GIS BASED MORPHOMETRIC ANALYSIS OF AKRA HALLA, CHIKODI AND RAIBAG TALUK, BELAGAVI DISTRICT, KARNATAKA, INDIA

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ABSTRACT

The drainage morphometric analysis of Akra Halla, Chikodi and Raibag taluk, Belagavi district, Karnataka, has been carried out in this study. Geographic Information System has proved to be an efficient tool in the delineation of drainage pattern for water resource management and planning. Strahler's System classification has been used to classify the stream order. In the present study sixth is highest stream order and watershed shows dendritic drainage pattern. Morphometric parameter such as Linear, Aerial and Relief Aspect has been calculated. Drainage texture having 5.23 indicates the moderate texture. Drainage density is 2.95 indicates the dominance of the surface runoff process in the watershed. Elongation ratio is 0.8 means the watershed is in elongated shape. Total relief of the present study area is 262m. Circularity ratio of the area is 0.39 indicating the elongated shape. The data generated from this work will help the researchers for further hydrological studies in this watershed.

1. INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke 1996; Agarwal 1998). Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of characterization of watersheds (Strahler 1964). It is well-known that the influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. The basin morphomatric characteristics of the various basins have been studied by many scientists using conventional (Horton, 1945; Smith, 1950; Strahler, 1957) and remote sensing and GIS methods (Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Narendra and Nageswara Rao, 2006). Geo-spatial technologies, such as Geographic Information Systems (GIS) and Remote Sensing (RS), are efficient tools in delineation of watershed and drainage network for the water resources planning and management.

2. STUDY AREA

The Akra Halla watershed covers an area of 156.22 sq km. The geographical extent of the study area ranges from 16°22'0"N to 16°32'0"N latitude and 74°38'0"E to 74°48'0"E longitude. The study area is predominantly underlain by basalt, clay and loamy soil have been observed in the Akra Halla watershed. The Akra Halla watershed shows dendritic type of drainage pattern and composed of fairly homogeneous rock without control by the underlying geologic structure (Fig: 4). The study area receives an average annual rainfall of 750 mm so classified as semi arid area. Agro-climatologically the study area falls under "Northern transitional zone" of Karnataka state (CGWB).

3. METHODOLOGY

The base map of the watershed is prepared from Survey of India (SOI) Toposheet No. E43U10, E43U11 and E43U15 on 1:50,000 scale. The drainages are delineated from toposheets and morphometric parameters of watershed are calculated using standard Methods. The basic parameters like watershed area, stream length, stream number and basin length are calculated in GIS platform. The applied parameters such as linear, aerial and relief parameters are calculated utilizing standard formulae. Digital Elevation Model and Slope of the study area also prepared using Shuttle Radar Topographic Mission of 30m resolution data (Source: **https://earthexplorer.usgs.gov**).

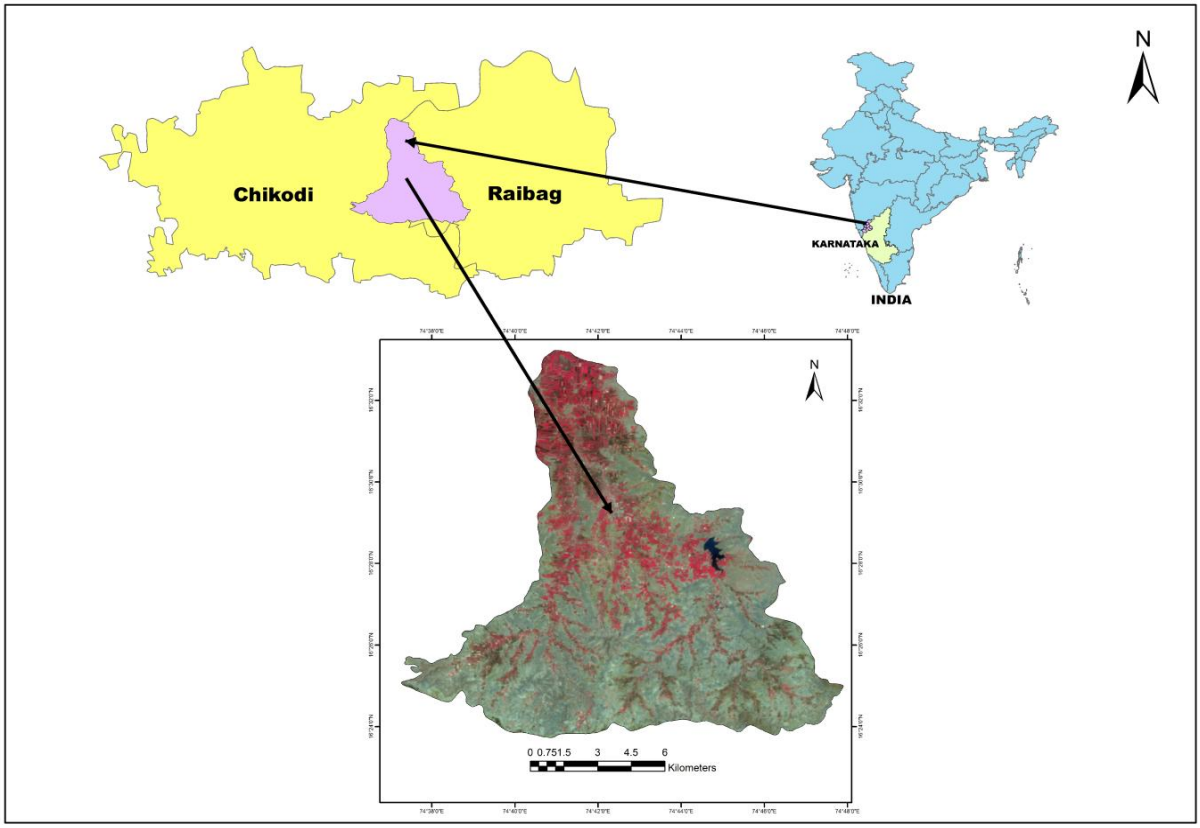

Figure: 1 Map of the study area

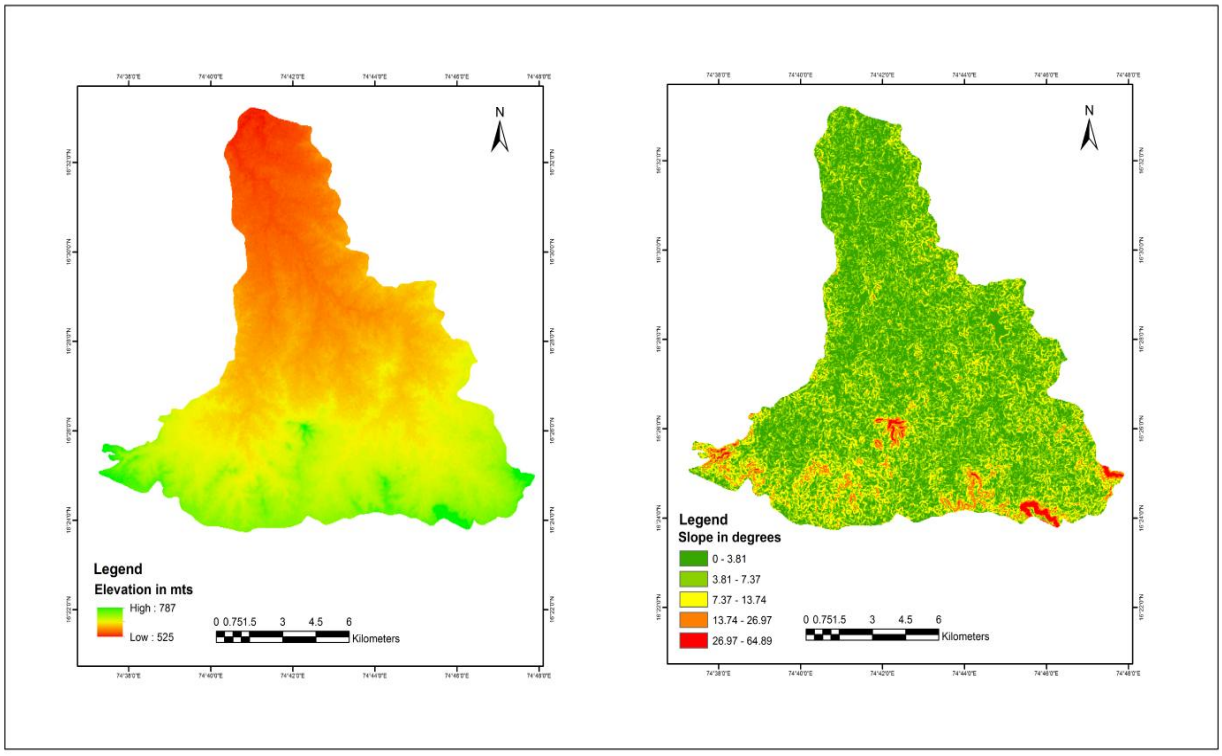

Figure: 2 DEM of the Study Area

Figure: 3 Slope Map of the Study Area

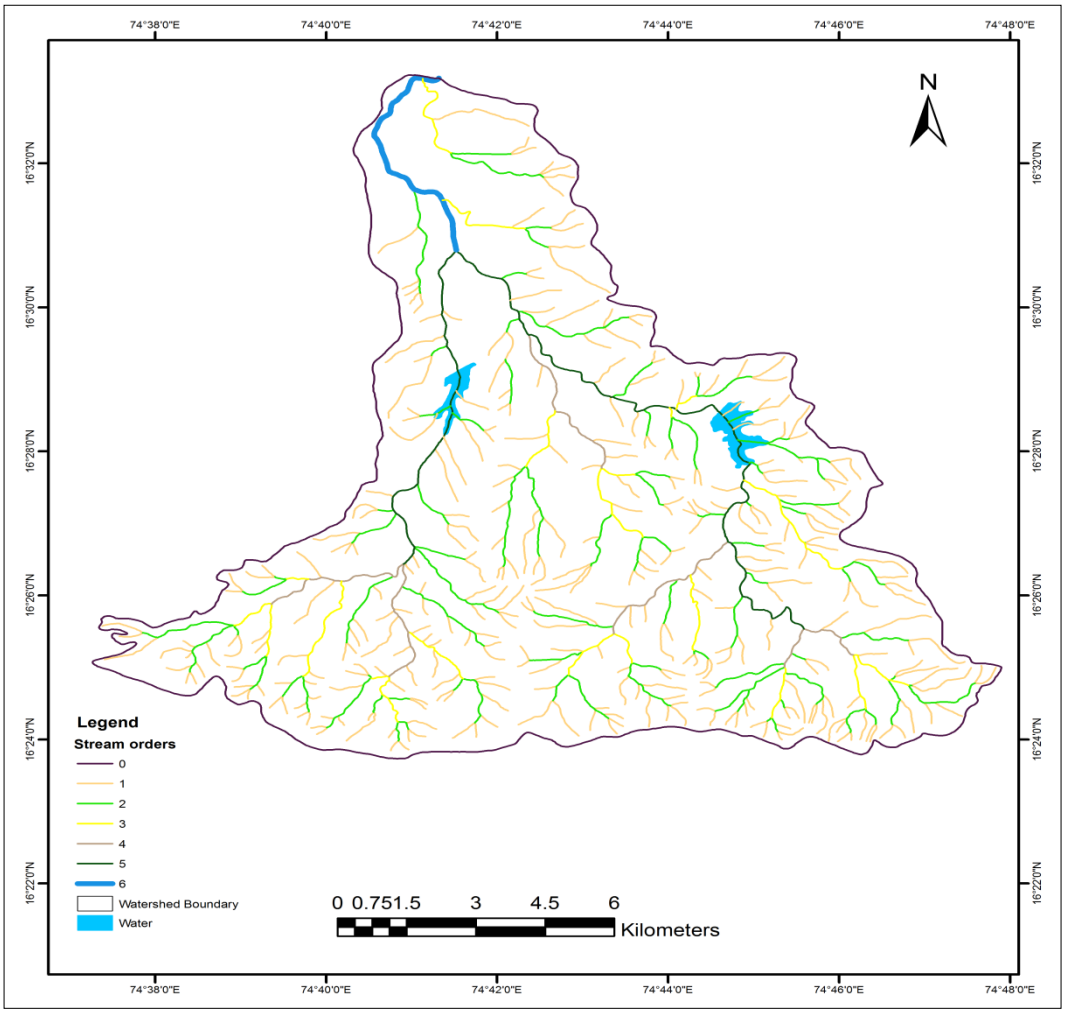

Figure: 4 Watershed of the study area

Table: 1 Formulae used for computation of Morphometric Parameters

Serial No.	Morphometric Parameter	Formula	References
1	Stream Order (Nu)	Hierarchical rank	Strahler (1964)
2	Stream Length (Lu)	Length of the stream	Horton (1945)
3	Mean Stream Length (Lsm)	Lsm = Lu/Nu Lu = Total stream length of order 'u' Nu= Total number of segments of order 'u'	Strahler (1964)
4	Stream length Ratio (Rl)	RL = Lu/Lu-1 Lu = Total stream length of order 'u' Lu-1 = The total number of stream segments of order 'u'	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / (Nu + 1) Nu = Total no. of stream segments of order 'u'	Schumn (1956)
6	Mean Bifurcation ratio (Rbm)	Rbm = Average bifurcation ratio of all orders	Strahler (1957)
7	Drainage density (Dd)	D = Σ Lu / A Σ Lu = Total stream length of all orders A = Area of the basin (km2)	Horton (1932)
8	Stream frequency (Fs)	Fs = Σ Nu / A Σ Nu = Total number of streams of all orders A = Area of the basin (km2)	Horton (1932)
9	Infiltration Number (If)	If = Dd*Fs Dd = Drainage Density	Faniran (1968)

		Fs = Stream Frequency	
10	Texture ratio (T)	T = Σ Nu /P Σ Nu = Total number of streams of all orders P= Perimeter of the basin	Horton (1945)
11	Circularity ratio (Rc)	Rc = 4πA/P2 Rc = Circularity ratio; π = 'Pi ' value i.e. 3.14; A= Area of the basin (km2); P=Perimeter (km)	Miller (1953)
12	Form factor (Ff)	$Ff = A/Lb^2$ A = Area of the basin (km2) Lb^2= Square of the basin length	Horton (1932)
13	Elongation Ratio (Re)	Re = 2 v (A / Pi) / Lb Re = Elongation Ratio A = Area of the Basin (km'-) Pi = 'Pi' value i.e., 3.14 Lb = Basin length	Schumn (1956)
14	Compactness Constant /Coefficient (Cc)	$Cc = 0.2821*(P/A)^{0.5}$	Horton 1945
15	Length of Overland Flow (Lg)	Lg = 1/Dd*2 Dd = Drainage Density	Horton (1945)
16	Relief (R)	R = H-h H = Highest Elevation h = Lowest Elevation	Hadley and Schumm (1961)
17	Relief ratio (Rh)	Rh = R/Lb R= Relief of the watershed Lb = Basin length	Schumm (1956)
18	Ruggedness Number (Rn)	Rn = Dd*R Dd= Drainage Density R= Relief of the watershed	Melton (1957)

4. RESULTS AND DISCUSSIONS

The morphometric parameter of watershed is categorized into Basic and Derived parameters.

4.1 Basic Parameters

The basic parameters of the watershed are calculated using GIS platform. The watershed covers an area of 156.22 Sq. Km. The Perimeter and basin length of the watershed is 70.98 Km. and 17.32 km respectively. The method suggested by Strahler was followed for stream ordering. In the present study area maximum sixth order stream was observed. Number of drainages of different stream orders of the watershed was counted. Length of all the stream orders is measured. First stream order is having the highest length of 202.37 km and lowest length of 6.05 km recorded at Sixth stream order. The total length of all stream order is 371.48 Km.

Table: 2 The Basic Parameters

Si.No	Parameters	Results
1	Watershed Area (A)	156.22
2	Basin Length (Lb)	17.32
3	Perimeter (P)	70.98
4	Stream Number (Nu)	
	I	341
	II	90
	III	21
	IV	6
	V	2

	VI	1
	∑Nu	461
5	Stream Length (Lu)	
	I	202.37
	II	88.82
	III	31.94
	IV	17.24
	V	25.06
	VI	6.05
	∑Lu	371.48

4.2 Derived parameters

4.2.1 Linear Parameters

The linear parameters are computed using standard methods and recorded in Table: 3 and are discussed below.
The mean stream length (Lsm) of the watershed is calculated by dividing the total drainage length of corresponding stream order (Strahler, 1964). The highest mean stream length 12.53 is observed in fifth order and lowest mean stream length is 0.59 observed in first order stream. It is directly proportional to size and topography of basin. Stream length ratio (RL) is defined as the ratio of mean stream length of one order to the next lower order of the stream segments (Horton, 1945). The RL of the watershed varies from 0.24 - 1.45. It depends upon variation of slope and topography.

Bifurcation ratio (Rb)

The ratio of number of stream segments of given order to the number of the next higher order segments is termed as Bifurcation Ratio (Schumm, 1956). The bifurcation ratio of the watershed varies from 2 - 4.29. The mean bifurcation ratio of watershed is 3.31.

Table: 3 The Linear Parameters

Si. No.	Parameters	Results
1	Mean Stream Length (Lsm)	
	I	0.59
	II	0.99
	III	1.52
	IV	2.87
	V	12.53
	VI	6.05
2	Stream Length Ratio (RL)	
	II/I	0.44
	III/II	0.36
	IV/III	0.54
	V/IV	1.45
	VI/V	0.24
3	Bifurcation Ratio (Rb)	
	I/II	3.79
	II/III	4.29
	III/IV	3.50
	IV/V	3
	V/VI	2
4	Mean Bifurcation Ratio (Rbm)	3.31

4.2.2Aerial Parameters

The Aerial parameters are computed using standard formulas and recorded in Table: 4 and are discussed below.

Drainage density (Dd)

It is ratio of total stream length of all the orders to the total area of the basin (Horton, 1932). It is one of the important parameter that directly related to speed of runoff followed by precipitation. The Dd of Akra Halla watershed is 2.95 km/km^2. The lower drainage density of any watershed indicates that it has permeable subsurface material, good vegetation cover and low relief and vice versa (Nag et al. 1998).

Stream frequency (Fs)

It is the total number of stream segments of all orders per unit area (Horton, 1932). The Fs of the watershed is 2.38. Stream frequency depends on rock structure, vegetation cover, relief, nature and amount of rainfall, infiltration capacity and subsurface material permeability.

Infiltration Number (If)

It's a parameter which gives an idea of the infiltration characteristics of the watershed. The infiltration factor in the study area is 7.02. The high values of If reflects dominance of relief features, hard and impermeable lithology resulting into less infiltration and high runoff in the drainage basin (Smith, 1954)

Texture ratio (T)

It is one of the important concepts of geomorphology, which gives an idea about the relative spacing of drainage lines. According to Horton (1945), it is the measure of total number of stream segments of all orders per perimeter of that area. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith, 1954). The dt < 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and >8 is very fine drainage texture. The drainage texture of the watershed is 5.23 i.e. the watershed grouped under moderate texture. Drainage texture is greatly influenced by infiltration capacity. Regions of low infiltration capacity will give rise to higher T and thus will lead to more erosion (Sadaf et al. 2014).

Form factor (Rf)

The form factor is the ratio of basin area to square of basin length (Horton, 1932). The watershed shows form factor of 0.52 represents watershed is in elongated shape.

Elongation ratio (Re)

It is the ratio of diameter of a circle having the same area as of the basin and basin length. Generally Re varies from 0.6 to 1.0 depends upon climate and geology. The elongation ratio value near to 1 is typically region of very low relief and values between 0.6 and 0.8 are generally associated with strong relief and steep ground slope (Strahler, 1964). These values are further classified as elongated (0.5-0.7), less elongated (0.7-0.8), oval (0.8-0.9), circular (>0.9). The present study area shows elongation ratio of 0.81.

Circulatory ratio (Rc)

It is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953) The Circularity ratio of the watershed shows 0.39. The circulatory ratio less than 0.5 indicate elongated shape.

Compactness constant (Cc)

According to Gravelius (1914), compactness coefficient of a watershed is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed (Pareta et al. 2011). The Cc of the watershed shows a value of 0.19. The Cc of a watershed directly corresponds to the infiltration capacity of the watershed (Sadaf et al. 2014).

Length of Overland Flow (Lg)

The length of Overland flow is defined as the length of river flow path from the divide to the stream in first order basin and is a measure of stream spacing and degree of dissection and is approximately one-half the reciprocal of

drainage density (Chorley 1969). The lg value of the Akra Halla watershed is 0.17. The low value of Lg indicates the rainwater will enter the stream quickly (Magesh et al. 2012)

Table: 4 The Aerial Parameters

Si. No.	Parameters	Results
1	Drainage Density (Dd)	2.95
2	Stream Frequency (Fs)	2.38
3	Infiltration Number	7.02
4	Texture Ratio (T)	5.23
5	Form Factor (Ff)	0.52
6	Elongation Ratio (Re)	0.81
7	Circularity Ratio (Rc)	0.39
8	Compactness Constant	0.19
9	Length of Overland Flow (Lg)	0.17

4.2.3 Relief Parameters

Relief is an important parameter in drainage basin analysis. It reflects the elevation difference between the highest and lowest point of a region. Relief aspects deal with the structural elevation and the relief parameters are computed and recorded in the table: 5. The relief of the watershed is defined as elevation difference between highest and lowest point of river valley **(**Hadley and Schumm, 1961). The highest point of Watershed is located at 787 meters and lowest point at 525 meters from the mean sea level. The total relief of the watershed noticed is 262 meters (Fig: 2). The high relief value of watershed indicates gravity of the water flow, low infiltration and high runoff conditions (Magesh et al. 2012). Relief Ratio (Rh) is the ratio of total relief of watershed to its basin length is termed as Relief ratio (Schumm, 1956). Relief ratio of watershed is 0.02. It reflects the steepness of the watershed.

Ruggedness Number (Rn) is the product of Relief Ratio and Drainage Density of the watershed. (Melton, 1957). The ruggedness number reflects structural complexity of the terrain. The Rn of the watershed shows a value of 0.79.

Slope is an important parameter for geomorphic studies. A detailed understanding of slope distribution as the map helps in planning for various aspects like, settlement, agriculture, planning of engineering structure, etc., (Sreedevi et.al. 2005). It helps to understand and to identify the prone area to erosion and surface runoff (Fig: 3). Slope has been calculated in degree and ranges from 0-64.89. The lower slope value indicates the flatness of the terrain and higher slope value indicates a steeper terrain.

Table: 5 The Relief Parameters

Si. No.	Parameters	Results
1	Relief (H)	262
2	Relief Ratio (Rh)	0.02
3	Ruggedness Number (Rn)	0.79
4	Slope	0-64.89

5. CONCLUSION

Morphometric analysis of drainage system is requirement to any hydrological study. Thus, determination of stream networks' behaviour and their interrelation with each other is of great importance in many water resources studies. Remote sensing satellite data and GIS techniques have been proved to be an effective tool in drainage delineation. The result calculated in this paper will suggest and recommend developing a better water usage mechanism for proper watershed management in the Akra Halla watershed.

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