

A Study on Characterization of Watershed Development Using GIS Approach

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Abstract

Remote sensing (RS) and geographical information system (GIS) are the effective tools in delineating drainage pattern. The Meghadrigedda watershed is selected for the present study and has a gross capacity of 1169 Mc. Ft. For the identification of morphological features and analyzing their properties of the Meghadrigedda basin various GIS and image processing techniques have been adopted. The linear and aerial aspects of the basin were calculated and computed. It is 7th order drainage basin and drainage pattern is dendritic type. It is observed that the drainage density value is high which indicates that the basin has impermeable subsurface and has more surface runoff. Bifurcation ratio shows that the geological structures of basin do not distort the drainage pattern.

Keywords: *Morphometric analysis, Meghadrigedda watershed, GIS, Watershed*

INTRODUCTION

Basin morphometry is the mathematical quantification of various characteristics which include stream number, stream length, bifurcation ratio, drainage density

and so on. Land is one of the important natural resource and it should be conserved to mitigate the increasing demand of land and water resources (Panhalkar S.S et al, 2012). In India 70%

of the people depend on agriculture directly or indirectly. The analysis of the drainage basin is important in assessing the ground water potential and ground water management. The study on morphometric analysis using remote sensing and GIS techniques was carried out by (Sangita Mishra et al, (2010); Biswas et al. 1999; Panhalkar S.S et al, 2012; Subodh Chandra Pal and Gopal Chandra Debnath, 2012; Jagadeeswara Rao, Harikrishna P and Suryaprakasa Rao.B, 2006).

Remote sensing and geographical information system are effective tools in monitoring and studying the basin morphometry. The main objective of this study is to compute basin morphometric characteristics of various parameters.

DESCRIPTION OF THE STUDY AREA

The Meghadrigedda watershed is selected for the present study and the area is enclosed between Northern latitude and Eastern longitude, covering an area of 453.40 sq. km falling in Survey of India (SOI) toposheet Nos: 65 O/1, O/2&O/3, O/5 and O/6 on 1:50,000 scale. Meghadrigedda reservoir was formed

across Meghadrigedda and Naravagedda just 400 mts above their confluence to supply drinking water to the people of Visakhapatnam city at the rate of 8Million gallons per day.

The 8MGD of water is being drawn from the reservoir and distributed to various industries and industrial colonies by Visakhapatnam Municipal Corporation. Meghadrigedda reservoir has a gross capacity of 1169 Mc.Ft and the flood bank was formed on the left side of the reservoir to protect the Howrah-Visakhapatnam railway line and the Chintalagraharam village. The average annual rainfall is around 110cm and occurs in the months of June to November.

December and January are coldest months in this region and April and May are hottest months. The area enjoys sub tropical climate and the temperature ranges from 14 to 22o C in December and 33-45oC in May. Relative humidity is high in day time and varies between 70-80% throughout the year. The two important reserved forests Narava and Yerrakonda covers the study area. See Figure 1.

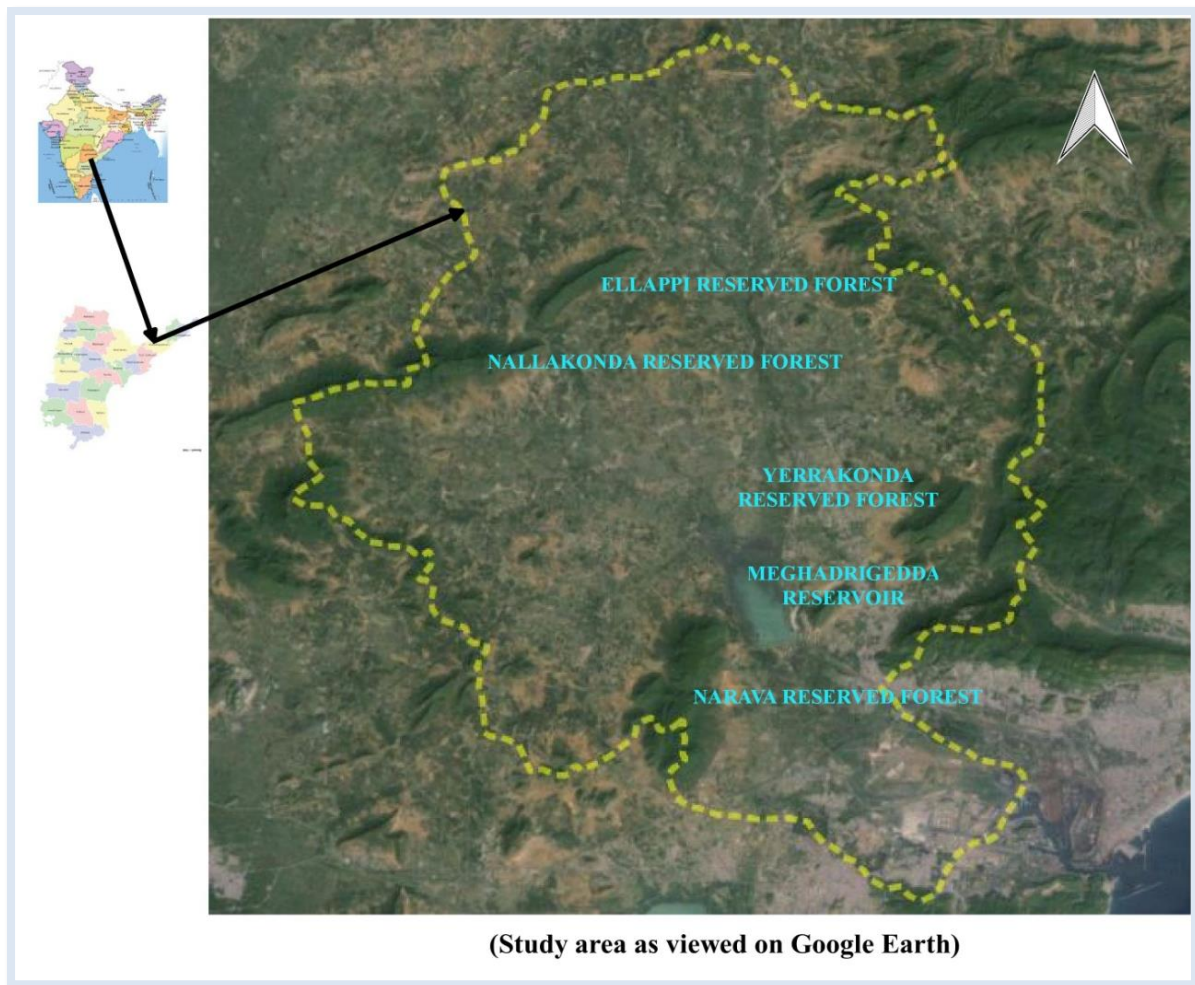


Figure 1: Location Map of the Study Area

MATERIALS AND METHODS

As reference and base map preparation, five toposheets on 1:50000 scale were used. The SOI toposheets are rectified and geo-referenced using digital image processing software (ERDAS IMAGINE ver: 9.1). Geo-referencing was performed using the nearest neighbor resampling algorithm with first order polynomial transformation. The toposheets have been assigned to Geographic (Lat/Lon)

projection with WGS 84 datum is used for standard geographic coordinate system. Using GIS software (QGIS) digitization has been carried out for the entire analysis of basin. By following Strahler stream order method, ordering was given to each stream for the entire study area. Various morphometric parameters such as linear aspects of the drainage network: stream order (Nu), bifurcation ratio (Rb), stream lengths (Lu) and areal aspects such as:

drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circulatory ratio(Rc), and form factor (Rf) of the basin were computed.

RESULTS AND DISCUSSION

The various morphometric parameters of Meghadrigedda basin area were determined and are summarized in Tables 1 and 2.

i. Linear Aspects of the Drainage System

The linear aspects of drainage network such as stream order (Nu), bifurcation ratio (Rb), and stream length (Lu) results are tabulated in Table 1.

a. Stream Order (Nu)

The first step in the drainage basin analysis is to determine the stream orders. The channel segment of the drainage basin has been ranked according to Strahler’s stream ordering in the present study.

According to Strahler (1964), the smallest fingertip tributaries are designated as order1. When two first order channel segments join, a order of 2 is formed; when two second order channel segments join, a order of 3 is formed; and so on. The study area is a 7th order drainage basin. The total number of 1284 streams were identified out of which 918 are 1st order streams, 274 are 2nd order, 66 are 3rd order, 19 in 4th order, 4 in 5th order , 2 in 6th order and one indicate the 7th order stream. A highest stream order is associated with greater drainage and has high velocity. Further, the total number of stream segments decrease with stream orders. The drainage pattern in the basin exhibits dendritic type which indicates the homogeneity in texture and lack of structural control while in some parts of the basin represent radial which indicates that the stream segments radiate outward from the central area.

Table 1: Table showing the linear aspects of drainage network covered under this study

Order	Number of streams	Length of streams (km)	Bifurcation ratio
N1	918	635.72	3.35
N2	274	242.534	4.15

N3	66	126.962	3.47
N4	19	75.194	4.75
N5	4	22.348	2
N6	2	19.246	2
N7	1	11.468	--
	$N_u = 1284$	$L_u = 1133.472 \text{ km}$	Mean = 3.28

Table 2: Table showing the aerial aspects of drainage basin covered under this study

Morphometric parameters	Formula/Symbol	Results
Area (sq. km)	A	453.40
Perimeter (km)	P	120.879
Drainage density (km/sq.km)	$D = \frac{L_u}{A}$	2.49
Stream frequency	$F_s = \frac{N_u}{A}$	2.83
Texture ratio	$T = \frac{N_l}{P}$	7.59
Basin length (km)	L_b	42.34
Elongation ratio	$R_e = \frac{2\sqrt{A/\Pi}}{L_b}$	0.567
Circulatory ratio	$R_c = \frac{4\Pi A}{P^2}$	0.389
Form factor ratio	$R_f = \frac{A}{L_b^2}$	0.25

Where

L_u = Total stream length of all orders,

N_u = Total no. of streams of all orders

N_1 = Total no. of 1st order streams

$P = 3.14$

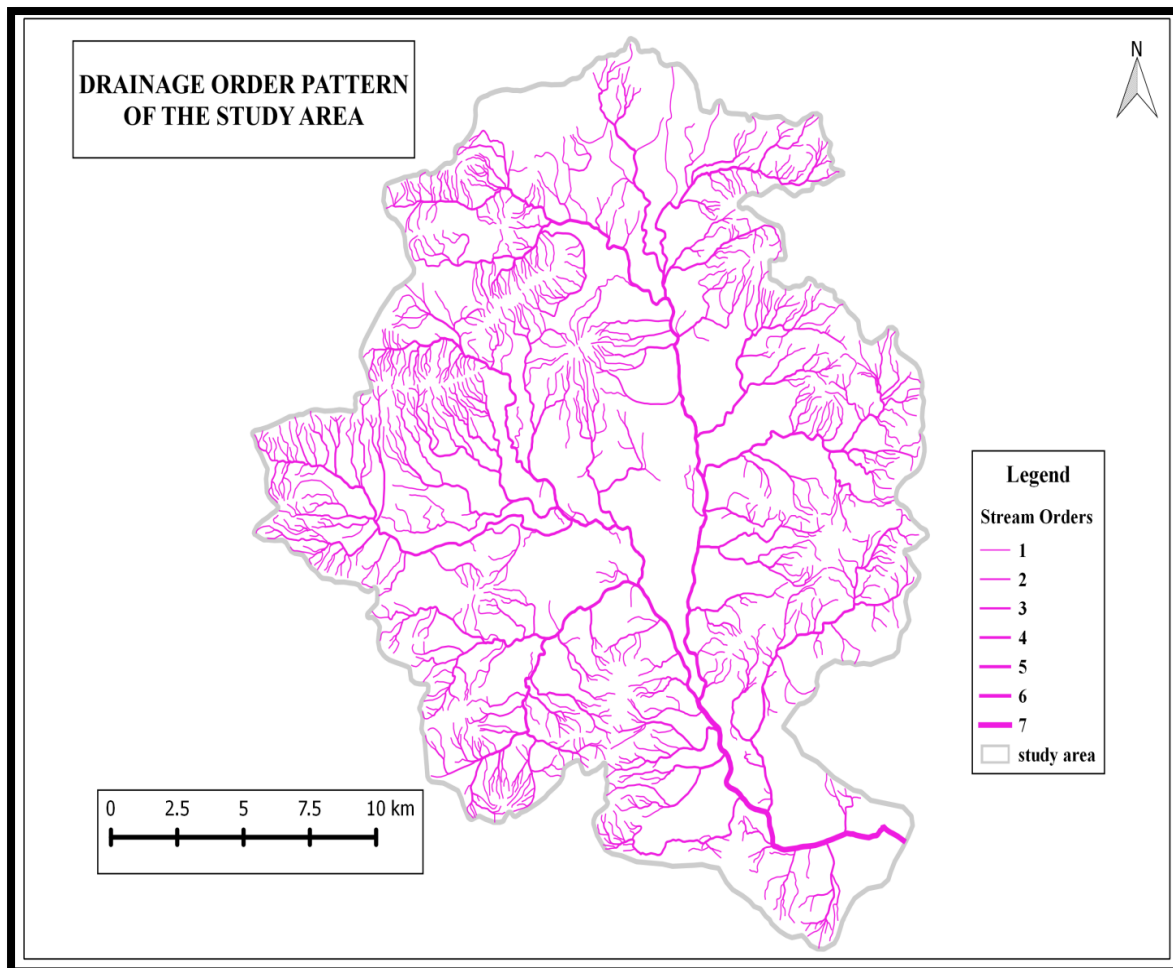


Figure 2: Drainage Pattern of the Study Area

b. Bifurcation Ratio (Rb)

It is defined as the ratio of number of streams of any order given to the number of streams in the next highest order. The range varies between 3.0 and 5.0 for the basins in which the geologic structures do not distort the drainage pattern. The mean

bifurcation ratio is 3.28 for the study area indicating that the geological structures are less distributing the drainage pattern.

c. Stream Length (Lu)

It is observed in the study area that the total length of stream segments is

maximum in case of first order stream segments. The stream length decrease as the stream order decrease and according to Horton's law of stream length, L_u of any given order is greater than that of lower order. The number of streams of various orders is counted and the length is measured with the help of QGIS software.

ii. Aerial Aspects of the Drainage Basin

The important parameters in drainage morphology are perimeter and area of the basin. The area of the basin is defined as the total area projected upon a horizontal plane that contributes to cumulate all orders of basin. Perimeter is defined as the length of the boundary of basin. The areal aspects are drainage density, stream frequency, texture ratio, elongation ratio, circulatory ratio, and form factor were calculated and results have been tabulated.

a) Drainage Density (D)

It is defined as the ratio of cumulative stream length of all orders within a basin to the basin area. It is expressed as km/sq. km. In humid regions, drainage density varies between 0.55 to 2.09 km and sq.km. Generally, D has a low value in regions underlain with highly resistant permeable material with good vegetative cover and low relief. High drainage density is

observed in the regions of weak and impermeable subsurface material and sparse vegetation. The drainage density of the study area is 2.49 km/sq. km indicating high drainage density. It is suggested that the high drainage density indicates the basin is weak and has impermeable subsurface.

b) Stream Frequency (F_s)

It is defined as the ratio of total number of stream segments of all orders per unit area. It relates to permeability, infiltration capacity and relief of basin. Further, it is noted that stream frequency decreases as the stream number increases. The stream frequency of the study area is 2.83/sq. km. The value of stream frequency exhibits good amount of vegetation in the basin.

c) Texture Ratio (T)

It is one of the important factor in the drainage morphometric analysis which depend on the underlying lithology, infiltration capacity and relief ratio of the terrain. The texture ratio of the study area is 7.59 and categorized as moderate in nature.

d. Elongation Ratio (Re)

The values generally vary from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are

typical regions of very low relief whereas, that from 0.6 to 0.8 have high relief and steep ground slope. It is classified into 3 categories; circular (>0.9), oval (0.9-0.7), less elongated (<0.7). The elongation ratio of the study area is 0.567 in which the basin is less elongated.

e. Circulatory Ratio (Rc)

Circulatory ratio is defined as the ratio of the area of basin to the area of circle having the same circumference as the perimeter of the basin. The characteristics that influence circulatory ratio are length, stream frequency, geological structure and relief. The circulatory ratio of the study area is 0.38 indicates low relief and have impermeable surface.

f. Form Factor Ratio (Rf)

It is one of the dimensionless factor defines as the ratio of area to the square of basin length. The basin with high form factor have high peak flows of shorter duration, whereas elongated basin with low form factor have low peak flow of longer duration. The form factor value of the basin is 0.25 indicates elongated basin with low value and has longer duration of peak flow.

CONCLUSIONS

The analysis of the drainage basin is important in assessing the ground water potential and ground water management. The drainage pattern exhibits mainly dendritic type which is well-integrated and in some parts of basin the pattern is radial which indicates that the streams radiate outward from the central area. It is observed that the drainage density value is high which indicates that the basin has impermeable subsurface and has more surface runoff. Bifurcation ratio shows that the geological structures of basin do not distort the drainage pattern. The quantitative analysis of morphometric parameters is carried out in micro level using GIS which helped us to understand various parameters such as nature of bed rock, infiltration capacity, and surface runoff etc.

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