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Determination of Geomorphological Characteristics of Dahikute Watershed Using Drainage Network Derived from GIS Technique

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ABSTRACT: *The present study was undertaken to determine the relationships between drainage characteristics and environmental aspects of dahikute watershed using the topographical maps. Environmental situations have affecting the morphometry of the basin. It is therefore needs to analyse micro level parameters of drainage and environment for suitable planning and management of any developmental plan. The total area of dahikute watershed is 64.85 sq.km.Drainage pattern of this river is dendritic one. The Morphometric parameters of the stream have been analysed and calculated by applying standard methods and techniques viz. Horton, 1945; Miller, 1953, Strahler, 1964.The Stream frequency and Stream length ratio of the basin is 2.69 and 1.55 respectively. The dimensional factors like Form factor (0.31), Elongation Ratio (0.63) and Circulatory Ratio (0.75) have also been calculated. Watershed response to produce runoff by a rainfall event depends upon the watershed characteristic and each watershed has its exclusive characteristics. Therefore, inthe present study a morphometric analysis has been carried out to determinethe drainage basin characteristics of the dahikute watershed in the Geographic Information System (GIS) environment.The basin is of Fifth order stream and lower order streams mostlydominate the basin. The mean bifurcation ratio indicates that the drainagepattern is not much influenced by geological structures. The shape parametersalso reveal the elongation of the basin and sub-basins.*

Keywords: *Drainage density, Bifurcation ratio, Stream frequency, Watershed, Geomorphology, GIS.*

INTRODUCTION

Morphometry can be defined as the measurement and mathematical analysis of the Configuration of the Earth's surface and of the shape and dimensions of its landforms (Bates and Jackson 1987). The Morphometric analysis of watershed is very important factors for the purpose of the management and conservation of soil, water, natural resources and environmental protection (Karnath and Zahoor, 2012 and Obi Reddy *et al*, 2002). Geomorphological analysis is systematic description of watersheds geometry and its stream channel system to measure the linear aspects of drainage network, areal aspects of drainage basin and relief aspects of channel network. The main purpose of morphological analysis is to extent stream properties from measurement analysis. This analysis can be achieved throughmeasurement of linear, aerial and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). According to Sreedevi etal (2000) Morphometric analysis have merits to study the surface structure, soil erosion, land degradation, drainage pattern and vegetation loss new a day many number of scholars have been used the different tools to study such features along with Morphometric analysis such as RS and GIS (Chavare, 2011; Nag and Lahiri, 2011; and Iqbal *et al*, 2013). Application of GIS to spatial data has proven to be instrumental in the analysis of complex problems in earth and environmental sciences (ESRI 2000). GIS provide rapid access, integration, and analysis of spatially referenced data stored in large numerical databases. It also displays the results graphically in maps and charts. Geomorphological analysis helps in better

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understanding of hydrological system of watershed which is useful for carrying out management strategies.

OBJECTIVES

1. To Study the quantitative analysis of drainage system.
2. To evaluate linear and areal aspects of morphometric characteristics.

MATERIAL AND METHODS

Study Area

The study area, named Dahikutelocated at Malegaon Tahsil, Nasik District of Maharashtra. Tapi is a major west flowing inter-state river in India. It originates in the state of Madhya Pradesh and passes through the states of Maharashtra and Gujrat. The area of Dahikute watershed is 64.85 km^2. It lies between North latitude 20° 31′ and 20° 43′ and East latitude 74° 28′ and 74° 46′. The elevation ranges from 435 m to 663 m above MSL.

Climate and rainfall

The study area has subtropical, semi-arid monsoon climate with average annual rainfall of 1100 mm. The climate of study area is hot in summer and cold in the winter and slightly humid in the rainy season

Data collection

Survey of India Toposheets in the scale of 1:50,000 numbering 46-P/14 and 46-P/13, corresponding to study area were used for preparation of drainage and contour map of watersheds.

Delineation of watersheds

To find out the geomorphological characteristics of the watersheds, first of all their boundary delineation is done in ArcGIS 9.3 software environment with the help of the digitized rectified layers. The watershed is delineating on the basis of elevation data and drainage pattern. The drainage and contours of selected watersheds are digitized in arc-GIS environment are shown in fig. from fig. and fig.3

Linear Aspects of Drainage Networks

1. ***Stream order:*** Stream ordering is the first steps in evaluation of morphometric parameters, which helps to understand the nature of linear, relief and areal properties of watershed .the concept of stream order in drainage network is

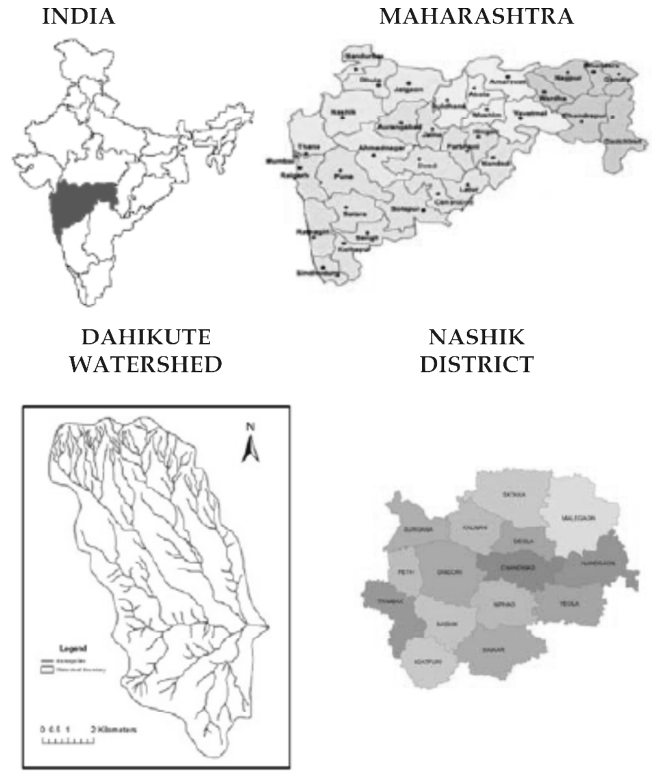

Figure 1: Location Map of Study area

introduced by Horton (1932) significantly modified by Strahler(1957) .The Strahler method is commonly stream ordering method.The stream ordering was done for all the selected watersheds as shown in the drainage maps (Fig.2)

2. ***Bifurcation ratio (R_b):*** It is the ratio of number of stream of any order (Nu) to the number of stream of next higher order (N_{u+1}). It is expressed as,

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

Where,

R_b = bifurcation ratio

Nu = number of streams of u order

N_{u+1} = number of streams of u + 1 order

3. ***Stream length ratio:*** Horton (1945) defined the stream length ratio, R_L, as the ratio of mean length, L_u, of segments of order u to mean length of segments of the next lower order,

$$\overline{L}_{u-1}$$

$$(R_L) = \frac{(\overline{Lu})}{(\overline{L_{u-1}})} \quad (2)$$

4. ***Length parameter:*** The length parameters of selected watersheds are length of perimeter (L_p), maximum length of watershed (L_b), width of watershed (L_w), the length of main stream channel (L_{ms}), Average lengths of contours (L_{ca}) and length-width ratio (L_{bw}). These parameters evaluated in the GIS environment.

Areal Aspects of Drainage Basins

1. ***Area of the watershed:*** The area of the watershed is another important parameter like the length of the stream drainage. The selected watersheds are delineated in ArcGIS environment and their areas have been determined. The areas are expressed in sq km.
2. ***Drainage density:*** Drainage density, D_d, as defined by Horton (1945), is the Ratio of total length of all streams of all orders within a watershed to the total area of watershed

$$Dd = \frac{\Sigma L_U}{A} \quad (3)$$

Where,

D_d = Drainage density.

L_u = Length of stream segments.

A = Watershed area.

3. ***Stream frequency:*** Horton (1945) introduced stream frequency, F_s, as the number of stream segments of all orders per unit area, or

$$F_s = \frac{\Sigma Nu}{A} \quad (4)$$

Where,

F_s = Stream frequency (Km^{-2})

Nu = number of streams of u order

A =area of the watershed (Km^2).

Higher the value of stream frequency more is the run off in watershed.

4. ***Circulatory ratio:*** Miller (1953) used the circulatory ratio to mark the basin shape. It is the ratio of area of watershed to the area of circle having same perimeter as that of watershed,

$$R_c = 3.544\frac{\sqrt{A}}{Lp} \quad (5)$$

Where,

R_c = Circularity ratio (dimensionless),

L_p = Watershed perimeter,

A = Area of watershed

If the watershed with circulatory ratio approaching 1 indicates that watershed shape are like circular as a result it gets low time of concentration.

5. ***Elongation ratio (Re) :*** Elongation ratio is defined (Schumm, 1956) as the ratio of the diameter of a circle with the same area as the watershed to the maximum length of the watershed

$$Re = 1.12838\frac{\sqrt{A}}{L_b} \quad (6)$$

Where,

Re = Elongation ratio (dimensionless)

L_b = Maximum basin length (m)

6. ***Basin shape factor:*** The basin shape factor (S_b) is defined by Horton (1932), is the ratio between the square of the maximum length of watershed and the area of the watershed.

$$S_b = \frac{L_b^2}{A} \quad (7)$$

7. ***Drainage factor:*** Drainage factor, D_f, is the ratio of stream frequency to the square of drainage density.

$$Df = \frac{F_s}{D_d^2} \quad (8)$$

Relief Aspects of Drainage Basins

1. ***Maximum watershed relief :*** Maximum watershed relief is the elevation difference between basin discharge point and the highest point on the basin perimeter. Maximum watershed relief is obtained from the available contour maps of the watersheds.
2. ***Relief ratio:*** Relief ratio is defined by Schumm (1956), is the maximum watershed relief divided by the maximum watershed length.

$$R_F = \frac{H}{L_b} \quad (9)$$

Where,

R_F is Relief ratio,

H is relief and

L_b is maximum watershed length

4. ***Relative relief:*** Relative relief is defined by Melton (1957), is the ratio of maximum watershed relief to the perimeter of watershed. This term is used to measure the relief of watershed.

$$R_r = \frac{H}{L_P} \quad (10)$$

Where,

R_r is relative relief and

L_p is watershed perimeter

4. ***Ruggedness number:*** Ruggedness number is defined by Strahler (1958), is the product of drainage density (D_d) and relief (H). It is computed from the following equation:

$$R_N = \frac{HD_d}{1000} \quad (11)$$

The units used for H and D_d are meter and km^{-1} respectively.

5. ***Average slope of watershed:*** The average slope of the watershed is calculated by using following formula:

$$S_a = \frac{H L_{ca}}{10 A} \quad (12)$$

Where,

S_a = Average slope of watershed, (%)

H = Maximum watershed relief, (m)

A = Area of watershed, (Km^2)

L_{ca} = Average length of contour, (Km)

The average slope of the watershed has influence on the erodibility of a watershed.

6. ***Main stream channel slope:*** The main stream channel slope of each watershed is calculated using the following expressions.

$$S_c = \frac{H_e}{1000 L_{ms}} \times 100 = \frac{H_e}{10 L_{ms}} \quad (13)$$

Where,

S_c = stream channel slope in per cent,

H_e = equivalent height in m.,

L_{ms} = length of main stream in km.

RESULTS AND DISCUSSION

Geomorphological Parameters

The boundary of selected watershed are drawn using digitized Survey of India topo sheets in the ArcGIS 9.3 software environment. In this study, GIS software's ArcGIS and ArcMap 9.3 were used for evaluating the selected geomorphic characteristics considering its simplicity and user-friendly application. The drainage network and contours have been mapped by digitization process using editor tool in the ArcGIS 9.3 software. The area and perimeter of each watershed were computed after converting boundary map to polygon map. The contour value and length of each contour line were computed using digitized Survey of India topo sheets in the ArcGIS 9.3 software and stored in attribute table. Geomorphic characteristics of the selected watersheds were evaluated using ArcGIS 9.3 software interface and are presented in Table 2 and discussed as follows;

The perimeter of the Watersheds ranges from 37.57 km. The total drainage area of the Watersheds varies from 64.85km². It is observed that the order of main stream channel ranges from 2 to 4 from Table 1. It is revealed from Table 1 that number of streams of a particular order decreases with the increase in stream order. It means that the number of streams

Table 1
Number of streams of different order, their length in watershed:

Stream order	*Drainage from toposheet*	
	No. of stream	*Total length of stream (m)*
I	128	88701.00
II	31	28272.68
III	11	21674.28
IV	4	15904.14
V	1	2717.00

Table 2
Morphological characteristics of watershed

Sr. No.	*Watershed Characteristics*	*GIS*
1.	Avg. length of contour, m	2.882 Km
2.	Length of basin, km	14.412
3.	Perimeter, km	37.57
4.	Area, km²	64.85
5.	Principle Stream order	5
6.	Maximum basin length, km	14.412
7.	Stream length ratio	1.55
8.	Bifurcation ratio	3.34
9.	Relief, m	228
10.	Relief ratio	0.0158
11.	Relative relief,	6.06
12.	Elongation ratio	0.6305
13.	Circularity ratio	0.7596
14.	Form factor	0.3122
15.	Shape index	3.20
16.	Stream frequency per sq. km	2.69
17.	Drainage density(km/km²)	2.42
18.	Ruggedness number	0.55
19.	Constant of channel maintenance	0.41
20.	Avg. length of overland flow, km	0.2066
21.	Average slope of watershed (Sa),%	0.10
22.	Length-width ratio	2.69
23.	Time of concentration, *h.*	69.48*h*
24.	Basin Shape factor	3.20
25.	Main stream channel slope	0.0166%
26.	Drainage factor	0.46

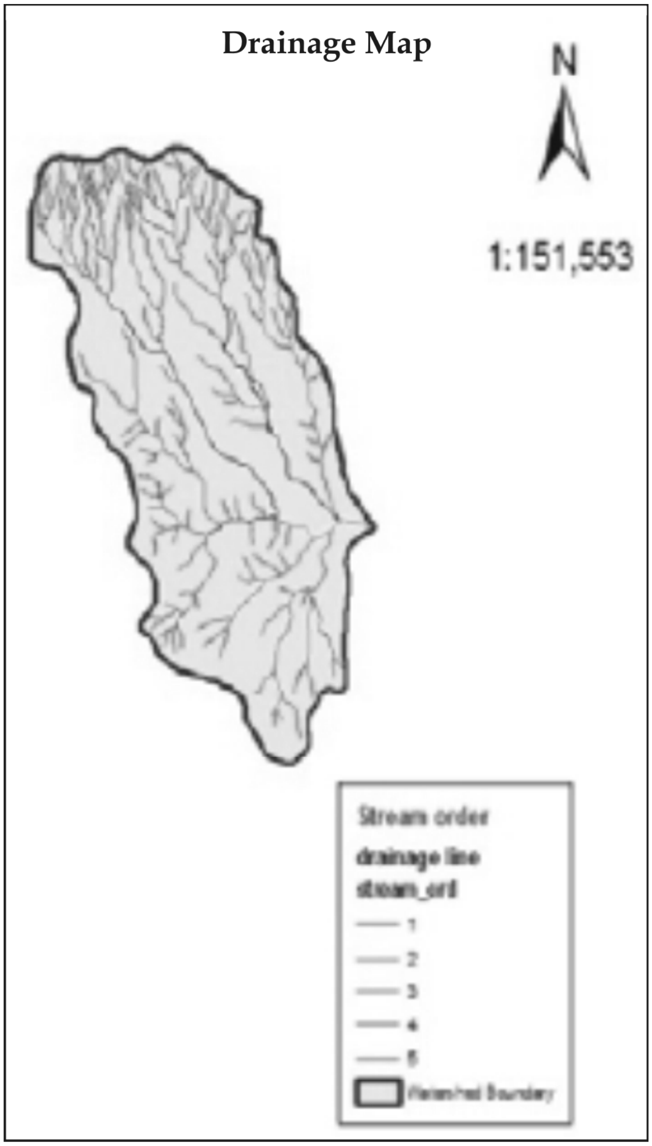

Figure 2: Drainage map of Study Area

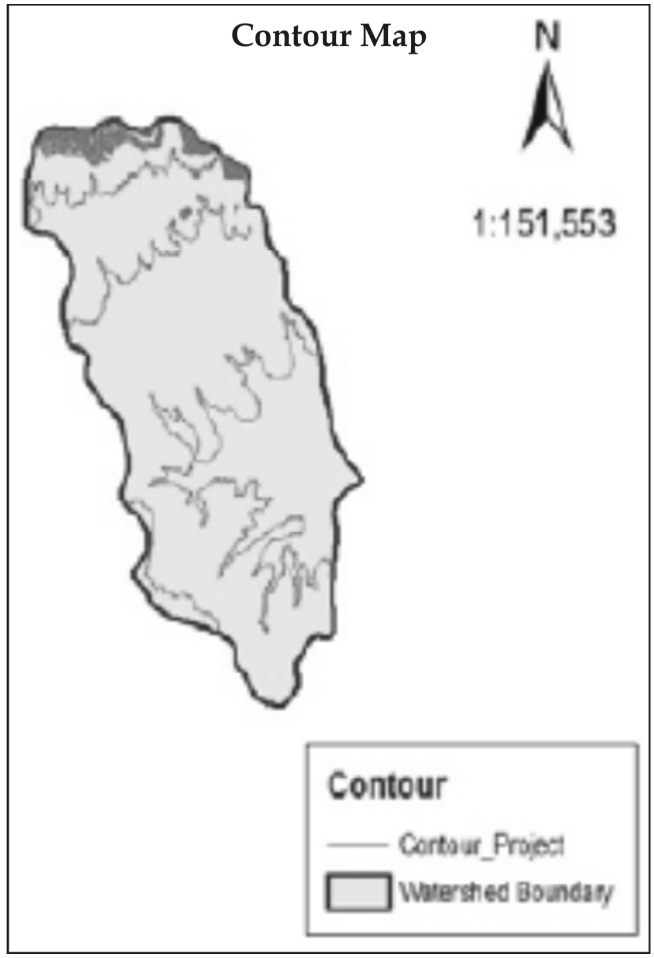

Figure 3: Contour map of Study Area

of any given order is less than that of immediate lower order but more than the next higher order. It is observed from Table 1 that the total length of stream segments is high in first order streams and decreases as the stream order increases. Stream length is maximum in the first order and decreases with the least at fourth order. This change may indicate again the morphology of the terrain and the slope.The Length of the Watersheds is 14.412 km and Width of the Watersheds is 5.34 Km. Stream frequency is related to permeability, infiltration capacity and relief of watershed. The stream frequency and drainage density of the watershed is 2.69 and 2.42 Km/km^2 respectively. It is observed in the watersheds thatthere is large variation in the elevation of the catchments as 228 m. The average length of the contour is 2.882 km.

The stream orders, number of stream, their length are given in Table 1

DIMENSIONLESS PARAMETERS

Thirteen geomorphic Dimensionless Parametersare calculated using data obtained from ARCGIS software.

Bifurcation ratio, stream length ratio, and drainage factor are all indicative of the drainage profile of a watershed. Bifurcation ratio reflects the complexity and degree of dissection of a drainage basin. The Values of bifurcation ratio and stream length ratio is 3.34 and 1.55 respectively. The drainage factor is 0.16 shown in Table No. 2. The linear parameters such as drainage density, stream frequency, bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility, higher the value, more is the erodibility. (NookaRatnam *et.al.*, 2005). The parameters circulatory ratio and elongation ratio are the indicative parameters of shape of the watershed. The circulatory ratio is pretentious by the lithological character of the watershed. The value of elongation ratio varies from 0 (in highly elongated shape) to the unity, that is, 1 (in circular shape). The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (< 0.5). It is observed from Table 2 that the watershed has elongated shape *i.e.* 0.63. The parameter circulatory ratio is observed as 0.75. The length-width ratio of the watershed is 2.69.The basin shape factor as 3.20. All these factors are indicative of the various shapes of the watershed. Shape parameters such as elongation ratio, compactness coefficient, circularity ratio, and basin shape and form factor have an inverse relationship with erodibility (NookaRatnam *et al*., 2005), lower the value, more is the erodibility.

The parameters which involve relief aspect of channel network are relief ratio, relative relief, ruggedness number, average slope and main stream channel slope. More the percentage of average slope of the watershed more are its erosion, Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope. The low ruggedness value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density. It is seen from computed values (Table 2) that average slope of the watersheds as 0.1%. The value of relief ratio, relative relief, ruggedness number and main stream channel slope are observed to range from 0.0158, 6.06, 0.55, and 0.0166 respectively. There is marked variations in regions differing in stage of development and geologic structure. The cycle of erosion can be divided into the three stages *viz.* monadnock (old) (H_{is} 0.3), in which watershed is fully stabilized; equilibrium or mature stage (H_{is} 0.3 to 0.6); and non-equilibrium or young stage (H_{is} > 0.6), in which the watershed is highly susceptible to erosion (Strahler, 1952).

CONCLUSIONS

The drainage network extracted from Arc GIS shows the similarity with toposheet network. It shows that GIS is very good and free source for geomorphological characteristics of watershed. As the circularity ratio (*Rc*) and elongation ratio (*Re*) are less than unity, Length-width ratio is more than two, shows watershed is elongated. The values of Bifurcation ratio (*Rb*) is 3.34. Which supports the watershed is elongated. (For elongated watershed the values generally range from (2-4) As the average slope of watershed is 0.01%, the time of concentration is more (t_c = 69.48 *h*.) The geomorphological characteristics found by GIS is gives better results as of toposheet, which indicates better representation of the topography of the watershed.

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