Research Article

Morphometric analysis of urmodi basin of bamnoli range of western Maharashtra dissecting lateritic terrain

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Abstract Attempt of this study is to use GIS for drainage analysis of Urmodi river basin of Satara district of Maharashtra. This river is tributary of Krishna, which originates at Kas Lateritic plateau of Bamnoli range. The aim of this paper is to understand a geomorphological change that has been taken place and to understand the geological role in these changes. GIS is a tool which is very useful and important in this case for assessment of drainage analysis. With the help of rosette diagram we tried to find out the structural control of different order streams of this basin for which Geo Rose software is used. All the parameters indicate steep slopes at higher altitude with high stream frequency on hard laterite and compact non porous basalt at lower level. There is structural, geomorphological and lithological control on basin development.
Keywords: Drainage analysis, GIS, Geo Rose, geomorphology, laterite, basalt, red boles.

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INTRODUCTION

Geomorphological study of an area is the systematic study of present day landforms, related to origin, geological changes recorded by surface features and their relationship to the underlying structures. Morphometric is the measurement of shape, length, and their ratio, which helps in the field of hydrology, were first initiated by Horton (1932) and Strahler (1952, 1957), later it was developed by Coates (1958) and Strahler (1964). Geohydrological behaviour of the basin, paleoclimate, geology, geomorphology, structural disturbances can be best understood by morphometric analysis. The morphometric analysis of Urmodi stream basin has been examined with the help of GIS techniques. The linear aspects of the drainage network morphometry incorporate stream order, stream length, drainage density, drainage frequency; bifurcation ratio, form factor and circulatory ratio carries inevitable significance in the analysis of river basin. Quantitative description of basin geometry, river characteristics, initial slope or inequalities in rock hardness, structural controls, recent diastrophism, geological and geomorphic history of the drainage basin can be understood by morphometric analysis.

STUDY AREA

Urmodi River is a tributary of Krishna river, which covers an area about 413 sq.km. Urmodi is 5^{th} order stream which rises from Kas plateau about 1260 mts from MSL, near Satara. Kas plateau is lateritic plateau which is well known for coloured wild flowers from mid July to mid October. The area of Urmodi basin (latitudes $17^0$43'25.8" to $17^0$28'1.8" N and longitudes $73^0$48'43.8" to $74^0$07'33.1" E) forms a part of SOI toposheet 47 G/14, 47K/2 and 47K/3, surveyed on the scale 1:50,000. River flows NW-SE direction and meet Krishna River at Kashil village of Karad taluka. Climate of study area is tropical with three distinct seasons. Temperature varies in the range 39^0C to 45^0C in summer and 5^0C to 20^0C in winter. In monsoon area received up to 5000 mm rainfall in between period of mid June to mid October. Urmodi river basin receives highest rainfall about 5000 mm at western

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part of the basin where it starts its journey and it is observed that it lowers down about 600 mm to 700 mm towards eastern part where it meets to the Krishna River. Urmodi river basin is characterised by different physiographic division, high ranges with flat topography covers west side of the basin, hilly areas with rugged topography on north and south, with floodplains in lower reaches. High ranges with flat topography locally called as Sadas or Pathar, include high elevated portion ranging from 1111 mt to 1260 mt from MSL. Hilly area with rugged topography is present between elevation 962 mt to 1036 mt with moderate slopes. Colluviums deposition along the hill slopes and flood plains with apparent alluvium with thickness more than 5 mts is recorded.

GEOLOGY OF THE AREA

Principally study area consist of three litho units viz laterites, Basalt and redboles. Most of the study area is covered by Deccan basalt formation, comprising nearly horizontal lava flows of late Cretaceous to early Eocene. The Deccan volcanic province (DVP) is unique in the geology of India because of its prodigious volcanism and its pivotal role in the studies of volcanology. The Deccan volcanics have erupted close to Cretaceous – Tertiary (K/T) boundry at about 65 Ma (Duncun and Pyle, 1988). 500,000 sq.km area of western and central India today covered by basalt. The type of basalt lava flows occurring in the area are simple (Aa-Aa type) and compound (Pahoehoe type). Top of the lava flows are covered with high level lateritic cap (Medlicott and Blanford 1879). In the study area lateritic cap is present at a range of 1065 mts to 1260 mts AMSL. Such duricrust result from impregnation of saprolite (rock weathered in situ) with iron oxides and hydroxides. They have usually been called as laterites (Widdowson and Cox 1996, Widdowson 1997, Widdowson and Gunnel 1999). Duricrust is general term for hard crust formed at or near ground surfaces. Widdowson (1997) interpreted the laterite profile of Bamnoli range – Koyana- Patan – Satara region are formed by insitu breakdown of the underlying basaltic lava flows. Sequences of basaltic lava flows commonly include spectacular red interflows strata widely known as ‘red bole’ which serve as marker bed in between two basaltic lava flows. Boles are recognised on its red colour. According to Sayyed and Hundekari, Ghosh and *et al*., (2006), the bole beds occur as prominent horizons composed of fine grained earthy material having colours in shades of red to chocolate brown, green, purple grey. Bole are made up of friable earthy clay and it was suggested that boles are made up of that material derived from weathering of neighbouring basalt and volcanic ashes (Wilkins *et al* 1994). Colour of bole beds in study area is red to reddish brown. Boulders are also present in some places along with the clay. These boulders geochemistry suggest that many of the boles are weathered pyroclast (Wilkins *et al* 1994).

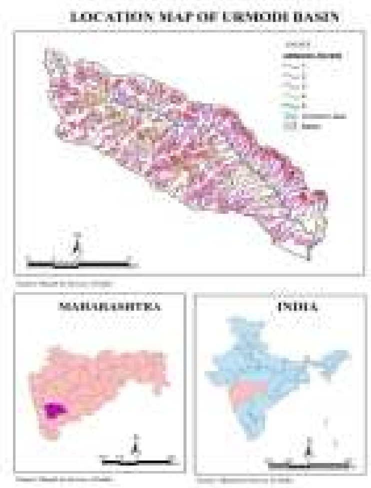

Figure 1: Location Map

MATERIALS AND METHODS

Base map was prepared using SOI toposheet no 47 G/14, 47K/2 and 47K/3 on 1:50,000 scales. For digitization of basin area and computing all morphometric parameters Arc-GIS 9.3 software was used. The first step in morphometric analysis of a drainage basin is the designation of stream orders. Geo rose software was used for rosette diagram. The Strahler system (1964) of stream orders based on a hierarchic ranking of streams has been used here.

RESULT AND DISCUSSION

We have examined different morphometric parameters in detail. Horton (1932, 1945) stated that a drainage basin is ideal unit for understanding the geo-morphological and hydrological processes and for evaluating the runoff patterns of the streams. The Urmodi basin is elongated leaf shaped basin, where basin length is more as compare to basin width. This basin possesses dendritic drainage pattern, characterised by irregular branching of tributaries in most of the cases in same direction as shown by rosette diagram. (Fig7). This indicates structural control as well as control of lithology. Thevarious morphometric aspects of the Urmodi basin area were determined and are summarized in table 1.

Stream order (Nu)

The first order Hortonian streams do not have any tributary and smallest recognizable stream is of first order and these channels normally flow during wet season (Chow *et al*., 1988). Where two first order channels join, a channel segment of order 2 is formed (Strahler 1964); where two of order two join, a segment of order 3 is formed; so forth. The trunk stream through which all discharge of water and sediments passes is therefore the stream segment of highest order. The number of stream segment decreases as the stream order increases, which follow Horton's law of stream ordering. In Urmodi basin there are total 1177, 311, 67, 15 and 1 first, second, third, fourth and fifth order streams respectively. Dendritic drainage pattern of stream is developed in homogenous fine grained compact basalt in lower part and porous hard laterite at higher altitude, which is formed due to in situ chemical weathering of basalt. But both litho units are hard. This pattern is characterised by tree like pattern with branches that intersect primarily at acute angle. The properties of the stream networks are very important to study the landforms making process (Strahler and Strahler 2002).

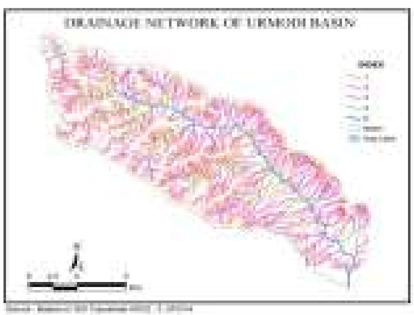

Figure 2: Drainage network

Stream Length (Lu)

Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. The stream length of river network has been measured with the help of GIS software. Investigations show that in Urmodi basin, total stream length has been decreasing with increasing stream order. This basin has the total stream length of about 1321.549 km and 5th order stream length is about 17.079 km. Smaller lengths of first and second order stream indicate steeper slopes and finer texture bed rock. In DEM model fourth and fifth order stream lengths are indicating flatter gradients (Fig. 6). Plot of the logarithm of stream order versus stream length and stream no (Fig 3, 4) showed the linear pattern which indicates the homogenous hard rock material subjected to erosion/weathering. Deviation from its general behaviour indicates that the terrain is characterised by variation in lithology and topography. Mean stream length (Lu) is dimensional, revealing the characteristic size of the components of drainage network and it contributes basin surfaces (Strahler 1964). In this study area Lu increases as stream order increases, which ranges between 0.72 and 17.08 km, it is due to variation in slope and topography.

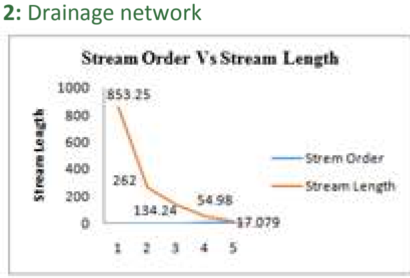

Figure 3:

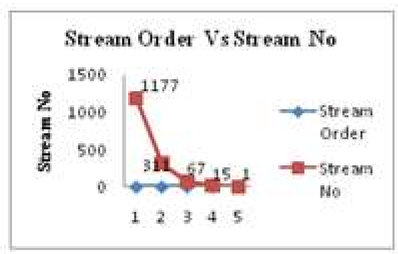

Figure 4:

Stream Length Ratio (R_L)

Stream length is the ratio of mean length of streams of one order to that of the next lower order that tends to be constant throughout the successive orders of a watershed (Hortan 1945). The highest value of length ratio for Urmodi basin is 3.25 and lowest is 1.95. Above values are the indicative of lithology. Highest values are for less permeable rock type like hard lateritic cap with fractures at higher altitude and ratio is lowered at lower level which indicates softer lithology like lithomarge clay and weathered basalt (1.95). Also increase in stream length ratio points towards hard impermeable compact basalt.

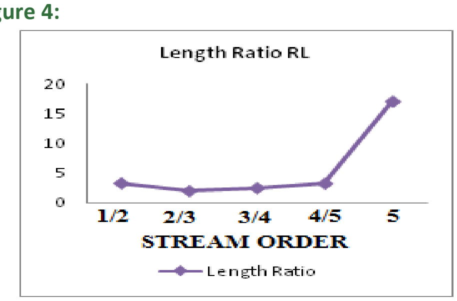

Figure 5:

Bifurcation ratio (Rb)

The term bifurcation ratio is used to express the ratio of the number of streams of any order to the number of streams in the next highest order (Horton 1945, Schumn 1956). Bifurcation ratio is an index of relief and dissection (Horton 1945). Bifurcation ratios of the study area have been calculated and its Rb values range between 3 and 5.0 for watersheds in which geometrical structures do not distort drainage pattern (Chow *et al*, 1988). Mean bifurcation ratio of all orders ranges from 4.81, suggesting geologically homogenous basin and also geological structures do not distort the drainage pattern (Strahler, 1964). The bifurcation ratio is indicative of shape of the basin. An elongated basin as Urmodi basin, likely to have high Rb, where as circular basin is likely to have low Rb. The values of Rb calculated for basins are given in table 1.

Table 1: Linear aspects of the drainage network of the Urmodi Basin

Basin	Stream order	No of segments	Length of Streams Km	Bifurcation ratio (Rb)	Mean Bifurcation ratio	Mean stream length	Stream length ratio (R_L)
Urmodi Basin	1	1177	853.25	3.78		0.72	3.25
	2	311	262	4.64		0.84	1.95
	3	67	134.24	4.46		2.00	2.44
	4	15	54.98	15	4.81	3.66	3.22
	5	1	17.079	1		17.08	17.079
Total	**5th**	**1571**	**1321.55**				

Area (A) and perimeter (P) of a basin are two important parameters in quantitative morphometry. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basin. Perimeter is the lengths of the boundary of the basin which can be drown from topographical maps. Area and perimeter are calculated with the help of GIS software. It is interesting that the maximum flood discharge per unit area is inversely related to size (Chorley, *et al*., 1957). The aerial and relief aspects of drainage network are parameters like drainage density, texture ratio, stream frequency, form factor; circularity ratio, elongation ratio and relief ratio are calculated and given in Table No 2.

Drainage Density (Dd)

It is the ratio of total length of the stream in a given drainage basin to the basin area Horton (1932) which is expressed in terms of km/sq.km. Drainage density indicates the closeness of spacing of channels. Drainage density (table 2) of this basin is 3.20 km/sq.km. The higher drainage density is due to result of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. The field investigation ravels that hard lateritic cap is present above 1065 mts from MSL. This is underlained by lithomargic clay with dense vegetation and at the bottom thick compact basaltic lava flows. Basalt flows occurred in study area below lithomargic clay at about 750 mts from MSL. Primary porosity of basaltic rock is very low, almost non porous because of its compact and massive nature, while weathered and fractured basalt show relatively higher porosity up to 5-30%. However specific yield is only 1-7%, which indicates poor interconnection between vesicles or fractures Wood (1960). In the upper part of the study area hills of higher elevation are present forming high relief.

Stream Frequency (Df)

Stream frequency is the number of stream segments per unit area (Horton, 1932, 1945). The stream frequency of Urmodi basin is 3.80 which support mountainous region, dense network of streams.

Form Factor (Rf)

Form factor is the dimensionless ratio of the basin area to the square of basin length (Horton, 1932), the Rf value of 0 indicates a highly elongated shape and the value of 1.0 indicates a circular shape with high peak flows for short duration but for elongated basin with low Rf with flatter peak flows for longer duration. The Rf values of Urmodi basin is 0.22 showing its elongated shape and the flood flows of such basin can be managed more efficiently than circular shape basin.

Circulatory ratio (Rc)

Circulatory ratio is the ratio of basin area (A) and the area of a circle with the same perimeter as that of the basin (Miller, 1953, Strahler, 1964). The circulatory ratio of Urmodi basin 0.45 for lateritic terrain, which indicates, the basin is under influence of length and stream frequency, geological structures, climate, relief and slope of the basin.

Elongation ratio (Re)

Elongation ratio **(**Re**)** is the ratio between the diameter of the circle having the same area as that of the basin and the maximum length of the basin (Schumm, 1956). The value of Re is 0.53 due to variety of climatic and geologic types, usually associated with high relief and steep ground slopes.

Relief Ratio (Rh)

Relief is defined as total relief of the basin divided by maximum basin length parallel to major drainage lines within the basin (height/length). This relief ratio has been found to be directly related to such other topographic characteristics as stream gradient, drainage density, or texture, slope angle and basin slope (Schumm 1956). Rh value of this basin is 0.029 which is characteristic feature of hilly region, with high slope angle and resistant rock.

Table 2: Arial and Relief aspects of the drainage network of the Kolamba Basin

Arial and relief aspects	Urmodi basin
Basin Area (A)	413 sq.km.
Perimeter (P)	107.79 km
Basin Length (Lb)	43.044 km
Drainage Density (Dd)	3.20 km/sq.km.
Stream Frequency (Df)	3.80
Form Factor (Rf)	0.22
Circulatory ratio (Rc)	0.45
Elongation ratio (Re)	0.53
Relie Ratio (Rh)	0.029

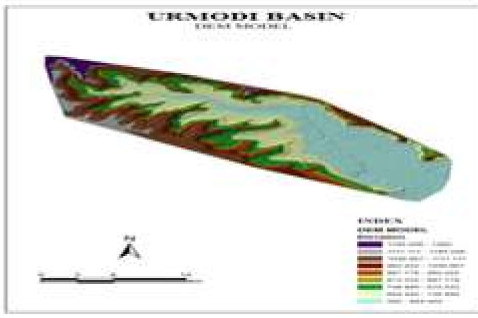

Figure 6: DEM Model

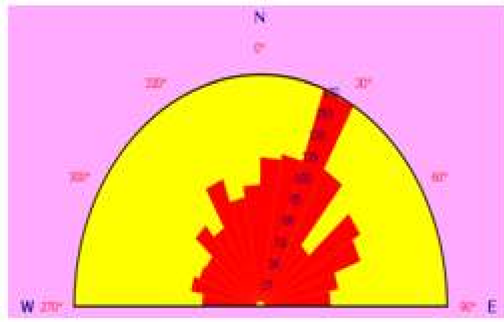

Figure 7: Rosette Diagram

CONCLUSION

Urmodi basin is developed in lateritic terrain which is hard rock formed due to chemical weathering of parental basalt rock. Basin is elongated due to which watershed management of such basin can be done with low cost dams. Dendratic drainage pattern is developed due to homogenous hard basalt and laterite and stream length ratio conform it. Stream length of I st and II nd order suggests steep gradients of Bamnoli range at higher altitude. Bifurcation ratio and elongated shape of basin are indicative of steep slopes and non porous compact bed rock. Structural control in the basin development is observed where maximum streams are in the direction N 20^0 -30^0 E to S 20^0 -30^0 W, which suggests total control is of lithology and geomorphology along with structures.

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