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Application of Morphometric Analysis for Geo-Hydrological Studies Using Geo-Spatial Technology –A Case Study of Kolamba River Basin

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Abstract-*The analysis of marphometric parameters of Kolamba river basin has been carried out using Arc GIS 10.5. This study involves Geographic Information System (GIS) techniques to evaluate and compare linear, relief and aerial parameters of Kolamba River and has been taken up for prioritization. Linear parameters include stream length (Lu), stream order (u) and stream number (Nu). In aerial parameters area (A) and perimeter (P) are important factors. Compound parameter (Cp) was calculated and prioritization ratings have been carried out. The present study area covers 88.69sq.km. Kolamba river basin has three sub streams which are Nigadi stream, Chikli stream, and Antwadi stream. The Kolamba river is 6th order stream having length of about 1.42 km. It has latitude 17°30′N and 17°30′N and longitude 74°0′E and 74°15′E. This area is included in Survey of India (SOI) topographic sheet no. 47 K/3 on the scale 1: 50000. The drainage network is delineated by using False Colour Composite (FCC) and Indian Remote Satellite (IRS-1D) LISS 3 satellite images and Survey of India toposheet. Cartosat DEM (30m) is used for this marphometric analysis. This area receives high rainfall but after mansoon this area suffers from drought condition. This area is high relief mountainous area. Drainage pattern is dendritic in nature. The marphometric parameters like Bifurcating ratio (Rb), Elongation ratio (Re), Drainage Density (Dd), Texture Ratio (Tu), Form Factor (Rf), Stream Frequency (Df) etc. gives brief explanation about study area. Hence marphometric analysis is very helpful to understand the various characteristics of drainage basin.*

Key Words: **Marphometric Parameters, GIS, Remote sensing, prioritization, Kolamba River Basin, Compound Parameters, DEM.**

1. INTRODUCTION

Now-a-days development like industrialization, population growth and agricultural activities of villages, city or town from past to present condition defines how rapid growth takes place in such areas. It creates hazardous problems related to land use, surface water and watershed management. Due to this water level is reduced and demand of water is increased. Hence to control this urban growth, structure settlements and hydrological problems, morphology becomes an essential key. Morphology is the mathematical analysis of earth's surface and its dimensions i.e. morphology defines the shape of particular area. The quantitative analysis of drainage basin such as stream length, stream number etc. i.e measurement and outlining this physical characteristic pre-requisite for defining particular stream area and water bearing qualities of various geological structures such as rocks.

In recent years marphometric analysis using Geographical Information System (GIS) and Remote Sensing (RS) plays an important role. Remote sensing (RS) provides synoptic view of the large area in single image. Arc GIS 10.5 is used for extracting terrain and marphometric parameters of river basin. Also Arc GIS IS used for scanning, Georefferncing, Digitization. Carto sat DEM (30M) is used for computing the marphometric parameters. Drainage networks are developed using False Colour Composite (FCC) and Indian Remote Satellite (IRS-1D) LISS 3 satellite images. The first marphometric study of river basin was initiated by Horton (1945). It was later developed by Coates (1958) and the Strahler (1964).

The Kolamba river basin has an area of about 88.69 sq.km which is lying between latitude 17°15′N and 17°30′N and longitude 74°0′E and 74°15′E. Kolamba river has threes sub-watersheds which are Nigadi stream, Chikhali stream, Antavadi stream. The stream length of river has been measured by using GIS software. The Nigadi sub-waters shed has total stream length about 112km, Chikhali sub-watershed has total stream length about 129.31km, Antavadi sub-watershed has total stream length about 101.66km. Kolamba stream is 6th order stream having length about 1.42km. This area has maximum elevation about 898m and minimum elevation 492 m. This area receives high rainfall during rainy season but after drought condition is observed. During this water demand is increasing bur water table is discharged.

The marphometric parameters are divided into three parts such as linear parameters, relief parameters, and aerial parameters. Linear parameters include Stream order (u), Stream length (Lu), Mean stream length (Lsm) and Bifurcation ratio (Rb). Relief parameters includes Basin Relief (Bh) and Ruggedness number (Rn) which are used for computing surface and sub-surface water flow,

permeability, landform development. Other parameters like Drainage Density (Dd), Stream frequency (Fs), Texture ratio (T), Form Factor (Rf), and Circulatory ratio (Rc) are used for drainage development which is important factor for landform element. The compound parameters for three sub-watersheds are calculated and prioritization rating completed. Due to difference in geological structure, natural vegetation, sloe and rainfall distribution gives different drainage pattern in marphometric parameters.

2. LITERATURE REVIEW

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3. AIMS AND OBJECTIVES

The aim of the study is highlighting the significance of geographic analysis in watershed management using geospatial techniques. The objectives of the study are

1. To study the geomorphologic setting of Kolamba River basin.
2. To study the hydrological characteristics of Kolamba River basin.
3. To study temporal changes in land use and land cover of the Kolamba River basin.
4. To prioritize sub watersheds based on marphometric parameters of the Kolamba River basin.

4. STUDY AREA

Kolamba River basin is situated in Satara district of Maharashtra. Kolamba stream is 6th order stream. It has area about 88.69sq.km. It is located between latitude $17^0 15'$N and $17^0 30'$N and longitude $74^0 0'$E and $74^0 15'$E which is included in Survey of India topographic sheet no. 47 K/3 on the scale 1:50000. The Kolamba river basin has three sub basins which are Nigadi stream, Chikhali stream, Antavadi stream. First Nigadi and Chikhali stream meet each other near Masur, thereafter Kolamba River forms. Kolamba stream and Antavadi stream meet each other near Konegoan village. The maximum elevation of area is 898m and minimum elevation is 492m. Kolamba stream has length about 1.42km. The basin length (Lu) of Kolamba River is 20km.Stream flows from North-East (NE) to South-West (SW) direction. The climate of the area is wet and dry according to three seasons as summer, winter and Monsoon. During monsoon area receives rain between Junes to October. In summer temperature varies from 35^0C to 45^0C and in winter it varies from 10^0C to 20^0C.It rise about 920 m above mean sea level. The present study area is divided into 3 zones like high ranges, intermontane valley and flood plains. High ranges include hills having elevation from 785m to 920m.Iintermontane valleys are occupied by colluviums formed by erosional processes. Flood plain with alluvial thickness more than 5m observed near village Konegaon. Black cotton soil is majorly observed in this area. At some places yellowish and brown colored soil is observed.

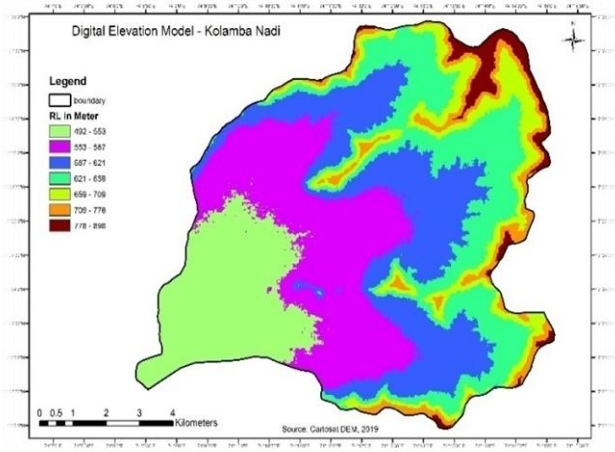


Fig.-1: Digital Elevation Model of Kolamba River

5. MATERIALS AND METHODS

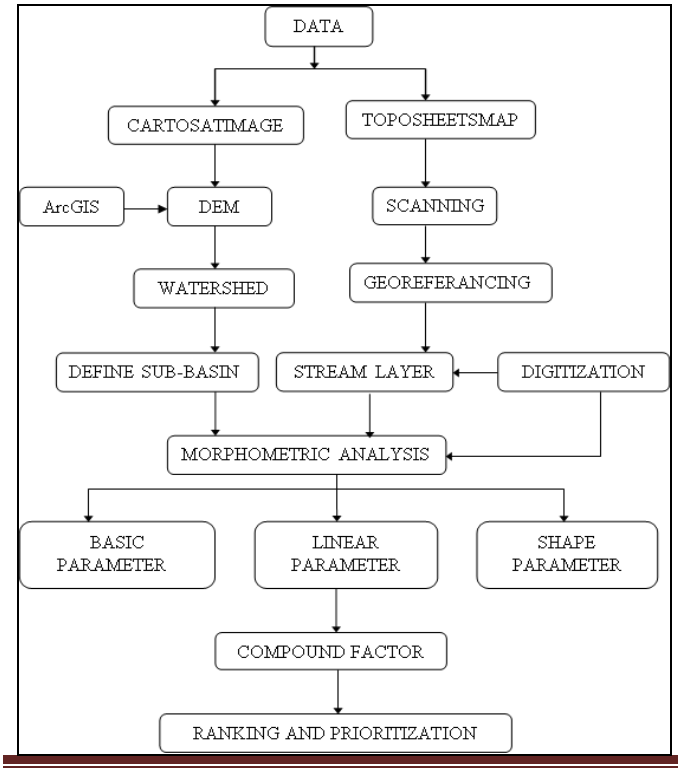
Arc GIS 10.5 software was used for digitization process, Georefferncing and computation of various parameters of morphology. Carto sat DEM (30m) was used for extraction of morphological parameters. Drainage networks were developed using Survey of India (SOI) topographic sheet

no.47K/3 with scale 1:50000 and False Colour Composite (FCC) and Indian Remote Satellite (IRS-1D) LISS 3 satellite images. Digitization of drainage network is carried out by method proposed by Strahler in 1964.

The following procedure was followed for analysis of morphometric parameters:

1. The Survey of India (SOI) toposheet was scanned, georeferanced using Arc GIS 10.5. Further geocoded toposheet was mosaic using Erdas Imagine 9.1. Software.
2. Catchment area of basin delineated from Cartosat DEM. Area of Interest (AOI) is prepared by using Erdas Imagine Software and it is used to cut the satellite image of the study area.
3. Landsat 8 Satellite Image is used to prepare land use/ land cover map.
4. Cartosat DEM (30m) was utilized to prepare topographic, slope and delineation of drainage map of basin using Arc GIS 10.5 software.
5. All morphometric parameters from satellite image and DEM such as stream number, stream length, drainage area, basin perimeter, total basin length and width were calculated using Arc GIS 10.5.
6. After that drainage frequency, drainage density, shape, form factor, circulatory ratio, elongation ratio etc. were calculated using above parameters.
7. Standard methods of Strahler's, Horton's, Miller's, Chorley's, and Schumm's were applied to examine this linear, aerial and relief parameter.

5.1 FLOW CHART



5.2PARAMETERS

6. RESULT AND DISCUSSION

The Kolamba River basin is divided into three sub-basins such as Nigadi basin, Chikhali basin and Antavadi basin. The various marphometric of this basin were calculated and summarized in tables given below. The morphometric parameters are discussed as follows.

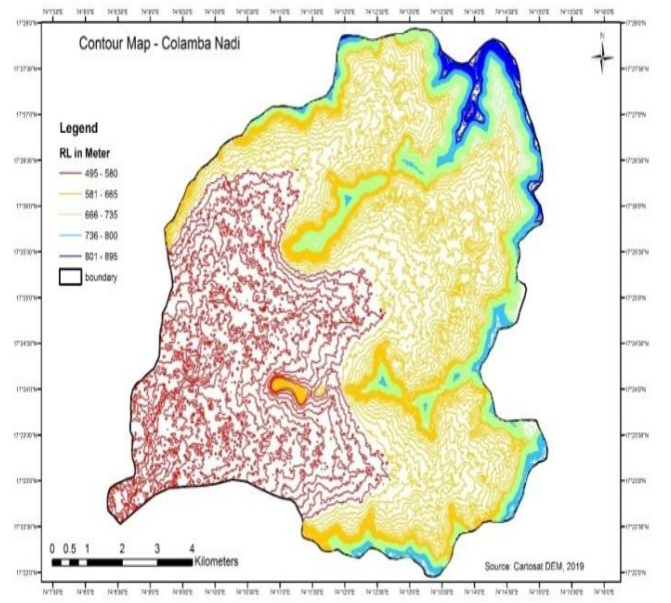


Fig-2: Contour Map of Kolamba River

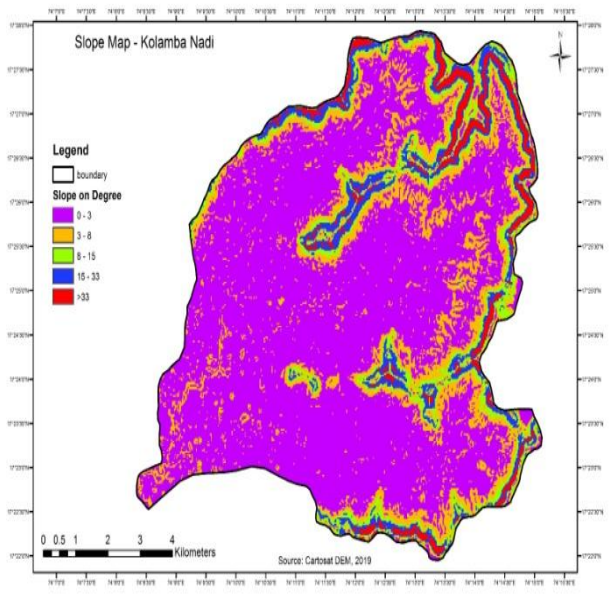


Fig-3: Slope Map of Kolamba River.

Table 1: Linear morphometric parameters of the drainage network of the Kolamba River basin.

Stream order (Sμ)	Stream number (Nμ)	Cumulative Stream number (Nμ) cum	Bifurcation ratio (Rb)	Stream length (L) (kms)	Cumulative Stream length (Lμ) cum (kms)	Mean stream length (Lsm) (kms)	Log Nu	Log Lu	Mean Stream length ratio (RL)	Mean bifurcation ratio (Rbm)
1st	435	435		204.088	204.088	0.47	2.63	2.30		
			3.22							
2nd	135	570		74.356	278.444	0.55	2.13	1.87		
			3.85							
3rd	35	605		40.245	318.689	1.14	1.54	1.60		
			5						0.57	3.51
4th	7	612		22.789	341.478	3.25	0.84	1.35		
			3.50							
5th	2	614		13.187	354.665	6.60	0.30	1.12		
			-							
6th	1	615		1.664	356.329	1.66	0	0.16		
Total	615			356.329						

Table 2: Linear morphometric parameters of the drainage network of Nigadi, Chikhali, and Antavadi Sub-Basin.

Sub-Basin	Stream order (Sμ)	Stream number (Nμ)	Cumulative Stream number (Nμ) cum	Bifurcation ratio (Rb)	Stream length (Lμ) (kms)	Cumulative Stream length (Lμ) cum (kms)	Mean stream length (Lsm) (kms)	Log Nu	Log Lu	Mean Stream length ratio (RL)	Mean bifurcation ratio (Rbm)
I Nigadi Sub-Basin	1st	150	150	3.125	64.930	64.930	0.43	2.17	1.81	0.53	6.375
	2nd	48	198	4	25.553	90.483	0.53	1.68	1.40		
	3rd	12	210	12	12.082	102.567	1.00	1.07	1.08		
	4th	1	211	-	9.284	111.849	9.28	0	0.96		
II Chikhali Sub-Basin	1st	155	155	3.22	72.682	72.682	0.46	2.19	1.86	0.60	3.30
	2nd	48	203	4	28.506	101.188	0.59	1.68	1.45		
	3rd	12	215	3	16.714	117.902	1.39	1.07	1.22		
	4th	4	219	3	6.111	124.013	1.52	0.60	0.78		
	5th	1	220	-	9.262	133.275	9.26	0	0.96		
III Antavadi Sub-Basin	1st	122	122	3.29	62.248	62.248	0.51	2.08	1.79	0.60	3.53
	2nd	37	159	3.36	18.932	81.180	2.19	1.56	1.90		
	3rd	11	170	5.5	11.449	92.629	1.04	1.04	1.96		
	4th	2	172	2	7.394	100.023	3.69	0.30	2.0		
	5th	1	173	-	3.925	103.948	3.92	0	2.01		
Total Kolamba Basin	6th	615			356.329					0.57	3.51

A. **Linear Aspects:**The linear aspects of drainage network are area of basin (A), perimeter (P), stream order (u), and stream number (Nu), basin length (Lb), bifurcation ratio (Rb), stream length ratio (Rl).

1. Area(A): The Kolamba River has an area about 88.69sq.km.
2. Perimeter (P): Kolamba river basin has perimeter about 44km.
3. Stream Order (u): It is defined as a measure of stream in tributaries. It first steps in drainage basin analysis. In this study Strahler's method is used which is modification of Horton's method. Which have no tributaries are first order streams. When two first order stream join, it gives second orderstream and the joining of two second order stream generates third order streams and so on. However, when two streams of different orders are joined then the order of highest stream continues. The Kolamba River basin is 6th order stream. Nigadi sub-basin is 4th order stream, Chikhali sub-basin is 5th order stream and Antavadi is 5th order stream.
4. Stream Length (Lu): It is defined as the total length of all the streams in a drainage basin. Length of streams of different orders was calculated using Ac GIS software. Total stream length has been decreases with increasing stream order. Nigadi sub-basin has stream length about 112km, Chikhali has 129.31km, and Antavadi has 101.66km total length. 6th order stream has total length of only 1.42 km. smaller lengths defines the area with longer slopes and longer lengths indicates flatter gradient.
5. Basin Length (Lb): Basin length is a measure of size and shape of drainage basin. Kolamba basin has basin length about 20km.
6. 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. Mean bifurcation ratio of all orders ranges from 3 to 4.99 the bifurcation ratio indicates shape of basin. An elongated basin of Kolamba has high Rb and circular have low Rb. The average value of Rb is 3.51.

7. Stream Length Ratio (Rl): The variation in stream length ratio indicates influence of regional geology.

B. **Aerial Aspects:** The aerial aspects include drainage density (Dd), stream frequency (Fs), length of overland flow (Lg), constant of channel maintenance (C), circulatory ratio (Rc), and elongation ratio (Re).

1. Stream Frequency (Fs): Stream frequency is defined as the total number of streams in a drainage basin. Nigadi has stream frequency about 7.17, Chikhali has about 6.82 and Antavadi has about 6.69. The high value of stream frequency indicates high relief area, greater surface run-off, homogeneity.
2. Drainage Density (Dd): Drainage density indicates closeness of spacing of channels. High drainage density is result of weak or impermeable subsurface material. Average drainage density of study area is 4.01 km/sq. in general drainage density represents highly dissected terrain with relatively lower infiltration capacity.
3. Length of Overland Flow (Lg): Low value of length of overland flow indicates early mature stage of development. The present study area has value about 0.12.
4. Constant of Channel Maintenance (C): Higher the drainage density lowers the constant of channel maintenance. Its low value indicates only rocks are relatively impermeable or terrain is very steep and low value indicates vice versa. The present study area has value about 0.249.
5. Circulatory ratio (Rc): It is influenced more by the length, frequency and gradient of stream of various orders than slope conditions and drainage patterns. The Kolamba river basin has circulatory ratio about 0.575.
6. Elongation Ratio (Re): It indicates shape of basin which is helpful to give an idea about hydrological characters of a drainage basin. The value of elongation ratio is varying from 0.6 to 1. The study area has 0.7 elongation ratio.
7. Texture ratio (Rt): It is important factor in morphometric analysis. The study area has 13.97 texture ratios which indicate very fine texture.
8. Form Factor Ratio (Rf): The study area has 0.22 form factor ratio which indicates the area is highly elongated in shape. Flood flows through this area are easy to manage than circular shape.

C. **Relief Aspects:**Relief aspects includes basin relief (H), relief ratio (Rh), ruggedness number (Rn), gradient ratio (Rg), Melton rugadeness number (MRn), basin slope (Bs).

1. Basin Relief (H): It is the vertical distance between maximum elevation and minimum elevation. The basin relief of Kolamba river basin is 406m.

Table 3: Linear, Areal, Relief parameters of the drainage network of Kolamba River Basin.

Sr. no.	Parameters	Unit	Nigadi sub-basin	Chikhali sub-basin	Antavadi sub-basin	Main basin
1	Stream order (u)	No	4	5	5	6
2	No of Stream Segments (Nu)	No	211	220	173	615
3	Stream length (Lu)	Km	111.849	133.275	103.948	356.129
4	Mean stream length (Lsm)	km	0.53	0.6	0.6	0.57
5	Basin area (A)	Sq.km	29.97	32.35	25.84	88.69
6	Perimeter (P)	Km	25	29	27	44
7	Basin length (Lb)	Km	14	16	13	20
8	Drainage density (Dd)	Km	4.301	4.164	3.99	4.151
9	Texture ratio (Rt)	Sq.km	8.44	7.58	6.4	13.97
10	Stream frequency (Fs)	Sq.km	8.11	6.87	6.65	6.93
11	Bifurcation ratio (Rb)	-	6.375	3.3	3.53	3.51
12	Mean bifurcation ratio (Rbm)	-	6.375	3.3	3.53	3.51
13	Form factor (Rf)	Km	0.132	0.125	0.153	0.22
14	Circulatory ratio (Rc)	-	0.52	0.47	0.44	0.57
15	Elongation ratio (Re)	-	0.41	0.39	0.44	1.4
16	Relief ratio (Rh)	-	0.026	0.022	0.03	0.02
17	Length of overland ratio (Lg)	Km	0.116	0.12	0.125	0.12

18	Basin relief (Bh)	meter	366	362	401	406
19	Ruggedness no. (Rn)	-	1.574	1.507	1.59	1.63
20	Time of concentration (Tc)	Sec	0.243	0.268	0.245	0.345
21	Constant of channel maintenance (C)	Km	0.23	0.24	0.25	0.249
22	Slope angle (S)	-	1.49	1.29	1.76	1.16
23	Compactness coefficient (Cc)	km	1.38	1.44	1.49	1.31
24	Shape factor (Bs)	-	7.53	8	6.5	4.51
25	Gradient ratio (Rg)	-				
26	Basin slope (Sb)	Percent				
27	Infiltration no (If)	No	34.88	28.6	26.53	27.82
28	Rhp coefficient (Rhp)	-	1.46	1.24	1.48	0.92
29	Dissection index (Dis)	-				
30	Hypsometric integral (Hi)	-				
31	Cumulative length of streams (L)	-				
32	Melton ruggedness ratio (MRn)	-	0.071	0.063	0.078	

2. Relief Ratio (Rh): When basin relief is divided by maximum basin length gives relief ratio. The study area has 20.3 relief ratios which indicate moderate relief and gentle terrain slope.
3. Ruggedeness Ratio (Re): Ruggedeness number is product of basin relief and drainage density.
4. Gradient Ratio (Rg): The higher gradient ratio indicates higher channel slope associated with steep v-shaped valleys. The gradient ratio varies from 0.1 to 0.38.
5. Melton Ruggedeness Ratio (MRn): It differentiates basins with debris flow potential from basins with bed load sediment transport. The MRn value varies from 0.28 to 0.55.
6. Basin Slope (Bs): Slope analysis is significant parameter in geomorphic studies and slope elements. Its value ranges from 36.16 to 54.13.

7. CONCLUSION

The present study proves the efficiency of GIS software in analysis of various morphometric parameters like linear parameters, aerial parameters and relief parameters of Kolamba River basin which is located in Satara district ofMaharashtra. The prioritization of study area will helpful for providing implementation of its development and management. Thus, the overall study shows that GIS and Remote Sensing is more appropriate techniques than conventional methods. It is useful in understanding the influence of these morphometric parameters on soils, landforms and eroded land in catchment area. Hence these Geo spatial techniques which are employed can help in decision making process for evolution of catchment area. Drainage network of the basin is dendritic type which indicates the homogeneity in texture and lack of structural control. Detailed study gives useful information about surface configuration of the watershed.

FUTURE SCOPE

To understand the geological processes of different environments. To efficiently detect natural and environmental hazards e.g. Earthquakes, floods, landslides, tsunamis, volcanoes, etc. Identifying the various terrain features and landscapes in satellite imagery. This helps coast and river research and insecurity studies.

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