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The Analysis of Geomorphometric Components of Himayat Sagar and Osman Sagar Catchment Using Remote Sensing and GIS

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ABSTRACT

In the present study, analysis of geomorphometric characteristics of osman sagar and Himayat sagar catchment was carried out using remote sensing and GIS and the drainage networks of the both the catchment were generated using SRTM DEM (90m resolutions). Two adjacent catchments, Himayath sagar and Osman sagar, located Rangareddy district of Telangana state, India were selected for study. Morphometric features and drainage network of Himayath sagar and Osman sagar catchments were extracted from DEM using ArcGIS software. Such as areal parameters: viz: Infiltration number, length of overland flow, circularity ratio, elongation ratio, form factor, lemniscates ratio, fitness ratio for both catchments were determined using ArcGIS.

Key words: *Infiltration number, Length of overland flow, Circularity ratio, Elongation ratio, form factor, Lemniscates ratio, Fitness ratio*

INTRODUCTION

Water is known as the liquid for sustenance of life. All living beings are depending on water, without which no life exists on the earth. Earth has plentiful water due to the presence of hydrological cycle on it, but most of it is unfit for living beings use and consumption. The study of the watershed morphometric analysis provides the beneficial parameters for the assessment of the groundwater potential zones, identification of sites for water harvesting structures, water resource management, runoff and geographic characteristics of the drainage system (Singh et al., 2014).Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape, dimension of its landforms (Clarke, 1996). Morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. These parameters affect catchment stream flow pattern through their influence on concentration time. River characteristics are reasonably understood by the morphometric analysis of that particular river basin.

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Morphometric analysis requires measurement of linear features, gradient of channel network and contributory ground slopes of the drainage basin. The morphometric parameters are relief aspects (Sreedevi et al., 2009). The parameters basin relief, relief ratio, relative relief, ruggedness number, gradient ratio, Melton ruggedness ratio, basin slope, laminscate ratio, form factor, circulatory ratio, elongation ratio and shape index are calculated by means of various mathematical equations (Thomas et al., 2010).

Remote sensing techniques using satellite images are convenient tools for morphometric analysis. The satellite remote sensing has the ability to provide synoptic view of large area at a time and very useful in analyzing drainage morphometry. The image interpretation techniques are less time consuming than the ground surveys which coupled with limited field checks yield valuable results. Geographical Informational System (GIS) is a computer-assisted system designed to capture, store, edit, display and plot geographically referenced data.

Study Area

The study area for the present work consists of catchment of Himayat sagar and Osman sagar reservoirs (Fig.1). Himayat sagar reservoir was constructed on Esa River in 1925 and is situated 9.6 km in southwest direction from Hyderabad, located at 17º02'00" N to 17º21'15" N latitude and 77º53'49" E to 78º26'48" E longitude. Osman sagar reservoir was constructed on Musi river in 1922 and is situated 9.6 km from Hyderabad in western direction located at 17º14'31" N to 17º29'50" N latitude and 77º50'30" E to 78º20'4" E longitude. The catchment area of Himayat sagar is 1358.53 km^2 with elevation range of 516 m to 730 m. Where the Osman sagar catchment area consists of 746.73 km^2 with elevation varies between 522 m to 722 m. Both reservoirs supply drinking water to Hyderabad city. The study area is pertaining to K6Dm4 Agro-Ecological sub region. It is part of North Telangana Plateau, hot moist semi-arid eco sub-region with deep loamy and clayey mixed red and black soils having very high available water content and 120-150 days growing period.

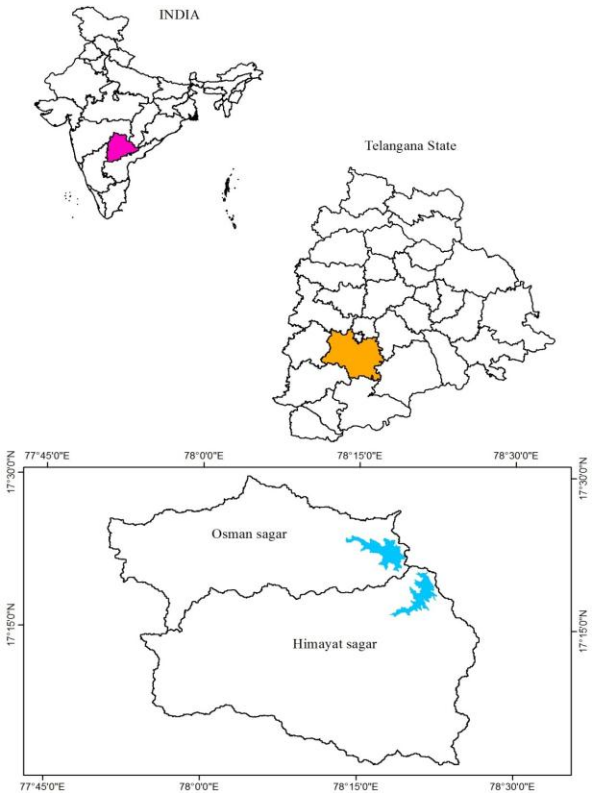

Fig. 1: Location of study area

MATERIALS AND METHODS

Remote sensing data

Topographic data: Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) version 4.1 with a 90 m resolution was downloaded from http://srtm.csi.cgiar.org. DEM of study area is depicted in Fig.2

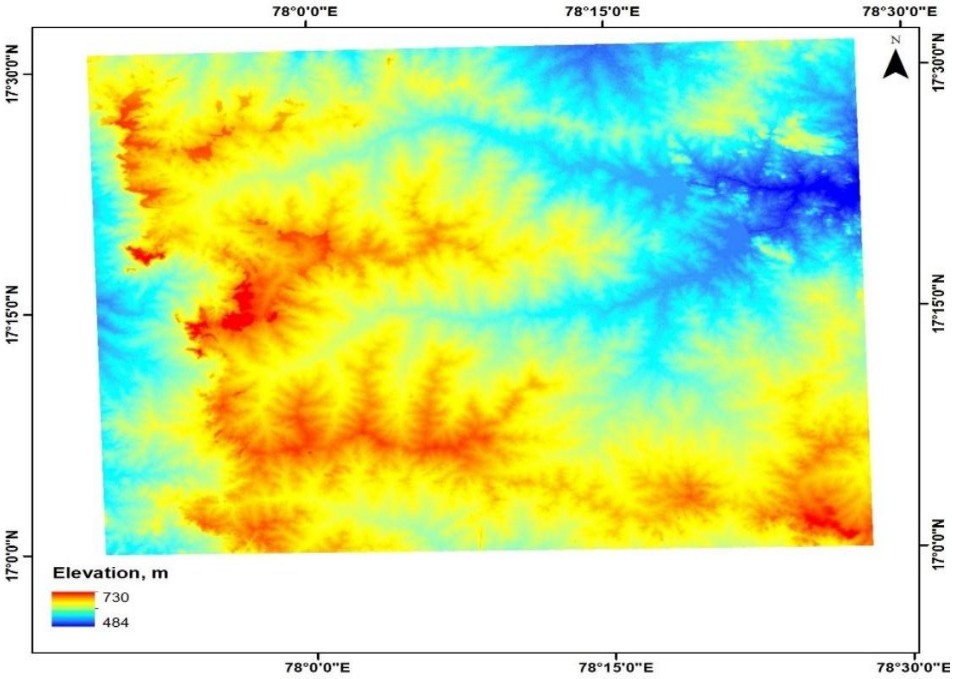

Fig. 2: Digital elevation model representation of study area

Catchment delineation

Catchment area is delineated from a DEM by computing the flow direction. To determine the contributing area, a raster representing the direction of flow is created. Once the direction of flow out of each cell is known, it is possible to determine which and how many cells flow into any given cell. This information is used to define catchment boundaries. A series of steps are preceded to delineate catchment and to define stream network. A process flowchart is depicted in Fig.3

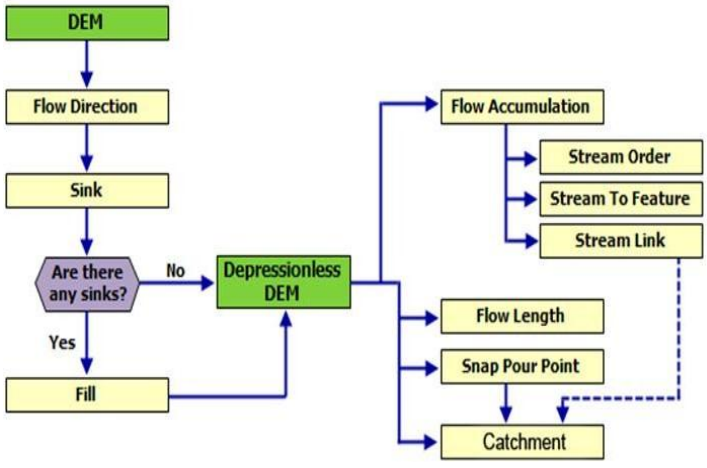

Fig. 3: Flow chart for catchment delineation

Morphometric Parameters Estimation

Morphometric analysis is the measurement of the three dimensional geometry of landforms and has traditionally been applied to watershed, drainages, hill slopes and other group of terrain features (Babar, 2005). Drainage basin or basins should be the study area for better understanding of the hydrologic system. Basin morphometry is a means of numerically analyzing or mathematically quantifying aspects of drainage channels. Spatial arrangement of streams has given rise to a particular design which is called the drainage pattern. Morphometric analysis requires measurement of linear features, gradient of channel network and contributory ground slopes of the drainage basin. Geographic information system and remote sensing satellite images are convenient tools for morphometric analysis.

To estimate the morphometric features of catchments of Himayath sagar and Osman sagar reservoirs, the drainage network was extracted from digital elevation model in ArcGIS software. Catchment areas of Himayath sagar and Osman sagar were extracted from SRTM DEM version 4.1, with a 90 m resolution using hydrology tool of ArcGIS. Geomorphometric characteristics such as linear, areal and relief aspect parameters for both catchments were determined using ArcGIS.

1. Infiltration Number

Drainage density and stream frequency of a watershed show the infiltration number it is defined by Faniran (1968).

$$I_f = F_s \times D_d \quad \cdots(i)$$

Where, F_s is the stream frequency; D_d is the drainage density.

2. Length of overland flow

According to Horton definition length of overland flow approximately equal to half of the reciprocal of the drainage density.

$$L_g = \frac{1}{2 \times D_d} \quad \cdots(ii)$$

Where, L_g is the length of overland flow; D_d is the drainage density.

3. Circularity ratio

According to Miller (1953) circularity ratio defined as the ratio of basin area to the area of circle having the same perimeter as the basin.

$$\frac{A_u}{A_c} \quad \cdots(iii)$$

Where, R_c is the circularity ratio; A_u is the basin area; A_c is the area of circle A_c having the same perimeter as the basin.

4. Elongation ratio

Schumm (1956) defined the elongation ratio as the ratio of diameter of a circle of the same area as the basin to the maximum basin length

$$R_e = \frac{D_c}{L_b} \quad \cdots(iv)$$

Where, R_e is the elongation ratio; D_c is the diameter of a circle of the same area as the basin; L_b is the maximum basin length

Form factor

Horton (1945 defined the form factor which is the ratio of basin area to the square of basin length.

$$F_f = \frac{A_u}{{L_b}^2} \quad \cdots(iv)$$

where, F_f is the form factor; A_u is the basin area; L_b is the square of basin length

6. Lemniscate ratio

Chorley (1957), express the lemniscates value to determine the slope of the basin.

$$K = \frac{{L_b}^2}{A} \quad \cdots(vi)$$

where, K is the lemniscates ratio, L_b is the basin length (km) and A is the area of the basin (km^2).

7. Fitness ratio

It is the ratio of the main stream length of the basin to the perimeter of the basin. Melton (1957)

$$R_f = \frac{C_i}{P} \quad \cdots(vii)$$

where, R_f is the fitness ratio; C_i is the main stream length of the basin; P is the perimeter of the basin.

8. Wandering ratio

It is the ratio of the main channel length to basin length (Smart, 1967).

$$R_w = \frac{C_1}{L_b} \quad \cdots(viii)$$

Where, R_w is the wandering ratio; C_1 is the main channel length; L_b is the basin length.

9. Shape Factor

The shape factor can be defined as the ratio of the square of the basin length to area of the basin and is in inverse proportion with form factor (R_f).

$$R_f = \frac{{L_b}^2}{A} \quad \cdots(ix)$$

where, R_f is the shape factor; L_b is the basin length; basin length; A is the area of the basin.

RESULTS AND DISCUSSION

The infiltration number in the present study area of Himayath sagar and Osman sagar is determined as 2.689 and 8.400, respectively. Himayath sagar catchment indicates high infiltration number compared to Osman sagar catchment. The infiltration number for Osman sagar catchment indicates moderate infiltration and medium runoff due to the impermeable lithology of basin. The higher values of infiltration number indicate the lower infiltration and the higher runoff. Length of overland flow according to Horton (1945) definition length of overland flow is approximately equal to half of the reciprocal of the drainage density. Length of overland flow of Himayath sagar and Osman sagar catchment is 0.262 and 0.247, respectively.

The length of overland flow generally ranges between 0.1-0.3. Higher the value of length of overland flow the delayed surface runoff and represents gentle to moderate slope. Circulatory ratio of Himayath sagar and Osman sagar catchment is 0.255 and 0.187. The circularity ratio shows lower values for Osman sagar catchment where there is strong structural control on the drainage development. Therefore the structural control of drainage is probably responsible for the low values of circularity ratio. Elongation ratio of Himayath sagar and Osman sagar catchment is 0.786 and 0.611, respectively. Elongation ratio is classified in five classes i.e., circular (>0.9), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7) and more elongated (<0.5). Elongation ratio of Himayath sagar shows that the catchment is less elongated, whereas Osman sagar catchment is elongated in shape. Form factor of the Himayath sagar and Osman sagar catchment has form factor of 0.485 and 0.293, respectively. The form factor values indicate that elongated drainage shape with low form factors has falter peak flow of longer duration. Flood flows of such elongated basins are easier to manage than those of the circular basin. Lemniscate ratio the value of the Lemniscate ratio for Himayath sagar and Osman sagar catchment is 2.061 and 3.414, respectively. Lemniscate ratio of both catchments shows that the watershed occupies the maximum area in its regions of inception with large number of streams of higher order. The fitness ratio is considered as the ratio of main stream length to the length of the basin perimeter. Fitness ratio of Himayath sagar and Osman sagar catchment is 0.254 and 0.263, respectively. Wandering ratio is defined as the ratio of the mainstream length to the catchment length. The value of wandering ratio of the study area of Himayath sagar and Osman sagar is determined as 1.243 and 1.166, respectively. The shape factor value for Himayath sagar and Osman sagar catchment is determined as 2.061 and 3.414 km^{-1}, respectively. The shape factor is the ratio of square of the basin length to the area of the basin. It is observed that both catchments have oval shape. The oval shape with dendritic networks is supposed to create a higher potential for confluence effects.

SUMMARY AND CONCLUSIONS

Growing population, urbanization and industrialization are leading to over-utilization of water resources, thus exerting pressure on the limited civic amenities many of which are on the brink of collapse. Assessment of water resources quantitatively is being critical task on account of ever increasing demand for water over past. Water plays principal role in the sustainability of livelihoods, agriculture and regional economy. Water management is the primary safeguard against drought and plays a fundamental role in achieving food security at the watershed, sub basin and basin from local to global planes. The study of the watershed morphometric analysis provides the beneficial parameters for the assessment of the groundwater potential zones, identification of sites for water harvesting structures, water resource management, runoff and geographic characteristics of the drainage system. Morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. These parameters affect catchment stream flow pattern through their influence on concentration time. River characteristics are reasonably understood by the morphometric analysis of that particular river basin. Morphometric analysis requires measurement of linear features, gradient of channel network and contributory ground slopes of the drainagebasin. Considering the above facts, the present study focuses on the analysis of geomorphometric characteristics in the two adjacent catchments. The specific objectives of the study are as follows to analyse geomorphometric characteristics of Himayath sagar and Osman sagar catchment using RS and GIS. Particular to the present study, the following salient conclusions are drawn. 1. A GIS technique characterized by very high accuracy of mapping and measurement proves a competent tool in geomorphometric analysis. 2. Geomorphometric analysis shows both

catchment areas have elongated shape and high time of concentration of surface flow. High infiltration number indicates less permeable subsurface material and moderate to high surface runoff.

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