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Morphometric Characterization of Chinnar River Basin-A Comparative Study Using Topographical Map and SRTM DEM

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Abstract- The study of drainage basin as an aerial unit is the fundamental concept of morphometric analysis. It is an open system defined by characteristics that can be measured quantitatively, thus providing an objective basis for analysis, comparison and classification. The present study is carried out to characterize and compare the morphometry of Chinnar River basin using geospatial techniques. The morphometric parameters were calculated and specialized through spatial analysis of GIS using Topographical Map and SRTM DEM. The Chinnar river basin is assigned to a 5th order basin having 405, 88,13,3 and 1 and Dem 452,88,16,3,1 number of streams in first, second, third, fourth, and fifth orders respectively. The Chinnar river basin having a drainage density of 1.057 km/km2and DEM 1.16 km/km2.The stream frequency of the basin is 1.06/ sqkm and DEM 1.17/sqkm. The length of overland flow of the basin is 0.47 km. The value of form factor is 0.40.The Rc of basin is 0.3541 which indicates that circular shape.

Keywords: - Chinnar River, GIS, Morphometry, Circular.

I. INTRODUCTION

The study of drainage basin as an aerial unit is the fundamental concept of morphometric analysis. It is an open system defined by characteristics that can be measured quantitatively, thus providing an objective basis for analysis, comparison and classification.

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke, 1966). This analysis can be achieved through measurement of linear, aerial and relief aspects of basin and slope contributions (Nag and Chakraborty, 2003). In the present study, the morphometric analysis is divided into linear, aerial and relief aspects.

Since 1945 there have been many advances in geomorphology. Horton (1932) realized that hydrological character of drainage hydrological character of a drainage system could not be separated from their morphometric characters. Interest in drainage basin morphometry has grown since Horton (1945) drew attention to certain relationship that exist between stream order and average stream length, stream order and drainage area. The overall morphometric characters help to understand the nature of the basin. In this context an attempt has been made to understand and compare the morphometry of the current study area using geospatial approach.

II. STUDY AREA

The study area covers an area of 477.42sq. Km and lies in the parts of Anekaltaluk of Bangalore urban district of Karnataka (Map-1). The Chinnar River rises at Kalkere in Bannerghatta hill ranges with an altitude of 936 mand joins Ponnair River at pedda - kulli near Hosur at an altitude of 813 m. It is an important tributary of Ponnair River. It flows towards south-eastern direction. The study area has dendritic to sub-dendric drainage pattern.

The study area lies between the longitudes of 770 15' to 770 48' E and latitudes of 120 40' and 120 52' N. The geology of the study area is largely granitic rock and gneiss. Red soil, loamy soil, alluvial soils are some of the common soil types observed in the study area.

Fig 1. Map 1- Study Area.

III. METHODOLOGY

In the present study, morphometric analysis is based on Topographical map and SRTM DEM. The remotely sensed data is geometrically rectified with respect to Survey of India (SOI) topographical maps at 1:50,000. The digitization of drainage is carried out in Arc GIS 10.2.2 software (Map - 2). Morphometric parameters under linear and shape are computed using standard methods and formulae (Horton 1932, 1945; Smith 1954; Strahler, 1964) both using survey of India top sheets and SRTM DEM.

The fundamental parameter namely; stream length, area, perimeter, number of streams and basin length are derived from drainage layer. The values of morphometric parameters namely; stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio and compactness constant are calculated based on the formulae suggested by Horton (1945), Miller (1953), Schumn (1956), Strahler (1964), Nookaratm (2005).

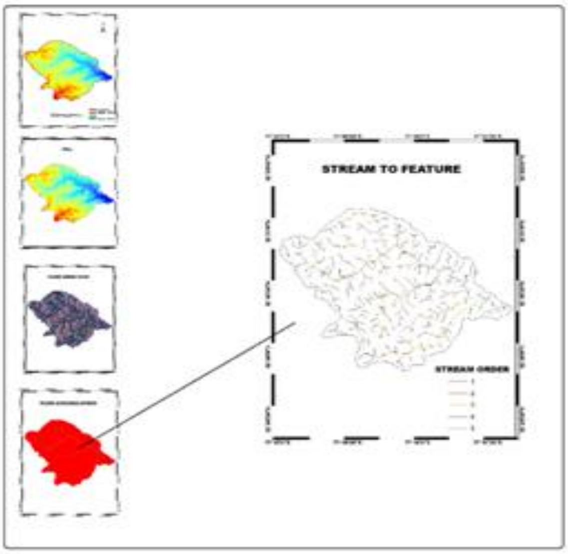

Fig 2. Map 2- Drainage.

IV. RESULT AND DISCUSSION

The morphometric analyses in parts of Chinnar River basin have been carried out and comparative study has been made with survey of India topographic map and SRTM DEM. The area shows dendritic drainage pattern forming dense and irregular network of stream joining main stream at less than right angle indicates uniform lithology. The results of linear, areal and relief parameters were calculated and tabulated.

1. Linear Aspects of the Basin:
Stream order, Bifurcation ratio, Stream length, Mean stream length and Stream length ratio are determined as follows:

1.1 Stream Order (u): The designation of stream order is the first step in drainage basin analysis and is based on a hierarchic ranking of stream. The work of Horton (1945) numerical analysis of drainage basin has relied on the concept of stream ordering. In the present study, ranking systems has been carried out based on the method proposed by Strahler (1964).

The Chinnar river basin is assigned to a 5th order basin having 405, 88, 13, 3 and 1 number of streams in first, second, third, fourth, and fifth orders respectively in survey of India topo map and 452, 88, 16, 3 and 1 number of streams in first, second third, fourth, and fifth order respectively in SRTM DEM. (Table- 2.1& 2.3).

1.2 Bifurcation Ratio (Rb): The term bifurcation ratio (Rb) is defined as the number of the stream segments of given (Nu) to the number of segments of the next higher order (Nu+1) (Schumm) 1956) (Table 2.1& 2.2). Horton (1945) considered the bifurcation ratio as an index of relief and dissection.

Strahler (1957) demonstrated that bifurcation ratio shows a small range of Ru=Nu/Nu+1 variation for different regions or for different environment except where the powerful geological control dominates, it is observed from the (table - 2.1), the Rb is not same from one order to its next order.

The bifurcation ratio of the study basin is 4.3 derived from SOI topo map and 4.7 from SRTM DEM indicating the mature stage of development of the basin and less disturbed by the underlying structures.

1.3 Stream Length (Lu): The number of streams of various orders in a basin is counted and their lengths from mouth to drainage divided are measured (Table 2.1& 2.2) with the help of GIS software. The stream length (Lu) has been computed based on the law proposed by Horton (1945).

Generally, the total length of stream segments is maximum in first order steams but decrease as the stream order increases. Some of the segments of various orders show variation from general observation; it indicates steep slopes (Singh and Singh 1997).

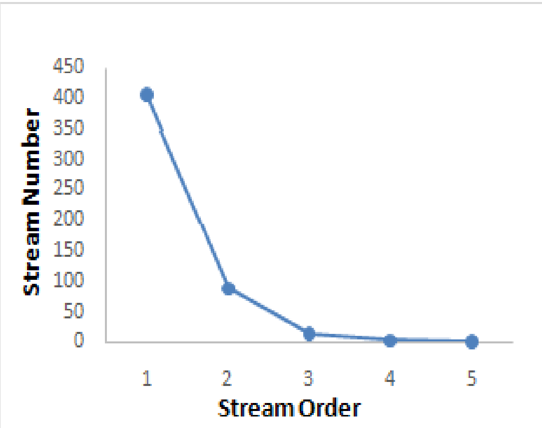

Fig 3. SOI.

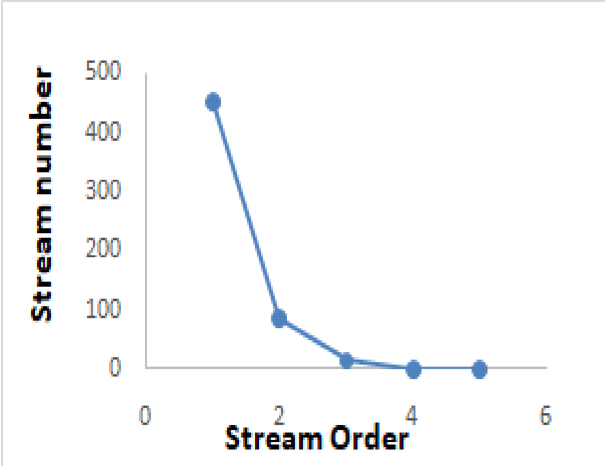

Fig 4. SRTM.

1.4 Mean Stream Length (Lsm): According to Strahler (1964), the mean stream length is a characteristics property related to the drainage network and its associated surfaces. The mean stream length (lu) has been calculated by dividing the total stream length of order 'u' and number of streams of an higher order 'u+1'.The mean stream length of Chinnar river basin varies from 0.63 to 14 kms.

1.5 Stream Length Ratio (Rl): Stream length ratio (RI) may be defined as the ratio of the mean length of an order to the next lower order of stream segment. Horton's law (1945) of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate direct geometric series with streams length increasing towards higher order of streams.

The length ratios of the Chinnar river basin are presented in Table 2.2. The average value of length ratio of basin obtained from the slope of the regression line on a plot of logarithmic mean of stream length versus orders is 2.1 and 2.5 from topo sheet and DEM respectively.

2. Areal Aspects:
Different areal parameters like drainage density, stream frequency, drainage texture, and length of overland flow, form factor, circularity ratio and, elongation ratio have been discussed in detail.

2.1 Drainage Density (Dd): Horton (1932) has introduced drainage density (Dd) as on expression to indicate the closeness of spacing of channels. It is defined as the ratio of the total channel segment lengths of all orders within a basin area (Table 2.1). The Chinnar river basin having a drainage density of 1.057 km/km2 (Table2.1) is a very coarse texture basin, typical regions of highly resistant rocks and low relief.

Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness has no significant correlation with drainage density. Smith (1950) has classified drainage density into five different textures as follows:

Table 1. Drainage Density.

Drainage density (km/km^2)	Textures
< 2	Very coarse
2 - 4	Coarse
4 - 6	Moderate
6 - 8	Fine
> 8	Very Fine

The Chinnar river basin having a drainage density of 1.057 km/km2from toposheet and 1.16 km/km2from DEM. This indicates that the study area has very coarse drainage texture.

2.2 Stream Frequency (Fs): Horton (1932) introduced stream frequency (Fs) or channel frequency which is the total number of stream segments of all orders per unit area (Table 2.1). Melton (1958) derived an empirical relation between drainage density and stream frequency. The stream frequency calculated for the basin is 1.06/ sq.km from toposheet and 1.17/ sq. km from DEM. This indicates that the development of stream segments may more or less affected by rainfall and temperature.

2.3 Length of Overland Flow (Lg): Horton (1945) defined the length of overland flow 'Lg' as the length of flow path, projected to the horizontal, of non-channel from a point on the drainage divide to a point on the adjacent stream channel. He considered the length of overland flow as one of the most important variables, affecting both the hydrologic and physiographic development of drainage basin. The length of overland flow of the basin is 0.47 km.

2.4 Form Factor (Ff): Form factor (Ff) may be defined as the ratio of basin area to square of the basin length (Horton, 1932). The Ff of Chinnar basin is 0.4044 (Table 2.1). The value of form factor indicates that, the basin is nearly circular in form.

2.5 Circularity Ratio (Rc): It is the ratio of the area of basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953) (Table 2.1).

The circularity ratio (Rc) is influenced by the length and frequency of streams, geological structures, land dues/land cover, climate. Relief and slope of the basin. The Rc of basin is 0.3541 which indicates that the basin is circular in shape.

2.6 Elongation Ratio (Re): Schumm (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Table 2.1). A circular basin is more efficient in the discharge of runoff than an elongated basin (Singh and Singh, 1977).

The value of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions having very low relief, whereas values in the range of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964), these values are grouped as follows:

Table 2. Elogation Ratio.

Re	>0.9	0.9-0.8	>0.7
Shape	Circular	Oval	Less elongated

The Re value of the basin is 0.71 is indicate that the basin is circular and basin area is associated with low relief.

2.7 Compactness Constant (Cc): The compactness constant defined as the ratio of the perimeter of the catchment to its perimeter of the circle whose area is that of the basin. It is depending mainly on the slope and independent on size of watershed.

The compactness constant value for the study area is 0.14indicating lesser elongated basin however, a lesser elongated pattern facilitates the low runoff thereby favouring to development of low erosion.

2.8 Constant of Channel Maintenance (C): This parameter indicates the requirement of units of basin surface to bear one unit of channel length. Schumn (1956) has used the inverse of the drainage density having the dimension of length as a property termed constant of channel maintenance.

The drainage basins having higher values of this parameter, there will be lower value of drainage density. The C value for the study area is 0.94 which in turn indicates higher permeability of subsoil.

2.9 Infiltration Number (In): The infiltration Number is defined as the product of Drainage Density (Dd) and drainage Frequency (Fs). The higher the infiltration number the lower will be the infiltration and consequently, higher will be run off.

This leads to the development of higher drainage density. It gives an idea about the infiltration characteristics of the basin reveals impermeable lithology and higher relief. The value obtained is 1.12. These lower infiltration numbers indicate moderate low-moderate infiltration and fewer run-offs.

2.10 Melton Ruggedness Number (MRn): Other important relief characteristics quantified in this study is Melton ruggedness number (MRn) which is a slope index that provides a particular representation of relief ruggedness within the watershed (Melton, 1965). Melton ruggedness number for Basin is 26.49 indicating that sediment transport is dominated by bed loads.

3. Relief Aspects of the Basin:

Basin relief in an important factor in understanding the extent of denudation in a basin.

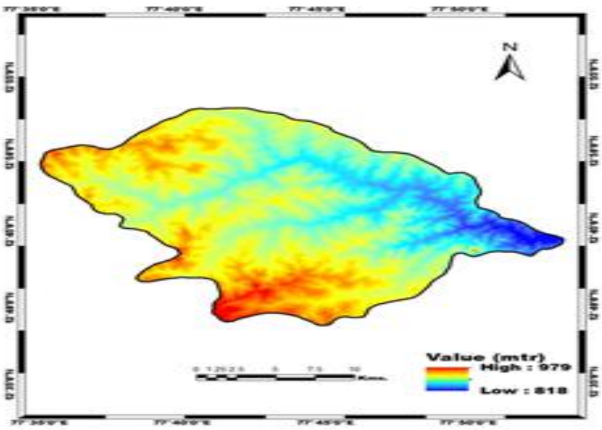

Fig 5. Map 3- Slope.

3.1 Slope Analysis: Slope analysis is an important aspect of geomorphic studies. It involves the preparation of a slope map showing variation of slope from area to area.

Slope analysis of the Chinnar river basin has been carried out by using topographic Map and DEM. The highest elevation in the study area is 979 mtrs and lowest is 818 mtrs. Overall slope of the study area follows gentle to moderate slope.

3.2 Ruggedness Number (Rn): It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit.

Higher values show uneven topography, litho logical heterogeneity of terrain and high amount of dissection, moderate value indicate flat topped surface or ridge and valley topography and moderate to moderately high degree of dissection and lower values are found in areas of less dissection and levelled surface.

Extreme high values of ruggedness number occur when both variables are large. The Ruggedness number for the study area is 0.6120, which indicates that the basin has low relief and plane in nature.

3.3 Relative Relief Ratio (Rnl): The term relative relief is defined as the ratio of maximum basin relief to the perimeter of the basin and was introduced. The relative relief of different watersheds have been determined, and given in (Table-2.1).

These results further validated with the Digital Elevation Model (DEM) of the study area indicating that elevation varies from 979 to 818 meter, which represent that the surface has gentle to moderate slope.

3.4 Relief Ratio (Rr): The relief ratio is a measure of the overall steepness of a drainage basin and is an indicator of the intensity of erosional process operating on slope of the basin.

It has been observed that there is a high degree of correlation between high relief and high drainage frequency, high stream frequency and high stream channel flow which brings out high discharge in short duration. The value of relief ratio in the area is 0.0016, which indicates low relief and moderate to gentle slope.

Table 3. Formulas Used for Computation of Results of Morphometric Parameters.

Morpho metric Parameters	Formula/ Method	References
LINEAR		
Stream order	Hierarchical Order	Strahler, 1964
Stream Length	Length of the Stream in km	Horton, 1945
Mean Stream Length (Lsm)	Lsm =Lu/Nu Where, Lu=Total stream length of order 'u' and Nu = Total no. of streams of order 'u'	Horton, 1945
Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu-1=The total stream length of its next lower order	Horton, 1945
Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order	Schumn, 1956
RELIEF		
Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumn, 1956
Relief Ratio (Rh)	Rh = H/Lb Where,H= Total Relief (Relative Relief) of the basin (km), Lb=Basin length	Schumn, 1956
Ruggedness Number (Rn)	Rn=Dd×H/1000 Where,Dd=Drainage density H=Total Relief	Schumn, 1956
Relative relief ratio (Rnl)	Hx100/P Where, H= total relief, P=Perimeter of basin	Schumn, 1956
AREAL		
Drainage density (Dd)	Dd=Lu/A Where, Lu=Total length of stream segments of all orders, A= Area of basin.	Horton, 1945
Stream frequency (Fs)	(Fs) Fs=Nu/A Where, L=Total number of stream of all orders, A=Area of basin	Horton, 1945
Texture ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin.	Horton, 1945
Form factor (Ff)	$Rf=A/(Lb)^2$ Where, A=Area of basin, Lb=Basin length	Horton, 1945
Circulatory ratio (Rc)	$Rc=4\pi(A/P^{2)}$ Where, A=Area of basin, π=3.14, P= Perimeter of basin.	Miller, 1953
Elongation ratio (Re)	Re=√(Au/π)/Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumn, 1956
Length of overland flow (Lg)	Lg=1/2Dd Where, Drainage density	Horton, 1945
Constant channel maintenance(C)	C=1/Dd Where, Dd= Drainage density	Horton, 1945
Compactness constant (Cc)	$Cc = 0.2821\ P\ A^{0.5}$ Where, P=Perimeter of Basin A = Area of basin	Partha et al., 2018
Infiltration Number (In)	In = Dd × Fs Where, Dd = Drainage Density (Km/ Km^2); Fs = Stream frequency ($Number/ Km^2$)	Faniran, 1968
Melton Ruggedness number (Mrn)	$H/A^{0.5}$ Where, H=Total relief, A=Area of basin	Schumn, 1956

Table 4. Morphometric Parameters.

1	Basin Area (sq. kms)	477.42				
2	Perimeter (Km.)	130				
3	Stream order	I	II	III	IV	V
4	No.of stream (Segments)	405/452	88/88	13/16	3/3	1/1
5	Bifurcation Ratio	4.60/5.13	6.77/5.5	4.33/5.3	3/3	-
6	Length of Stream (Km)	256/292	128/130	71/80	36/30	14/25
7	Mean Streams Length (km.)	0.6321/0.64	1.4545/1.48	5.462/5.0	12/10.05	14/25
8	Streams Length Ratio (order)	2.30/2.31	3.75/3.37	2.20/2.1	1.17/2.48	-
9	Drainage Density (Km/Sq Km.)	1.057/1.16				
10	Drainagefrequency (Stream)	1.07/1.17				
11	Circularity Ratio (Rc)	0.3541				
12	Length of overland flow(Lg)	0.47				
13	Form factor (Ff)	0.4044				
14	Elongation Ratio (Re)	0.7177				
15	Compactness constant (Cc)	0.1472				
16	Constant of Channel Maintenance (C) (sq.km)	0.9454				
17	Infiltration Constant (In)	1.1299				
18	Relief Ratio	0.00168				
19	Relative Relief Ratio	0.0761				
20	Ruggedness Number	0.6120				
21	Melton Ruggedness Number	26.49				

Table 5. The Different Morphometric Characters derived from SOI Toposheet.

Stream order (u)	No of streams (Nu)	Bifurcation ratio (Rb)	Stream Length of each order(Lu)	Mean length (km) (Lsm)	Cumulative Mean length (km) (Lsm)	Length ratio(km) (Rl)
1	405	4.60	256	0.6	0.6	2.3
2	88	6.76	128	1.4	2.0	3.8
3	13	4.33	71	5.4	6.8	2.2
4	3	3	36	12	17.4	1.1
5	1	-	14	14	26.0	-

Table 6. The Different Morphometric Characters derived from SRTM DEM.

Stream order (u)	No of streams (Nu)	Bifurcationratio (Rb)	Stream Length of each order (Lu)	Mean length (km) (Lsm)	Cumulative Mean length (km) (Lsm)	Length ratio(km) (Rl)
1	452	5.13	292	0.6	0.6	2.3
2	88	5.5	130	1.4	2.0	3.3
3	16	5.3	80	5.0	6.4	2.1
4	3	3	30	10.0	15.0	2.4
5	1	-	25	25.0	35.0	-

V. CONCLUSION

Morphometric analysis has been carried out to the Chinnar river basin using Topographical Map and SRTM DEM using geospatial technique. The study area is assigned to a 5th order basin having 405, 88, 13, 3 and 1 and dem values 452,88,16,3,1 number of streams in first, second, third, fourth, and fifth orders respectively. The bifurcation ratio of the study basin obtained from the slope of the regression line drawn by plotting logarithmic number of streams versus orders is 4.3 indicating the mature stage of the basin.

The stream length is 256 to 14 km. The mean stream length varies from 0.63 to 14 kms. The stream length ratio is 2.30 to 1.17. The Chinnar river basin having a drainage density of 1.057 km/km2and dem 1.16 km/km2.The stream frequency of the basin is 1.06/ sqkm and dem 1.17/sq km. The length of overland flow of the basin is 0.47 km. The value of form factor indicates that is 0.40. The Rc of basin is 0.3541 which indicates that circular.

A circular basin is more efficient in the discharge of runoff than an elongated basin value is 0.71.Constant of channel maintenance is 0.94 sq km. Infiltration number is 1.12.Ruggedness Number is 0.61.It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. Thus comparative study by both topographic method and SRTM DEM helps to study the basin characteristics more accurately.

However, the morphometric parameters derived from SRTM DEM seems to have an accurate set of results compared to topographical maps. Also geospatial techniques coupled with field data proved to be an efficient method to characterize the morphometry of the area.

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