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Morphometric analysis of Urmodi basin, Maharashtra using geo-spatial techniques

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ABSTRACT

Morphometric analysis was carried out to analyze and determine the drainage pattern and characteristics of Urmodi river basin using topographical maps, SRTM data and geo-spatial technique. The study area, Urmodi river basin is one of the sub-basin of Krishna river basin in Satara district of Maharashtra and it covers 412. 29 sq. km area. Morphometric parameters like stream order, stream length, bifurcation ratio, drainage density, stream frequency, relief ratio, elongation ratio, circularity ratio and compactness constant are calculated using various techniques. The drainage density of the basin is 3.30 km/sq. km.

Keywords: Morphometric analysis, Geo-Spatial Techniques, Urmodi basin

1. Introduction

Morphometry is defined as the measurement of the shape and mathematical analysis of drainage (Clarke, 1966). Morphometric studies in the field of hydrology were first initiated by Horton (1940) and Strahler (1950). Geo-spatial technologies, such as Geographic Information Systems (GIS) and Remote Sensing (RS), are efficient tools in delineation of watershed and drainage network for the water resources planning and management. In the present study attempt has been made to analysis the nature and structure of Urmodi basin by applying various morphometric techniques. The morphometric analysis of the drainage basin and channel network play a vital role for understanding the hydrological behavior of drainage basin and to analyze flood, geological and geomorphological structure.

1.1 Objective of the study

The main objective of the present work is analyzing the morphometric characteristics of Urmodi basin using Geo-spatial techniques.

2. Study area

The study area Urmodi river basin extends between 17^0 28’ to 17^0 44’ N Latitude and 73^0 47’ to 74^0 7’ E Longitude and it covers the 412.29 sq.km area (Figure 1). The Urmodi basin is one f the sub-basin of Krishna river basin in Satara district of the Maharashtra state situated in western Maharashtra. Major part of the Basin is undulating and hilly area. The upper river course is surrounded by Sahyadri off shoots and water divider. The average height of this area is 950 m above mean sea level.

2.1 Database and methodology

The Survey of India toposheet numbers 47 G/14, 47K/2, and 47K/3, on the scale of 1:50000 were used for the present study. The topomaps are georeferenced and rectified using ArcGIS

9.2 software with WGS 1984 datum and digitized the drainage network of the river. Stream ordering method as suggested by the Strahler has been employed. The different morphometric parameters have been calculated by using various formulae.

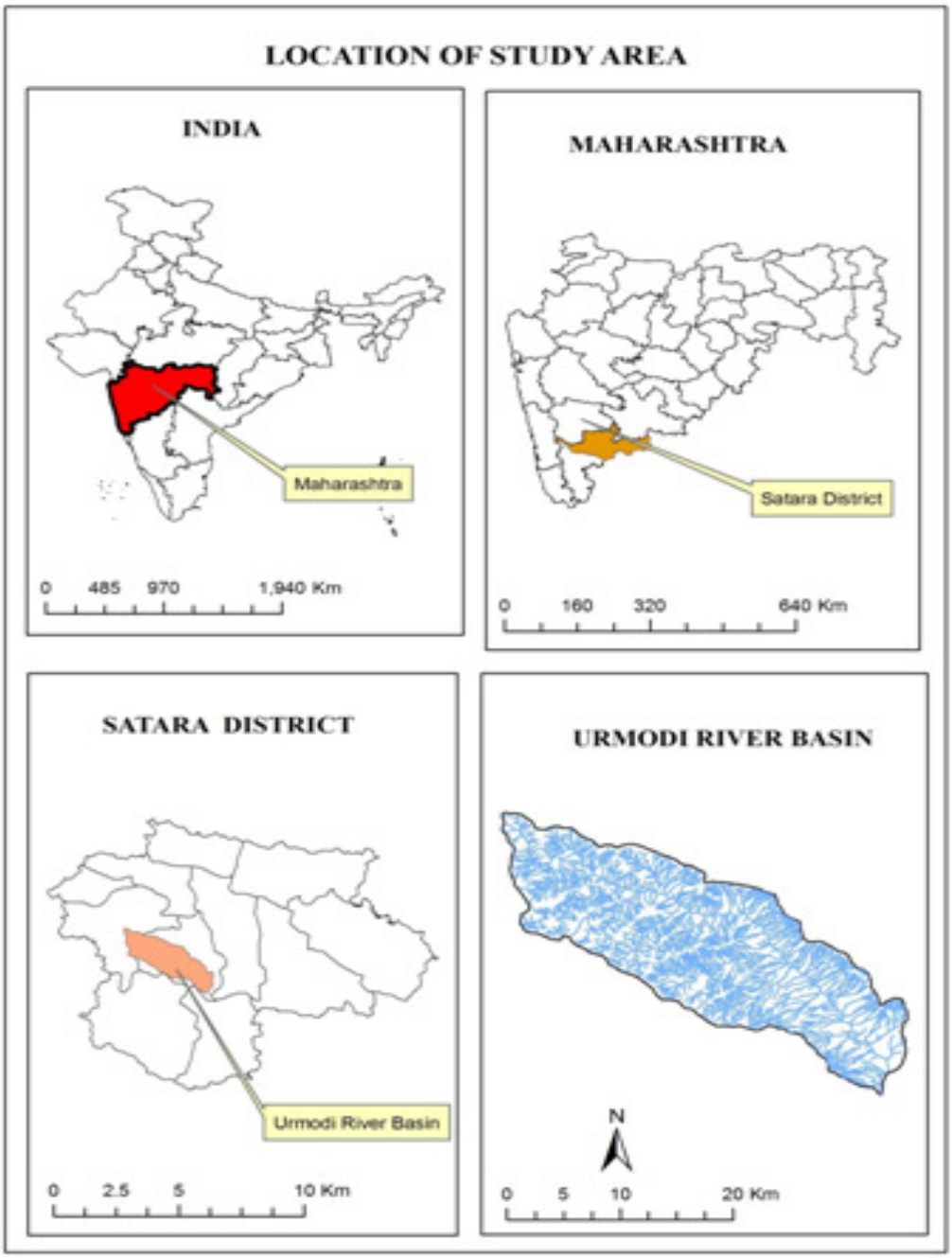

Figure 1: Location map of the study area

3. Result and discussion

The linear aspect of the drainage network morphometry incorporates stream order, stream length, drainage density, drainage frequency and bifurcation ratio etc. The aerial aspect of the drainage network morphometry incorporates basin area, stream frequency, constant of channel maintenance, texture ratio, Elongation Ratio, circulatory ratio and form factor etc. Relief aspects

3.1 Linear aspects of the basin

The linear aspects of drainage network such as Stream Order (Nu), Bifurcation Ratio (Rb), Stream Length (Wu), and stream length ratio.

3.2 Stream order

In the present study, first step is to determine the stream orders for the drainage analysis (Table 1). The channel segment of the drainage basin has been ranked according to Strahler stream ordering method (Figure 2).

Table 2: Stream Order, Number of Stream, and Stream Length

River Basin	Stream order (u)	Number of Stream (Nu)	Total Length of Stream in km(Lu)	Stream Length Ratio (R1)
Urmodi	I	1148	876.97	3.12
	II	285	281	2.63
	III	59	106.81	1.98
	IV	14	54	1.31
	V	1	41	-
Total		1507		-

3.3 Stream length (Lu)

Stream length is one of the most significant hydrological features of the basin as it levels surface run off characteristics streams of relatively smaller length are characteristic of areas with larger sloped and finer textures longer length of streams are generally indicative of flatter gradients generally the total length of streams segment is maximum in first order stream and decreases as the number of stream of various order in the basin are counted and there length from mouth to drainage divide are measured with the help of GIS software.

3.4 Stream Length Ratio (RL)

The ratio in between the average lengths of successive orders is stream length ratio (Horton 1945) In the southern half part of basin large number of small streams are developed where the formations at upstream side and are less permeable stream length ratio of Urmodi basin (Table 1).

3.5 Bifurcation Ratio (Rb)

Bifurcation Ratio (Rb) is defined as ratio of the number of stream of a given order (Nu) to the number of streams of the next higher order (Table 2). Bifurcation ratio characteristically ranges between 3.0 and 5.0 for basin's in which the geologic structures so not distort the drainage pattern (Strahler, 1964).

Table 2: Bifurcation Ratio (Rb)

1^{st} order /2^{nd} order	2^{nd} order/3^{rd} order	3^{rd} order/4^{th} order	4^{th} order/5^{th} order	Mean Bifurcation Ratio
4.02	4.83	4.21	14	6.765

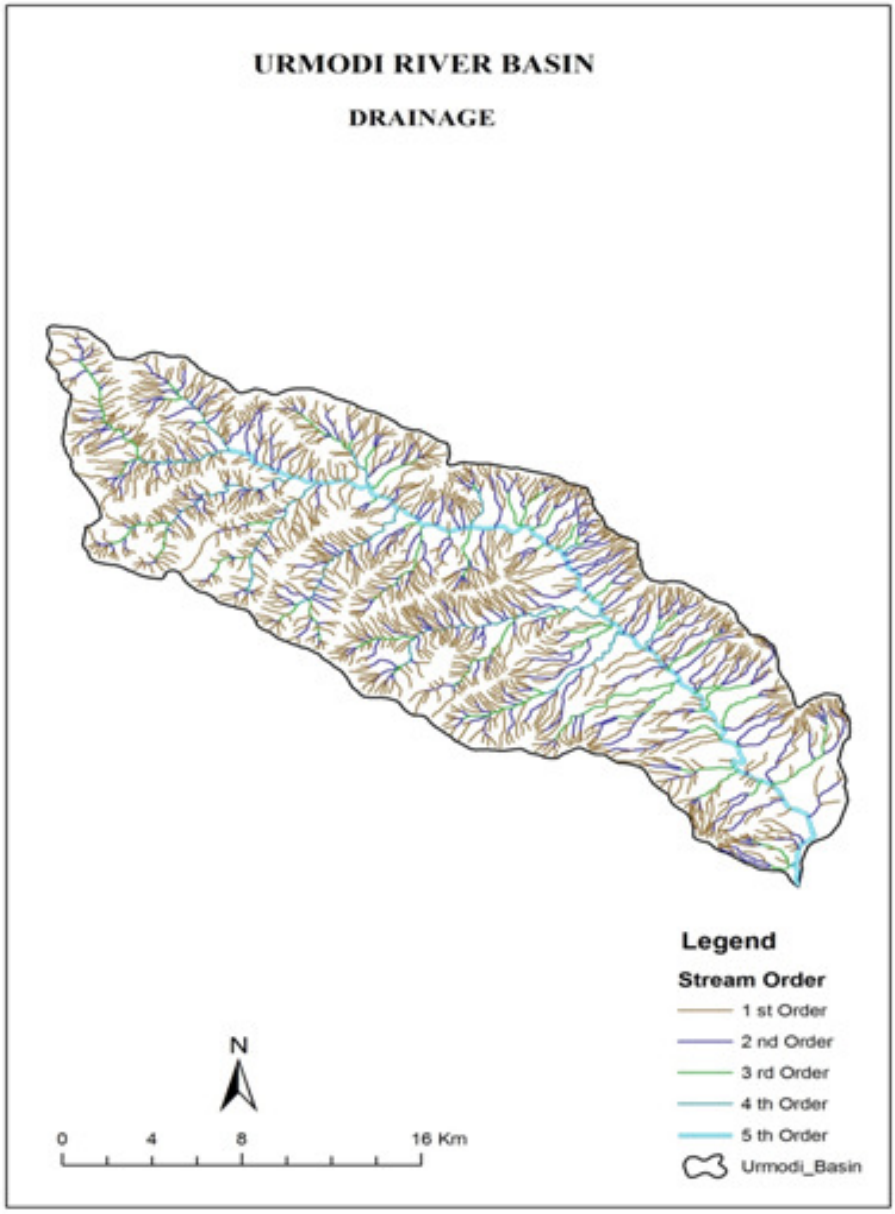

Figure 2: Stream Order of Drainage Network

3.6 Aerial aspect of drainage basin

3.6.1 Basin area (A)

Basin area is the direct outcome of the drainage development in a particular basin. The area of Urmodi basin is about 412.29 km. which indicates that rainwater will reach the main channel more rapidly where the water has much further to travel (Table.3).

3.7 Drainage density (Dd)

Drainage density is defined as a ratio of total length of all streams to the total area of the basin (Horton, 1932). Urmodi Basin is 3.30 km/sq km (Table.3).

3.8 Stream frequency (Fs)

The stream frequency of the basin is the ratio of the ratio of total number to the basin area (Horton, 1945). It is a good indicator of drainage pattern. Stream frequency has been calculated by the number of streams divided by the total area of basin in sq km. The stream Frequency value of the Urmodi Basin is 3.66 (Table.3).

Table 3: Aerial aspects of the drainage basin

Morphometric Parameters	**Calculated Value**
Perimeter (P) (km)	107.78 km
Basin Area (A)	412.29 sqkm
Drainage Density (Dd)	3.30 sqkm
Stream Frequency (fs)	3.66
Constant Of Channel Maintenance (C)	0.30
Texture Ratio (Rt)	14
Elongation Ratio (Re)	0.52
Circulatory Ratio (Rc)	0.44
From Factor Ratio	0.21

3.9 Constant of channel maintenance (C)

The Constant of channel Maintenance is the inverse of the drainage density (Schumm, 1956) Therefore higher the drainage density lowers the constant of channel maintenance and vice versa. Regarding the Urmodi basin, the average constant of channel maintenance is 0.30 (Table.3).

3.10 Texture ratio (Rt)

It is the ratio of total stream numbers to the total perimeter of the basin (Horton, 1945). Texture ratio of the Urmodi basin is 13.98, which indicate fine texture and area under high relied and steep slopes (Table.3).

3.11 Elongation ratio (Re)

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). The Elongation ratio of the Urmodi basin is 0.52, which indicate basin is highly elongated (Table 3).

3.12 Circulatory ratio (Rc)

Circulatory ratio is the ratio of basin area to the area of circle having to some perimeter as the basin (Miller, 1953). It is influenced more by the length, frequency and gradient of streams of various orders than slope condition and drainage pattern of the basin (Strahler, 1957) Circulatory ratio of Urmodi basin is 0.44 (Table.3).

3.13 Form factor ratio (Rf)

From Factor ratio is the dimensionless ratio of the basin area to the square of basin length (Horton, 1932). The form Factor ratio value of the Urmodi basin is 0.21.

3.14 Relief aspects of drainage basin

The relief aspect of drainage network such as, Basin relief (H) Relief Ratio (Rh) and Ruggedness Number (Rn) (Table 4)

Table 4: Relief aspects of drainage basin

Morphometric Parameters	Calculated Value
Maximum Elevation In The Area (mts)	1200
Minimum Elevation In The Area (mts)	600
Basin Relief (mts)	600
Relief Ratio (Rh)	13.88
Ruggedness Number (Rn)	1980

3.15 Basin relief (H)

The vertical distance difference between point of maximum elevation (1200 m.) and minimum elevation (1600 m.) is the relief of basin .The basin depth of Urmodi basin is 600 meters.

3.16 Relief ratio (Rh)

When basin relief (H) is divided by maximum basin length (Lb) gives the relief Ratio of Urmodi basin is 13.88, which Indicates that the basin has strong relief and steep slope.

3.17 Ruggedness number (Rn)

Ruggedness number is the product relief of basin (H) and drainage density (Dd) The ruggedness number of Urmodi basin is 1980.

Table 5: Formulae for drainage morphometric analysis

Sr.No.	Morphometric Parameters	Formula	Reference
1	Stream Order	Hierarchical Rank	Strahler (1964)
2	Stream Length (Lu)	Length of the Stream	Horton (1945)
3	Mean Stream Length (LSm)	LSm = Lu / Nu Where, LSm = Mean Streamlength Lu = Total Stream length of order Nu = Total no. of Stream Segments of order 'u'	Strahler (1964)
4	Stream Length Ratio (RL)	RL = Lu / Lu-1 Where, RL =Stream Length Ratio Lu = The Total Stream length of the Order 'u' Lu-1 = The Total Stream Length of its next lower order.	Horton (1945)

5	Bifurcation Ratio (Rb)	Rb = Nu/Nu+1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of the order 'u' Nu+1 = Number of segments of the next higher order.	Schumn (1956)
6	Mean Bifurcation Ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders.	Strahler (1957)
7	Drainage density(D)	D = Lu / A Where, D = Drainage density Lu = Total stream Length of all orders. A = Area of the basin (km)^2	Horton (1932)
8	Stream Frequency (Fs)	Fs = Nu/A Where, Fs = Stream frequency Nu =Total no. of streams of all orders. A = Area of the basin (km)^2	Horton (1932)
9	Form Factor (Rf)	Rf = A/Lb^2 Where, Rf = Form Factor A = Area of the basin (km)^2 Lb^2 = Square of basin Length.	Horton (1932)
10	Circularity Ratio (Rc)	Rc =4*Pi* A / P^2 Where, Rc = Circularity ratio Pi = 'Pi' Value i.e , 3.14 A = Area of the Basin (km)^2 P^2 = Square of the Perimeter (km)	Miller (1953)
11	Elongation Ratio (Re)	Re =2$\sqrt{}$(A/Pi)/Lb Where, Re = Elongation ratio A =Area of the Basin (km)^2 Pi = Pi Value i.e , 3.14 Lb = Basin Length	Schumn (1956)
12	Relief ratio (Rh)	Rh = H / Lb Where, Rh = Relief ratio H = total relief [Relative relief] of the basin (km). Lb = Basin Length	Schumn (1956)

4. Conclusion

The morphometric analysis is powerful tool in river basin management and planning, watershed prioritization, soil and water conservation, and management of natural resources at different levels. The morphometric parameters analyzed using geo-spatial techniques helped to understand various parameters such as rock structure, infiltration rate, runoff and erosion of the soil etc. The morphometric analysis carried out in the Urmodi basin shows that the basin is

having eastward relief and elongated shape. Drainage network of the basin shows dendritic pattern which indicates the homogeneity in the rock structure.

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