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Morphometric analysis of Urmodi basin using geographical information system

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Abstract
Morphometric analysis of Urmodi basin was carried out using geographical information system. Detailed drainage map of the area was prepared from the Survey of India (SOI) to posheets. The morphometric parameters considered for analysis includes the linear, areal and relief aspects of the basin. The Urmodi basin covers an area of 43,719 ha and is a 5th order drainage basin. Form factor of Urmodi basin was 0.38 per km represents elongated type of watershed. Circulatory ratio of Urmodi basin was 0.32 indicated that basin was elongated in shape having low discharge of runoff and high permeability of sub soils conditions. Elongation ratio of Urmodi basin was 0.69 indicated high relief and steep slope in some portion of the study area. There is need of conservation, utilization and management of the land and water resources for betterment of economic status of country. This study would help the local people to utilize the land and water resources for sustainable development of the basin area.

Keywords: Morphometry, drainage, Urmodi basin, geographical information system

1. Introduction

Watershed is an independent hydrological unit from which runoff resulting from precipitation flows past a single point into a large stream, river, lake or pond. The large variety of factors that can affect the behavior of a watershed fall into two categories, first the permanent characteristics of drainage basin, such as, its size or drainage density i.e. drainage morphometry and second, transient or variable characteristics, such as amount of precipitation, type of land use so on. Morphometric analysis of watershed requires measurement of linear features, gradient of channel network and contributing ground slopes of drainage basin.

To effectively interpret the morphometric parameters, remote sensing and geographical information system (GIS) based have been used. The Geographical Information Systems (GIS) is gaining importance as a powerful tool for the management of information in agriculture, natural resources assessment, environmental protection, and conservation. There is considerable potential for the use of GIS technology as an aid to soil erosion inventory with reference to soil erosion modeling and erosion hazard assessment. A number of modeling approaches both empirical and physical process based are in vogue to quantitatively assess erosion by soil loss. GIS technique is very effective tool for integrating inputs for modeling of soil loss.

2. Materials and Methods

The Krishna river catchment lies between the latitude 13^0 00’ N and 19^0 30' N and longitude 73^0 23' E and 80^0 30' E. The basin has drainage area 2, 58,945 sq.km out of which 26.8% lies in Maharashtra, 43.8% in Karnataka and 29.4% in Andhra Pradesh (Rao 1975) [5]. In terms of catchment area, this basin is fifth among the Indian rivers and the largest river after Godavari in southern India. The river rises in the Western Ghats from a slender spring near Mahabaleshwar in the Maharashtra state at an elevation of 1337 m, about 64 km from Arabian Sea. Krishna is the main river and its main tributaries are Koyna, Kudali, Venna, Urmodi, Tarli, Yerla, and Wasna. The study area lies between 17°30' N to 17°45' N latitude and 73°45' E to 74°00' E longitude. The total valley area covered by Urmodi basin is 43,719 ha. Mean annual rainfall in the basin is of the order of 1250-1800 mm and about 80% of rain precipitates during the summer monsoon (June to September). Urmodi basin is having an undulating topography with slope ranging between 4 to 33%.

The maps showing drainage details were prepared from SOI toposheet 47 K/14, 47 K/02, 47 K/03 of 1:50,000 scale. Morphological characterization is the systematic description of watershed’s geometry. Geometry of drainage basin and its stream channel system required the following measurements (Singh, 2003):

1. Linear aspect of drainage network
2. Areal aspect of drainage basin
3. Relief aspect of channel network and contributing ground slopes

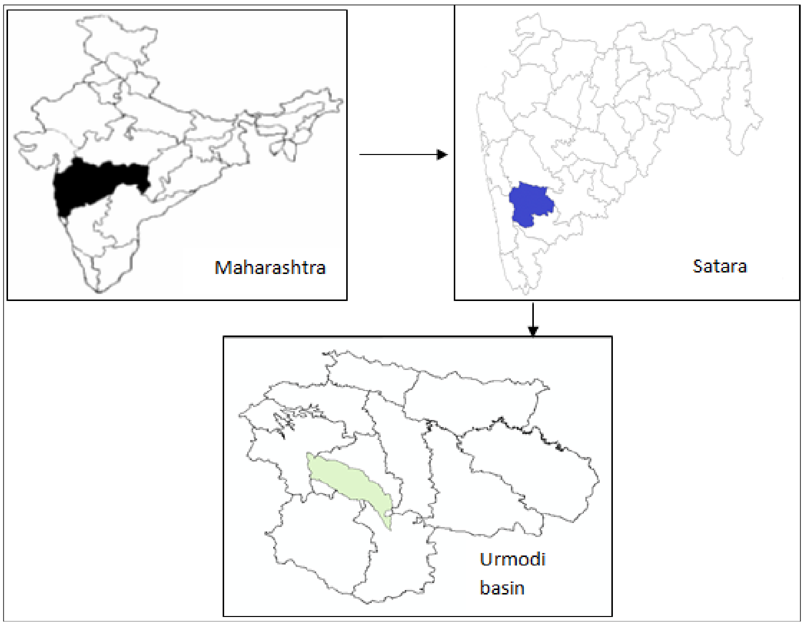

Fig 1: Location map of study area

2.1 Linear Aspects of Drainage Networks

Stream order: The stream order represents the degree of stream branching with watershed.

Stream number: The count of stream channel in its order is known as stream number.

Bifurcation ratio (R_b): Bifurcation ratio is defined as the ratio of number stream segments (N_u) of a given order u to the number of stream segments of next higher order.

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

Where
R_b = bifurcation ratio
N_u = number of streams of order u,
N_u+1= number of streams of order u+1

Mean stream length ($\bar{L}_u$): Stream length is defined as the summation of the total length of all streams to the number of stream.

$$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$$

Where,
$\bar{L}_u$ = mean length of channel of order u,
N_u = total number of stream segments of order u

Stream length ratio (R_l): It is defined as the ratio of mean length of stream segment (L_u) of order 'u' to the mean length of stream segment of next lower order.

$$R_L = \frac{\bar{L}_u}{\bar{L}_u - 1}$$

Where,
$\bar{L}_u$ = average length of stream of order u,
$\bar{L}_u - 1$ = average length of stream of next lower order

2.2 Areal Aspects of Drainage Networks

Form factor (R_f): Horton (1932) [1] explained the basin shape through a term called as form factor, which is defined as the basin area to the square of the basin length.

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

Where,
A_u = basin area,
L_b = basin length

Circulatory ratio (R_C): Circulatory ratio is the ratio of basin area to the area of circle having equal perimeter as the perimeter of drainage basin.

$$R_c = \frac{A_u}{A_c}$$

Where,
A_u = basin area,
A_C = area of circle

Elongation ratio (R_l): Schumn (1956) used the elongation ratio as an index to mark the shape of drainage basin. It is defined as the ratio of diameter of a circle which has same area as the basin to the maximum basin length.

$$R_l = \frac{D_c}{L_{bm}}$$

Where,
D_c = diameter of circle,
L_{bm} = maximum basin length

Drainage density (D_d): It is defined as the ratio of total length of all stream segments within the watershed to the total area of the watershed.

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

Where
Lu = length of stream segment,
A = watershed area

Constant of channel maintenance (C): The constant of channel maintenance is the inverse of drainage density.

$$C = \frac{1}{D_d}$$

D_d = drainage density

2.3 Relief Aspects of Drainage Networks

Relief: It is the elevation difference between reference points located in drainage basin.

Relief ratio (R_n): It is defined as the ratio of relief to the horizontal distance on which relief was measured.

$$R_n = \frac{H}{L_h}$$

Where,
H= relief,
L_h = horizontal distance

Relative relief (R_{hp}): It is defined as the maximum basin relief (H) to the perimeter (P) of basin.

$$R_{hp} = \frac{H}{P} * 100$$

Where,
H = basin relief,
P = perimeter of basin

Ruggedness number: The product of relief (H) and drainage density (D_d) is called ruggedness number.

$$Ruggedness\ number = H * D_d$$

Where,
H = basin relief,
D_d = drainage density

Length of overland flow (L_g): The length of overland flow is approximately equals to half of reciprocal of drainage density (Horton, 1945) [2]. It is the length of water over the ground before it gets concentrated into definite stream channels.

$$Length\ of\ overland\ flow = \frac{1}{2D_d}$$

D_d = drainage density

3. Results and Discussion

3.1 Linear Aspects of Drainage Networks

Stream order

In the present study, ranking of streams has been carried out based on the method proposed by Straphler, 1964 [10]. The total numbers of streams were 3245 of which 1169 were 1st order streams, 576 were 2nd order, 272 were 3rd order, 186 were 4th order, 143 were 5th order. It was also observed that there was decrease in total number of streams as the stream order increases.

Stream number

The numbers of the stream segments were decreasing as the stream order were increasing. The higher amount stream order indicated lesser permeability and infiltration. It was observed that maximum frequency was in case of first order streams. It was noticed that there was decrease in stream frequency as the stream order increases.

Bifurcation ratio

Bifurcation ratio of watershed varied from 1.30 to 2.12. Bifurcation ratio of I/II, II/III, III/IV, IV/V was 2.03, 2.12, 1.46 and 1.30. It was observed that the bifurcation ratio was not same from one to another. These irregularities were dependent upon the geological and lithological development of the drainage basin (Straphler, 1964) [10]. In the study area bifurcation ratio were showing low values indicates that the sub-basins were less affected by structural disturbances.

Mean stream length

Mean stream length of 1st order stream was 0.77 m, 2nd order stream was 0.50 m, 3rd order stream was 0.42 m, 4th order stream was 0.28 m, 5th order stream was 0.35 m. Total length of stream decreases with increase in order of stream. However, the 4th order mean stream length was less as compared to 5th order streams. This may be due to the geomorphologic, lithological and structural control and contrast.

Stream length ratio

Stream length ratio of V/IV order was 1.23, IV/III order was 0.68, III/II order was 0.83 and II/I order was 0.65. These variations in ratio in the study area were due to variations in slope and topography.

3.2 Areal Aspects of Drainage Networks

Form factor

The form factor value of Urmodi basin was 0.38 per km. The lower value of form factor represented elongated shape of watershed. The elongated basin with low form factor indicated that the basin had flatter peak for longer duration. Flood flows in such elongated basins were easier to manage than of the circular basin.

Circulatory ratio

The circulatory ratio of Urmodi basin was 0.32. Circulatory ratio less than 0.5 indicated that it is elongated, where as circulatory ratio the greater than 0.5 indicated that basin is circular in shape and are characterised by the high to moderate relief and the drainage system were structurally controlled. In the study area circulatory ratio value was 0.32, indicating that the basin was elongated in shape having low discharge of runoff and high permeability of sub soils conditions.

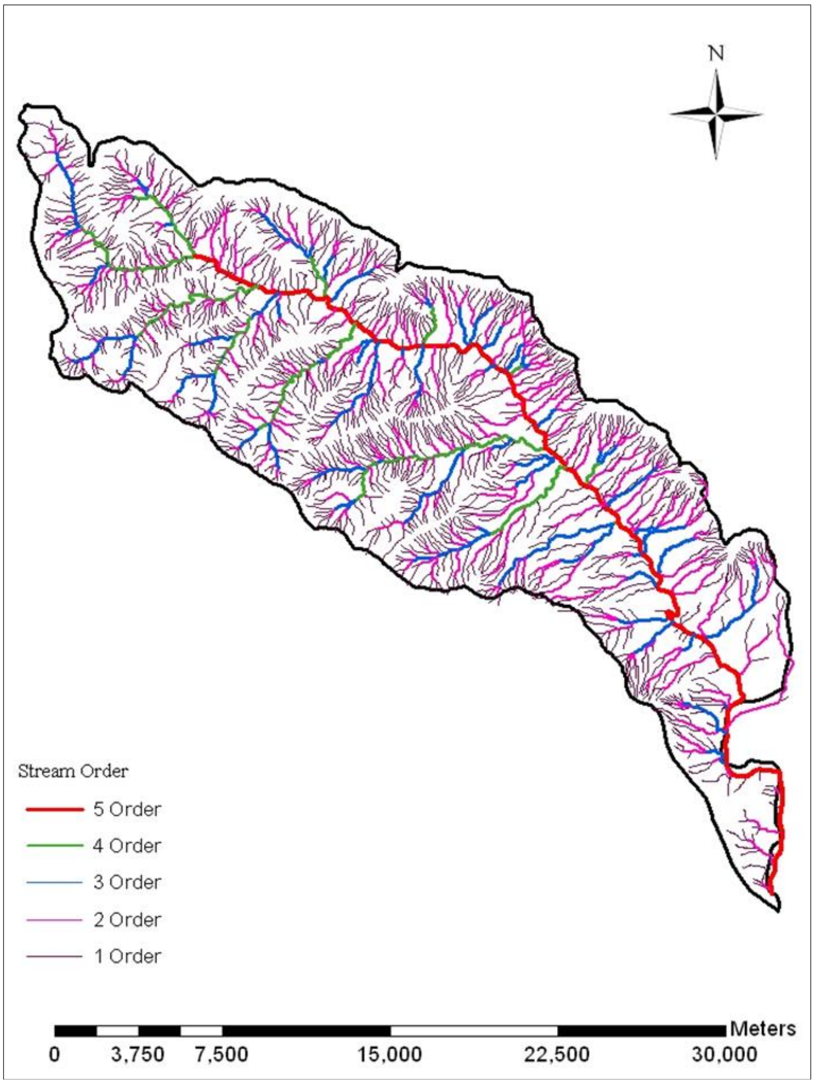

Fig 2: Drainage map of Urmodi Basin

Elongation ratio

The elongation ratio values generally exhibit variation from 0.6 to 1.0 over a wide variety of climatic and geologic types. The elongation ratio of Urmodi basin was 0.69. This elongation ratio indicated high relief and steep slope in some portion of the study area.

Drainage density

The drainage density of Urmodi basin was 3.22 km/Km^2. The high drainage density was due to the regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief.

Constant of channel maintenance

The constant of channel maintenance was found 0.31 km for Urmodi basin. It indicated that magnitude of surface area of watershed needed to sustain unit length of stream segment.

3.3 Relief Aspects of Drainage Networks

Relief

Total relief for Urmodi basin was 600 m. This indicated high relief and steep slope in the Urmodi basin.

Relief ratio

The relief ratio was 0.017 for Urmodi basin. This value of relief ratio indicated the presence of hilly region in the watershed.

Relative relief

Relative relief for the Urmodi basin was 0.47 which is considered low.

Ruggedness number

In the present study, ruggedness number was 1.92. This number represented that if drainage density was increased; keeping relief as constant, the average horizontal distance from drainage divide to the adjacent channel was reduced. On the other hand if relief is increased by keeping drainage density constant, the elevation difference between the drainage divide and adjacent channel goes on increasing.

Length of overland flow

The length of overland flow of the study area was 1.60 km^2/km. The high value of length of overland flow indicating high relief whereas low values of length of overland flow are indicating low relief. In the study area high value of length of overland flow indicates the high relief.

4. Summary and Conclusion

The geomorphological analysis has been carried out through measurement of linear, areal and relief aspects of basin. The quantitative analysis of morphometric parameters is found to be immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. The presence of the maximum number of the first order segments shows that the basin was subjected to erosion and also that some areas of the basin were characterized by variations in lithology and topography. In Urmodi basin stream frequency decreases as the stream order increases. In the Urmodi basin bifurcation ratio were showing low values indicates that the sub-basins were less affected by structural disturbances. The variations in stream length ratio in the Urmodi basin were due to variations in slope and topography. The values of form factor and circulatory ratio suggested elongated type of watershed. Elongation ratio indicated that watershed has high relief and steep slope. High drainage density indicated that the region was of weak or impermeable surface materials, sparse vegetation, and mountainous relief. The geo morphological characteristics of Urmodi basin are helpful for the people living in the area for sustainable development.

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