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Morphometric Analysis of Tungabhadra River Basin of Kurnool District, Andhra Pradesh Using Geographical Information System

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Abstract

Geographical information system has been used for the calculation and delineation of the morphometric characteristics of the River basin. The study of morphometric analysis of Tungabhadra river basin has been based on the secondary source. The Dem data (Digital elevation model) for the study area downloaded from USGS earth explorer website. The downloaded data has been analysed using Arc GIS Software. In addition, we study linear, relief and aerial parameters of drainage basin Retrieved that (indices were computed). The stream order ranges from first to six orders. The analysis has revealed that the total number and length of stream segments is maximum in first order streams and decreases as the stream order increases. The stream order of the basin is form first order to sixth order , where the total number of the streams for the basin is 2580 out of which 1326 are first order 643 are second order 378 are the third order, 120 are the fourth order,78 are the fifth order streams and 35 are the six is order. The streams have been formed in Dendric drainage pattern drainage pattern with drainage density of 0.622 km^2 infers the less permeable surface of the basin with thin vegetation and moderate to high elevation. The Bifurcation ratio (R_b) between different successive orders varies revelling the geostructural the shape parameters circulatory ratio (R_c)=0.28,Elongation ratio(R_e) =0.31, form factor (R_f)=0.24 indicates elongated shape of the basin which increases the chance of infiltration. These studies are very useful for identifying and planning the ground water potential zones and watershed management.

Key words: Drainage network, Tungabhadra River basin, SRTM Dem, Arc GIS10.3

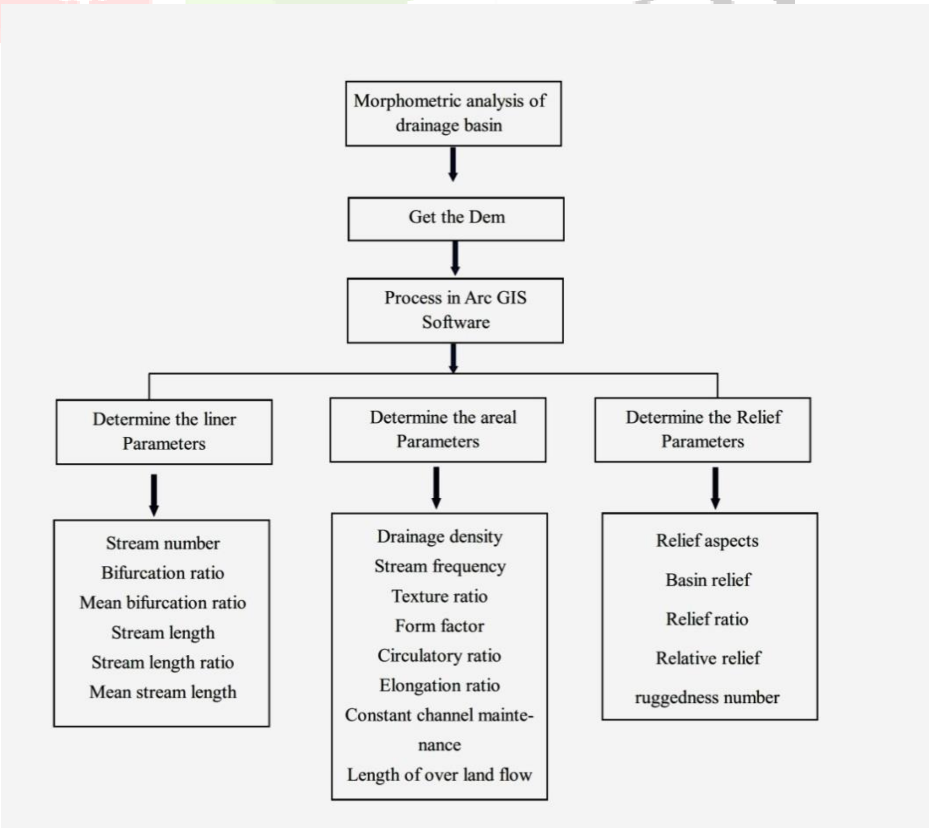
Introduction

Morphometric analysis plays a significant role in understanding the geohydrological characteristics of the drainage basin. Remote sensing and GIS are the proven efficient tools in the delineation updating and morphometric analysis of drainage basin. The study of stream orders has been classified based on its relative position in the stream.

Measurement and quantitative expression of the Drainage basin perhaps began with the idea of james hutton, ,whose law ofAccordant Tributory junctions as expressed by playfair in 1802. R.E. Horton(1932) added new Measures and proposed general methods for the description of drainage basin characteristics . subsequently several persons like langbein(1947),Johnston (1949), strahler (1964).

De martonne(1934) in his Trait de geographic physique ' adopted the expression 'morphometry and defined it as 'the numerical systematisation of the forms of the land relief as it can be interpreted form a topographic map. Clarke(1967) defined 'morphometry ' as the measurement and mathematical analysis of configuration of earth's surface and of the shape and dimensions of its landforms. Morphometric analysis assimilates Quantitative specification of the area, altitude, volume, slope , profile and texture of the land forms as well as the varied characteristics of river and drainage basins and its net work and examine the effects of variables such as rock structure, rainfall, recent diastrophism, geology, geomorphologic parameters. Morphometric analysis of river basin to explore interrelationship between hydrological parameters and geomorphologic parameters.

Procedure for morphometric analysis of drainage basin



Recently many researchers have attempted to generate more precise data using geographical information system (GIS) tools in different parts of the sphere for automated determination of drainage basin parameters .it is a powerful tool for evaluating drainage characteristics and continuous monitoring found that GIS tools for analysis of drainage characteristics from the different data sources.

The study of streams and water ways in general is known as surface hydrology and it is a core element of environmental geography. In recent years development of geographical information system helps the researchers and scientists to study the stream orders accurately & also easily has been done using GIS technique to analysis the current study Tungabhadra river basin.

Study area:

The river Tungabhadra originates in chikmanalur district of Karnataka, which is formed by the convergence of the Tunga and Bhadra rivers. The Tungabhadra rises in western ghats and after forming parts of northern boundary for some distance separates kurnool from the Telangana area flown in an Eastern direction receives Hundari and falls in to the Krishna river at kudalisangam after winding north wards.Maliganur (village), kowthalam (Mandal)which is entry point of Tungabhadra river basin of Kurnool district It covers an area of 6913.23 km^2 lying between latitude 15^0 10’ to 16^0 00’N and longitudes 77^0 00’ to 78^0 00’E.

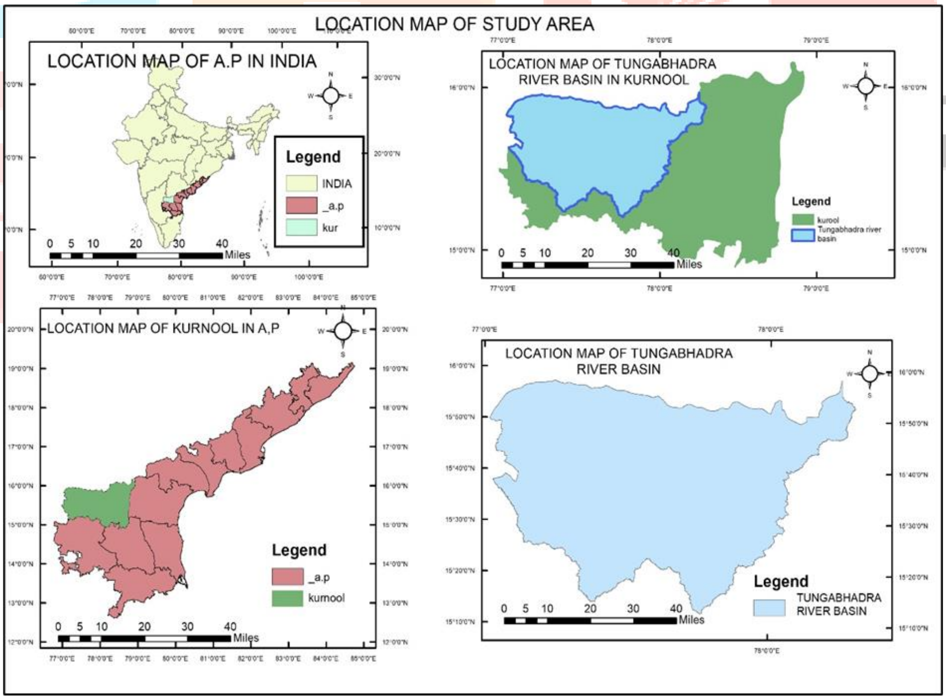
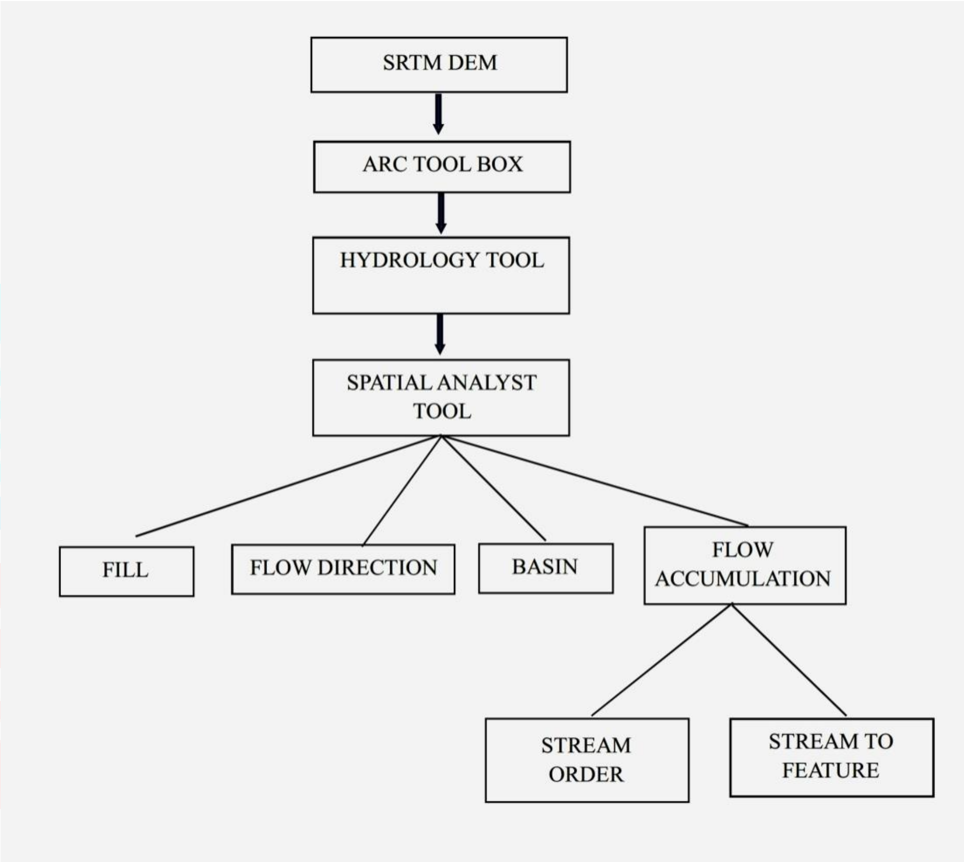


Fig .1 Location map of the study area (Tungabhadra River Basin)

Methodology

The study is based on the secondary data. The SRTM Dem (shuttle Rader topographic mission dem data) has been downloaded from USGS Earth explorer website and processed according to the steps using Arc GIS 10.3 SOFTWARE Hydrology tool set. The Arc GIS software has been used to analysis stream order of drainage basin. By using hydrology tool processing topographic data to identify sinks, determine flow direction,calculate flow accumulation. Delineate basin, create stream network and perform morphometric and hydrologic analysis. Stream order was made according to Strahler's law and the morphometric parameters and indices were calculated according to the formulas to different Geographer's ideas.



TUNGABHADRA RIVER BASIN ATTRIBUTE EXTRACTION STEPS (Arc GIS 10.3)

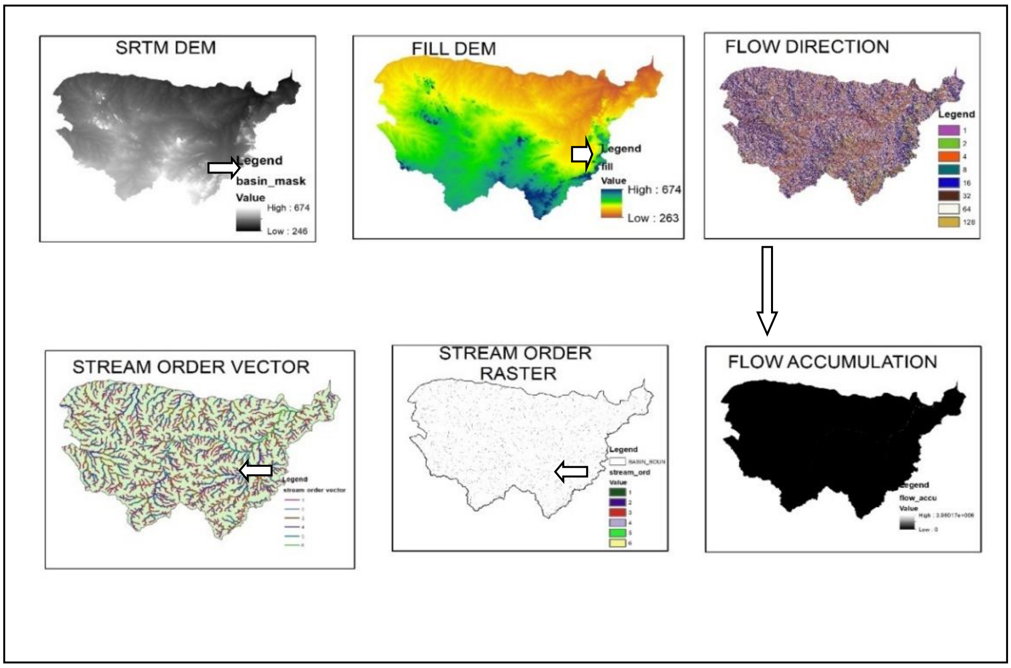


Fig.2 Automatic extraction of streams through SRTM Dem data

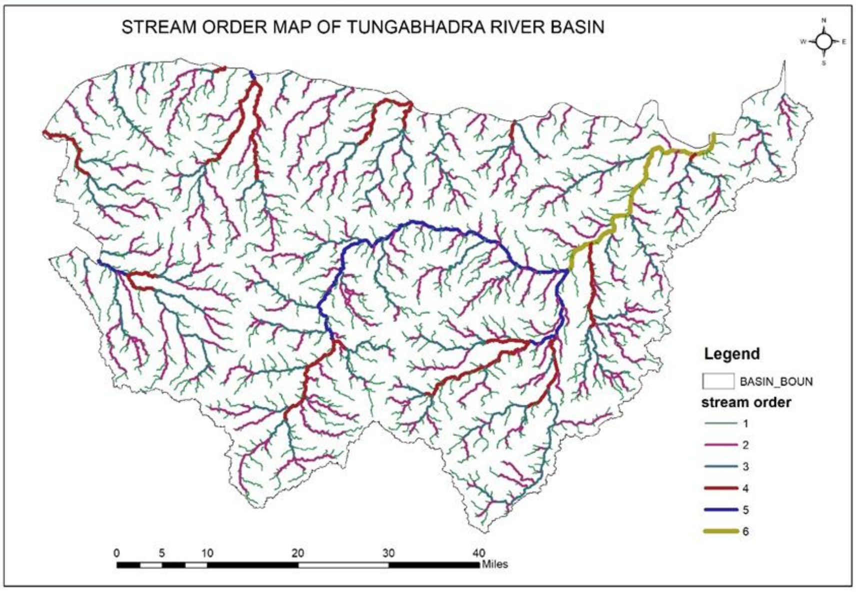


Fig .3 Stream Order Map of Tungabhadra River Basin

The downloaded SRTM Dem corrected using fill tool in arc GIS hydrology tool fill (fill&sink) in a surface raster to removed small imperfections in the data. flow direction creates a raster of flow direction from each cell to its steepest down slope neighbour. flow accumulation creates raster of accumulated flow in to each cell. The weight factor can optionally be applied.

TABLE:1 Methods of Calculating Morphometric Parameters of Drainage Basin

	Morphometric parameters	Methods	References
LINER	Stream order (U)	Hirarchical order	Strahler,1964
	Stream length (L_u)	Length of the stream	Horton,1945
	Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$, where L_u =stream length of order 'U' N_u=Total number of stream segments of order 'U'	Horton,1945
	Stream length ratio (R_L)	RL=Lu/Lu-1; where Lu=Total stream length of order 'U', Lu- 1=Stream length of next lower order.	Horton, 1945
	Bifurcation ratio (R_b)	R_b = Nu/ Nu+1; where, Nu=Total number of stream segment of order 'u'; Nu+1=Number of segments of next higher order	Schumn,1956
AREAL	Drainage density (D_d)	$D_d = L_b/A$ where, L=Total length of streams; A=Area of watershed	Horton, 1945
	Stream frequency (F_s)	F_s = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1945
	Texture ratio (T)	T = N1/P where, N1=Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor (R_f)	R_f=A/(Lb) 2; where, A=Area of watershed, Lb=Basin length	Horton, 1932
	Circulatory ratio (R_c)	R_c=4Πa/P2; where, A=Area of watershed, π=3.14, P=Perimeter of watershed	Miller, 1953
	Elongation ratio (R_e)	$R_e=2\sqrt{(A/\pi)}/Lb$; where, A=Area of watershed, π=3.14, Lb=Basin length	Schumn,1956
	Length of overland flow (L_g)	L_g = 1/2Dd where, Dd=Drainage density	Horton, 1945
	Constant channel maintenance (C)	Lof = $1/D_d$ where, D_d=Drainage density	Horton, 1945
RELIEF	Basin relief (B_h)	Vertical distance between the lowest and highest points of watershed.	Schumn, 1956
	Relative relief (R_r)	$R_r=B_h/p$, where ,B_h=Basin relief, p= perimeter of the basin	melton (1957)
	Relief ratio (R_h)	$R_h=B_h/L_b$; Where, B_h=Basin relief; L_b=Basin length	Schumn, 1956
	Ruggedness number (R_n)	$R_n = B_h \times D_d$, where B_h =Basin relief; D_d=Drainage density	Schumn, 1956

Result and discussion

The result of the linear, relief and Arial properties of Tungabhadra river basin are given below

TABLE: 2 Result of morphometric analysis in liner aspects

Stream order	Number of streams	Bifurcation ratio R_b	Stream length (L_u) Km	Stream length ratio (R_L)	Mean stream length(L_{sm})
1	1326	-----	2169.28	---	1.63
2	643	2.06	1190.09	1.13	1.85
3	378	1.70	599.75	0.85	1.58
4	120	3.15	201.21	1.05	1.67
5	78	1.53	99.32	0.76	1.27
6	35	2.22	46.89	1.04	1.33

TABLE: 3 Result of morphometric analysis in Arial and Relief aspects

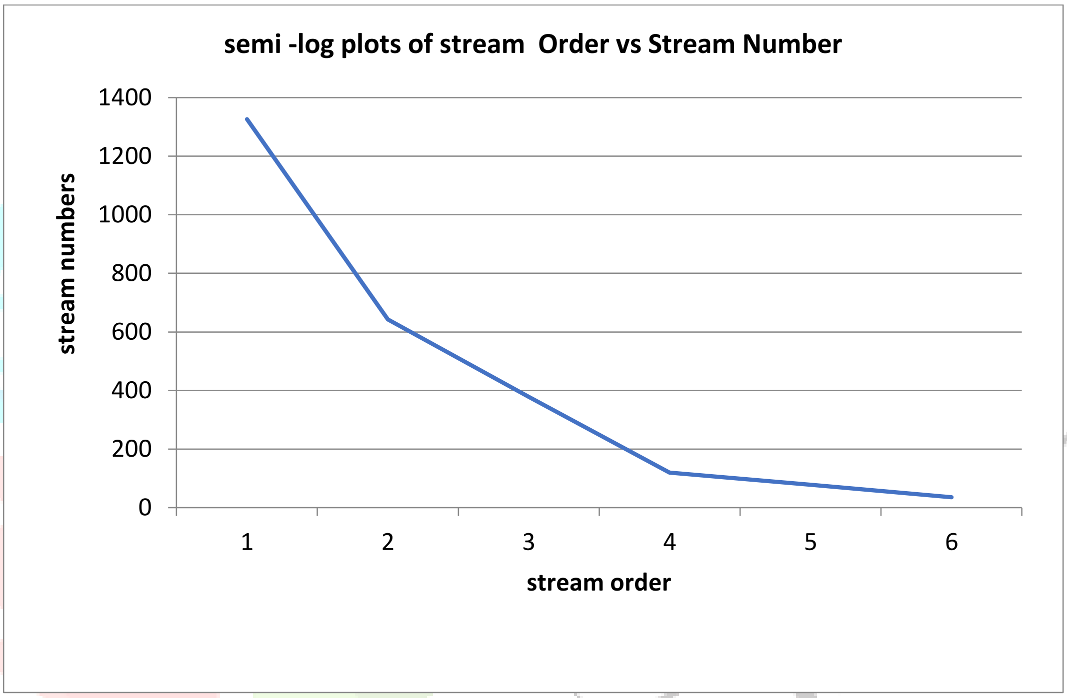
Morphometric parameters	Result
Basin area($km^{2)}$	6913.23
Perimeter(km)	550.12
Basin Length(km)	166.52
Basin relief(m)	405
Relief ratio	2.43
Relative relief	0.736
Ruggedness number	0.251
Drainage density	0.622
Stream frequency	0.37
Texture ratio	2.41
Form factor	0.24
Circulatory ratio	0.28
Elongation ratio	0.31
Length of over land flow	0.80
Constant channel maintenance	1.61

Linear aspects

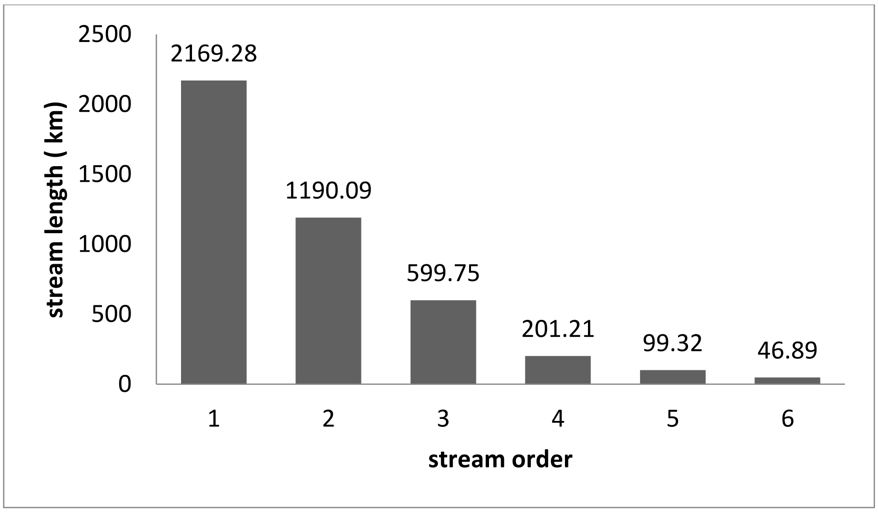
Linear aspects include the measurements of linear features of drainage such as stream order, bifurcation ratio, stream length, stream length ratio, mean stream length etc. The linear characteristics of the drainage basin are discussed below.

Stream order

The first step drainage basin analysis is designation of stream orders ,following a system introduced by Horton and slightly modified by Strahler (1964).Assuming that one has available drainage network map including all intermittent and permanent flow lines located in clearly defined valleys, the smallest fingertip tributaries or designated order ,where two first stream order join a stream segment of order two is found ,where two of order two joins segments of order three found , where two of three stream order joins segment of order four is found , where two of order four joins segment of order 5 is found and so sixth order .The stream order of the basin is form first order to sixth order , where the total number of the streams for the basin is 2580 out of which 1326 are first order 643 are second order 378 are the third order, 120 are the fourth order,78 are the fifth order streams and 35 are the six is order as shown in table 2.



Graphical representation of stream order vs. stream length



Bifurcation ratio

Bifurcation ratio (R_b) which is related to the branching pattern of the drainage network, is defined as the ratio of the number of streams of a given order (nu) to the number of streams of the next higher order (nu+1) and it is expressed in terms of following equation

$$\mathbf{R_b = N_u/N_u+1}$$

The study area bifurcation ratio results shows that low in fifth order &high in fourth order ranges between 1.53 to 3.15 as shown in table 2. The mean bifurcation ratio R_b of the basin 2.13, i.e. the average bifurcation ratio of all orders. The R_b value suggests the need for structural control due to higher permeability and more geological complexity, which can be done by more vegetation and check dam formation in the basin.

Stream length

The stream length is calculated on the basis of the law proposed Horton (1945) .The length of various order ,in drainage basin has been calculated using by Arc GIS .The length of first orders 2169.28,second order stream length 1190.09 ,third order stream length is 599.75, fourth order stream length is 201.21, fifth order stream length is 99.32and sixth order stream length is 46.89.as shown in table 2.the length stream segments is maximum for first order streams 2169.28 and minimum for the sixth order 46.89, decrease as the stream order increases.

Meanstream length

Mean stream length of a stream channel segment of order is a dimensional property of a drainage network and its contributing basin surface to obtained the mean stream length of the channel Lu of order U, the total length is divided by the number of stream segment Nu of that order thus,Its values varies due to slope, size and topography with in the basin for different orders.

$$\mathbf{L_{sm} = L_u/N_u}$$

The mean stream length of the study area first order 1.63, second order1.85, third order 1.58, fourth order 1.67, and fifth order 1.27and sixth order is 1.33. as shown in table 2. This variation is probably due to changing topographic slope and elevation.

Stream length ratio

Stream length ratio is defined as the ratio of mean length given of order to mean stream length of the next lower order Lu-1.

$$\mathbf{R_L = L_u/L_u-1}$$

The stream length ratio ranges from 0.76 to 1.13. as shown in table 2. The ratio between orders in the study area, differ from one order to another order, which indicates late youth to mature stage of geographic development.

Areal aspect

Drainage density

Drainage density is a measure the total stream length in a given basin to the total area of the basin (Strahler, 1964)

$$D_d = L_b/A$$

Drainage density is related to various features of land scape dissection such a valley density, channel head source area, relief, climate & vegetation, soil& rock properties and land scape evolution process. The drainage density of the Tungabhadra River basin 0.622 per km^2, as shown in table 3. Which indicates that basin area has highly permeable subsurface material with intermediate drainage and low to moderate relief.

Stream Frequency

The stream frequency is defined as the total number of stream segments of all order for unit area (Horton, 1932).

$$F_s = N/A$$

The present study area has 0.37 per km^2 of stream frequency as shown in table 3.Therefore there is a chance of recharge in more permeable sub surface areas. The value of stream frequency for the basin exhibits positive Correlation with the drainage density value of the area indicating the increase in stream population with respect to increase drainage density.

Texture ratio

Texture ratio (T) is an important factor in the morphometric analysis which is depending on thelithology, Infiltration capacity and relief aspects of the terrain, it is defined as the ratio of total number of first order to basin perimeter.

$$T = N1/P$$

It indicates relative spacing of streams(smith,1950) categorised the drainage texture in five classes as very course (<2), course (2-4),moderate (4-6) fine(6-8) and very fine (>8) here texture ratio in Tungabhadra river basin has a 2.41 that indicates course texture.

Form factor

Horton (1932) stated from factor as the ratio of the area of the basin square of the basin length.

$$R_f = A/(L_b)^2$$

The value of form factor would always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor more elongated will be the basin. R_f value of the Tungabhadra river basin is 0.24 thus Tungabhadra river basin is elongated one.

Circulatory ratio

The circulatory ratio defined as the ratio of the basin area to the area of circle having the same perimeter as the basin.

$$\mathbf{Rc = 4\Pi a/P^2}$$

Which is dimensionless and expresses the degree of circulatory of the basin(Miller,1953). He described the basin of the circulatory ratio ranges 0.42 to 0.5 which indicates strongly elongated and highly permeable homogeneous, geologicalmaterial the circulatory ratio calculated for the study area is 0.28 as shown in table 3.Indicates that basin is elongated in shape, low discharge run off highly permeability of the subsoil condition.

Elongated ratio

The ratio between the diameter of a circle of the same area as the drainage basin and the maximum length of the basin (schumn, 1956).

$$\mathbf{Re = 2\sqrt{(A/\pi)}/L_b}$$

Smaller form factor shows more elongation of the basin. The basin higher form factor will have higher peak flow for shorter duration. Whereas elongated Basin with low form factor, will have a flatter peak of flow for longer duration. The value of elongation ranges from 0.4 to 1, lesser the value, more is elongation of the basin. For the present study elongation ratio is calculated 0.317 as shown in table 3.

Length of overland flow

The length of overland flow (Lo) is the length of water over the ground surface before it gets concentrated in to definite stream channel (Horton,1945).

Lof= 1/2Dd

The length of overland flow is approximately equal to the half of the reciprocal of drainage density.L_o one of the most important independent variables affecting hydrologic and physiographic development of drainage basins. The length of overland flow of the study area is 0.80 as shown in table 3.

Constant channel maintenance

The constant channel maintenance (c) is the drainage density reciprocal (schumn 1956).

$\mathbf{C=1/D_d}$

This represents the drainage area needed to sustain the channel unit length (Strahler 1957). It has the dimension of the length with the scale of the land forms units. A low value is incorporated with week resistance soils with mountainous terrain and sparse vegetation, consequently where water discharges rapidly,where a high value indicates resistance soils with almost plain topography.Its value present study area is 1.61 exhibiting steep to very steep slopes with scarce vegetation cover as shown in table 3. Through proper planning, vegetation cover can be created in the basin, which will help to restore biodiversity and water recharge.

Relief aspects

The relief aspects are an important factor in understanding the extent of denudational process undergone with in the catchment it is indicator of water. The relief aspects determined include basin Relief, Relative relief, Relief ratio, Ruggedness Number.

Basin relief

Basin relief is the difference in elevation between the remotest point in the water divide line and the discharge point of the basin.

$\mathbf{B_h=H-h}$

The highest relief is found in the basin at an elevation 670.000 m above mean sea level. The lowest relief is found at an elevation of 265.000m.The overall relief calculated for the basin was 405 m.

Relief ratio

As per Schumn (1963), Relief ratio (R_h) is the ratio of basin relief to basin length ($R_h = B_h / L_b$). The basin area with high values of R_h refers to mountainous regions and low R_h values denote Pedi plains and valleys. It is a dimensionless attribute as it is a height-length ratio. The relief ratio value is 2.43 as shown in table 3. This stands for the basin steepness and impacts peak discharge and runoff intensity.

Relative relief

Relative relief(R_r) is the ratio of the maximum basin relief to the perimeter of the basin $\mathbf{R_r= B_h /p}$ Suggested by melton (1957). R_r value of this study0.73 as shown in table 3. It is also dimension less entity.

Ruggedness number

It is the product of maximum basin relief (B_h) and drainage density (D),where the both parameters in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep. The value of ruggedness number in present basin is
0. 251.as shown the table 3.which denotes being more prone to erosion.

Conclusion

The quantitative analysis morphometric parameters evaluated using by Geographical information system is found to be enormous value in River basin study. Based on the Tungabhadra river basin has been classified as 6thorder exhibiting dendritic pattern.The Bifurcation ratio ranges from1.53 to 3.15.In the present study, the higher values of R_b indicates strong structural control on the drainage pattern, while the lower values indicative that are not affect by structural disturbances. The value of the ruggedness number was estimated to be 0.251 and the region is more vulnerable to erosion. The basin drainage density is 0.622 km^2, it shows that sparse vegetative area and moderate relief. The drainage texture is 2.41 indicates course texture.The value of the circulatory ratio (0.28) and low form factor (0.24) represent the basin elongated nature, which will help in water infiltration.Morphometric characteristics of Riverbasin and important hydrological parameters such as bifurcation ratio, elongation ratio, circulatory ratio texture ratio, drainage density, relief ratio. Which are responsible for the river basin evaluation, soil &water conservation, natural resource management & Ground water potential forefficient planning management these works will be useful for natural resource management at micro level of any terrain for the sustainable development by planners and decision makers.

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