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Drainage Morphology Approach For Water Resources Development of Sub Watershed in Krishna Basin

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Abstract

The morphometric analysis of study area has been carried out using Arc GIS software. The study area covers 3035 sq.km. The drainage network was delineated using SOI topographical map of no. 47 K – 5, 6, 7, 8, 10, 11, 12, 47 L - 9 on the scale 1:50,000. Morphological characterized of the drainage line as appear in shape ,size, number, order, length, Dd, Sf, Rb, Fs, T, Rc are derived to trace its usefulness for surface development .

The present study involves Geographic Information System (GIS) analysis technique to evaluate and compare linear relief and aerial morphometry of Yerala watershed of Krishna River. Yerala watershed is basically 7^th^ order drainage and is mainly dendritic to sub dendritic. Drainage density and texture of the drainage basin is 6.89 km/km^2, 18.60 respectively.

The drainage frequency of Yerala watersheds is 1.96 where as the bifurcation ratio ranges from 2 to 11. Hence from the study it can be conclude that GIS technique proves to be competent tool in morphometric analysis.

Keywords: Morphometric analysis, Drainage

frequency, Drainage density

Introduction

The available surface and ground water resources are inadequate to meet the growing water demands due to rapid urbanization and increasing population. The demand for water has increased over the years, due to which the assessment of quantity and quality of water for its optimal utilization is necessited.

Identification and outlining of various ground features such as geological structures, geomorphic features and their hydraulic characteristics may serve as direct or indirect indicators of the presence of ground and surface water. The geomorphic conditions are essential pre-requisites in understanding the water bearing characteristics of hard rocks. The role of rocks types and geologic structure in the development of stream networks can be better understood by studying the nature and type of drainage pattern and by a quantitative morphometric analysis. The morphometric parameters of a watershed are reflective of its hydrological response to a considerable extent and can be helpful in synthesizing its hydrological behaviour. A quantitative morphometric characterization of a drainage basin is considered to be the most satisfactory method for the proper planning of watershed management because it enables us to understand the relationship among different aspects of the drainage pattern of the basin, and also to make a comparative evaluation of different drainage basins developed in various geologic and climatic regimes.

Krishna basin is located at 73^0 E to 78^0 E and 15^0 N to 19^0 N of Maharashtra covering total area about 90,000 sq km. In Maharashtra it covers an area of 15116sq km in the district of Satara, Sangli, Kolhapur. It is the fourth largest river basin in

India It has an average rainfalls ranging between 600 mm to 1900 mm per annum. The origin of the river is located at Mahabaleshwar at the height of 4500 ft above MSL. The Krishna basin running across Maharashtra, Karnataka, Andhra Pradesh and has an area of 2, 58,948 sq km i.e.7.9 % of India's surface area. The length of the Krishna within Maharashtra 304 km. The term morphometry is the measurement and mathematical analysis of configuration of earth's surface, shape and dimension of its landform (Clark 1966). In the present study, Geographic Information System technique has been used to assessing various terrain and morphometric parameter of drainage basins and watershed. Linear, relief and aerial morphometric parameters are evaluated for development planning of sub watershed in Krishna Basin. Linear parameter analyzed includes stream order (u), stream length (Lu), mean stream length (Lsm) and bifurcation ratio (Rb).

Relief parameter analyzed includes Basin Relief (Bh) and Ruggedness number (Rn). Relif aspect of watersheds plays an important role for computing, surface and subsurface water flow, permeability, landform development, Drainage density (Dd), stream frequency (Fs), Texture ratio(T), Form factor (Rf), circulatory ratio(Rc) and Constant Channel Maintenance (C) which helps for drainage development. Drainage density is one of the important indicators of the landform element. It provides a numerical measurement of landscape dissection and runoff potential. The drainage pattern differs a lot in linear, relief and areal morphometric parameters due to difference in geological structure, land form configuration, slope, vegetation and rainfall distribution.

Study area

The study area lies in west part of Maharashtra state bounded by Latitude 16^0 55' to 17^0 28' N and Longitude 74^0 20' to 74^0 40' E. falling in part survey of India topographical sheet no 47 K – 5, 6, 7, 8, 10, 11, 12, 47 L - 9 on the scale 1:50,000 (Figure No. 1) it covers total area of 3035 km^2 includes two districts (Satara and Sangli) in Maharashtra.

The average annual rainfall increases from 1900 mm in the western side to 600 mm in the east side. Geology of the area is dominantly covered by basaltic rock. The area has suffered a lot by tectonic movement in the past as evidenced by varying fold, fault and lineament association with hills located in the western side of study area.

Methodology

Entire study area is delineated from rectified, mosaiced SOI topographic maps no. 47 K – 5, 6, 7, 8, 10, 11, 12, 47 L - 9 on the scale 1:50,000 on polyconic projection system with the help of Arc-GIS software.

Drainage network was digitized (Figure No. 2) and stream order was calculated using method proposed by Stahler (1964). Arc-GIS 9.3 software was used for computing all morphometric parameter (Table - 1)

Hypothesis

Different segments of Yerala River network exhibit different morphometric and hydrologic characteristics and relationship. These will analyses by ordering scheme. This scheme is applied to prepare different morphometric tables and it helps for deriving idea for suggesting drainage capacity and discharge form the segment which helps to develops Decision Support System (DSS) for water conservation.

Results and Discussion

Linear aspect of drainage basin includes stream order, stream length and length of overland flow are the most common attribute .The number of stream in various order is countered and total number of segment (Nu) in each order (u) was computed on basis of Horton (1945) method as modified by Strahler A.N. Stream order in this drainage basin are numbered upto 7th order (Figure No. 2)

Stream length (Lu) has been computed based on the law proposed by Horton(1945) for all three watersheds. 1st order and 2nd order stream are mostly in highly elevated with moderate slope while higher order stream occurred in low elevation with deep dissects. Generally higher the order longer the length of stream is noticed in the nature. Longer length of stream is advantages over the shorter length, in that the former collects water from wider area and greater option for construction a bund along the length. It is observed form (Table 4) that Lsm value is 0.83.

The plot (Figure No. 4) of logarithm of stream length (ordinate) as a function of stream order (abscissa) yields a set of points lying essentially along a straight line fit following Horton's law (1945) of stream length. The straight line fit indicates that the ratio between Lu and u constant throughout the successive order of basin and suggest that geometrical similarities is preserved in basin of increasing order. The length of over land flow is the length of water over the ground slope before it becomes concentrated into definite stream channel (Horton, 1945)

The length of over landflow is one of the most important variables affecting terrain development of drainage basin. The length of overland flow (Lg) approximately equal to half of the reciprocal of drainage density, i.e. one half the Constant Channel Maintenance (Horton,1945) (Figure No. 3). The shorter length of overland flow, the quicker surface runoff will enter the stream in the present study the length of overland flow is 0.29.

The relief parameter may include Basin Relief (Bh) and Ruggedness number (Rn). Relief aspect of the watershed play an important role in drainage development, surface and subsurface water flow, permeability, landform development and associated feature of the terrain.

Yerala watershed shows basin relief (Bh) more than 550m and it indicates low infiltration, high runoff. Bifurcation ratio (Rb), Ruggedness (Rn) indicates the structural complexity of the terrain in association with relief and drainage density (Table - 4). The Bifurcation ratio is an indicative tool for the shape of basin. Elongated basins have low Rb value while circular basins have high Rb value (Morisawa 1985). Rb value of Yerala watershed is 4.95. It is varies from order to order. Highest Rb value is 11 indicates corresponding highest overland flow and discharge due to hilly area with high slope.

The aerial parameter analyzed as Dd, Df, T, Rf, Rc, Rb, Re, C. Drainage density (Dd) is one of important indicator of land form. It provides a numerical measurement of landscape dissection and runoff potential. It also indicates closeness of spacing of streams. In present study drainage density (Dd) i.e. 6.89 and Drainage frequency (Df) is 2.73 of Yerala watershed. High Df, value indicates high relief and low infiltration capacity of the bed rock. The texture ratio (T) is dependent on the underlying lithology, infiltration capacity and relief aspect of the terrain.

In the present study area texture ratio (T) of Yerala watershed is 18.60 and categorized as moderate to fine texture in nature. The value of Form factor (Rf) has direct relation to stream flow and shape of watershed. Yerala watershed has high Rf value. This shows drainage basin are moderately elongated in nature with less less side flow for shorter duration and high main flow for longer duration. The circulatory ratio (Rc) is influenced by the length and frequency of stream, geological structure, land use / land cover, climate, relief and slope of the basin.

An Rc value is 0.37 it indicates that watershed is elongated in nature. Constant Channel Maintenance (C) for this watershed is 0.44, it indicates of high structural disturbance, steep to very steep slope with high surface runoff (Figure No. 4) Drainage frequency (Df) in the study area is 2.73, and it indicates the high relief and growth of new channel or lengthening of existing stream.

Their are total 1 stream segment of high order. High order i.e. 7th order stream is noting but main rivers in the study area.

Conclusion

Areal, Linear and Relief properties for the quantitative analysis of morphometric parameter, using GIS software is found to be immense utility in drainage basin, elevation, watershed prioritization for soil and water conservation, flood prediction and natural resources management. Application of Morphometric approach revealed that there are total 8294 streams grooved with each other from order 1st to 7th sprawled over 3035 km^2 area of the catchment. Detailed study of Yerala watershed gives a useful direction for surface runoff and helps for natural resource development. Bifurcation ratio indicates that the drainage has covered by impermeable sub surface and high mountainous relief. Circulatory ratio, elongation ratio shows watershed have high slope and high peak flow. Texture ratio give idea about infiltration capacity and relief aspect of terrain.

The study area shows that terrain is made up of mainly basaltic rock and exhibits dendritic to sub dendritic drainage pattern and is classified as highly sloping and high runoff zone which give rise to high drainage discharge.

Thus study shows that the morphometric analysis using GIS helps to understand complete terrain parameters which lead to finalize watershed development planning and management with respect to water conservation.

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Figure No. 1 Location Map

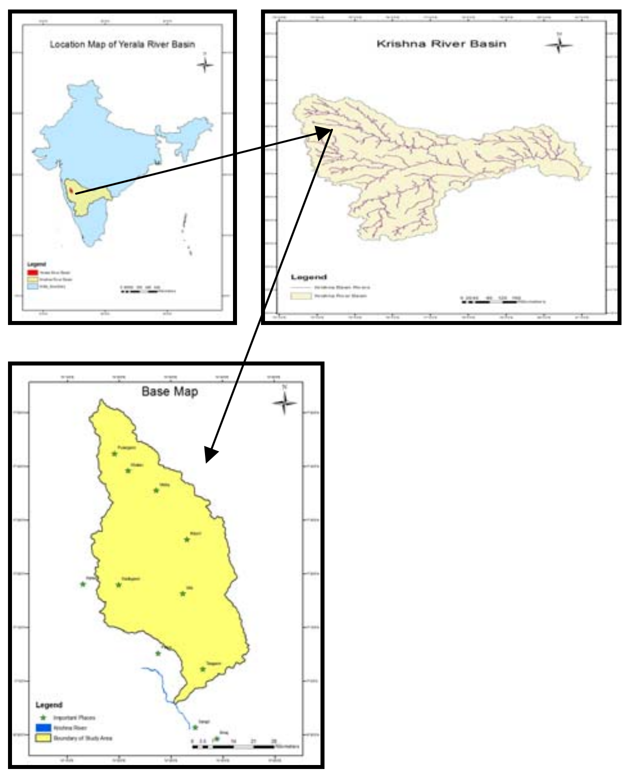

Figure No. 2 Drainage Network

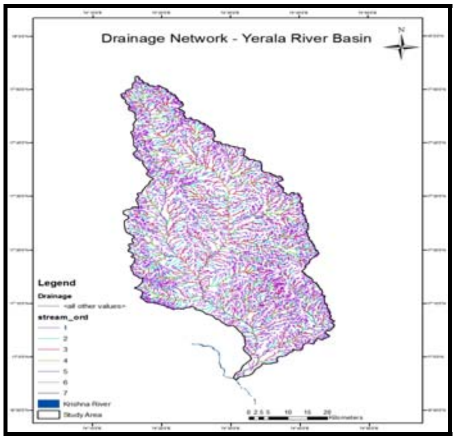

Figure No. 3 Drainage Density Map

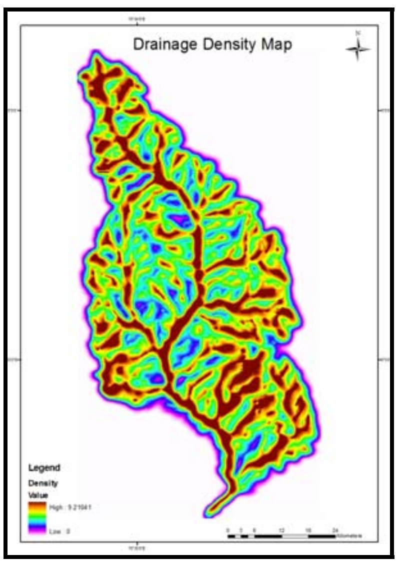

Figure No. 4 DEM of Study Area

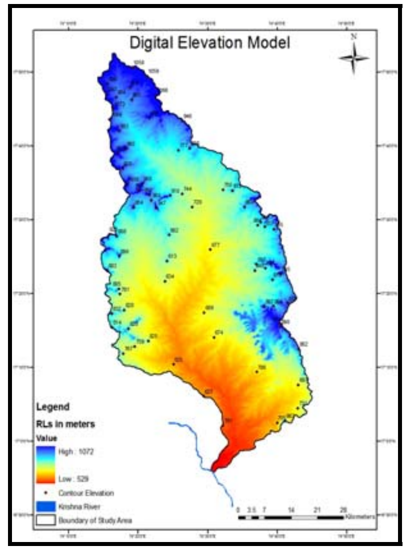

Fig No.5 Regression of logarithm of number of streams versus stream order.

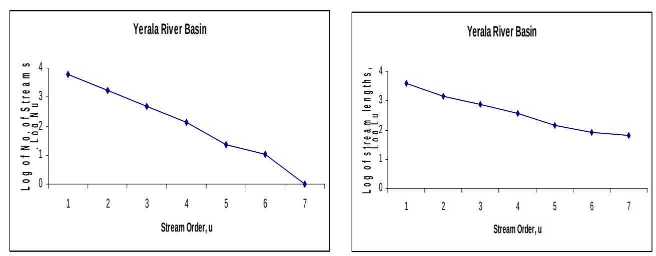

Figure No.6 Land use/cover of the Study area

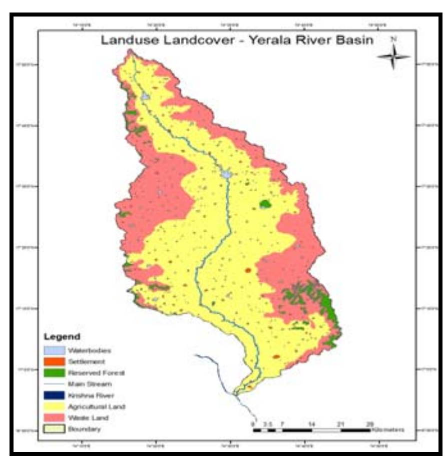

Table - 1 Formulae adopted for computation of morphometric parameters

Sr. No.	Mophometric Parameters	Formula	Reference
1	Stream order	Hierarchial rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm = Lu / Nu Where, Lsm = Mean stream length Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (RL)	RL = Lu / Lu – 1 Where, RL = Stream length ratio Lu = The total stream length of the order 'u' Lu – 1 = The total stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of order 'u' Nu+1 = Number of segments of the next higher order	Schumn (1956)
6	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
7	Relief ratio (Rh)	Rh = H / Lb Where, Rh = Relief ratio H = Total relief (Relative relief) of the basin (km) Lb = Basin length	Schumm (1956)
8	Drainage density (D)	D = Lu / A Where, D = Drainage density Lu = Total stream length of all orders A = Area of the basin (km2)	Horton (1932)

9	Stream frequency (Fs)	Fs = Nu / A Where, Fs = Stream frequency Nu = Total no. of streams of all orders A = Area of the basin (km2)	Horton (1932)
10	Drainage texture (Rt)	Rt = Nu / P Where, Rt = Drainage texture Nu = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
11	Form factor (Rf)	$Rf = A / Lb^2$ Where, Rf = Form factor A = Area of the basin (km2) Lb^2 = Square of basin length	Horton (1932)
12	Circularity ratio (Rc)	$Rc = 4 * Pi * A / P^2$ Where, Rc = Circularity ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (km2) P^2 = Square of the perimeter (km)	Miller (1953)
13	Elongation ratio (Re)	Re = 2 / Lb Where, Re = Elongation ratio A = Area of the basin (km2) Pi = 'Pi' value i.e., 3.14 Lb = Basin length	Schumn (1956)
14	Length of overland flow (Lg)	Lg = 1 / D * 2 Where, Lg = Length of overland flow D = Drainage density	Horton (1945)

Table - 2 Stream Analysis of Yerala River Basin

Stream Order	Stream Number Nu	Stream Number Cumu.	Stream Length (Km)	Stream Length (Km) Cumu.	Length Ratio	Mean Stream Length	Bifurcation Ratio	Mean Bifurcation Ratio	Mean Length Ratio
1	5954	5954	4006.337	4006.337	0.36	0.672	3.56	4.95	0.51
2	1670	7624	1443.885	5450.222	0.53	0.864	3.37		
3	495	8119	770.878	6221.100	0.49	1.557	3.53		
4	140	8259	384.510	6605.61	0.36	2.746	6.36		
5	22	8281	138.436	6744.046	0.61	6.292	2		
6	11	8292	85.722	6829.768	0.73	7.792	11		
7	1	8293	63.185	6892.953	-	63.185	-		

Table - 3 Linear aspect of drainage network of Yerala River Basin

Watershed	**Stream order**	**Number of stream (Nu)**	**Total length of stream in km(Lu)**	**Log Nu**	**Log Lu**
Yerala River	1	5954	4006.337	3.77	3.60
	2	1670	1443.885	3.22	3.15
	3	495	770.878	2.69	2.88
	4	140	384.510	2.14	2.58
	5	22	138.436	1.34	2.14
	6	11	85.722	1.04	1.93
	7	1	63.185	0	1.80

Table - 4 Morphometric Analyses

Watershed	Morphometric Parameters	
Yerala River	A (Km^2)	3035
	P (Km)	320
	Lu	8294
	Lsm	0.83
	Rb	4.95
	Bh	543
	Rn	3.74
	Dd	6.89
	Rf	0.19
	Rt	18.60
	Rc	0.37
	C	0.44
	Lg	0.29