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Research Article

MORPHOMETRIC EVALUATION OF BARWA TAL WATERSHED A PART OF JHANSI DISTRICT, U.P.; A GIS APPROACH

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A B S T R A C T

The study area is a part of Jhansi district, Uttar Pradesh, India. It covers an area of 136.52 km2. The drainage pattern of the watershed is delineated using Geo-coded FCC bands 2, 3, 4 of IRS 1D (LISS-III) on 1:50,000 scale and Survey of India toposheets. The morphometric parameters are computed using Arc GIS software. The drainage pattern of the study area is dendritic to sub-dendritic with stream orders ranging from I to IV orders. Drainage density ranges from 0 to 1.16 km/km2 suggesting coarse to moderate drainage texture. The change in values of stream length ratio indicates their late youth stage of geomorphic development. The lower orders of streams are mostly dominating the basin. The development of stream segments in the basin area is more or less affected by rainfall. The mean Rb of the entire basin is 3.89 which indicate that the drainage pattern is not much influenced by geological structures. Relief ratio indicates that the discharge capability of the watersheds is very high and the groundwater potential is stringy. Elongation ratio 0.95 indicates that the Barwa Tal watershed is a region-wide variety of climatic and geologic types. It is concluded that remote sensing and GIS have been proved to be effective tools for drainage delineation and mapping. In the present study, these updated drainages have been used for the morphometric analysis.

INTRODUCTION

The Geomorphic characteristics of a drainage basin are important for hydrological investigations involving the assessment of groundwater potential, watershed management and, environmental assessment. The correlation between physiographic characteristics of drainage basins such as size, shape, the slope of drainage area, drainage density, size and length of the tributaries, etc., to various hydrologic phenomena, has been used by Rastogi and Sharma (1976).The morphodynamic evaluation of drainage data provides a quantitative explanation of basin geometry used to reveal the geological and geomorphic history of each drainage basin. This necessitates the analysis of various drainage parameters such as ordering of various streams,measurement of drainage area and perimeter, length of drainage, drainage density (Dd), stream frequency (Fs), bifurcation ratio (Rb), texture ratio (T), basin relief (Bh) and length of overland flow (Lg) to predict the approximate behavior of the watersheds during periods of heavy rainfall (Verstappen 1983; Kumar et al. 2000).The present paper describes the drainage characteristics of Barwa Tal watershed in Jhansi District a part of Bundelkhand region, Uttar Pradesh to understand their hydrological behavior through remote sensing and GIS analysis.

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Study area

The Barwa Tal watershed is in the Jhansi district of Uttar Pradesh (Fig. 1). This watershed cover an area of 136.52 km^2, and lie between 78°59’49.257” to 79°10’32.073”E longitudes and 25°28’36.049 to 25°28’45.511”N latitudes. The study area has low relief and steep slopes.The type of drainage is dendritic to sub-dendritic which is characterized by irregular branching of tributary streams in many directions joining the main channel. Major rock types found in the study area are Granite gneiss and Quartzite (Bundelkhand Granitoid Complex). Typical tropical climate prevails in the catchment for the better part of the year. The climate of the catchment is generally dry, except during the monsoon months. Generally, the study area experiences two seasons: dry (Dec–May), and wet (June–Nov). The study area receives about 880.0 mm rainfall annually. The Temperature of the area varies from 20° to 38° C. The elevation varies between 164 m in the South-East to 236 m above sea level in the South-West.

METHODOLOGY

The base map of the Barwa Tal watersheds was prepared based on Survey of India Topographic Maps on a 1:50,000 scale and also with LISS-III and SRTM data. TheUS Geological Survey was able to provide SRTM 90 m Digital Elevation Data for the entire world. Global Mapper 15 software was used for delineating the study area and exporting the information to DEM format. The SRTM DEM data was then imported to ArcGIS 10.2.2; Based on these data, the slope, aspect, and topographic elevation maps with contours for the watershed was prepared. The drainage networks of the watershed was scanned from Survey of India (SOI) Toposheets no. 54K/14, 54O/2 and 54O/3 (1:50,000) and digitized in ArcGIS 10.2.2 platform. Based on the drainage order, the channels were classified according to drainage order following Strahler (1964). Watershed parameters, such as, area, perimeter, length, stream length, and stream order was also calculated. Later, these parameters were used to determine other influence factors, such as bifurcation ratio, Stream length ratio, stream frequency, drainage density, elongation ratio, circulatory ratio, form factor. Table 1 provides a list of the main parameters and, where appropriate, the formulae used to calculate them.

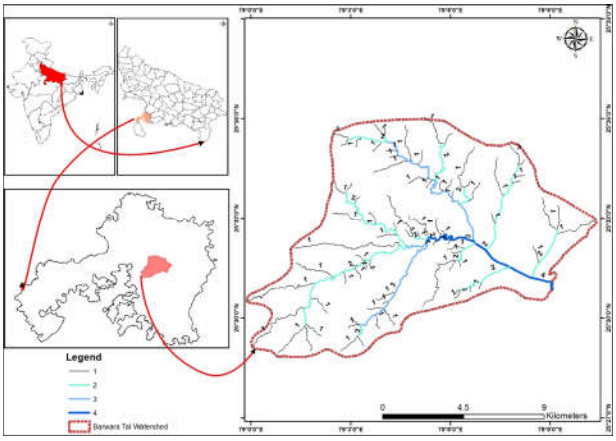

Fig.1

Stream Parameter of Barwa Tal Watershed

Stream Order	I	II	III	IV
Number of Streams	81	14	3	1
Length (Km.)	93.46	38.17	18.02	9.08
Bifurcation Ratio	I/II 5.4	II/III 3.5	III/IV 3	

Table 1

Basin Morphometric Parameters		
S.N.	**Parameters**	**Computed Values**
1	Watershed Area	136.52 Sq.Km.
2	Watershed Perimeter	53.78 Km.
3	Circulatory Ratio	0.59
4	Mean Bifurcation Ratio	3.96
5	Drainage Density	1.16 Km./Sq.Km.
6	Number of Streams	99
7	Elongation Ratio	0.95
8	Form Factor	0.49
9	Stream Frequency	1.42
10	Watershed length	13.85Km.
11	Total Stream Length	158.73 Km.
12	Average Stream length	1.60 Km.

Table 2

S.N.	Parameter	Formulae
1	Stream Order (U)	Hierarchial Rank
2	Stream Length (Lu)	Length of Stream Order
3	Mean Stream Length (Lsm)	Lsm=Lu/Nu
4	Bifurcation Ratio (Rb)	Rb=Nu(Nu+1)
5	Mean Bifurcation Ratio (Rbm)	Rbm= Avg. of bifurcation ratio of all order
6	Drainage Density (Dd)	Dd=Lu/A
7	Stream Frequency (Fs)	Fs=Nu/A
8	Elognation Ratio (Re)	Re=D/L=1.128√A/L
9	Circularity Ratio (Rc)	Rc=4
10	Form Factor (Ff)	Ff=A/L2

RESULT AND DISCUSSION

The total drainage area of Barwa Talwatershed is 136.52 km^2. The SRTM DEM has been obtained with a pixel size of 90 m, which covers the watershed (Fig. 2). Furthermore, the DEM has been used to calculate slope, contour and aspect maps. The development of drainage networks depends on geology and precipitation, apart from exogenic and endogenic influences. The drainage pattern of the basin is dendritic to sub-dendritic. Based on the drainage order, the Barwa Tal watershed is classified as fourth order basins to interpret the morphodynamic parameters listed in Table 1. (Horton 1932, 1945; Smith 1950; Schumm 1956, 1963; Hadley and Schumm 1961; Strahler 1964; Sreedevi et al. 2005; Mesa 2006).

Aspect

Aspect generally refers to the direction to which a mountain slope faces. The aspect of a slope can make very significant influences on its local climate because the sun's rays are in the west at the hottest time of day in the afternoon, and so in most cases a west-facing slope will be warmer than sheltered east-facing slope. This can have major effects on the distribution of vegetation and bio-diversity in the study area. The value of the output raster data set represents the compass direction of the aspect. 0° is true north; a 90°aspect is to the east, and so forth. The aspect map of Barwa Tal watershed is shown in Fig. 3.

Slope

Slope analysis is an important parameter in geomorphic studies. The slope elements, in turn, are controlled by the climate morphogenic processes in areas having rock of varying resistance. An understanding of slope distribution isessential, as a slope map provides data for planning, settlement, mechanization of agriculture, deforestation, planning of engineering structures, morpho-conservation practices, etc., (Sreedevi et al. 2005). A slope map of the study area was prepared based on SRTM data using the spatial analysis tool in Arc Map 10.2.2 Slope grid is identified as ''the maximum rate of change in value from each cell to its neighbors'' (Burrough 1986). The degree of slope in Barwa Tal watershed varies from 0°to 31°. Higher degree of slope results in rapid runoff and increased erosion rate with feeble recharge potential.

Stream number (Nu)

It is obvious that the total number of streams gradually decreases as the stream order increases. The number of streams of each order and the total number of streams were computed (Table 2) using GIS tools.

Stream order (u)

The stream orders of the study area are classified according to Strahler's (1964) method of classification. The order wise stream length and stream numbers of Barwa Tal watershed is presented in Table 2. The variations in stream order and the basin area are largely due to physiographic and structural conditions of the region. Application of this ordering procedure through GIS shows that the maximum drainage networks of watershed correspond to a fourth-order basin (Fig. 4).

Mean stream length (Lsm)

Mean stream length (Lsm) is a characteristic property related to the size of drainage network components and its contributing basin surfaces (Strahler 1964). This has been calculated by dividing the total stream length of order ''u'' by the number of streams of segments in the order (Table 2). It should be noted that the Lsm values of the Barwa Tal watershed is 1.60 Km. Lsm of any given order is greater than that of the lower order and less than that of its next higher order in the watershed.

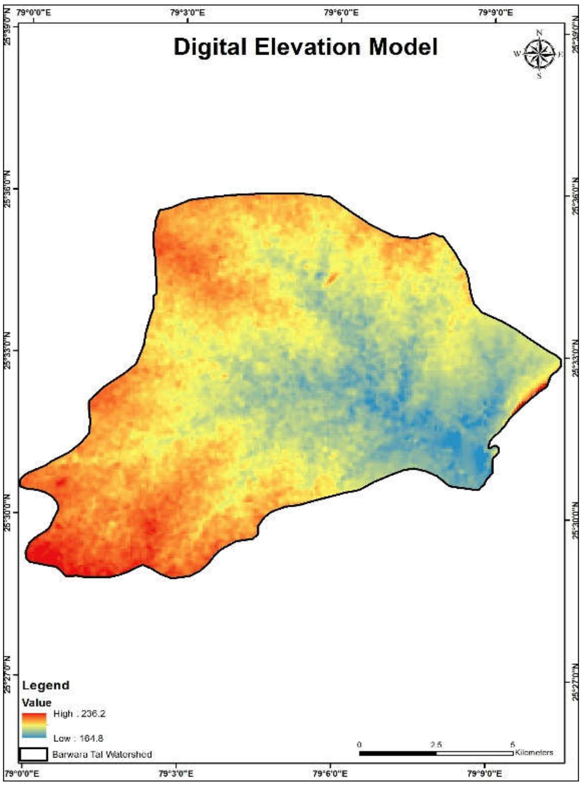

Fig 2

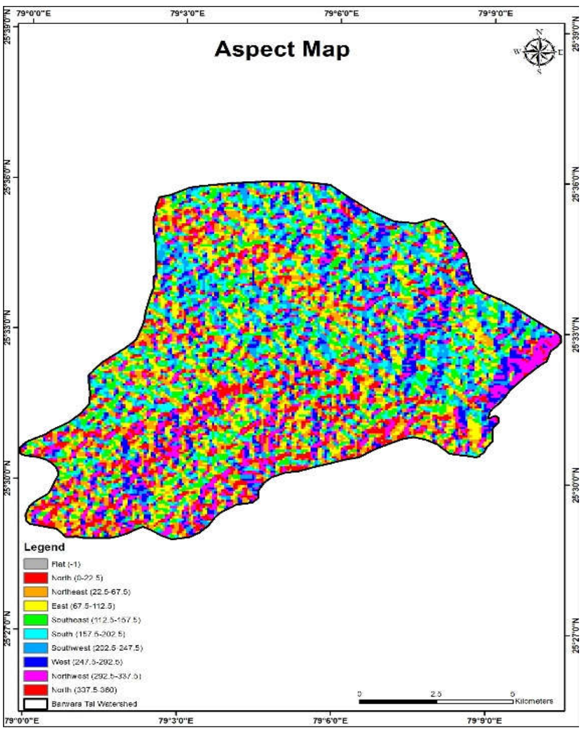

Fig 3

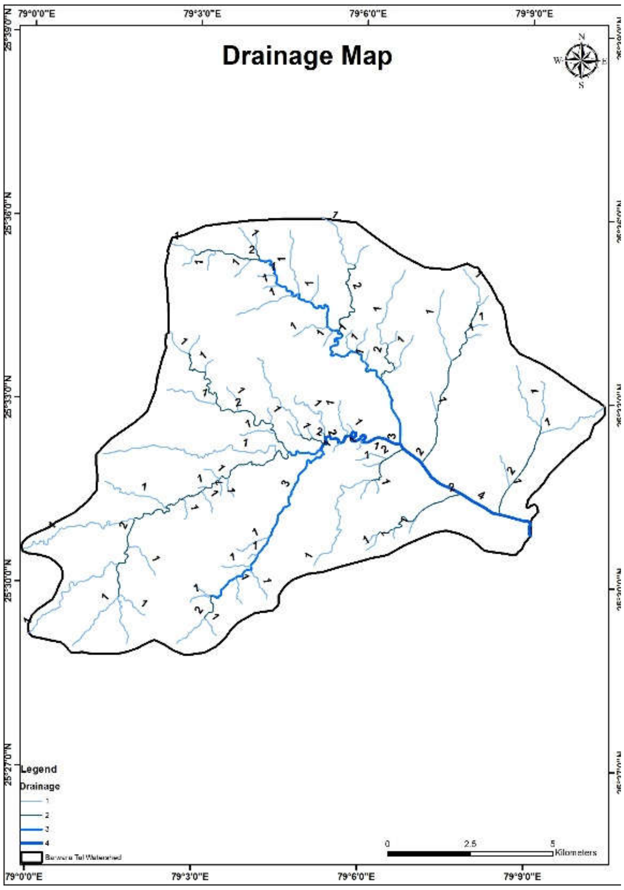

Fig 4

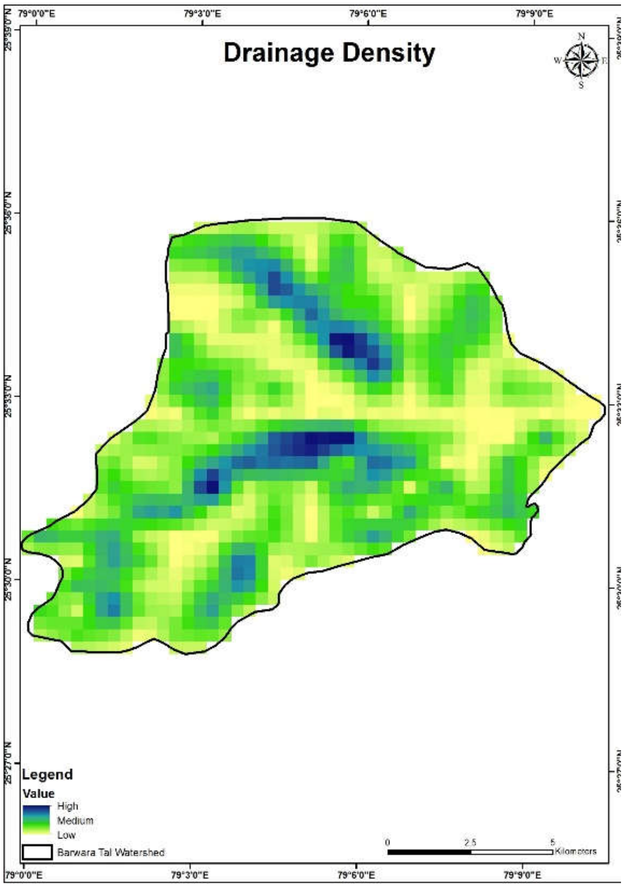

Fig 5

Bifurcation ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumm 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is not the same from one order to its next order. These irregularities depend upon the geological and lithological development of the drainage basin (Strahler 1964). The mean bifurcation ratio of Barwa Tal watershed is 3.96, which indicate that these watersheds do not exercise a dominant influence on the drainage pattern.

Drainage density (Dd)

Drainage density is defined as the closeness of spacing of channels. It is a measure of the total length of the stream segment of all orders per unit area. Slope gradient and relative relief are the main morphological factors controlling drainage density. Strahler (1964) noted that low Dd occurs where basin relief is low, while high Dd is favored where basin relief is high. The Dd values for Barwa Tal watershed is 1.16km/km^2. The Dd of Barwa Tal watershed reveals that the nature of subsurface strata is permeable, which is a characteristic feature of coarse drainage as the density values are less than 5.0. The measurement of drainage density provides a numerical measurement of landscape dissection and runoff potential.

Stream frequency (Fs)

The stream frequency (Fs) of a basin may be defined as thenumber of streams per unit area (Horton 1945). The Fs value for the Barwa Tal watershed is 1.42 km/km2, respectively. Fs mainly depend on the lithology of the basin and reflect the texture of the drainage network. It is found that the Fs and the drainage density values of the watersheds are positively correlated.

Elongation ratio (Re)

Elongation ratio (Re) is defined as the ratio between the diameter of a circle of the like as the area of basin and the maximum basin length (Schumm 1956). Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions are low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories namely-Circular (0.9), Oval (0.9–0.8), Less elongated (0.7). The Re values of the Barwa Tal watershed is 0.95. This reveals that the area has high relief, is steep sloped, and that the watershed is circular.

Circularity ratio (Rc)

Circularity ratio (Rc) is defined as the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller 1953). It is influenced by the length and frequency of streams, geological condition, land use/land cover, climatic condition, relief and slope of the basin. Rc is a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of Rc indicate the young, mature, and old stages of the life cycle of the tributary watershed. The Rc values of Barwa Tal watershed is 0.59 which indicates Barwa Tal watershed stage of topographical maturity.

Form factor (Ff)

Form factor (Ff) is defined as the ratio of the basin area to the square of the basin length. The Form factor indicates the flow intensity of a basin of a defined area (Horton 1945). The form factor value must be always less than 0.7,854 (the value corresponding to a perfectly circular basin). The smaller the value of the form factor, the more elongated the basin. Basins with high-form factors experience larger peak flows of short period, whereas elongated watersheds with low-form factors experience lower peak flows of longer duration. The Ff values for Barwa Tal watershed 0.49, indicating watershed comprise elongated basin with lower peak flows of longer duration than the average

Relief (R)

Relief is defined as the difference in elevation between the lowest and the highest point of a basin. Basin relief is an important factor in understanding the denudational characteristics of the basin. It plays a significant role in landforms development, drainage development, surface and subsurface water flow, permeability and erosional properties of the terrain. The total relief of the Barwa Tal watershed is 236 m. The high relief value indicates the gravity of water flow, low infiltration and, high runoff conditions. Figure 5 presents relief maps for the watershed.

CONCLUSION

The drainage basin is a fundamental landform unit in fluvial terrain and it is of particular relevance to morphometric analysis. Landscape morphology is a function of drainage, climate, and structure of a given basin. The present paper has described morphometric analysis of the Barwa Tal watershed based on several drainage parameters, by which the watershed has been classified as fourthorder basins. The basin is mainly dominated by lower order streams. The drainage density values of the Barwa Tal watershed has value below 5 revealing that the subsurface strata is permeable, a characteristic feature of coarse drainage. The aspect of Barwa Tal watershed is dominated by east-facing slopes indicative of high-moisture content. This is because the sun’s radiation intensity is greater on west-facing slopes, causing increased evaporation. For the Barwa Tal watershed, the stream length ratio fluctuates according to local changes in slope and topography. The bifurcation ratio indicates that the watershed areas do not exercise a dominant influence on drainage patterns. The study area experience intermediate to fine drainage textures. Rainfall may affect the development of stream segments in the watershed. However, present-day drainage has evolved from high-density drainage when the climate was wetter in the past compared to drainage characterized by intermittent runoff consistent with recent drier climatic conditions. The elongation ratio indicates that watershed has high relief, steep slopes and is circle. The latter mainly due to the guiding effect of thrusting and forcing. The relief ratio indicates that the discharge capability of this watershed is very high and the potential groundwater resource is meager. Work is underway to correlate data from drainage analysis with relevant data from bedrock, sediment, and geochemistry to identify sites, which are suitable for assessing the fluvial ecosystem with future mineral exploitation in mind.

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