

Morphometric Analysis of Vela Hari Watershed using GIS

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Abstract - The summarization of Morphometric analysis based on several drainage parameters of the selected area, by which the watershed streams have been classified up to fifth order streams. The calculated facet of watershed was carried out i.e., stream order (529.00), bifurcation ratio (4.80), stream length (431.1Km) and aerial aspects such as drainage density ($D_d=2.25$), stream frequency ($F_s=2.76$), form factor ($F_f=0.02$), circulatory ratio ($R_c=0.25$) and elongation ratio ($R_e=0.60$) has been carried out on the basis of soil erosion. The reading of the figures exposed that the total no of streams were 529 in that 412 in first order, 94 in second, 18 in third 4 in fourth and 1 in fifth simultaneously. The low R_b value reveals that a lower peak flow would result from the watershed and it can be more risk of flooding. The low D_d value indicates that the basin has moderately low permeable soil (black soil) and sparse vegetative cover. The low R_c value also indicates as the basin is almost drawn out in shape, it has a high discharge rate of runoff and poorly permeable soil condition.

Key Words: Toposheet, GIS, aerial aspects, relief aspects, morphometric, Vela Hari etc.

1. INTRODUCTION

India is one of the major country fastest growing in urbanization and industries in the world. Urbanization and heavy industrial growth has made its impact on the ecosystem and environment balance is potentially affected. To conserve water during drought period is a main goal by government and NGOs and to increase watershed conservation and to this lots of efforts were taken into drainage development and characterizations of a watershed. (Ashok S. Sangle *et al.* 2015).

The parameters worked out include bifurcation ratio, stream length, form factor, circulatory ratio, elongation ratio, drainage density, constant of channel maintenance, and stream frequency. National Institute of Hydrology (1998) has carried out morphometric analysis of Suddagedda basin in the state of Andhra Pradesh and many more in different parts of India. For quantitative analysis of the watershed involve various components such as stream segments, basin perimeter, basin area, elevation difference, slope and profile of land has been responsible for the natural development of basin (Horton, 1945)

2. STUDY AREA

The area selected for the study is the Vela Hari from watershed of Nagpur(R) Taluka of Nagpur District in Maharashtra State the location is 15 km away from Nagpur main. The taluka is situated at 21°00'58" North Latitude and 78°00'58" East Longitude with an Elevation above sea level 314 m. The study area is falling under the Survey of India toposheet of 55 O/4 (1:50,000) Slope of the watershed area varies from 1 to 5%. The watershed falls under semi critical zone Based on the Thornthwaite system of climatic classification, Nagpur(R) is classified under the category of Tropical Dry-sub-humid climate. The mean annual rainfall of the watershed area ranges between 900 mm to 1100 mm, of which about 80% is received from south-west monsoon during June to September. The average numbers of rainy days are 68 those spread during 4 months. The region experiences hot summer and mild winter with mean summer temperature of 44.2°C and mean winter temperature of 7.6°C. The geographical area of selected watershed is around 192 km² area.

Objectives

1. Analysis of morphological parameters of a watershed,
2. To infer hydrological characterizations of the watershed area.

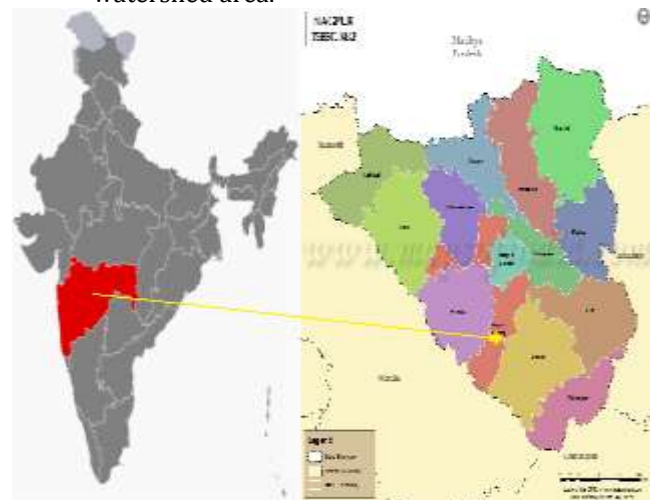


Fig-1 Location of study area

3. MATERIALS AND METHODS

Computation of the basic parameters (i.e. area, perimeter, stream order, stream length, stream number and elevation) of the watershed analyses by using the GIS approach. Finally bifurcation ratio (R_b), drainage density (D_d), stream frequency (F_s), texture ratio (R_T), form factor (F_f), circulatory ratio (R_c), elongation ratio (R_e) and compactness constant (C_c).

Stream Length Ratio (RL): The stream length ratio (RL) is the ratio of the mean length of the stream of a given order ($L_{\bar{u}}$) to the mean length of the streams of the next smaller order ($L_{\bar{u}-1}$).

$$RL = \frac{L_{\bar{u}}}{L_{\bar{u}-1}}$$

Bifurcation Ratio (R_b): The bifurcation ratio is the ratio of the number of streams in lower order (N_u) to the next order (N_{u+1}). It is seen that the bifurcation ratio is lower in alluvial region as compare to the Himalayan zone.

$$R_b = \frac{N_u}{N_{u+1}}$$

Form factor (R_f): Form factor is defined as the ratio of basin area (A) to square of the maximum length of the basin (L_b). The smaller value of form factor, more elongated will be the watershed. The watershed with high form factors have high peak flows of shorter duration (Horton, 1932).

$$R_f = \frac{A}{L_b^2}$$

Elongation Ratio (R_e): It is calculated as the ratio of equal diameter of the circle which has same area as that of the watershed to the maximum length of the basin. Elongation ratio is denoted by (R_e).

$$R_e = \frac{2}{L_b} \sqrt{\frac{A}{\pi}}$$

Circulatory Ratio (R_c): The circulatory ratio is influenced by the length and frequency of stream. The circularity ratio is a similar measure as elongation ratio, originally defined by (Miller, 1953), as the ratio of the area of the basin to the area of the circle having equivalent circumference as the basin perimeter and it is denoted by the (R_c).

$$R_c = \frac{12.57 A}{P_r^2}$$

Drainage Density (D_d): The unit of the drainage density is km/km^2 , which is indicate the proximity of channel spacing, thus provide an idea about quantity measures of the watershed (Strahler 1964). Drainage density is denoted by (D_d).

$$D_d = \frac{L_u}{A}$$

4. RESULT AND DISCUSSION

Stream Order:

The term "stream orders" is the primary step of morphometric analysis. Which is based on the delineated streams and their branching proposed by (Strahler, 1964). From the Table 1 found that watershed designed as Fifth order. Bifurcation ratio is depending on stream order as well as number of streams. Total number of streams and stream length of all order is 529 and 431.1 km respectively.

Stream Length:

The values of length (L_u) and total stream length are shown in Table 1. According to Horton's second law (1945) the stream length characteristics of the sub-basins validates the "laws of stream length". Which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio (Horton, 1945). In general logarithms of the number of streams of a given order, when plotted against the order, the points lie on a straight line (Horton, 1945). Most drainage networks show a linear relationship with a small deviation from a straight line (Chow, 1964). Generally, the total length of stream segments decrease with stream order. Deviation from its general behavior indicate that the terrain is characterised by high relief and/or moderately steep slopes, underlain by varying lithology and probable uplift across the basin (Singh and Singh, 1997).

Bifurcation Ratio:

The bifurcation ratio is of the catchment is reflect the geological as well as tectonic characteristics of the watershed (Gajbhiye et al., 2013). Lower value of R_b indicates the partially disturbed watershed without any distortion in drainage pattern (Nag, 1998). High value of R_b indicates the severe over land flow and low recharge for the sub-watershed. In this study the value of mean bifurcation ratio is 4.80 which is shown in Table 1.

Drainage Density

Drainage density depends upon both climate as well as physical characteristics of the drainage basins. It is a basic length scale in the landscape, is recognized to be the transition point between scales where unstable channel-

forming processes yield to stable diffusive processes (Tarboton et al., 1992). Drainage density is effected by various factors, among which resistance to erosion of rocks, infiltration capacity of the land and climatic conditions rank high (Verstappen, 1983). According to (Langbein, 1947), the significance of drainage density as a factor which determine the time of travel by water within the basin and suggested that it varies between 0.55 to 2.89km/km² for humid region. In this study drainage density is 2.25 and is shown in Table 1.

Stream Frequency

Drainage frequency or channel frequency is directly related to stream population per unit area of the watershed (Horton, 1932). It is indicate the close correlation with drainage density value of the sub watershed. Higher value of drainage frequency shows the high runoff. In this study WS producing more runoff and value is shown in Table 1

Circulatory Ratio

Circulatory ratio (Rc) influenced by the length and frequency of the stream, geological structures, land use land cover (LULC), climatic variability, relief and slope of the watershed. In this present study circulatory ratio is 0.25 and shown in Table 1.

Form Factor

Most of the researcher are suggested that the value of form factor is less than 0.7854 for perfectly circular basin (Gajbhiye et al., 2013; Rekha et al., 2011). In watershed, the smaller value of the form factor show maximum elongation of the basin. The high value of farm factor shows high peak in short duration and vice versa. In this study found that the value of form factor is 0.02.

Elongation Ratio

Generally the range of elongation ratio lies between 0.6 to 1.0 which has follow high to low relief respectively. However value categorized into three segments greater than 0.9, lie between 0.9 to 0.8 and less than 0.8 following circular, oval and elongated respectively. In this watershed elongation ratio is 0.60 where as the feature of watershed lies elongated in nature. In order to archive, watershed to be elongated and steep slope with high relief (Chopra et al., 2005; Gajbhiye et al., 2013).

Texture Ratio

Texture ratio is depends upon properties of lithology of the basin, infiltration of the soil and relief aspect of the terrain (Vijith and Satheesh, 2006). In the present study the texture ratio of the watershed is 5.34 and categorized as fine gravel soil. The lower values of texture ratio indicate that the basin is plain with lower degree of slopes. The value of texture ratio is shown in Table 1.

Compactness Coefficient

A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin (Javed et al., 2009; Ratnam et al., 2005). The value of compactness coefficient was found 0.38 in watershed.

Relief Ratio

The values of relief ratio are given in Table 3 and is 0.01 It is noticed that the low values of R_h indicate less steepness of the basin (Vittala et al., 2004) and is an indicator of intensity of erosion process operating on the slopes of the watershed.

Length of overland flow

The length of overland flow (Lg) approximately equals half the reciprocal of the drainage density (Horton, 1945). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow. The value of length of overland flow in watershed is 1.12.

Vela Hari Watershed Nagpur (Total area- 192 Km²)

Number of Streams (N_s)	Elevation (m)- 1. Max. 302.00 2. Min. 269.00	Mean Bifurcation Ratio (R_b) - 4.80 Drainage density (D_a)- 2.25
i-412,ii-94,iii-18, iv-4.0,v-1.0	Perimeter- 99.00	
Total number of streams- 529.00	Basin length in Km (L_b)- 25.99	Stream frequency (F_s)- 2.76
Stream length in Km (L_w) i-238,ii-103.8,iii-35.6, iv-43.3,v-10.2	Total Relief (m)- 33.00 Relief Ratio (R_h)- 0.01	Circulatory ratio (R_c)- 0.25 Form factor (R_f)- 0.02 Texture Ratio (R_t)- 5.34 Elongation Ratio (R_e)- 0.60 Compactness Coefficient (C_c)- 0.38 Length of overland flow-1.12

Table-1

Shown figures is discussing about some feasible measurements such as areal, linear and relief aspects of the watershed area. Using Toposheet and some calculation we prepare the data as it shown in table.1, which having dendritic drainage pattern which can predict for nature of watershed along with low recharge problems. We can utilize

and flood can be managed by creating some obstruction and designed structure through the watershed.

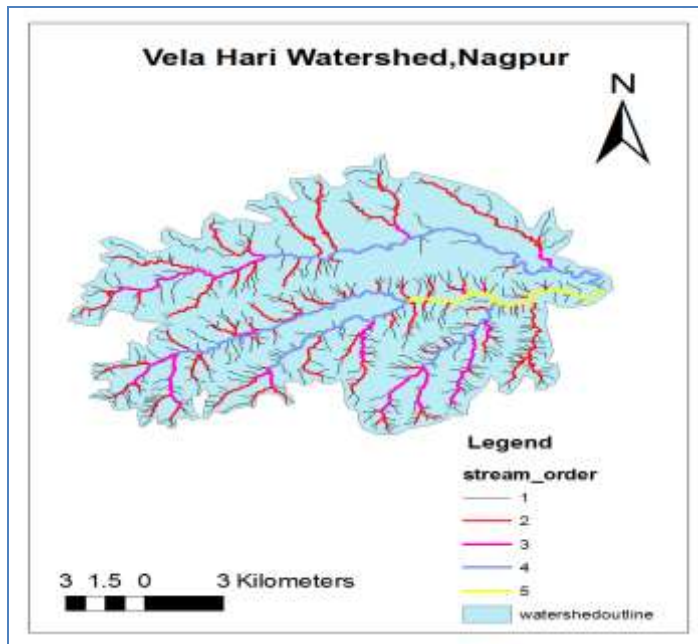


Fig-2 Result of Vela Hari W.S

5. CONCLUSIONS

Morphometric can help in designing and adequacy of network hydrological data stations. Low D_d and R_c values indicating low permeable sub soil conditions, accompanied with the low R_b values and all the low values of R_e , R_f , and F_s indicating a flatter peak of flow for a longer duration thus the basin is not well capable of absorbing water into the soil and less groundwater recharging whereas more risk of flooding. If such floods would be emerged, those could be managed easily from this type of elongated basins than from circular basins by adopting suitable precautionary measures. But, synchronization with scientific accuracy and ease in data collection is still a task at micro level.

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