Morphometric Analysis of Kadavur Basin in Karur District, Tamil Nadu, India-Using GIS

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Abstract

The study of watershed characteristics is necessitated for working out a comprehensive development plan of the watershed for optimum use of its resources. The morphometric analysis can be achieved through measurement of linear, aerial, and relief aspects of the basin. In the present study, quantitative morphometric analysis is carried out for 6 sub basins of Ponnani Ar Basin, which is located in Karur district, Tamil Nadu. The Geographical Information System (GIS) has been made in this study, Since it is an excellent tool for the management of large bodies of spatially extensive data with all the advantage of a computer environment; precision, consistency and absence of computational error. This powerful tool holds a very large potential in the field of regional and micro-level spatial planning particularly in sub-watershed planning and management.

Keywords: Sub Basins, Drainage Patterns, Dendritic, Stream Patterns Sculpturing And Morphometric Parameters.

I. INTRODUCTION

Morphometric is the measurements and mathematical analysis of the configuration of the earth's surface. Shape and dimension of its landforms (Clarke, 1996). The quantitative analysis of drainage system is an important aspect characteristic of watershed (strahler, 1964). The Morphometric study of the drainage basin is aimed to acquire accurate data of measurable features of stream network of the drainage basin. A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold & Maddock, 1953; Abrahams, 1984). Geographical information (GIS) techniques are used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study stream number, order, frequency, density and bifurcation ratio are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the topographical maps (scale 1:50,000).

A. *Study Area:*

The investigated area s enclosed between 10° 35' N latitude and 78° 11' E covering an area of 83 sq.km. falling in survey of India(SOI) toposheet Nos.58 J/2, J/6 on 1:50,000 scale.

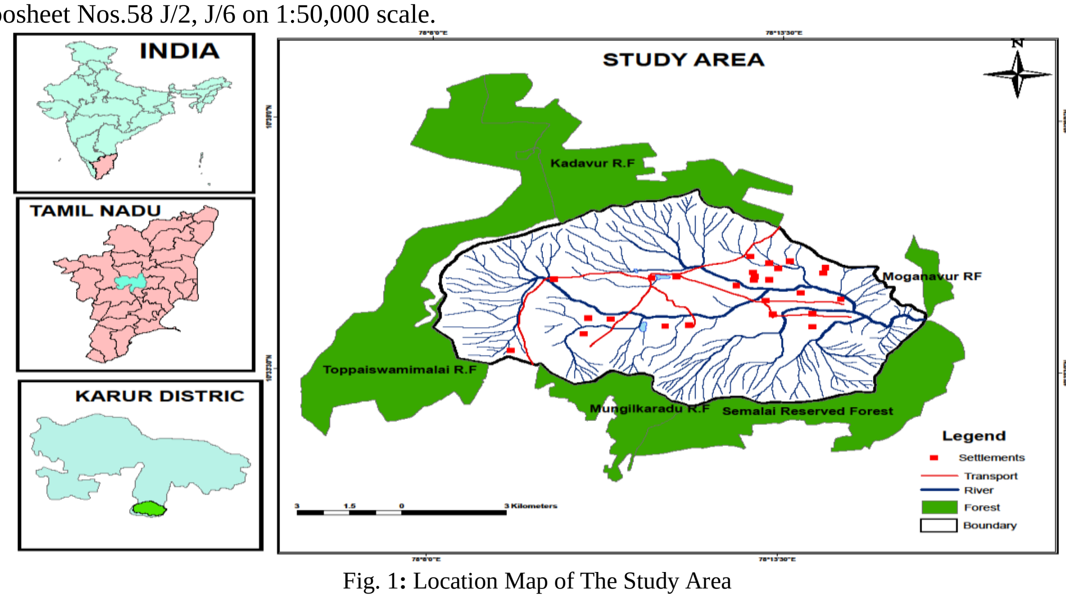

Fig. 1: Location Map of The Study Area

The Ponnani Ar joins on the right side of the Cauvery river between Upper Anicut and Grand Anicut It originates in the scattered hills near Kadavur in Kulithalai taluk of Karur district as shown in Figure.1. The area is well represented by structural hills and this basin around the four following Reserved forests 1. Kadavur R.F,2. Toppaiswamimalai R.F, 3. Mungilkaradu R.F, and 4. Semalai R.F. the area enjoys tropical climate of semi arid in nature and the temperature is obtained in early may to early June usually about 34^o C, though it usually exceeds 38^o C for a few days most of year daily temperature during January is around 23^o C though the temperature rarely falls below 17^{o}C. The average annual rainfall is about 775m (30.5 inch.). It gets most of its seasonal rainfall from the north east monsoon winds form late September to mid November. The red soil predominantly seen in kadavur basin. Ponnani Ar dam one of the picnic spot in Karur district.

II. MATERIALS AND METHODS

The study area delineated from SOI topographical map and IRS LISS III image as shown in Figure.3&4. were digitization work has been carried out for entire analyses of basin morphomerty using GIS Software (Arc GIS 9.3). The order was given to each stream by following Strahler (1964) stream ordering technique, various morphometric parameters such as linear aspects of the drainage basin. Drainage density (D), Stream frequency (Fs), Texture ratio (T), Elongation ratio (Re), Circulatory ratio (Rc), Form factor (Rf) of the basin computed. The Various steps employed in the study area given in Figure.2

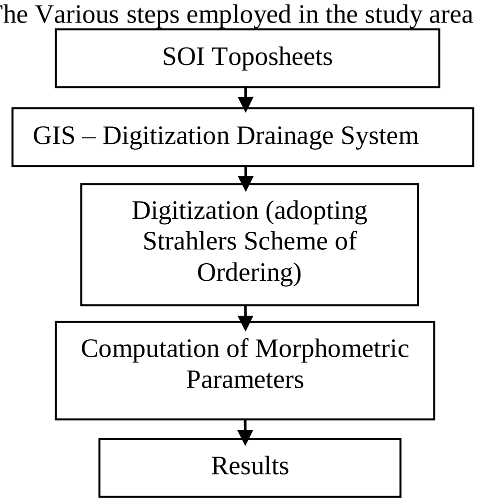

Fig. 2: Steps of Methodology

III. RESULTS AND DISCUSSION

The present area surface water divided marks the heights elevation, slope and outlet point on the area for detailed quantitative analysis have been done and the study area is divided into 6 sub basins named by Sbn1,2,3,4,5 & 6 as shown in Figure.5. The Various morphometric parameter of the Kadavur basin have been computed and summarized as follows.

A. Linear Aspects

Drainage network of the kadavur basin is presented Stream links (the different drainage lines) and the nodes (the stream junctions) characteristics Linear aspects of the basin. The linear aspects include the stream order(u), Stream length (Lu), Mean stream length (Lsm), Stream length ratio (Rl) and Bifurcation Ratio (Rb), were determined and results have been presented in Table.1&2.

1) *Stream Order (u)*

The Primary step in any drainage basin analysis is order designation, stream orders and is based on a hierarchic ranking of streams. Ranking of streams has been carried out based on the method proposed by Strahler (1964). The smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of 2nd order is formed and so forth. It has been formed that the study area us in 5th order drainage basin. Altogether, 223 number of streams were identified, out of which 168 are of 1st order 38 are of 2nd order, 11 are of 3rd order, 5 are 2nd order and one is indicating 6th order stream. Drainage pattern of stream network from the basin have been observed as mainly dendritic type which indicates the homogeneity in texture and lack of structural control shown in Figure.4. This pattern is characterized by a tree like of fernlike pattern with branches that intersect. The properties of the stream network are very important to study the land form making process (strahler and strahler 2002).

Table – 1
Morphometric Parameters-Formula

Sl. No.	*Morphometric Parameters*	*Formula/ Definition/Methods*	*Reference*
Linear aspect:			

1	*Stream order*	*Hierarchical rank of streams*	*Strahler (1952)*
2	*Bifurcation Ratio (Rb)*	*Rb=Nu/Nu+1 Nu=Total no. of stream segments of order "u' Nu+1= Number of segments of the next higher order*	*Schumm (1956)*
3	*Mean Bifurcation Ratio (Rbm)*	*Rbm= Average of Bifurcation ratios of all orders*	*Strahler (1957)*
4	*Stream Length (Lu)*	*Length of the stream (Km)*	*Horton (1945)*
5	*Mean Stream Length (Lsm)*	*Lsm=Lu/Nu Lu=Total stream length of order 'u' Nu=Total no. of stream segments of order 'u'*	*Horton (1945)*
	Stream Length Ratio (Rl)	*Rl= Lu/Lu-1 Lu=Total stream length of the order 'u' Lu-1=Total stream length of its next lower order*	*Horton (1945)*
Relief Aspects:			
6	*Relative Relief (R) (or) Basin Relief (Bh)*	*R = H-h H=Maximum height (m) h=Minimum height (m)*	*Strahler (1952)*
7	*Relief Ratio (Rh)*	*Rh= R/Lb R= Relative relief (m) Lb= Basin length (m)*	*Schumm (1956)*
Arial Aspect:			
9	*Drainage Density (Dd)*	*Dd=Lu/A Lu=Total stream length of all orders (Km) A=Area of the Basin (Km2)*	*Horton (1945)*
10	*Texture Ratio (Rt)*	*T=Nu/P Nu=Total no. of streams of all orders P=Perimeter(Km)*	*Smith (1950)*
11	*Stream Frequency (Fs)*	*Fs= Nu/A Nu= Total no. of streams of all orders 37 A=Area of the Basin (Km2)*	*Horton (1945)*
12	*Form Factor (Ff)*	*Ff=A/Lb2 A=Area of the Basin (Km2) Lb2= Square of the basin length (m)*	*Horton (1932)*
13	*Elongation Ratio (Re)*	*Re=2√(A/Pi)/Lb A= Area of the Basin (Km2), Pi=3.14 Lb=Basin length (m)*	*Schumm (1956)*
14	*Circularity Ratio (Rc)*	*Rc=4*Pi *A/P2 A= Area of the Basin (Km2), Pi=3.14 P2 =Square of the perimeter (Km)*	*Miller (1953)*
15	*Length of Overland Flow (Lg)*	*Lg=1/D*2 Lg=Length of overland flow Dd=Drainage density*	*Horton (1945)*

Table – 2
Stream Order And Stream Length of The Drainage Network Of The Study Area

Number of Stream(Nu)								*Stream Length in Km (Lu)*				
Sl.No	*Name of the Sub Basins*	*1*	*2*	*3*	*4*	*5*	*total*	*1*	*3*	*4*	*5*	*total*
1	*Sbn1*	*31*	*8*	*5*	*1*	*-*	*45*	*22.5*	*4.4*	*1.2*	*-*	*35.7*
2	*Sbn2*	*31*	*10*	*4*	*1*	*-*	*46*	*25.1*	*5.2*	*3.1*	*-*	*43.3*
3	*Sbn3*	*24*	*7*	*1*	*1*	*-*	*33*	*17.4*	*3.9*	*6.9*	*-*	*34.1*
4	*Sbn 4*	*22*	*7*	*2*	*1*	*-*	*32*	*17.8*	*4.8*	*3.0*	*-*	*32.3*
5	*Sbn 5*	*30*	*7*	*2*	*1*	*-*	*40*	*17.0*	*2.6*	*1.9*	*-*	*27.2*
6	*Sbn 6*	*30*	*6*	*1*	*-*	*1*	*38*	*19.1*	*1.6*	*-*	*5.7*	*32.1*

Source: Compiled by Author

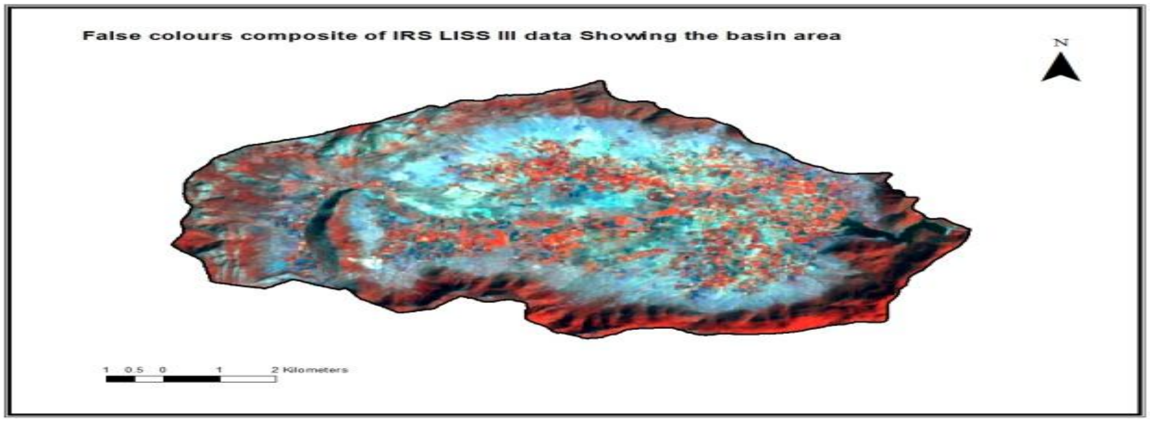

Fig. 3**:** FCC Composite of IRS LISS III Data Showing The Basin Area

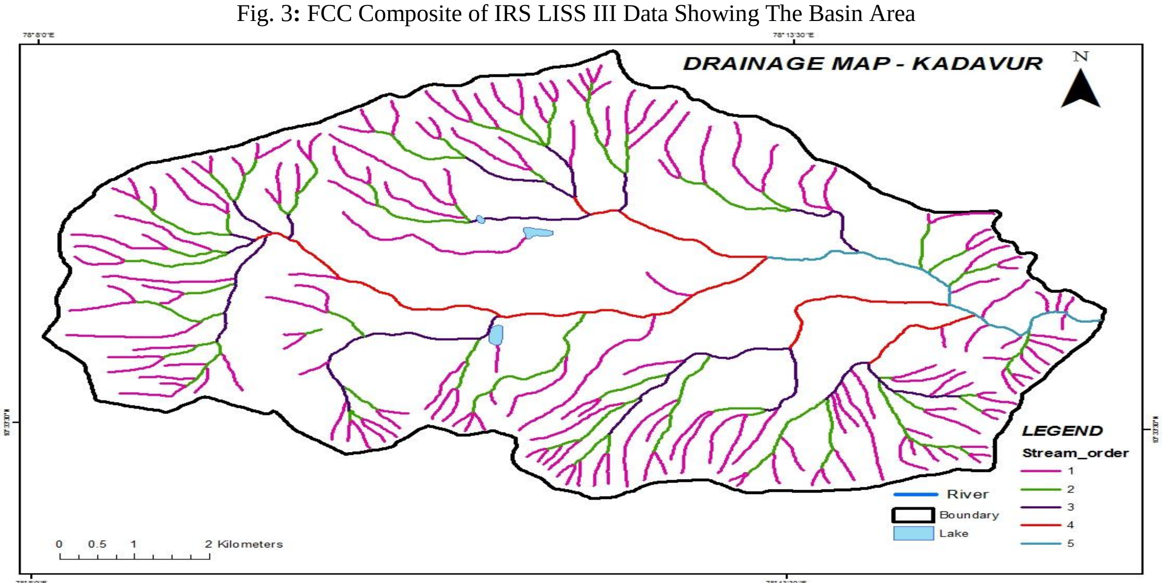

Fig. 4**:** Drainage Pattern And Their Order Identified From The Study Area

2) *Stream Length (Lu)*

Stream length is one of the most important hydrological feature of the basin as it reveals that the surface run-off behaviors. The number of streams of various orders in a sub-basins is counted and their lengths form mouth to drainage divide is measured given in Table.2. According to Horton's law (1945), the stream length (Lu) has been calculated for all the 41 micro-watersheds. The total stream length of the watershed is 204.8 km. The large sub-watershed (Sbn2) has the total stream length of 43.3 km and Sbn 5 watershed has less stream length of 27.2 km. Fifth order stream length is found more in Sbn 5 watershed (5.7 km), where all the streams are confluence here due to flatness of terrain in the watershed. The stream length (Lu) has been computed based on the low proposed by Horton (1945) for all the 6 Sub-basin. Generally the total length of stream segment in maximum is first orders streams and decreases as the stream order increases.

3) *Mean Stream Length (Lsm)*

The mean stream length is a dimensional property, characterizing the size aspects of drainage network and its associated surface (strahler, 1964). It is obtained by dividing the total length of stream of an order by total number of segments in the order shown in Table.3. In the study area the mean stream length varies from 0.98 to 1.06 and mean stream length of any given order is greater than that of the lower order and less than of its next higher order in the entire sub watersheds except which might be due to variation in slope and topography. The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of streams. Table 3 indicates that Lsm in these micro-watersheds ranges between 1.0 km and 1.6 km found at Sbn3 and Sbn1watersheds respectively. Lsm of any given order is greater than that of the lower order and less than that of its next higher order in 6 watersheds, which might be due to variations in relief, slope and lithology of the area.

Table -3
Linear Aspects of Sub-Basins of Kadavur Basin

Sl.No	*Name of the Sub Basins*	*Mean Stream Length (Lsm)*	*Stream Length Ratio (Rl)*	*Rb1*	*Rb2*	*Rb3*	*Rb4*	*Rb5*	*Mean Bifurcation Ratio (Rbm)*
1	*Sbn1*	*1.67*	*1.04*	*4.9*	*2.6*	*6.0*	*-*	*-*	*2.7*
2	*Sbn2*	*1.23*	*1.10*	*4.1*	*3.5*	*5.0*	*-*	*-*	*2.5*

3	*Sbn3*	*1.00*	*1.35*	*4.4*	*8.0*	*2.0*	-	-	*2.9*
4	*Sbn 4*	*1.13*	*1.14*	*4.1*	*4.5*	*3.0*	-	-	*2.3*
5	*Sbn 5*	*1.31*	*1.10*	*5.3*	*4.5*	*3.0*	-	-	*2.6*
6	*Sbn 6*	*1.27*	*0.92*	*6.0*	*7.0*	-	*1.0*	-	*2.8*

Source: Compiled By Author

4) *Stream Length ratio(Rl)*

It is the ratio between the mean lengths of streams of any two consecutive orders. Horton's law (1945) of stream length states that the mean length of stream segments of each of the successive orders of a basin tends to approximate a direct geometric series, with stream lengths increasing towards higher stream order. All the sub basins in the study area (Table.3) show variation in stream length ratio between streams of different order changes of stream length ratio from one order to another order indicating their late youth stage of geometric development (singh and singh.1997) Stream Length Ratio (Rl) in these micro-watersheds varies between 0.92 and 1.35km found Sbn 6 and Sbn3 watersheds respectively as like Lsm. This variation might be due to changes in slope and topography.

5) *Bifurcation Ratio(Rb)*

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total number of stream segments of order to that of the next higher in drainage basin (Schumn,1956).The bifurcation ratio (Rb) is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Nu+1) (Table-1formula) Horton (1995) considered the bifurcation ratio as index of relief and dissertation strahler (1957) demonstrated that bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. It is observed from the 'Rb'is not same from one order to its next order these irregularities are dependent upon the geological and lithological development of the drainage basin (strahler 1964). All the sub basins in the study area (Table.3) show variation in Bifurcation ratio (Rb) the lower of Rb are characteristics of the sub-basins which have suffered less structural disturbances (strahler 1964). And the drainage pattern has not been distorted because of the structural disturbances (Nag 1998). In the present study, the higher values of Rb indicate strong structural control on the drainage pattern. While the lower values indicative of Sub-watersheds that are not affect by structural disturbances. In the present case, Rb Values reveals that all sub-basins fall under normal basin category Strahler (1957).

B. Relief Aspect

The channel gradient is estimated from the contour crossing in to topographic sheet. The relief aspects determined include, relief ratio(Rh), relative relief (R) and ruggedness number (Rn) and the results of the analysis are given in Table.4

Table -4
Relief Aspects of Sub-Basins of Kadavur Basin

Sub Basins	*Basin in Height*		*Basin Length*	*Relative relief*	*Relational Relief (Rh)*	*Ruggedness number (Rn)*
	Max(Z)	*Max(z)*				
Sbn1	*1031*	*828*	*17.4*	*203*	*0.83*	*1.48*
Sbn2	*920*	*302*	*18.3*	*618*	*0.92*	*3.29*
Sbn3	*553*	*280*	*18.5*	*273*	*0.93*	*2.11*
Sbn4	*689*	*264*	*16.3*	*425*	*0.73*	*3.55*
Sbn5	*500*	*254*	*12.7*	*246*	*0.63*	*3.11*
Sbn6	*460*	*300*	*19.4*	*160*	*0.64*	*2.42*

Source: Compiled By Author

1) *Relief Ratio (Rh)*

Difference in the elevation between the highest point of a basin (on the Main divide) and the lowest point on the valley floor is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief ratio of a basin and the largest dimension of the basin parallel to the main drainage line (Schumm, 1956). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by scheme who found that sediments loose per unit area is closely correlated with relief ratios. In the study area, the values of relief ratio vary from 0.63(Sbn5) to 0.93(Sbn3). It is noticed that the high values of Rh indicate steep slope and high relief (246m), while the lower values may indicate the presence of basement rocks that are exposed in the form of small ridges of small ridges and mounds with lower degree of slope.

2) *Ruggedness number (Rn)*

Ruggedness number (Rn) is the product of relief and drainage density in order to define the slope steepness and length. The present study area indicates the ruggedness value 1.5 so that area is extremely rugged with high relief and high stream density.

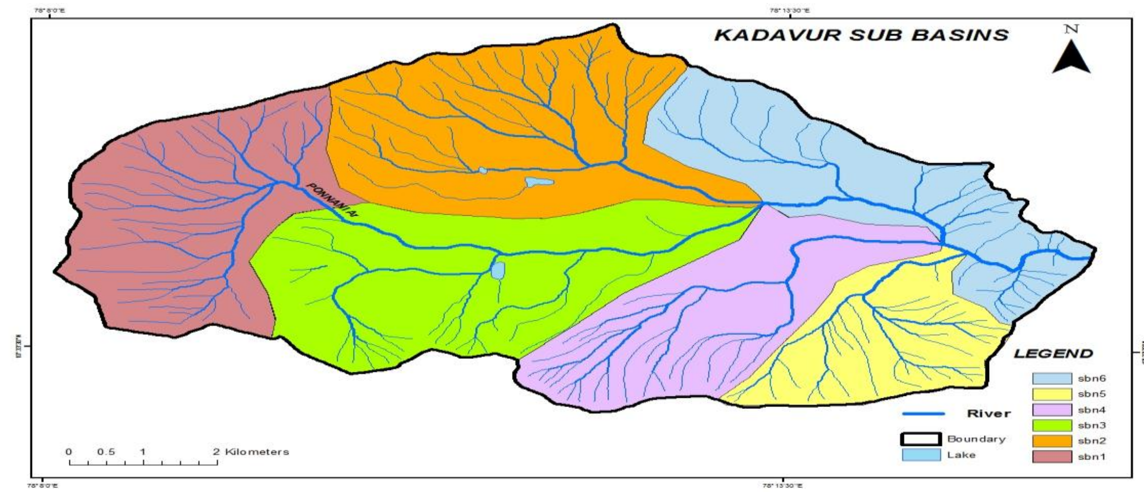

Fig. 5**:** Drainage Map of Sub Basin

C. Aerial Aspects

Different morphometric parameters like drainage density, texture ratio, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow have been discussed in detail given in Table.5.

1) *Drainage Density (Dd)*

It is a measure of the length of stream per unit (Hortton , 1932) in the watershed it is significant point in the linear scale of landform elements in stream eroded topography and does not change regularly with order within the basin. It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area, which is expressed in terms of mi/sq.mi or km/sq.km. The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. Among the aerial parameters analyzed the measurements of drainage density a numerical measurements of the landscape dissection and run-off potential, high drainage density of 2.74 is the result of weak or impermeable subsurface material, sparse vegetation and mountainous relief. The amount and type of precipitation an influence directly the quality and character of surface run-off an area with high precipitation as thundershowers loses greater percentage of rainfall absorption capacity of soil. Which influences the rate of surface run-off affects the drainage texture of an area.

Table - 5
Areal Aspects of Sub-Basins of Kadavur Basin

Sl. No	*Sub Basins*	*Area of Basin in sq.km (A)*	*Stream Frequency (Fs)*	*Form Factor Ratio (Ff)*	*Elongation Ratio (Re)*	*Length of Overland flow(Lg)*	*Drainage Density in km (Dd)*	*Total no of stream segment*	*Length Over Land Flow*	*perimeter in Km(P)*	*Texture Ratio (Rt)*	*Circularity RatioRc=4*Pi *A/P2*
1	*Sbn1*	*14.60*	*0.32*	*0.84*	*0.64*	*17.41*	*1.19*	*45*	*0.6*	*15*	*3*	*0.8*
2	*Sbn2*	*16.92*	*2.72*	*0.92*	*0.68*	*18.33*	*1.08*	*46*	*0.54*	*18*	*2.6*	*0.7*
3	*Sbn3*	*17.29*	*1.91*	*0.93*	*0.82*	*18.54*	*1.07*	*33*	*0.54*	*19*	*1.7*	*0.6*
4	*Sbn4*	*11.99*	*2.67*	*0.74*	*0.69*	*16.28*	*1.36*	*32*	*0.68*	*16*	*2*	*0.6*
5	*Sbn5*	*8.019*	*4.99*	*0.63*	*0.51*	*12.66*	*1.58*	*40*	*0.79*	*13*	*3.1*	*0.6*
6	*Sbn6*	*12.29*	*3.09*	*0.63*	*0.64*	*19.42*	*1.58*	*38*	*0.79*	*19*	*2*	*0.4*

Source: Compiled by Author

The similar condition of litho logy and geologic structures semi-arid regions have finer drainage density generally results in the areas of highly resistant or permeable subsoil material.

2) *Stream Frquency (Fs)*

The stream frequency (Fs) of a basin may be defined as the number of streams per unit area (Horton, 1945). The Fs values for the study area having 2.75 km/km2 respectively. The area have more agricultural land high drainage density frequency. Sbn1 and Sbn3 are having poor frequency Sbn2 having moderate and Sbn4,5,6 are having high to very high stream frequency (Table.4) Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity.

3) *Form Factor (Rf)*

The form factor Rf points out the shape or outlines form of a drainage basin capable of being understood and effects stream discharge behaviors. The ratio basin area to the square of basin length is called the form factor (Horton,1932). It is dimension less property and is used as a quantitative expression of the shape of basin form. The form factor varies between 0.63 to 0.93. So all sub basins are relatively circular shape.

4) *Circularity Ratio (Rc)*
Basin of the circularity ratio Rc is a shape measured depending on stream flow in the sub basin. (Miller, 1953) Table.1shows that the circularity ratio is influence by the length and frequency of stream, geological structures, land use-land cover, climatic relief and slopes of the basin. He described the basin of the circularity ratios range 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. In the present study, the circularity ratio value 0.5 of the basin corroborates the miller's range which indicating that the basin is elongated shape, low discharge of runoff and highly permeability of the sub soil conditions.

5) *Elongation ratio (Re)*
Schumm (1956) used an elongation ratio Re defined as the ratio of diameter of a circle of the basin same area as the basin to the maximum basin length. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin values near to 1.0 are typical of regions of very low relief (Strahler, 1964). A circle basin is more efficient in the discharge of run-off than an elongation basin (Singh and Singh 1977). The values of Re generally vary from 0.6 to 1.0 over a wide variety of climate and geological types values close to 1.0 are typical regions of very low relief, where as values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler 1964). The values can be grouped into 4 categories namely (a) circle (>0.9), (b) Oval (0.9 to 0.8) , (c) Less elongated (<0.7). The value Re of the study area is 1.6 indicates that the high relief of the terrain and circular in shape.

6) *Constant channel maintenance (C)*
Schumn (1956)has used the reciprocal of drainage density as a property termed constant of channel maintenance. 'Lg' can be defined as the mean horizontal length of flow path from the divide to the stream in a first-order basin and is a measure of stream spacing and degree of dissection and is approximately one-half the reciprocal of the drainage density (Chorley 1969).Constant channel maintenance (C) 0.36 indicates that area is under the influence of structural disturbances having high run-off and low permeability.

7) *Length of Overland flow (Lg)*
Horton (1945) defined length of overland flow as the longest drainage path that water takes before it gets concentrated; the length of overland flow (Lg) approximately equals half the reciprocal of the drainage density. He further noted that Lg is one of the most important independent variable affecting both hydrologic and physiographic development of drainage basins. This factor relates inversely to the average slope of channel and is quite synonymous with the length of sheet flow. The study area length of overland value varying from 0.54 to 0.79 respectively.

8) *Drainage Texture (Rt)*
Horton (1945) defines drainage texture as the total number of segments of all order per perimeter of that area. Smith (1950) classified drainage density into five different textures. The drainage density texture <2 indicate very coarse, 2-4 indicates coarse, 4-6 indicates moderate, 6-8 indicates fine texture and >8 indicates very fine texture. According to this classification drainage texture of study area having 4.29 respectively falls under coarse to moderate drainage texture.

IV. CONCLUSION

The present study has proved that the geoprocessing technique used in GIS is an effective tool for computation and analysis of various morphometric parameters of the basin and helps to understand various terrain parameters such as nature of the stream flow is likely to be high in the river basin. The analysis of the Bifurcation value shows the Ist order river stream has well developed drainage network, further the 2^{nd} order stream value shows ,this area mountainous as well as dissected region.

The form factor value (0.63 to 0.93.) calculated for the Kadavur basin reveals that the basin is less elongated in shape. The analysis of drainage density value (2.74) reveals the Kadavur basin is likely to be impermeable subsurface. In the case of stream frequency (2.75), the river basin is occupies in a more dissected area. The value Re of the study area is 1.6 indicates that the high relief of the terrain and circular in shape. The quantitative analysis of linear, relief and aerial parameters using GIS is found to be of immense utility in river basin evaluation, basin prioritization for soil and water conservation and natural resource management. The geoprocessing techniques employed in this study will assist the planner and decision makers in basin development and management studies.

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