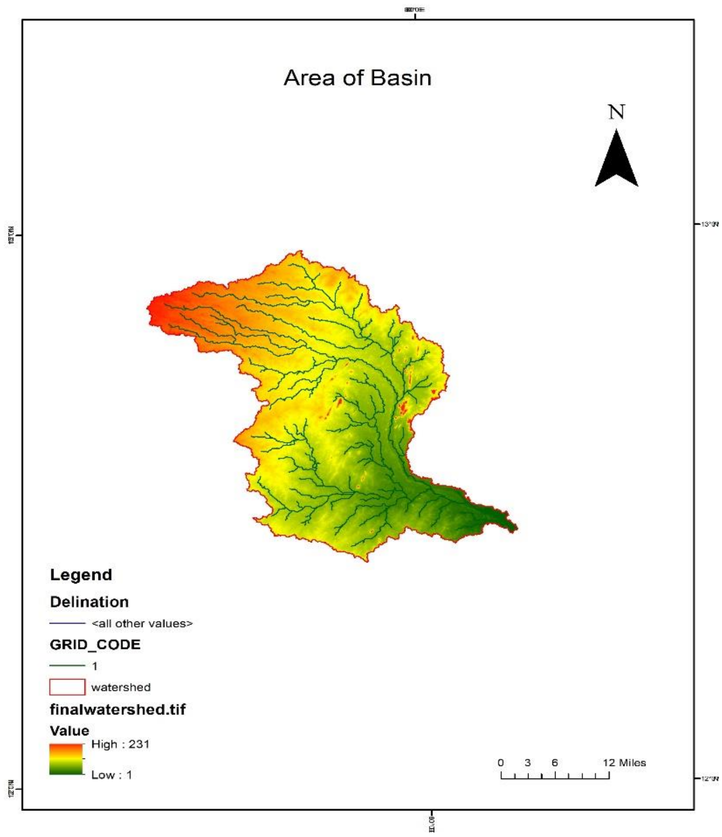



Figure 2: Area of basin

## Length of the Stream (LU)

From the source to the confluence, the stream length (LU) is the portion of the basin with the greatest length (Horton 1945). The Nandi Hills, which are situated in the Indian state of Karnataka, are the source of the Palar River Basin. It is a large river system that flows through Tamil Nadu, Andhra Pradesh and Karnataka before emptying into the Bay of Bengal in Southern India. The form of the basin is determined by its length. A lengthy basin is indicated by a high basin length. The basin's LU is 795.203856 km.

Figure 3: Length of the Stream

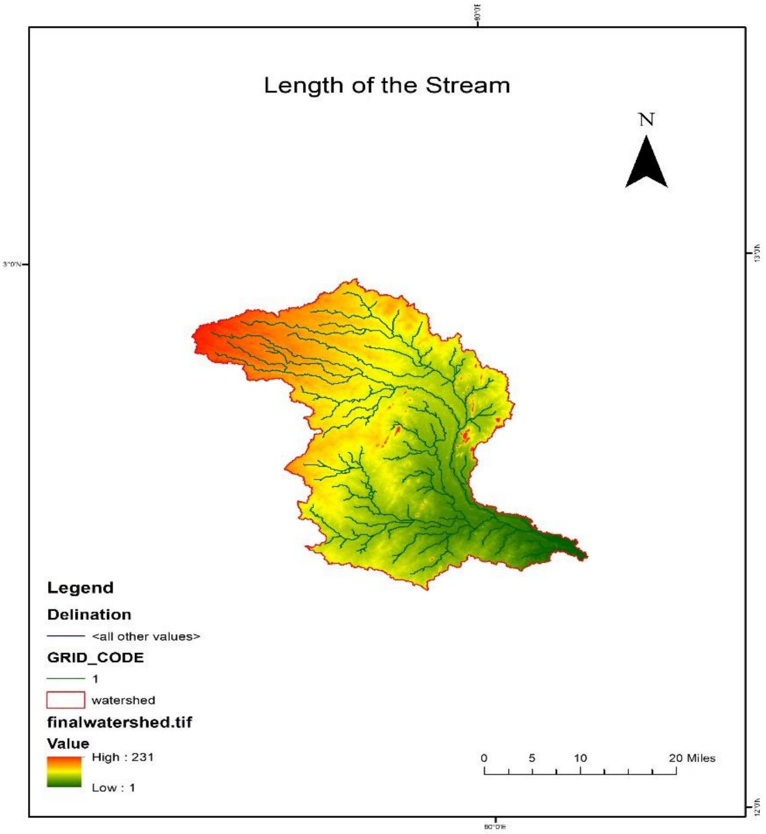



Figure 3: Length of the Stream

## Stream Order

Horton first proposed the idea of stream order in 1932. A strategy that is frequently used to classify streams in a river basin is stream ordering. The Palar River Basin's streams have been designated using the Strahler's system of stream ordering, which is a measure of a stream's position in the hierarchy of tributaries. The basin's stream order, including the total number of stream segments in each order. In the research area's hilly sector, more first-order streams are seen, indicating that the topography is denser there and that the underlying lithology is more compacted. Additionally, the existence of numerous streams in the basin suggests that the terrain is still eroding, whereas the absence of numerous streams denotes mature topography. The estimated outcome was consistent with Strahler's (1964) theory, according to which the number of streams overall steadily declines as stream order rises.

Table 2: Morphometric Analysis of Stream Order

| Stream Order | Stream Order Count | Average Stream Length | Variance Stream Length |
|---|---|---|---|
| 1 | 175 | 5.3531 | 0 |
| 2 | 56 | 2.9582 | 0 |
| 3 | 31 | 4.1105 | 0 |
| 4 | 2 | 1.265 | 0 |
| 5 | 1 | 3.3115 | 0 |

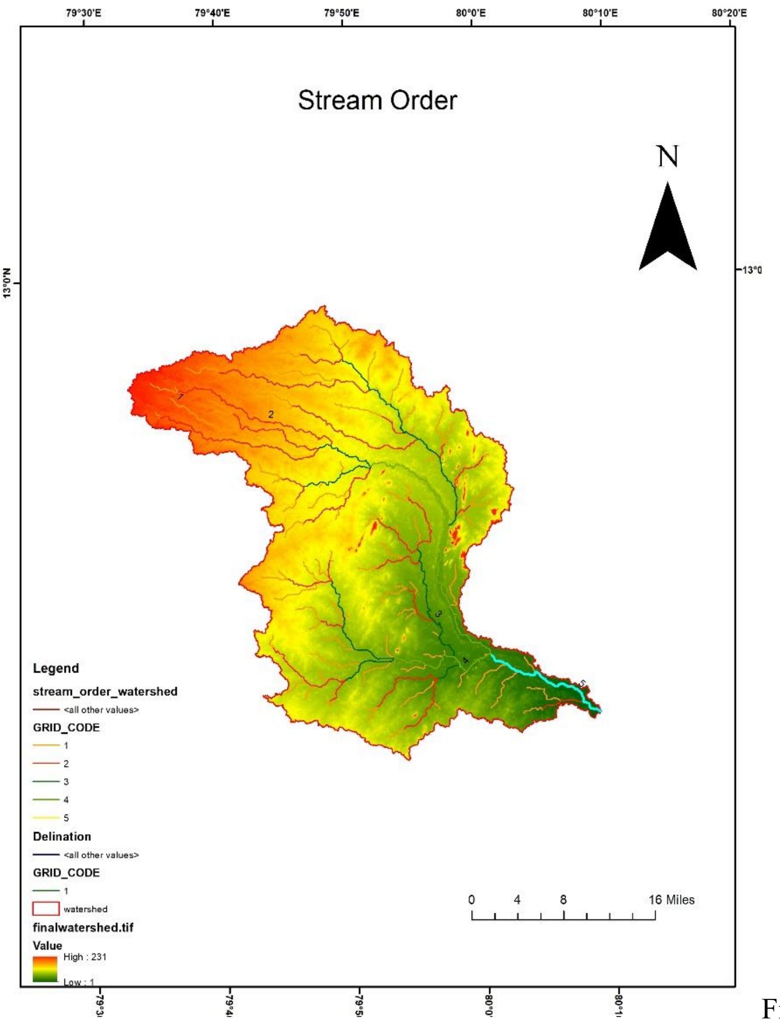
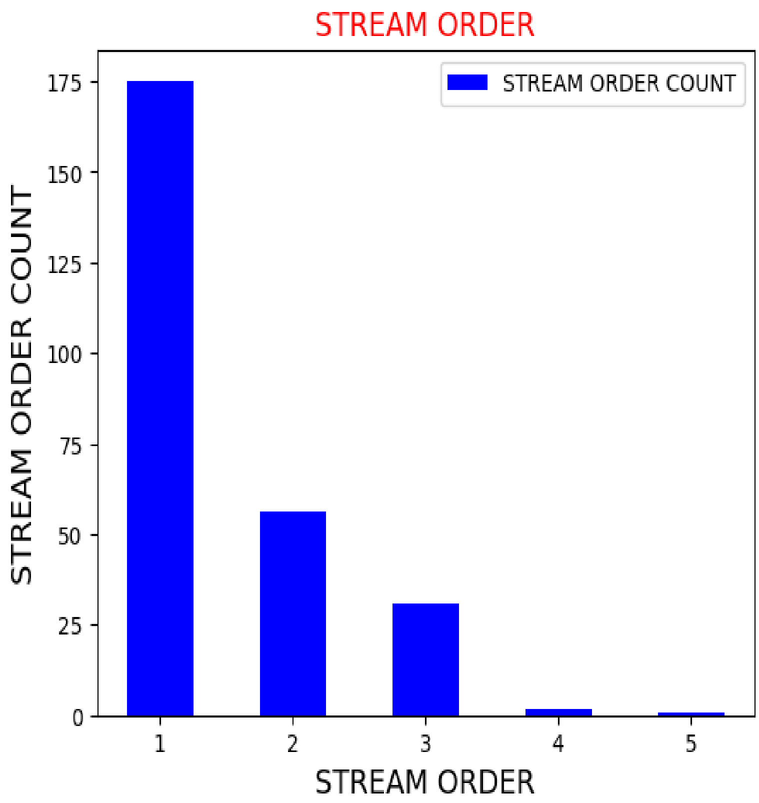



Figure 4: Stream Order



Drainage Density (Dd)

One of the key indicators of the landform element, drainage density (Dd), gives a numerical measurement of the runoff potential and division of the terrain. According to Horton (1945), Dd is the ratio of the basin's total area to all its streams.

Table 3: Morphometric Analysis of Drainage Density

| Point | Grid Study | Drainage Density |
|---|---|---|
| 1 | A1 | 0.343069 |
| 2 | A2 | 0.360644 |
| 3 | B1 | 0.429085 |
| 4 | B2 | 0.450338 |
| 5 | B3 | 0.121878 |
| 6 | C1 | 0.241555 |
| 7 | C2 | 0.449544 |
| 8 | C3 | 0.509728 |

Figure 5: Drainage Density

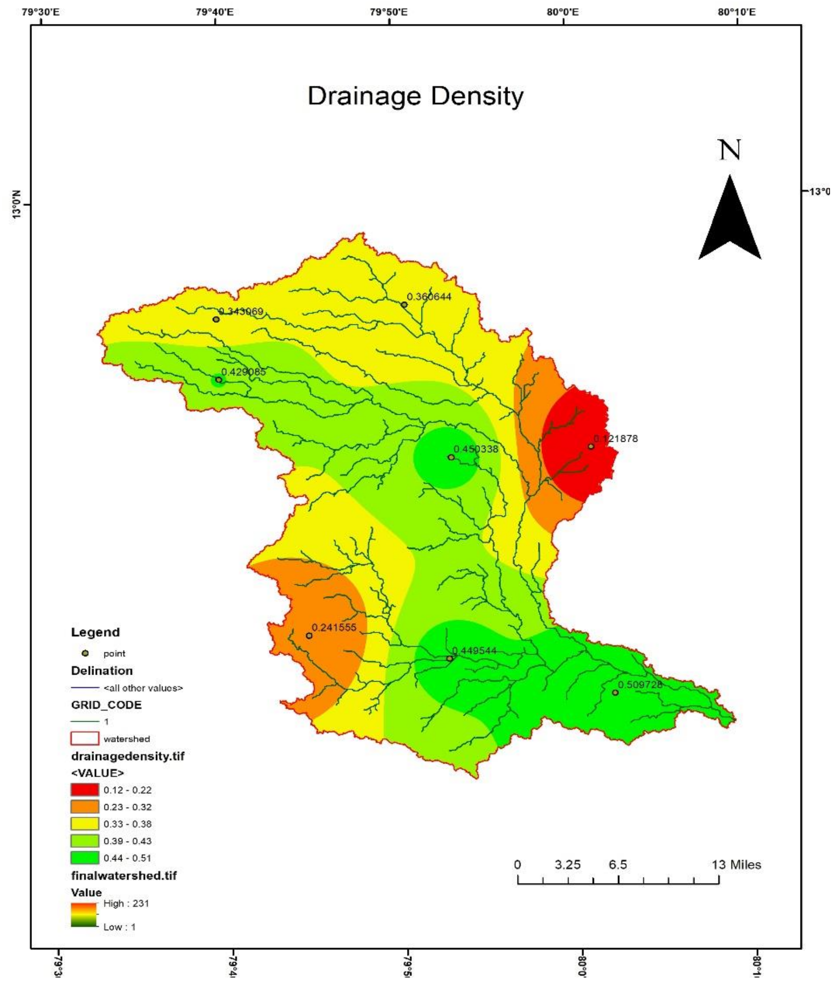
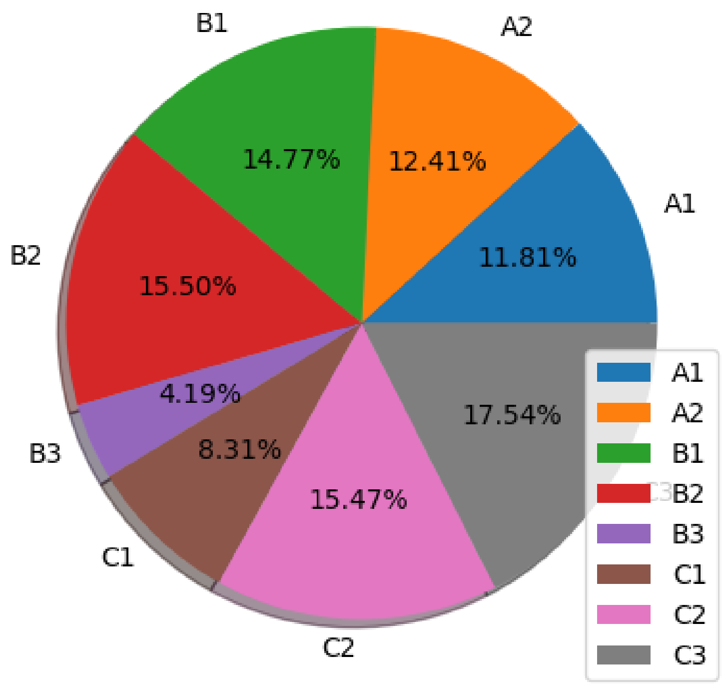
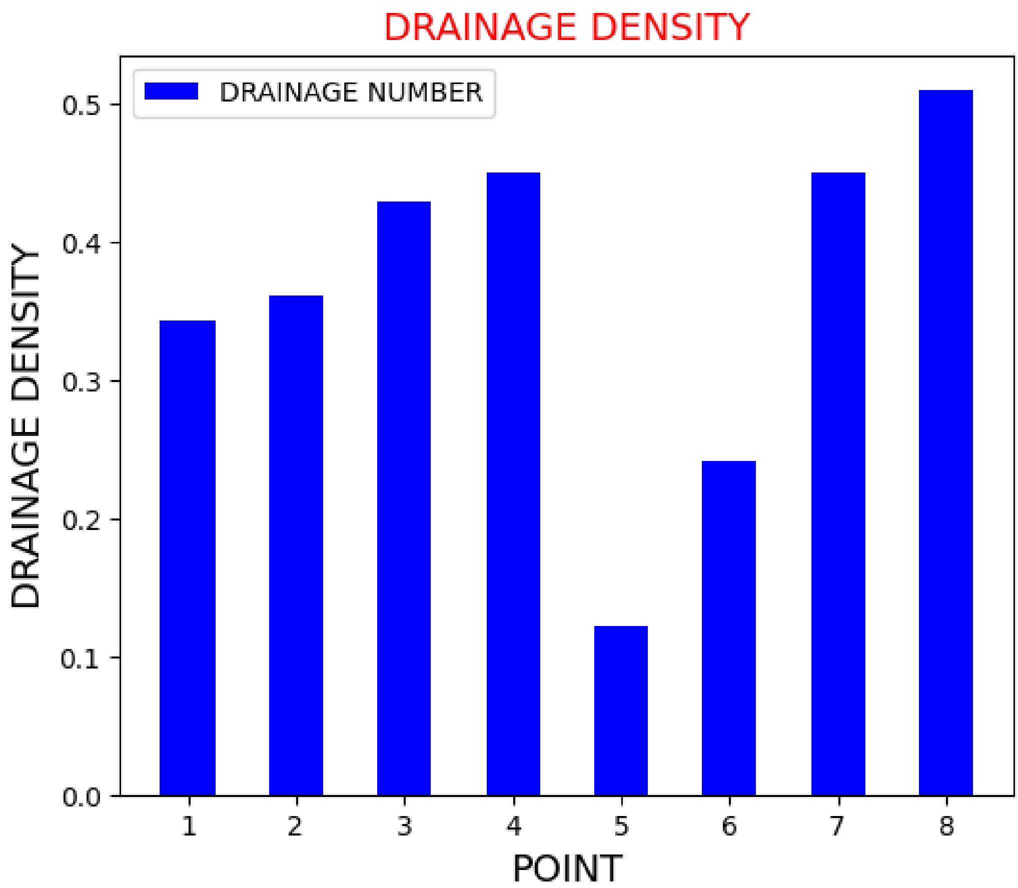



Figure 5: Drainage Density




Stream Density

In morphometric analysis, stream density measures how many streams are present in a certain region. It is computed by dividing the sum of the streams' lengths in a watershed by its area.

A dense network of streams is indicated by a high stream density, whereas fewer streams are indicated by a low stream density. Here, there are 417.555 km^2 of streams.

Figure 6: Stream Density

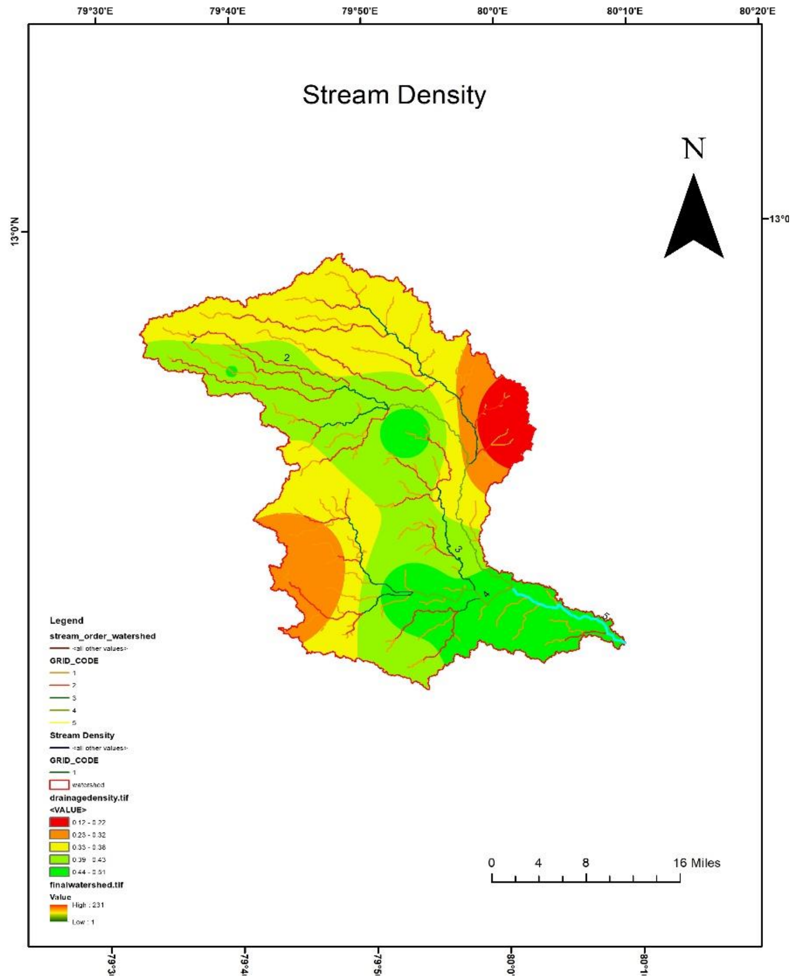



Figure 6: Stream Density

Perimeter of Basin (P)

The perimeter of a basin in morphometric analysis refers to the length of the boundary or outline that completely encloses the drainage basin. It is a crucial variable that is used to evaluate the basin’s size and shape and provide information about its hydrological properties. Understanding the flow pathways and the distribution of water throughout the drainage region is aided by perimeter measurement (Horton, 1945). The research area’s 344.7763 km perimeter.

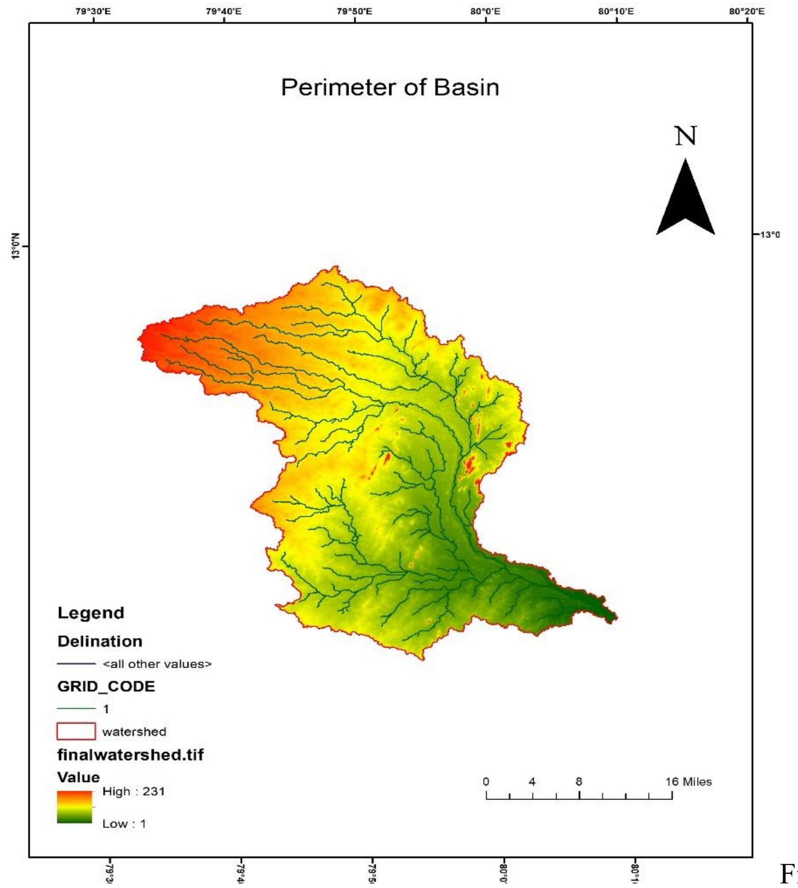



Figure 7: Perimeter of Basin

## Stream Network Number (Nu)

The five streams of various orders and the overall number of streams in the basin are separately tailed with the use of GIS (Table 1). In general, as stream order rises, the number of streams gradually declines. The size of tributary basins and variance in stream order are strongly influenced by the region's physiographic and structural conditions. In Palar River Basin, there are 265 identified stream segments (Table 1). In the research region, a sizable runoff drainage pattern has been identified. All these morphometric criteria are used to designate runoff zones, groundwater recharge zones, and storage areas in established watershed management. High first-order stream values point to the potential for an unforeseen flash flood following significant downstream rainfall (Strahler, 1964).

Table 4: Morphometric Analysis of Stream Network Number

| Stream Order | Stream Network Number |
|---|---|
| 1 | 175 |
| 2 | 56 |
| 3 | 31 |
| 4 | 2 |
| 5 | 1 |

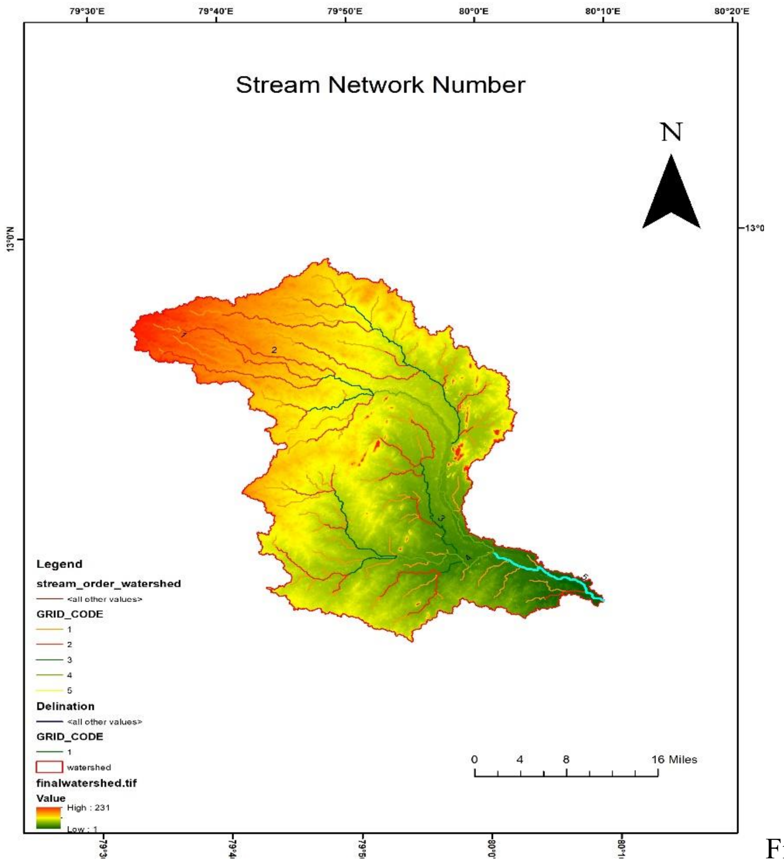
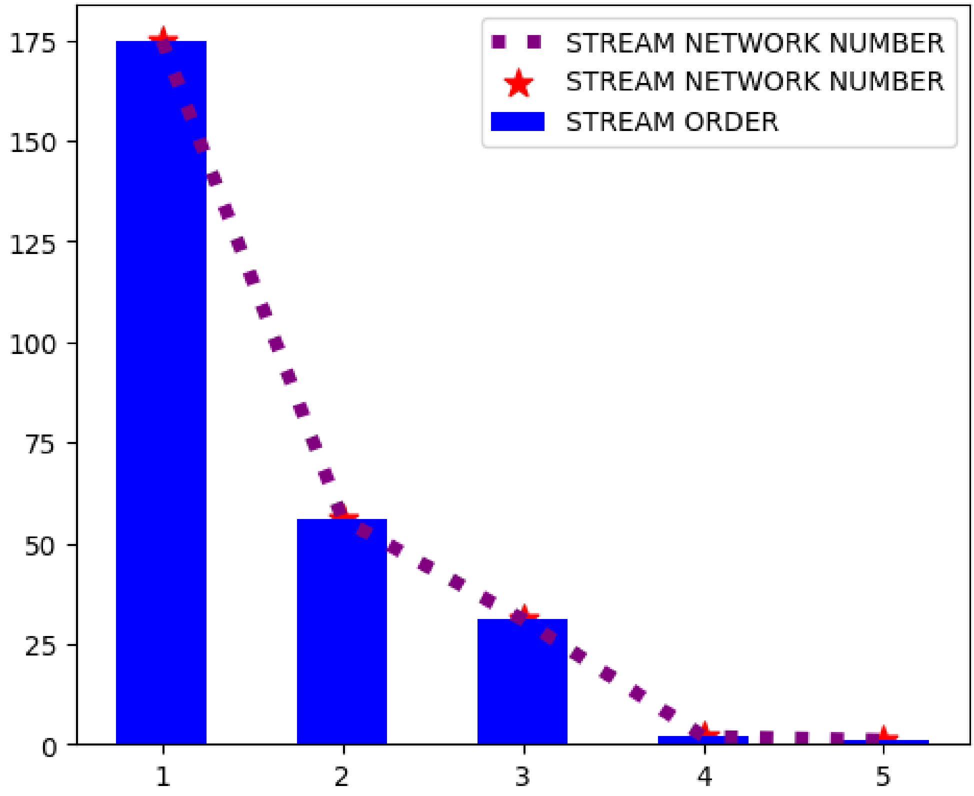



Figure 8: Stream Network Number




Circularity Ratio (Rc)

According to Strahler (1964) and Miller (1953), circularity ratio (Rc) is defined as the ratio of the basin's area (A) to a circle with the same perimeter (P) as the basin. Geology and structure, relief, slope, climate, stream frequency and length, and LULC within the basin region are the key controlling factors. The "RC" values between 0.4 and 0.7 denote homogeneous geologic materials that are strongly elongated and very permeable (Miller 1953). Lower circularity ratios produce more elongated basin forms, which can have an impact on things like runoff patterns and drainage effectiveness. It would be easier to comprehend the relevance of this value considering the management or research objectives for the basin at consideration. In order to assess the geometry of basins by morphometric analysis, the circularity ratio is utilised as a dimensionless measure. An irregular or extended form for the basin is suggested by a circularity ratio of 0.2012197194.

## Elongation Ratio (Re)

Elongation ratio (Re) is defined as the ratio of a circle's diameter to the longest possible basin length (Schumm, 1956). Using the "Re" index, the varying slopes of the basin may be classified as circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5). The "Re" value of the basin is 0.0253, which is more elongated. The value ranges from 0.8 to 0.6 are associated to highly steep gradient and high elevation, while the "Re" near to 1.0 suggest the region belongs to extremely low relief with minimal structural effects (Strahler 1964).

## Form Factor (Ff)

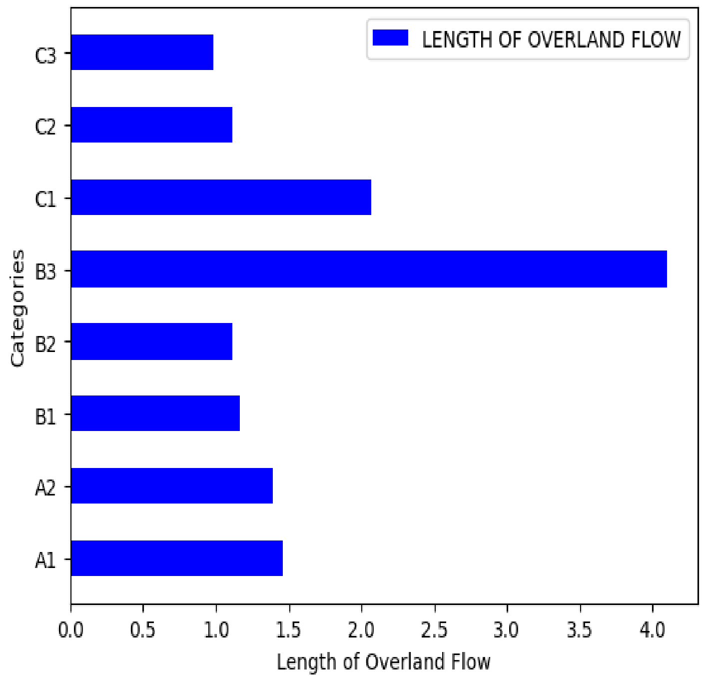
According to (Horton 1945), the form factor (Ff), which is used to estimate a basin's intensity, is the ratio of the basin's area to its square root. A basin with a low "Ff" value will be longer and have lower peak flows that last for a longer time, whereas a basin with a high "Ff" value will experience greater peak flows that last for a shorter time. Here, the form ratio of 0.003014 indicates a low value, which signifies that the basin is extended or irregular in shape.

## Length Of Overland Flow (Lg)

The length of overland flow (Lg) is the distance between a location on the stream divide and a point on the adjacent stream channel projected to the horizontal, non-channel flow (Horton 1945). The "Lg" is scaled to a size appropriate for the first order drainage basin, and it roughly equates to one-half the reciprocal of the "Di".

Table 5: Morphometric Analysis of Length of Overland Flow

| Point | Drainage Density | Lg |
|---|---|---|
| 1 | 0.343069 | 1.4574 km |
| 2 | 0.360644 | 1.3864 km |
| 3 | 0.429085 | 1.1652 km |
| 4 | 0.450338 | 1.1102 km |
| 5 | 0.121878 | 4.1024 km |
| 6 | 0.241555 | 2.0699 km |
| 7 | 0.449544 | 1.1122 km |
| 8 | 0.509728 | 0.98091 km |




## Length Area Relation (Lar)

Hach (1957) discovered that for a significant number of basins, the stream length and basin size are related by the following straightforward power function: Lar = 1.4 * A 0.6. The basin's Lar' is 1580.837.

## Compactness Coefficient (Cc)

According to Gravelius (1914), the compactness coefficient (Cc) is the ratio of a basin's perimeter to its circumference, which is equal to the basin's area. The Cc is solely reliant on slope and irrespective of watershed size. The basin's "Cc" is 2.240.

## Constant Channel Maintenance (c)

According to Schumm (1956), a key component of a landform is the constant of channel maintenance (C), which is the inverse of the function "Dd". The constant is the amount of basin surface per km^2 required to create and maintain a canal 1 km in length. It is primarily influenced by the kind of rocks, its permeability, the climate, the amount of vegetation present, the relief, and the rate of erosion. The "C" value, which has a specific genetic meaning (Strahler 1957), denotes the relative size of landform components within a river basin. Any basin with a high "C" value shows that the area of the lower stream order drainages is somewhat bigger than the area of the sub-basins with a lower "C" value. Low basin "C" value shortens overland flight (Lg), causing water to discharge quickly as channel flight in sparse plant cover.

Table 6: Morphometric Analysis of Constant Channel Maintenance

| Point | Drainage Density | C (km^2) |
|---|---|---|
| 1 | 0.343069 | 2.9148 |
| 2 | 0.360644 | 2.7728 |
| 3 | 0.429085 | 2.3305 |
| 4 | 0.450338 | 2.2205 |
| 5 | 0.121878 | 8.2049 |
| 6 | 0.241555 | 4.1398 |
| 7 | 0.449544 | 2.2244 |

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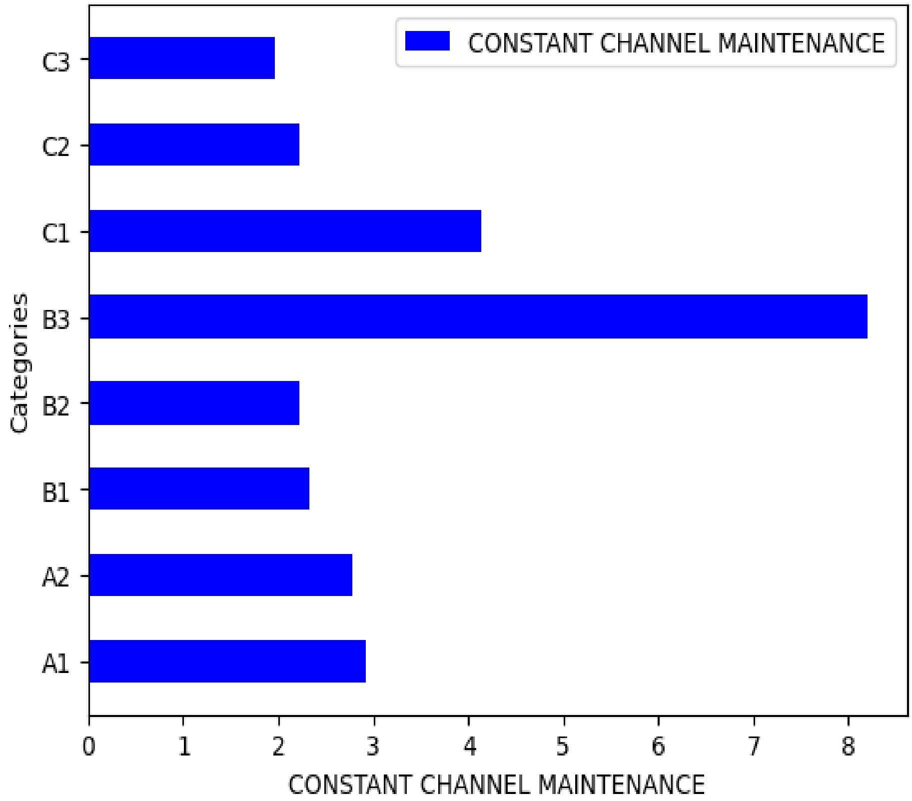
|---|---|---|
| 8 | 0.509728 | 1.9618 |

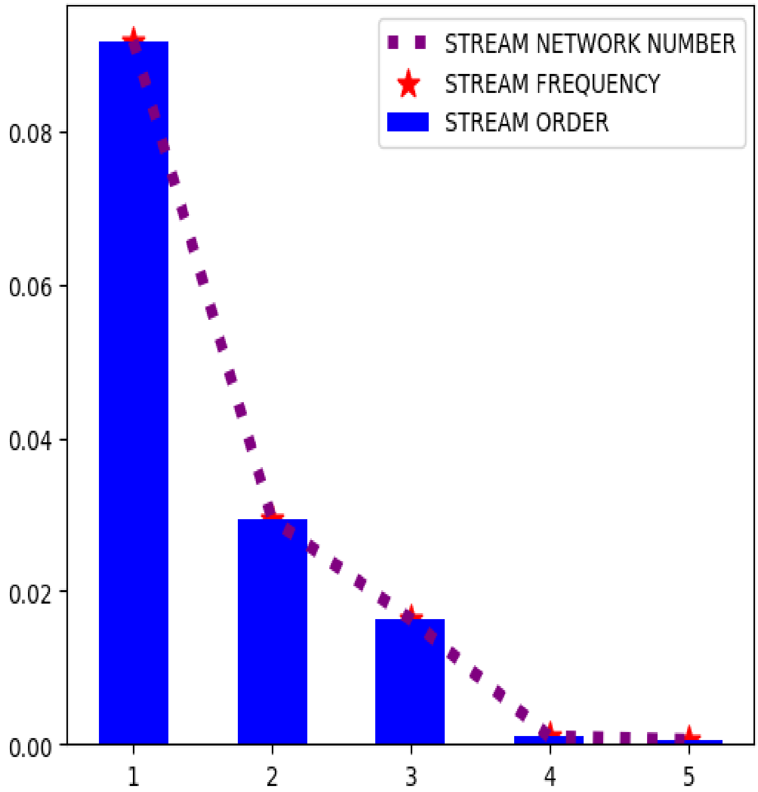



Stream Frequency (Sf)

According to Horton (1932, 1945), the stream frequency (Sf) is the number of stream segments per area. This shows a connection between the growth of the stream's population and that of "Dd". It is often governed by the lithology of the basin, which also specifically determines the stream network's texture.

Table 7: Morphometric Analysis of Stream Frequency

| Stream Order | Stream Network Number | Stream Frequency (sq.km) |
|---|---|---|
| 1 | 175 | 0.0918 |
| 2 | 56 | 0.0294 |
| 3 | 31 | 0.0163 |
| 4 | 2 | 0.0010 |
| 5 | 1 | 0.0005 |

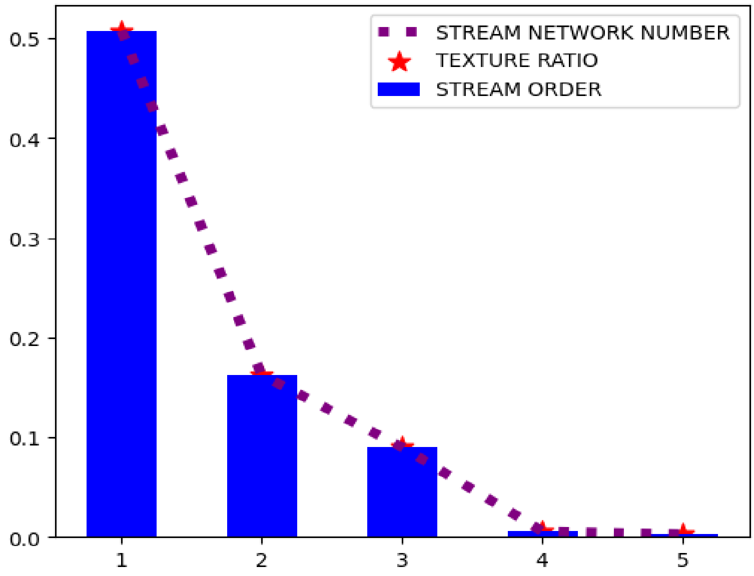



## Texture Ratio (Rt)

Schumm (1956) established the texture ratio (Rt), which is defined as the ratio between the first order streams and basin perimeter and depends on the lithology, infiltration capacity, and relief aspect of the topography.

Table 8: Morphometric Analysis of Texture Ratio

| Stream Order | Stream Network Number | Texture Ratio (km) |
|---|---|---|
| 1 | 175 | 0.5075 |
| 2 | 56 | 0.1624 |
| 3 | 31 | 0.0899 |
| 4 | 2 | 0.0058 |
| 5 | 1 | 0.0029 |

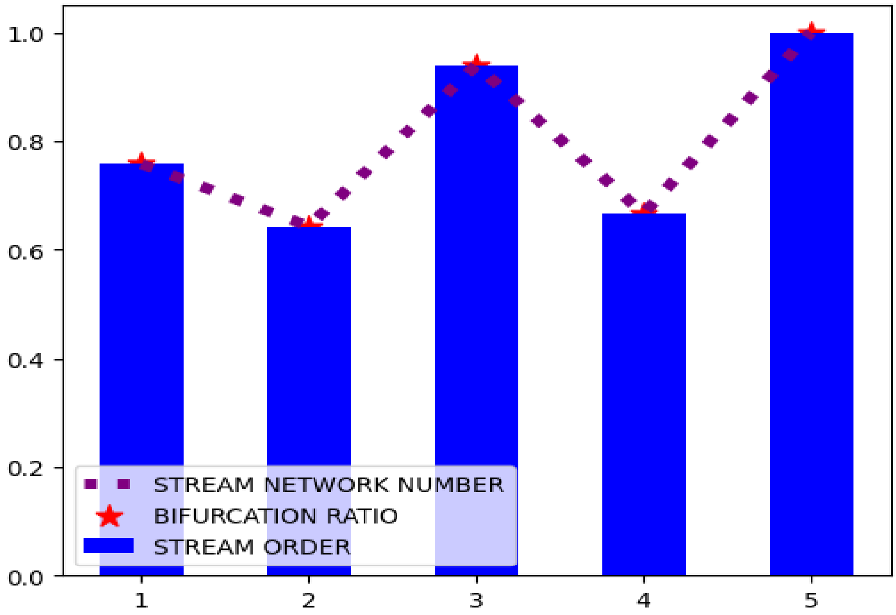



Bifurcation Ratio (Rb)

The branching pattern of a river's tributaries within a drainage basin is described by the morphometric measure known as the bifurcation ratio (Rb). Its ratio between streams of one order (n) and streams of the next higher order (n+1).

Table 9: Morphometric Analysis of Bifurcation Ratio

| Stream Order | No. of. Streams | Rb |
|---|---|---|
| 1 | 175 | 0.7576 |
| 2 | 56 | 0.643 |
| 3 | 31 | 0.9394 |
| 4 | 2 | 0.6667 |
| 5 | 1 | 1 |

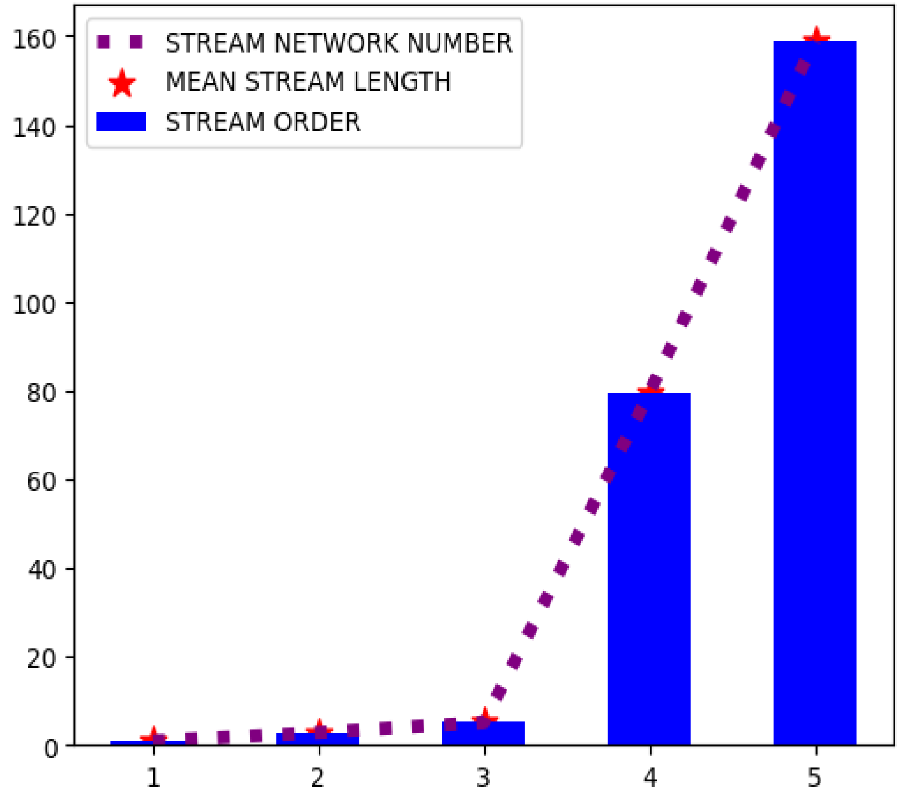


Mean Stream Length (Lsm)

Mean stream length is a characteristic parameter associated to the surface that contribute to Palar River Basin drainage network components and a drainage network (Strahler 1964). It may be calculated by dividing the overall length of a stream by the overall number of segments. Since the Lsm values are inversely proportional to the basin's size and topography, they vary with regard to different basins. The Lsm is a distinctive attribute connected to the size of the drainage network and its accompanying surface, according to Strahler (1964).

Table 10: Morphometric Analysis of Mean Stream Length

| Stream Order | No. of. Streams | Lsm |
|---|---|---|
| 1 | 175 | 0.9088 |
| 2 | 56 | 2.8400 |
| 3 | 31 | 5.1303 |
| 4 | 2 | 79.5203 |
| 5 | 1 | 159.0407 |




Conclusion

The findings of this study suggest that ASTER-DEM may be effectively used to collect morphometric features characterising basin geometry as well as form, length, and stream network topology and topographical dissection, and accomplished to create data on stream number and basin relief. Numerous linear, areal, and relief morphometric evolution characteristics were listed and discussed in relation to the hydrological process. The morphometric indicator investigated in the current investigation exhibits significant geographical heterogeneity. Food susceptibility and risk in the downstream zone of the Palar River will be greatly impacted by the hydrological behaviour of the Palar basin. We were able to understand several topographical characteristics, such as the composition of the bedrock, infiltration capacity, surface runoff, etc., thanks to the morphometric parameters that were evaluated using GIS. It demonstrates that the Palar basin area's stream order is growing but their frequency is decreasing, making stream channel construction irrelevant. The Palar River's morphology and morphometry research of the fluctuation in discharge demonstrates that both anthropogenic intervention and natural processes are responsible for the river's dynamism. A quantitative link between hydrological and topography data would be obtained by selecting an appropriate hydrological model and modelling the basin region using several topographic features. From the study above, the plan and policy for siting recharge and water-harvesting measures deliver an improved groundwater conservation and management plan when the morphometric data of the basin are integrated with the other hydrological characteristics of the river basin.

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