GIS BASED MORPHOMETRIC CHARACTERISTICS OF KADAVANAR RIVER BASIN IN TAMIL NADU, INDIA

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***Abstract*: *The Remote Sensing and GIS technique is an effective tool for analyzing the morphological characteristics of a river basin. The geographical location of Kadavanar river basin between latitudes 10° 52' 34.70"N and 10° 10' 57.59"N, and longitudes 77° 37' 48.14"E and 78° 13' 27.69"E, and one of the contributors to Cauvery river. The study focused on the river basin linear, areal, and relief aspects of morphometric characteristics. The study concentrated on the morphometric parameters and evolution of the stream order (U), stream length (Lu), bifurcation ratio (Rb), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), elongation ratio (Re), circularity ratio (Rc), form factor (Rf), basin relief (Bh), relief ratio (Rh) and ruggedness number (Rn). The Kadavanar basin has a six-order of the drainage system, with a total of 841 stream networks, of which are 653 in the first-order, 143 in the second-order, 34 in the third-order, 8 in the fourth-order, 2 in the fifth-order stream, and 1 in the sixth-order stream according to morphometric study. The first order of the stream has a longer overall length, which decreases as the stream order increases. The average bifurcation ratio is 3.80, signifying that there were more structural disruptions due to geological influence. There has observed a low drainage density of the value of 0.91 km/km^2. It indicates that the river basin has a dense vegetation cover and is highly permeable. The basin morphometric study revealed that it has a slight risk of soil erosion and flood of the basin, indicating that surface runoff of the upland region of the river basin is significantly infiltration gently downstream of the basin, contributing to the groundwater potentiality of the region. Further study of Remote Sensing and GIS techniques is more effective in developing an appropriate natural resource for the groundwater management system of the region.*

***Keywords*: Remote Sensing, GIS, Morphometric Analysis, and Kadavanar River Basin.**

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I. INTRODUCTION

The quantitative description of the river morphometric analysis to characterize and describe a river basin and its drainage system is important because these parameters demonstrate the evolution of the drainage system and the correlation between processes associated with soil degradation [1]. Because they can provide quantitative information on morphometric parameters is the significantly important characteristic used to analyse a river basin [2]. The Remote Sensing ad GIS techniques are effective tools for analysing the river basin and hydrological process [3]. The river basin analysis is essentially used for the assessment and managing of both groundwater and surface water resources. The important characteristics of the river basin such as shape, size, slope, and length of tributaries and their distributaries are highly correlated with the river basin and its hydrological process [4]. Drainage systems exhibit spatial and temporal variations. The river basin characteristics of the surface runoff patterns significantly change hydrological systems and also basin catchment inputs and outputs such as suspended sediment, stream discharged solutes, and litter. [5]. The drainage basin and its hydrological behaviour are used to construct the appropriate methods of groundwater and soil erosion management system, as also prior work for the soil erosion-prone areas, analysis of flood, and site selection for various water infrastructural facilities [3][6]. Drainage basins are also adequate for considering onsite and offsite ecology they may have an impact on the basin area. The surface water that flows in and out of the river basin deposits and picks up various elements including sediment, nutrients, and pollutants [7]. Hence investigating the river basin process has the ability to better understand the surface water movements in the drainage system. The aim of this paper is by using Remote Sensing and GIS to investigate the drainage pattern of the Kadavanar River Basin and its

hydrological process. Understanding the hydrology of a drainage basin is essential for planning and designing the appropriate type of soil erosion and water conservation management work.

II. MATERIALS AND METHODS

The basin area, perimeter, basin length, stream segments number, stream order, and drainage patterns of the drainage basin were delineated from the SRTM DEM (30 m) which is downloaded from the https://earthexplorer.usgs.gov/. The stream networks were verified with the Survey of India toposheet (1:50,000). Which is downloaded from https://onlinemaps.surveyofindia.gov.in. Additionally, using the ArcGIS 10.3 software for the linear, areal, and relief features are delineated from the SRTM DEM data. These parameters are used to determine morphometric parameters like stream order (U), stream length (Lu), bifurcation ratio (Rb), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), elongation ratio (Re), circularity ratio (Rc), form factor (Rf), basin relief (Bh), relief ratio (Rh) and ruggedness number (Rn).

III. STUDY AREA

The study area of the Kadavanar river basin is located in the Dindigul district, and also a small part of the Karur district, and its tributary contributes the Cauvery river. The river basin is located between 10° 10' 57"N and 10° 52' 49"N latitude and 77° 37' 31"E and 77° 13' 47"E longitude. The river contributing area is 2259.42 km^2, and the longest path of the flow is 112.78 km (Fig 1). The river basin is surrounded by Namakkal and Erode districts in the north, Madurai district in the south, Tiruchirappalli district in the east, and Tiruppur district in the west. The Kadavanar river originates in the Sirumalai hills and Kallar hills and flows over the Dindigul and Karur districts in the western region of Tamil Nadu. The higher elevation ranges are in the south, southwest, and southeast part and the remaining of the area is relatively uniform. The digital elevation model (DEM) of the Shuttle Radar Topography Mission (SRTM) has shown that the altitude of the river basin is from 135 m to 1908 m a.m.s.l. The Kadavanar river is an important source of water for the surrounding peoples. The river basin is geologically made up of thirteen different rock types and the general slope trending of these rock groups in the Kadavanar river basin area is down to the north [8].

IV. RESULT AND DISCUSSION

A. SLOPE (Sa)

The slope is a significant factor in determining the morphometric characteristics of river basin. This is the degree of inclination of the topographical structures in relation to the horizontal terrine. The slope map was delineated to SRTM DEM data (30 m) in ArcGIS 10.3 software using the surface analyst tool. This slope range in the river basin is observed from 0 to 62 degrees (Fig. 2). The slope trend of the area towards down to the north; however, the ridged structural hills in the southeast and southwest have multiple slope orientations. The flow direction of drainage networks is directly influenced by the slope gradient of this hilly area. Consequently, morphometric processes throughout the rocky surface, in which resistance range is vary and also regulate the slope characteristics. Runoff of the surface and erosional characteristics of the river basin area are directly influenced by the spatial variability of consequent slope gradients.

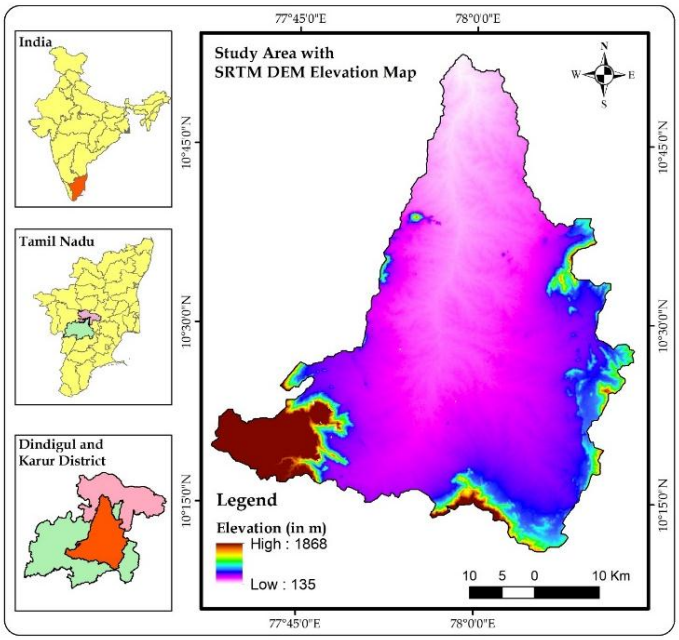

Fig. 1. Study area map with DEM derived elevation model.

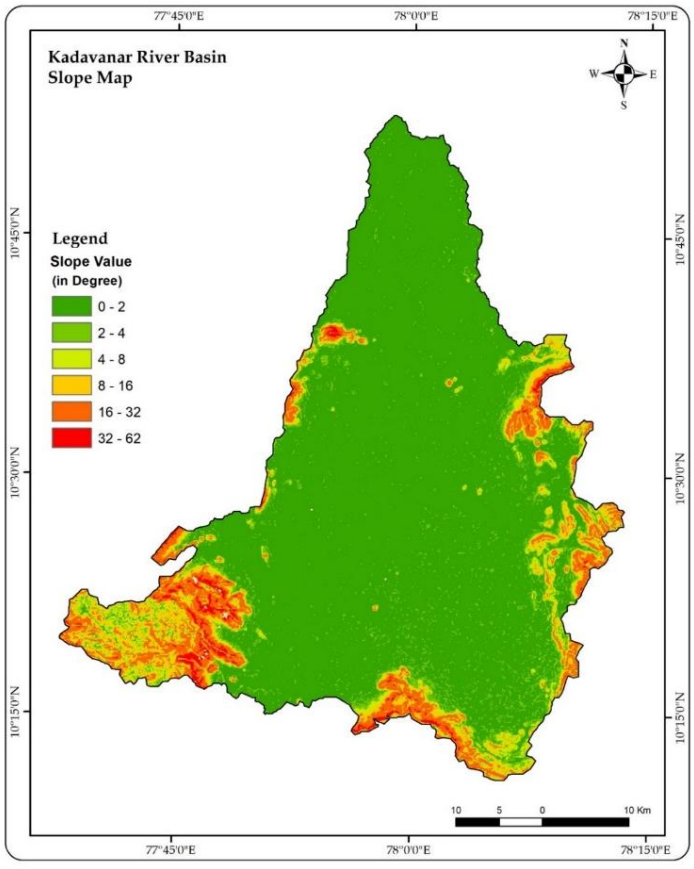

Fig. 2. Slope map.

TABLE I. THE MORPHOMETRIC PARAMETERS AND ESTIMATED VALUES.

Morphometric Parameters	Formula	Result
Linear Aspects		
Basin Length (m)	Lb	77.94
Total Stream Order	U	6
Total Stream Length (m)	Lu	2037157.55
Total Stream Number	Nu	841
Bifurcation ratio	Rb = Nu/Nu+1	3.80
Areal Aspects		
Area (sq. km)	A	2259.42
Basin perimeter	P	304.71
Drainage Density (km/km^2)	Dd = Lu/A	0.91
Drainage texture	Rt = Nu/P	2.75
Stream Frequency (number/km^2)	Fs = Nu/A	0.37
Elongation ratio	Re = 2/Lb ×(A/π)0.5	0.68
Circulatory ratio	Rc = 4×π× A/P^2	0.30
Form factor	Rf = A/Lb^2	0.36
Relief Aspects		
Basin Relief (m)	Bh	135 to 1868
Relief ratio	Rh = Bh/Lb	0.022
Ruggedness Number	Rn = Bh×Dd	1.58

B. STREAM NETWORK GENERATION

The river networks are delineated with ArcGIS Spatial Analyst tools from the SRTM DEM data. The river basin slope is compared to the delineated river networks. The river basin has a steep slope along the southwestern and southeastern of the study area and a smooth gentle slope in the northern and central part of the river basin (Fig. 3). The steep slope generates a large number of sensitivity to small streams, whereas the gentler section of the river basin has a smaller number of long streams.

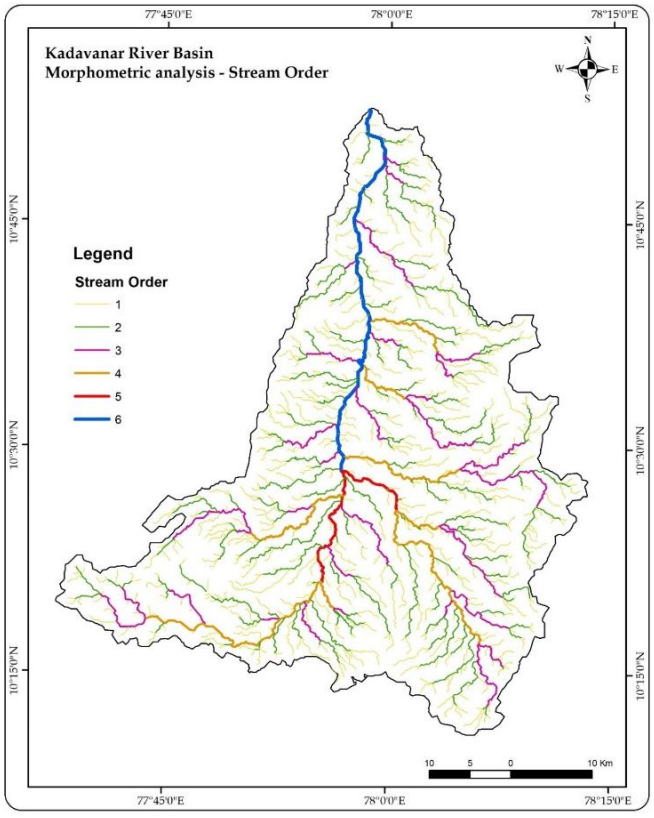

Fig. 3. Stream Order map

C. LINEAR ASPECTS

The linear aspects river basin and its morphometric analysis are discussed below, including stream order (U), stream length (Lu), and bifurcation ratio (Br).

1) Stream order (U)

The U in the morphometric analysis is a positive whole number that determines the branching level in the river system. The stream order delineation has various types of methods [1][9]. The stream order was analysed using the Strahler method. In the first order in the smallest unbranched streams, where the first-order two streams merge, they develop second-order, and two streams of the second-order merge to form the third order until two different levels of streams meet and remained the highest one. The six orders of streams were observed in the Kadavanar river basin. A total of 841 streams were observed, with 653 first-order streams, 143 second-order streams, 34 third-order streams, 8 fourth-order of streams, 2 fifth-order streams, and 1 stream sixth-order. Understanding basin hydrological processes necessitate a study of stream order parameters.

2) Stream length (Lu)

The Lu is the linear parameter for determining the morphological characteristics of river basin. With the finer texture in the steep slope of the river basin, a large number of streams with comparatively small lengths were observed. The longer length of a stream indicates a generally flatter catchment. The cumulative length of the stream segment is greatest in the first order decreases while the stream order increases. The basin stream characteristics followed Horton's law of stream length defines the cumulative stream length number tends to form the geometric series beginning with the first-order average segment length and increasing by the constant length ratio [9][10]. The total observed stream length is 2037157.55 m in the Kadavanar river basin. A total of six order streams were observed, with 1030568.44 m in first-order streams, 567478.50 m in second-order streams, 234471.83 m in third-order streams, 125036.21 m in fourth-order streams, 27332.24 m in fifth-order and 52270.30 m in sixth-order stream. The stream flowing from of high elevated area, lithological variance, and from the steeper slope to flatter ground is indicated by the changing of streams between orders.

3) Bifurcation ratio (Br)

The Br is the parameter for defining the basin stream patterns, which are strongly linked to the morphology and climate conditions of the river basin. It illustrates the geometry of the basin and helps to understand the river basin runoff behaviour, and it is a valuable technique to measure flood-prone areas. A high bifurcation ratio may indicate a short duration of concentration and a high probability of flooding. The mean bifurcation ratio for the kadavanar river basin is 3.80. In flat and rolling terrain, the Br Value is from 2 to 4 respectively, and 5 in hilly or heavily dissected drainage basins.

D. AERIAL ASPECTS

It relates to the anticipated region and surface flow of the stream in various stream orders. Aerial elements include drainage texture, drainage density, elongation ratio, stream

frequency, circularity ratio, and form factor. Significant quantitative properties are the morphology of basin area and basin perimeter.

1) Perimeter (P) and Area (A)

The river basin area is defined as the whole area projection on a horizontal surface that adds to the total accumulation of basin orders. The P of the river basin is defined as the length of the basin boundary [11]. The basin area has a strong direct relationship with the annual mean runoff [12]. The kadavanar river basin has a perimeter of 304.71 Km and an area of 2259.42 Km^2 (Table 1).

2) Drainage density (Dd)

It is a factor that affects the hydrological process of a river basin. This is determined by the ratio of the total stream length to the total area [13]. Both the duration of concentration and the volume of the flow will get affected by drainage density. High drainage density leads to higher flood peaks, while low drainage density leads to lower flood levels [14]. This is because the longer concentration duration, there are more possibilities to infiltrate and distribute the water flow throughout time. Dd and volume of flood have a straight relation with each other. The research area drainage density is 0.91 km/km^2 (Table 1).

3) Drainage texture (Rt)

The Rt define as the sum of total stream segments per region perimeter of all orders. A coarse drainage texture has been indicated by a lower drainage density, whereas a fine drainage texture is indicated by a coarser drainage density. Smith [14] created the term texture ratio to denote the proximity of two streams. A river Rt ratio is influenced by the elements of the slope, infiltration capacity, type of soil, vegetation, climate condition, and rainfall. The more drainage texture, the more disintegration, and erosion will occur. There are five different types of drainage texture: extremely fine (8 to 10), fine (6 to 8), moderate (4 to 6), coarse (2 to 4), and very coarse (<2). The observed value study area representing a coarse texture for the river basin having a value of Rt is 2.75 (Table 1).

4) Stream frequency (Fs)

The Fs have been measured using the stream segment's total number to the per unit area [9]. The catchment reveals a rise in stream frequency in proportion to a rise in Dd, whereas Fs have a positive correlation with Dd [3], [15]. The frequency value of the stream in the study region is 0.37 $Number/km^2$ (Table 1). This value has shown that rainfall and topographical factors are the primary determinants of stream origin and development in the river basin.

5) Elongation ratio (Re)

It describes the river basin shape. This is the proportion of the circle diameter to the drainage corresponding area as well as the maximum basin length [9]. Because of the short duration of concentration, when the elongation ratio value increases, the basin will become more circular and vulnerable to floods, and vice versa. Study area Re value is 0.68 (Table 1) indicating less prone to flood in the basin with a moderate to a slightly steep slope. This result illustrates that the drainage basin region has a significant infiltration capacity all along the river discharge course, which is associated with a steep slope and high relief.

6) Circulatory ratio (Rc)

It is useful for understanding and assessing the risk of flood. The Circulatory ratio value grows as the flood volume and flood risks at the basin discharge rise. This is the Rc of the river basin area of the surface area circulatory value has a similar circumference as the river basin perimeter [16]. Rc value reflects the basin form; as the Rc value rises, the shape of the basin has become more circular, and the short flow duration raises the risk of flooding at the discharge area. kadavanar basin Circulatory Ratio is 0.30 (Table 1) indicating that is basin elongated and less prone to flooding.

7) Form factor (Ff)

The Ft is to describe drainage basin flow characteristics. The Ft define as the ratio of river basin area to the basin length square [9]. The more elongated basin as the form factor value decreases. The low runoff will result in a longer duration of runoff when the form factor value is lower. A circular-shaped basin with a high form factor value, on the other hand, suffers significant runoff with a short concentration time and is very vulnerable to floods. The form factor threshold value is less than 0.7854 [3]. The study area form factor ratio has estimated a value of 0.36 (Table 1). This number shows the river basin is highly elongated in shape, and that such an elongated river basin is more prone to flood flows than compared with circular-shaped basins.

E. RELIEF ASPECT

The three-dimensional characteristics such as area, perimeter, volume, and elevations of the vertical scale of landscapes are used to determine various geo-hydrological features is related to the relief aspects of drainage basin analysis [17].

1) Basin relief (Bh)

The study of geomorphic processes and landform characteristics provides a broad overview of the river basin relief of the area. The basin vertical distance between the lower to higher value was used to measure the basin relief [18]. The maximum relief area is 1868 m in the southeast and southwest, while the lowest relief area is 135 m in the north, where the ground is generally flat (Fig. 1). The basin relief values from 135 m to 1868 m (Table 1) projected and slope toward the north. It shows erosional rates are greater in the study region.

2) Ruggedness number (Rn)

Strahler defined Rn as the product of drainage density and basin relief, those parameters are measured in a similar unit [19]. Those factors are high on the steep slope, the roughness number reaches an abnormally high value. The ruggedness number in this study area is 1.96 (Table 1).

V. CONCLUSION

The Remote Sensing and GIS techniques are to analyze the morphometric parameters of river basin hydrology are valuable tools. It contributes to a better understanding of the basin hydrology, which prioritizes the river basin, effective conservation activities of soil erosion, river basin

management, assessments of flood risk, and natural resource management. The morphometric investigation took performed in the Kadavanar river basin. The results revealed that the river basin is prone to flood and soil degradation in the higher elevation part of the river basin, while more surface runoff is infiltrated and sediment accumulation in the part downstream because the gentle terrine has a groundwater potential is high. The kadavanar river basin morphometric analysis with Remote Sensing and GIS technologies demonstrates the topography factors which are capable of infiltration, relief, runoff, and lithology are impact the basin hydrogeological processes.

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