Quantitative Morphometric Analysis of a Watershed in the Region of Bangar Area, Dewas District, Madhya Pradesh, India.

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ABSTRACT

The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. In the present paper, an attempt has been made to study the quantitative geomorphological analysis of a watershed of Bangar area basin in Madhya Pradesh, India. The morphometric characteristics on the basis of Survey of India toposheets no. 46 M/16 and 55 A/4, at 1:50,000 scale. The drainage basin has been divided in to three sub basin, A, B, and C. result obtained indicated that studied basin exhibits high spatial variation in there morphometric properties, Bifurcation Ratio: 3.96, Drainage Density: 0.25, Length of Overland Flow: 2.02, Stream Frequency: 2.59, Circulatory Ratio: 0.74, Elongation Ratio: 0.74, Form Factor: 0.44, Lemniscates Method: 0.57, Basin Relief: 13.66 and the Ruggedness Number: 3.13. This study would help the local people to utilize the resources for sustainable growth of the basin area.

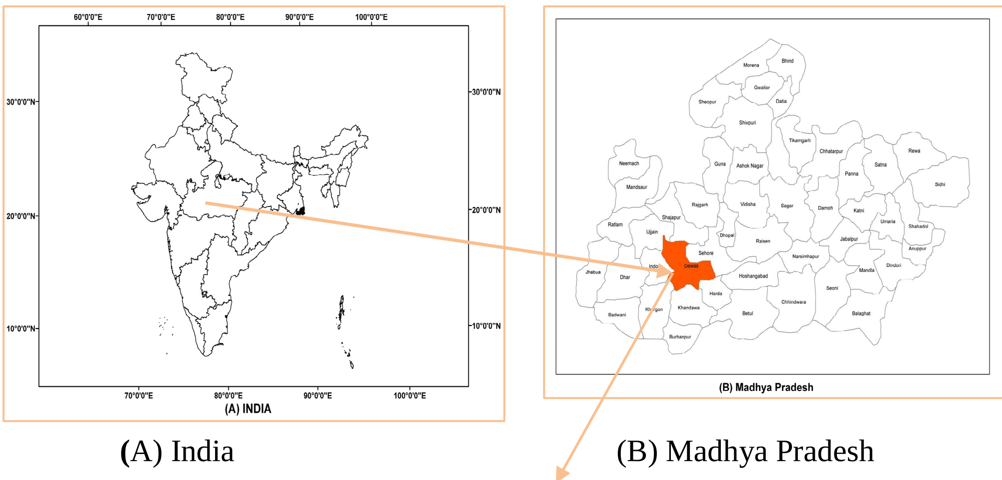
Keywords: Watershed, Morphometric Analysis, Geomorphology, Drainage System,

1. Introduction

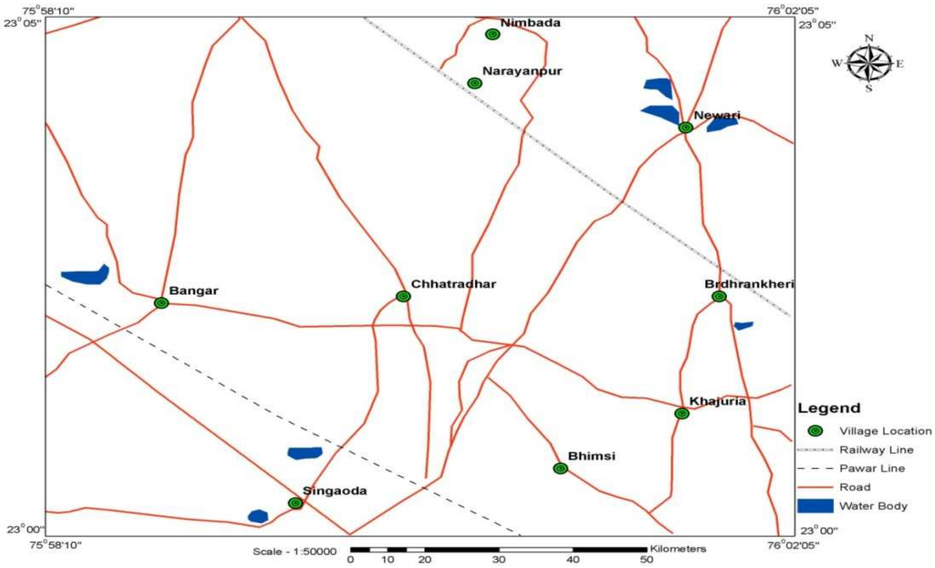
There is no general theory of geomorphology. We cannot cast the subject in a single equation, or set of equations. As with geology, geomorphology is a tangle of physics, chemistry, biology and history. It is also geometry, as the geomorphology plays out in a complex geographic, topographic setting in which both the tectonic and climate processes responsible for driving evolution of the topography change in style and intensity. There is no grand quest for a Universal Law of Geomorphology. Our subject is often sub divided according to the geographic elements of the geomorphic system: hill slopes, rivers, eolian dunes, glaciers, coasts, karst, and so on (Anderson, 2008). “Geomorphology is the interpretative description of the relief features of the earth”. It is distinct branch of science that describes the surface of the lithosphere, explains its origin and interprets its history. In order to do these things successfully, it is necessary to know a good deal about the composition and structure of the rock of the earth and also to understand the processes of weathering, erosion, diastrophism and volcanism that singly or together change the land surface (Worcester, 1939, 1948). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). A main importance in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold & Maddock, 1953; Abrahams, 1984).The quantitative analysis of morphometric parameters is found to be of vast utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods.

2. Location of study area

The study area Bangar constitutes a part of Dewas district of Madhya Pradesh. Bagar area is located that at a distance of 10 kilometer from Dewas Town, Dewas is an important railway station on the Bhopal broad gauge section of western railway and line in amid latitudes 23^0 0’ to 23^0 5’N and longitudes 75^0 58’ 10’’ to 76^0 2’ 5”E. (Survey of India toposheet number-46 M/16 and 55 A/4, Figure 1).



(A) India (B) Madhya Pradesh



(C) Study Area

Figure 1. Location map of study area, Dewas district Madhya Pradesh.

3. Physiographic of Study Area

The research area is dominantly occupied of basaltic lava flow. These rocks are found to expose in the plains as well as along with plateaus of varying heights. The characteristic climate features of the area are- moderate rainfall, high temperature, cold winter and dry summer. The minimum temperature range 1^0C to 2^0C in January and The maximum temperature is of the area varies from 34^oC in March to 45^0C in May and the monsoon period prevails from June to September. The maximum rainfall is occurs during the period from July and August and the humidity of the area observed during April and it gradually increases to August, from September onwards it decreases till April. In summer and monsoon seasons the winds are strong. Winds mainly blow with a speed of 9 to 32 kilometer par hours during March to September. The area witnesses mild winds coming from North-East quarters in the month of October.

4. Geology of the Study Area

The study area forms a part of the Deccan traps volcanic province and is located in Dewas district. Based on the work of geological survey of India the following stratigraphy succession has been established in the area.

Table 1. Geological succession on the Study area.

AGE	FORMATION	LITHOLOGY
Quaternary to Recent	Alluvial	Alluviam composed of fine grained material i.e. clay, silt block cottan soil.
Eocene to Cretaceous	Deccan Trap	Lateritic soil cap, basaltic lava flows.
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The area is covered by the Deccan trap lava flows. The tropical forms of the land include the lava plain, lava plateau and the lava hills. The lava flows are horizontal in their disposition, show variation in thickness. Total eight flows in the Dewas district have been recognized Small patches of alluvium are deposited along Basin of Chambal River and sub-basin of Kshipra River. During traverse, Bangar area is encounter with three different flows of varying thickness.

The bottom and top R.L.S. of basaltic lava flows and their thickness in meters are as given below:

Table 2. Characteristics of Basaltic Lava flows of study area.

S. No.	Flow No.	R.L. in meters above M.S.L.		Thickness in meters
		Bottom	Top	
3.	Flow III	670.00	707.00	37.00
2.	Flow II	640.00	670.00	30.00
1.	Flow I	519.00	549.00	30.00

Source: National Hydrology project, Dewas district.

5. Geomorphic Features of Study Area

The study area Bangar constitute a part of malwa plateau, the Deccan basalts in the area are almost horizontal in extent, except at few place exhibiting the presence of small moulds. The study area in the lava flow their lithological variation drainage patterns relief features. Thickness of soil covers, nature of weathering and climate condition. The small mounds or hillock's soil are found on both side of the state highway Dewas- Ujjain road. These are approximately 535 meter high from the m.s.l. The block cotton soil is present in study area, it is a totally weathering effect on the basaltic rock so it is called black cotton soil, in this soil having high clay content, high moisture content, high plasticity and present the water retaining capacity. Some area is developed in alluvial soil the study area. This is light yellow to gray color soil.

6. Morphmetric Analysis

The morphometric study of the Bangar watershed was prepared based on published topographic maps 46 M/16 and 55 A/4, on a 1:50,000 scale. The different type of morphometric parameters have been determined by use of Rota meter. The bangar drainage basin has been divided three sub-basins, A, B, and C and these having different of streams Ist order, IInd order and IIIth order. The geomorphic observation of the study area verified by undertaking field observed. The drainage map of the study area has been prepared (Figure. 2).

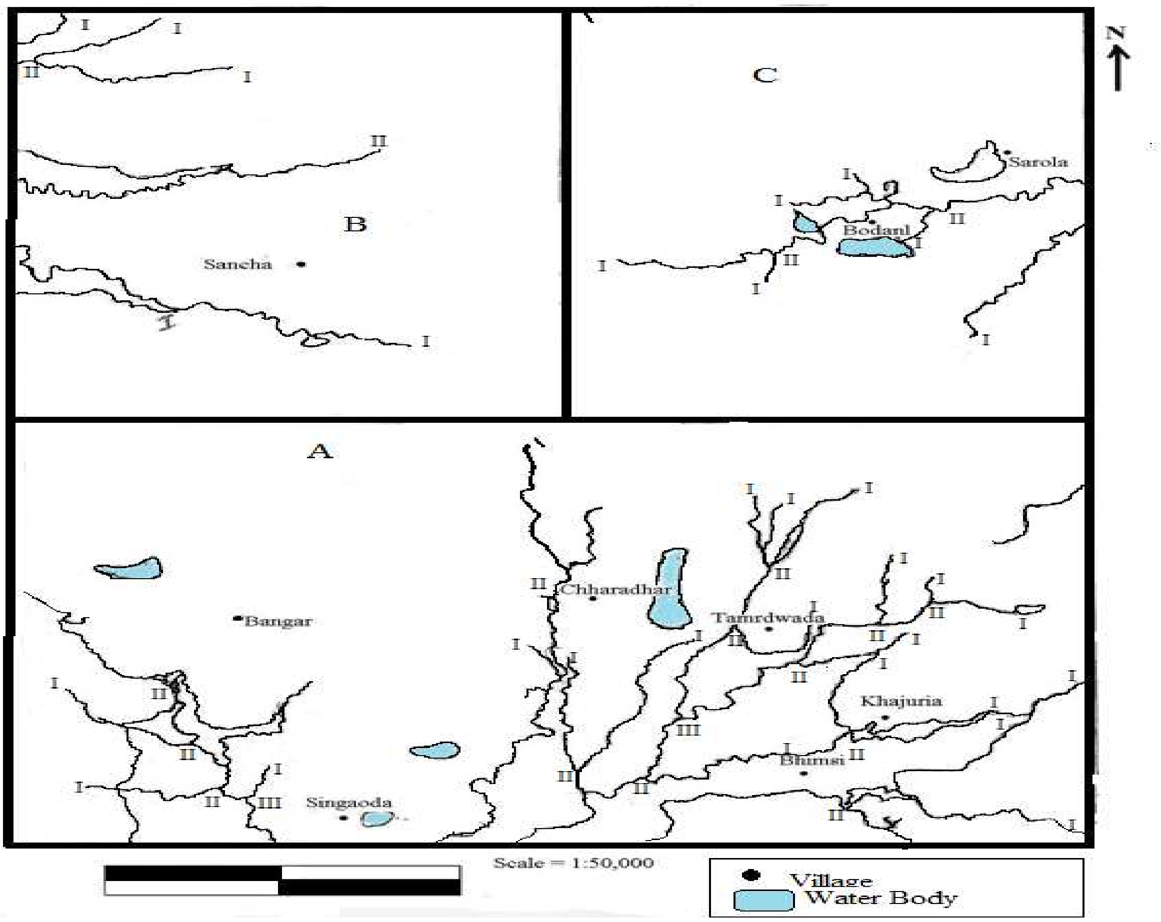

Figure 2. Showing drainage basin of Bangar Study area, Dewas district, Madhya Pradesh, India.

6.1. Bifurcation Ratio

The bifurcation ratio describe the S.A. Schumn (1956) which is related to the branching pattern of the drainage network, it is used the ratio of the number of streams of any given order to the number of streams in the next higher order and is expressed in terms of the following equation –
Bifurcation ratio is a dimensionless property of the drainage density, stream entrance angle, lithological characteristics, basin shapes, basin areas etc.

$$Rb = \frac{N\mu}{N\mu+1}$$

Where,

Rb = Bifurcation ratio
$N\mu$ = No. of stream segments of a given order and
$N\mu + 1$ = No. of stream segments of next higher order

Table 3. Showing values of Bifurcation Ratio of drainage basin, Dewas district, Madhya Pradesh.

Sub-basin	Stream Order	Stream No.	Rb	Average
A	1	41	1.86	3.96
	2	21	3.00	
	3	6	-	
B	1	19	9.5	
	2	1	-	
C	1	9	1.5	
	2	5	-	

The bifurcation ratio (Rb) sub basin A, B and C, these are different basin values. The lowest values basin 'C' is a 1.5 and then 'A' basin 1.86 and higher bifurcation ratio value of basin 'B' 9.5. The average of the bifurcation ratio is 3.96.

6.2.Drainage Density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. It is equal to the reciprocal of the constant of channel maintenance and equal to the reciprocal of two times the length of overland flow. Drainage density denoted the total stream length per unit area. Horton (1932) explains density as: A ratio of total length all stream segment in a given drainage basin of total basin area. It is derived as follows-

$$D_d = \frac{L_k}{A_K}$$

Where,

L_k = Total length of all stream segments of a basin

A_k = Total area of the basin

Table 4. Show drainage density of study area drainage basin of Dewas district, Madhya Pradesh.

Sub basin	Area of basin	Total length of basin	D_d	Ratio
A	44	9	0.20	0.25
B	32	9.1	0.28	
C	32	9	0.28	

The low drainage density (D_d) of basin A, B and C. the value of D_d value, basin, 'A' 0.20, 'B' 0.28 and 'C' 0.28. The lowest drainage density value is basin, 'A' 0.20. Low drainage density exists having high permeable sub soil material under dense vegetation cover and low relief in contrast high. The high drainage density value basin 'B' and 'C' 0.28, high drainage density indicate the presence of impermeable sub surface material and high relief and drainage density average of all basins 0.25.

6.3.Length of Overland Flow

Overland flow or popularly known as surface runoff is considered to be effective agent and process of slope erosion and slope modification. The surface flow of water resulting from rainfall parallel to the slope is called overland flow. According to Horton (1932) and Schumn (1956) considered the length of overland flow as horizontal flow path from the divided to the stream in first order basin and is a measure of stream spacing and degree of dissection and is approximately one half. The mutual drainage density,

$$L_O = \frac{1}{2D_d}$$

Where,

Lo = Length of overland flow

D_d = Drainage density

Table 5. Showing length of overland flow of study area drainage basin**.**

Basin	Drainage Density	Lo	Average
A	0.20	2.5	2.02
B	0.28	1.78	
C	0.28	1.78	

The length of over land flow value is basin 'A' 2.5 'B' 1.78 and value of 'C' basin also 1.78. The total value of average 2.02 and indicate the water covers a very short distance before immerging into the drainage channel.

6.4.Stream Frequency

A measure of topographic texture expressed as the ratio of the number of streams in a drainage basin to the area of the basin, also known as channel frequency.

$$S_f = \frac{\sum N\mu}{A}$$

Where,

S_f = Stream frequency

Nμ = Sum of all number of stream basin

A = Total area of drainage in kilometer square

Table 6. Showing stream frequency of study area drainage basin.

Sub basin	Area of basin(Km^2)	No. of stream	Sf.	Average
A	44	68	1.54	2.59
B	32	20	0.62	
C	32	14	0.43	

The lowest stream frequency (Sf) value is C 0.43. It is indicate the high permeable lithology and low relief of the basin. The sub basin 'A' is the high value stream frequency it is 1.54 and it's indicate the high relief, impermeable sub surface material and low the infiltration capacity of basin. The total average is stream frequency value of the area 2.59.

6.5.Circulatory Ratio

According to Miller (1953), the circulatory ratio (Rc) is the ratio between the basin and the area of circle having the same perimeter as that of the basin. It is calculated by this method-

$$Rc = \frac{4\pi A}{\rho^2}$$

Where,

A = Stream frequency

ρ^2= Basin parameter

Table 7. Show the Rc of study area drainage basin.

Sub basin	Area of basin	Perimeter basin	Rc	Average
A	117	44	0.75	0.74
B	60	32	0.73	
C	61.2	32	0.75	

The circulation ratio (Rc) value is indicating that the basin shape is like circular as a result it scope for uniform infiltration, which further subjected to lithology shape and overland. The sub basin ‘B’ is the value of 0.73, it is lowest value and high value of circulatory basin ‘A’ and ‘C’ are same value 0.75and the average value of circulatory ratio 0.74.

6.6.Elongation Ratio

The elongation ratio described the S.A. Schumm (1956); it is the ratio between the diameters of the circle having the same area and the maximum length of the basin. This formula is-

$$Re = 2\sqrt{\frac{A}{\Pi / L}}$$

Where,

A = Area of basin

L = length of basin

Table 7. Showing Elongation Ratio of study area drainage basin.

Sub basin	Area of basin	Basin length	Re	Average
A	44	9	0.83	0.74
B	32	9.1	0.69	
C	32	9	0.70	

In the elongation ratio (Re), show the higher value indicates high infiltration and low runoff and the lower value show the low infiltration and high runoff. The higher value of elongation ratio basin ‘A’ 0.83and low value of elongation ratio basin ‘B’ 0.69.the all average of elongation ratio value 0.74.

6.7.Form Factor

The form factor is expressed on the ratio between area and square root of the basin length.

$$F = \frac{A}{L^2}$$

Where,

F = Area of basin

L = Basin length

Table 8. Showing Form Factor of study area drainage basin.

Sub basin	Area of basin	Basin length	F	Average
A	44	9	0.54	0.44
B	32	9.1	0.38	
c	32	9	0.39	

The form factor (F) shows having high side flow for large duration and low form factor show the main flow for shorter duration.sub basin 'A' value of 0.54 show the high side flow for large duration and 'B' basin value is 0.38 so less side flow for shorter duration, and the 'C' basin value of form factor 0.39, and the total average value FF 0.44.

6.8.Lemniscates Method

This method described the Pogorzelski (1957), it is generally believed that if all the factors controlling drainage basin development remain constant, the basin shape becomes more and circular with the advancement of stages of cycle of erosion and the basin of its development. It is based upon the expression at the basin with lemniscates curve (ratio of basin area and basin length). Lemniscates determined by the symbol 'K' it is generally expressed by the following method-

$$K = \frac{L^2}{4A}$$

Where,

L = Basin of length

A = Basin of area

Table 9. Showing lemniscates of study area drainage basin.

Sub basin	Length of basin	Area of basin	K	Average
A	9	44	0.46	0.57
B	9.1	32	0.64	
C	9	32	0.63	

The value of lemasinscate ratio (K) is calculated for the study. The total drainage sub basin are A, B and C, it is a show the different value, the lowest value sub basin 'A' 0.46 and 0.63 sub basin 'C'. High value of basin 'B' 0.64 and the total lamonscate ratio value 0.57. The drainage is more or less elongated in shape.

6.9.Basin Relief

Basin aspect of the sub basin plays an important role in drainage development surface sub surface water flow, permeability, landforms, development and associated features of the terrain. Basin is the difference between the highest and lowest point in the basin area (Strahler, 1952).

H = highest point – lowest point of basin

Table 10. Show the Basin relief in study area.

Basin	Highest point of basin	Lowest point of basin	H	Average
A	541	515	26	13.66
B	532	526	6	
C	537	525	9	

Basin relief has been calculated for all sub basins, its show the value for basin 'A' 26, B 6 and basin 'C' 9 meter with an average of 13.66 meter. The low basin relief value show the low gravity of water flow, high infiltration and low runoff condition of sub basin, when high basin relief value just opposites. The high basin relief value shows the high gravity of water flow, low infiltration and high runoff.

6.10. Ruggedness Number

Strahler (1958) defined the Ruggedness number, it as the product of maximum relief and drainage density.

$$n_d = H \times D_d$$

Where,

H = maximum basin relief.

Table 11. Showing nd of study area drainage basin.

Sub basin	Maximum basin relif	Dd	nd	Average
A	26	0.20	5.2	3.13
B	6	0.28	1.68	
C	9	0.28	2.52	

Ruggedness number (n_d) indicates the structural complexity of a terrain in association with relief and drainage density. The sub basin 'B' having a low rugged no. 1.68 value and sub basin 'A' ruggedness number value a high 5.2 and the average ruggedness number value is 3.13. The basin having high ruggedness number value is susceptible to soil erosion and sedimentation load (Strahler, 1958).

7. Conclusion

Watershed prioritization is considered as one of the most important aspects of planning and development for natural resources for water conservation measures. The present study recapitulates the integrated approach for developing a preliminary prioritization of watersheds in Bangar area catchment. The area reveals lithological variation, drainage patterns. Relief features, thickness of soil cover, nature of weathering and climate condition. These parameters help in the considerate the nature of drainage basin. The Bangar drainage basin specify that study area is characterized by presence of stream ranging from 1st order to 3rd order, the low bifurcation ratio indicates less structural disturbance, length of overland flow point out that before reaching to drainage channel flow to a very small distance. The small mounds or hillocks of soil are present. These are approximately 535 meter high from the M.S.L. Morphometric parameters are determined and described.

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