Environment and Ecology 37 (4) : 1296—1300, October—December 2019
Website: environmentandecology.com ISSN 0970-0420

GIS Data Based Morphometric Analysis : Chivvemla Watershed, Suryapet Districts of Telangana State, India

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Received 11 June 2019 ; Accepted 29 July 2019 ; Published on 29 August 2019

ABSTRACT

The morphometric analyses were key role in the watershed evaluation, planning and management of the hydrological behavior, such as runoff, soil erosion, sediment yield. The Chivvemla study area covered under semi-arid region of Krishna basin, Telangana state. The morphometric parameters were analyzed such as linear and areal aspects in GIS environment, the acquisition of the data was compute and calculated using by formulae based on input values. The results of study area such as relief, drainage frequency, mean bifurcation ratio, drainage density, elongation ratio and circularity ratio are 0.69 km, 1.47 sq km, 3.24, 2.31 sq km, 0.29 and 0.36 respectively, these are appearing significantly higher values its indicates high runoff, high sediment yield, less infiltration, steep limbed hydrograph and mature to old stage topography. Finally, it can be concluded ; the GIS techniques are competent tool in morphometric analysis.

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Keywords Chivvemla area, Geographic Information System, Morphometric analyses.

INTRODUCTION

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Singh et al. 2003, V.C. Miller 1953, S. A. Schumn 1956). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics (Nageswara Rao et al. 2010). Geographical Information System (GIS) techniques are now a day's used for assessing various quantitative morphometric parameters of the watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study various morphometric parameters such as linear and areal aspects were computed, derived and tabulated using GIS based on drainage lines as represented over the topographical maps (scale 1 : 50,00).

Study area

The study area covering about 147.63 sq km, in Chiv-

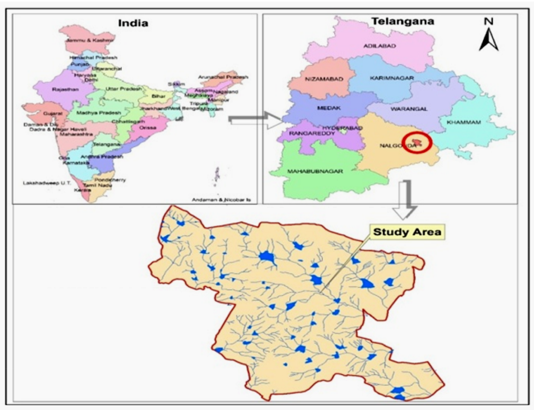

Fig. 1. Study area of Location Map.

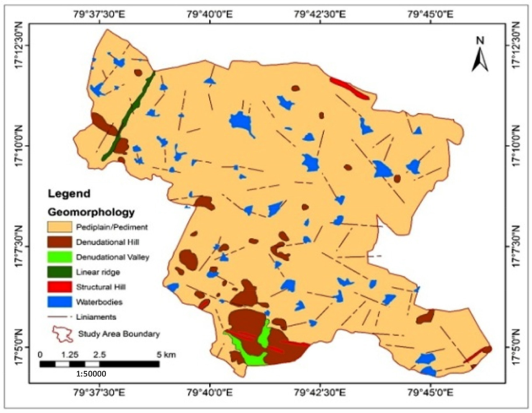

Fig. 3. Study area Geological Map.

vemla Mandal Suryapet district of Telangana State. The area topographically lies between 17º 03´ to 17º 13´ N and 79º 37´ to 79º 45´ E (Figs. 1 and 2). The mean regular precipitation dissemination is 510.36 mm. The Chivvemla area is occupied predominantly of Peninsular gneisses complex of oldest granites rocks. These granites are later intruded by dolerite dykes and pegmatites veins. Pink and grey granites are distinctly occupied in the entire study area (Figs. 3 and 4). The main soils types in the study area red sandy and loamy soils mostly cover the upland area and the low-lying area is dominated by black or clay soils. The topography of the area is gently sloping towards the boundaries.

MATERIALS AND METHODS

All streams of different extents and patterns were digitized from Survey of India toposheets No: 56 O/12 and 56 O/16 (1 : 50,000 scale), entire analysis of watershed morphometry using GIS software (Arc GIS 9.2). Each stream order was given by following Strahler (1964) stream ordering technique. The attributes were assigned to create the digital data base for drainage layer of the watershed. The map showing drainage pattern in the study area (Fig. 2) was prepared after detailed ground check with GPS survey on channel network and water tanks. Various morphometric parameters are calculated such as linear and areal aspects. The input parameters for morphological studies such as perimeter, area, elevation, stream length were obtained directly in Arc View GIS software using query based algorithm, other morphometric parameters were calculated using formulae based on input values. Various morphometric parameters such as linear and areal aspects were computed

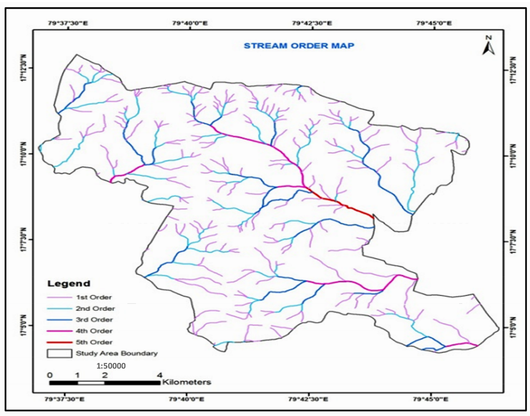

Fig. 2. Study area of Drainage Map.

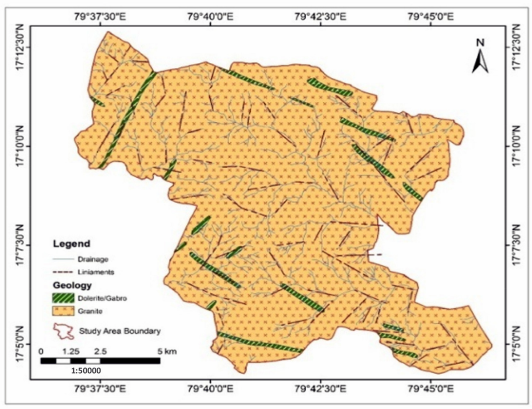

Fig. 4. Study area Geomorphological Map.

Table 1. Formula used for computations of morphometric parameters.

Morpho-metric Parameter	Formula	Description	Reference
Stream order (u)	Hierarchical rank	The stream order is a measure of the degree of stream branching within a watershed. Each length of stream is indicated by its order (for example, first - order, second-order).	Strahler (1964)
Stream length	Length of the stream	The number of streams of various orders in the basin and sub-basins are counted and their lengths from mouth to drainage divide are measured. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases.	Horton (1932)
Elongation ratio (R_e)	$R_e = 2 A / L$	(R_e) was as the ratio between the diameters of the circle of the sane area as the drainage basin and the maximum length of the basin, the values of R_e generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Where : Re = Elongation ratio, 2 = Constant, A = Area of the basin, L = Maximum of the length ratio.	Schumn (1956)
Circularity ratio (R_c)	$R_e = 4\pi A/P^2$	(R_e) was calculated as the ratio of the basin area to the area of the circle whose perimeter is equal to the perimeter of the basin. The P is the perimeter of the basin. It is also influenced by the length and frequency of stream, geological structures, land use and cover, climate, relief and slope of the basin expressed , where : R_c = Basin circularity, A = Area of the basin, P=Perimeter of the basin.	Miller (1953)
Form factor (R_f)	R_f=A/(Lb)2	(R_f) was computed as the ratio between the basin area and square of the basin length. Where: R_f = Form factor, A=Area of the basin, $(Lb)^2$ = Square of basin length.	Horton (1945)
Bifurcation ratio (R_b)	Rb=Nu/(Nu+1)	(R_b) was computed as the ratio between the numbers of streams of any given order to the number of streams in the next higher order. It is shown a small range of variation for different regions or different environment except where the powerful geological control dominates. The bifurcation ratio is not same form one order to its next order. Where : Nu =Numbers of streams, (Nu + 1) = Number of streams in the next higher order.	Schumn (1956) Horton (1945)
Drainage frequency (D_f)	D_f=N/A	(F_u) was computed as the ratio between the total number of streams and area of the basin. Where: Fu = Drainage frequency, N= Total number of streams, A=Area of the basin.	Horton (1945)
Drainage density (D_d)	$D_d = \sum L/A$	(D_d) was measured as the length of stream channel per unit area of drainage basin. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness and run-off intensity index. The amount and type of precipitation such as thundershowers, loses greater percentage of rainfall as run-of resulting in more surface drainage lines. Where: D_d = Basin circularity, A=Area of the basin, P=Perimeter of the basin.	Horton (1945)
Length ratio (R_L)	$RL = L_u / L_{u-1}$	(R_L) is defined as the ratio of the average stream length (L_u) of order *u*, to average stream length (L_{u-1}) of the next lower order *u–1* :	Horton (1945)
Relief ratio (R_h)	R_h = H/Lb	(R_h) is the total relief of watershed divided by the maximum length of the watershed. It is an indicator of the potential energy of the system to drain off. There is direct relationship between the relief and channel gradient. The relief ratio normally increases with decreasing drainage area and size of the drainage basin. Where ; R_h = Relief ratio, H=Total relief, Lb = Basin length.	Schumn (1956)
Constant of channel maintenance (C_m)	C=(D_d)	C is expressed as the inverse of drainage density.	——

Table 1. Continued.

Morpho-metric Parameter	Formula	Description	Reference
Basin relief (B_h)	B_h=hmax–hmax	(B_h) was defined as the maximum vertical distance between the lowest and the highest points of a sub basin. Where: B_h = Basin relief, hmax = Highest point, hmax=Lowest point.	——
Relative relief (R_r)	$R_r = B_h/P$	(R_r) is the ratio of the maximum watershed relief to the perimeter of the watershed. Where: R_r = Relative relief, Bh = Basin relief, P=Perimeter of the basin.	——
Ruggedness number (R_n)	$R_n = B_h \times D_d$	(R_n) was calculated as the product of the basin relief and its drainage density. Where: R_n = Ruggedness number, Bh = Basin relief, Dd=Drainage density.	——
Relative relief (R_f)	$R_f = B_h /P$	(R_r) is the ratio of the maximum watershed relief to the perimeter of the area. Where: Rf = Relative relief, Bh = Basin relief, P=Perimeter of the basin.	——
Main stream length (L_{ms})		(L_{ms}) is the length of the stream having maximum stream length. The time of concentration along the main stream will be maximum time.	——
Maximum length of watershed (L_b)		(L_b) is the distance between watershed outlet and farthest point in the watershed.	——

in GIS environment as shown in following Table 1.

RESULTS AND DISCUSSION

In the study area, 299 streams are identified (1, 2, 3, 4 and 5th order streams). The total stream length of the different orders is 241 km. Out of the total stream length, 73% of 1st order streams, 2nd, 3rd and 4th order streams stand at 19%, 7% and 1% respectively. 5th order streams are highest order in the stream network, shown in Table 2. The total relief value is 0.69 km ; it is high relief value indicates quick depletion of water, which results large peaked and steep limbed hydrograph. The elongation ratio value is 0.29 it is higher value. It is indicative mature to old stage topography with high relief and steep ground slope. The circularity ratio value is 0.36, it is also higher value and it is also indicative mature to old stage topography. The mean bifurcation ratio value is 3.24. It higher value is indicate high runoff, less infiltration and mature to old stage topography, which is the results of variation in higher and lower order stream segments. Drainage frequency is 1.47 sq km, it's reflects geologic and tectonic characteristics of the area. The measurement of drainage density provides and useful numerical measure for runoff potential. The drainage density is

Table 2. Computed morphometric parameters results.

Sl. No.	Stream orders	Total no. of streams	Cumulative stream length	Mean stream length	Bifurcation ratio: Stream orders	Bifurcation ratio: Mean stream orders	Length ratio: Stream order	Length ratio: Mean stream order
1	1	218	134.12	0.62	3.75			
2	2	57	53.51	0.94	2.72		1.51	
3	3	20	36.41	1.82	5	3.24	1.94	1.51
4	4	3	13.83	2.77	1.5		1.52	
5	5	1	3.06	3.06			1.1	

Table 3. Computed morphometric parameters results.

Morphometric parameter	Values	Morphometric parameter	Values
Max. Length of Watershed (in km)	21.0	Relative Relief (R_r)	0.69
Basin width (in km)	9.0	Ruggedness Number (R_N)	22.0
Basin Perimeter (in km)	72.0	Elongation Ratio (R_e)	0.29
Basin Area (in sq km)	148	Circularity Ratio (R_c)	0.36
Maximum Elevation (in msl in m)	220	Form Factor (R_f)	0.36
Minimum Elevation (in msl in m)	170	Mean Bifurcation Ratio (R_b)	3.24
Number of Streams	299	Drainage Frequency (D_f)	1.47
Higher Stream Order	5.00	Drainage Density (D_d) in km	2.31
Cumulative Stream Length (in km)	241.0	Constant of Channel Maintenance (C_m)	0.43
Mean Stream Length (in km)	9.00	Mean Length Ratio	1.51
Basin Relief (in km)	50.00	Relief Ratio (R_h)	2.30

2.31 sq kms, it is high indicating valve and drainage densities are sometimes less than 1 km per square kilometer, on highly dissect surfaces densities of over 500 km per square kilometer are often reported. Low drainage density indicative it has highly resistant and impermeable sub-soil materials with dense vegetative cover and low relief, high drainage density value is indicative a situation conducive for quick disposal of runoff, a region of weak subsurface materials and high relief. The other factors are climate, topography, soil infiltration capacity, vegetation and geology also key role in evolution of watershed. Computed morphometric parameters results are presented in following Tables 2 and 3.

CONCLUSION

In the study area outcome results are indicating high runoff, high sediment yield, less infiltration, steep limbed hydrograph and mature to old stage topography. Therefore, soil and water conservation management are required in the study area. The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at micro level. It can be concluded that GIS techniques are characterized by very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis.

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