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MORPHOMETRIC ANALYSIS AND PRIORITIZATION OF WATERSHED FOR SOIL RESOURCE MANAGEMENT IN YERALA RIVER BASIN

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Abstract: The development of morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network. Watershed prioritization on the basis of morphometric parameters is necessary in order to develop a sustainable watershed management plan. The present study aims to assess the linear and shape morphometric parameters and prioritization of twenty three sub-watersheds of Yerala river basin for soil resource management. Yerala river basin has an area of 3041 km2 and lies between in 160 55' to 170 28' North and 740 20' to 740 40' East Longitude in Satara and Sangli districts. Remote Sensing (RS) and Geographical Information System (GIS) techniques and Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) data was used for evaluation of morphometric parameters. Watershed boundary has been prepared using Arc-Hydro Tool. The prioritization was carried out by assigning ranks to the individual indicators and a compound value was calculated. Watersheds with highest compound value were of low priority while those with lowest compound value were of high priority. The highest priority zone consists of eight watersheds, medium of eleven and low of four watersheds. High priority indicates that watersheds are much more susceptible to soil erosion hence it should be provide with immediate soil resource management measures.

Keyword: Morphometric analysis, prioritization, Yerala River Basin, SRTM, DEM,

INTRODUCTION:

A watershed is a perfect unit for management of natural resources and mitigation of the impact of natural disasters for attain sustainable development. The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes happen within the watershed.

Morphometry is the measurement and mathemati cal analysis of the formation of the earth's surface, shape and dimension of its landforms. Morphometric studies involve area, altitude, shape, size, slope and profiles of watershed. (Singh S. 2000).Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order for soil conservation measures. Morphometric analysis could be used for prioritization of sub-watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas et al., 1999).

Morphometric characteristics of many river basins and sub basins in different parts of the world have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Various scholars have carried out morphometric analysis of river basins by using RS and GIS techniques. Morphometric analysis was employed for characterizing watersheds {Nag, 1998, Vittal et al., 2004, Vijith, H et al., 2006, Rudraiah, M et al., 2008, Thomas et al., 2009, Al Saud, M 2009, Rao, N et al., 2010, Rao, L et al., 2011, Zende, A et al., (2011), Mishra, A et al., 2011, Pareta, K et al., 2011, Pal, S et al., 2012, Senadeera, K et al., }, for the prioritization of sub watersheds {Shri Mali et al., 2001, Nooka Ratnam, K et al., 2005, Thakkar and Dhiman 2007, Javed, A et al., 2009, Mishra and Nagarajan, 2010, Londhe et al., 2010, Deo Kumar, T et al., 2012, Panhalkar, S et al., 2012, Kanth, T et al., 2012}

The quantitative analysis of morphometric parameters is found to be of vast utility in watershed prioritization for soil resource management and conservation at micro level for sustainable development. The present paper evaluates to prioritize Yerala river basin on the basis of morphometric analysis.

Objectives:

The main objective of the present study is to assess the morphometric characteristics of Yerala river basin to prioritize the sub-watershed for soil resource management and conservation.

Materials and Methods:

In the present study, morphometric analysis and prioritization of sub-watersheds in Yerala river basin is based on the integrated use of RS and GIS techniques. SRTM (90 m resolution) data is used. Yerala river basin was delineated with the help of ARCHYDRO software. Sub-watersheds are also demarcated by using the same software to carry out the sub-basin wise morphometric analysis. Twenty three sub-watersheds are identified for further analysis.

The linear morphometric parameters such as drainage density, stream frequency, bifurcation ratio, texture ratio and shape parameters such as form factor, elongation ratio, compactness constant and circulatory ratio were computed based on the formula suggested by Horton, Strahler, Schumn and Miller given in Table I.

The linear morphometric parameters have a direct relationship with erodibility, higher the value, more is the erodibility. Shape morphometric parameters have an inverse relationship with erodibility, lower the value, more is the erodibility. Hence, the ranking of the sub-watersheds has

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been determined by assigning the highest rank based on highest value in case of linear parameters and lowest value in case of shape parameters. Prioritization rating of all the twenty three sub-watersheds of Yerala river basin was carried out by calculating the compound parameter values. The sub-watershed with the lowest compound parameter value was given the highest priority. The final priority classification has been given into three major classes i.e. High priority, Medium priority and Low priority. The high priority indicates need of reclamation process and action plan for soil resource management and conservation.

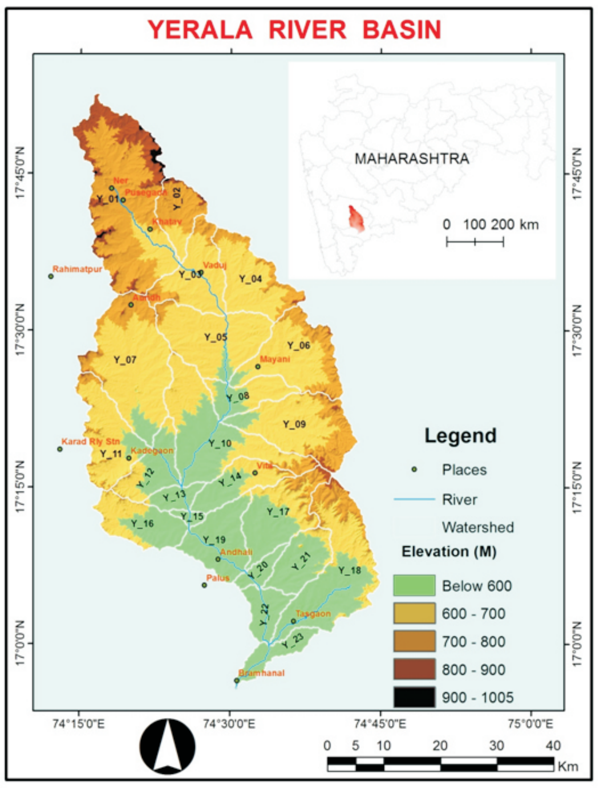
Formulation for Computation of Morphometric Parameters

Sr. No.	Morphometric Parameter	Formula	Reference
1.	Basin Area (A) Sq Km.	GIS Software Analysis	-
2.	Basin Perimeter (P) Km.	GIS Software Analysis	-
3.	Stream Order (Nu)	GIS Software Analysis	Strahler (1964)
4.	Stream Length (k.m.)	GIS Software Analysis	Strahler (1964)
5.	Basin Length	**$Lb=1.312*A^{0.568}$** Lb = Length of Basin (km) A = Area of the basin (km^2)	-
6.	Bifurcation Ratio (Rb)	**Rb= Nu/Nu+1** Nu= Total number of stream segment of order u Nu+1= Total number of stream segments in next higher order	Schumm (1956)
7.	Mean Bifurcation Ratio (Rbm)	Rbm = Average of Bifurcation ratio of all orders	Strahler (1964)
8.	Drainage Density (Dd) km/km^2	**Dd =Lu/A** Lu =Total stream length of all order, A= Area of the Basin (km^2)	Strahler (1964)
9	Texture Ratio (T)	**T = Nu/ P** Nu = Total number of streams of all orders, P = Perimeter of the Basin (km)	Horton (1945)
10	Stream Frequency (F)	**F = Nu/A** Nu=total number of stream segments of all order, A= Area of the Basin (km^2),	Horton (1945)
11	Circulatory Ratio (Rc)	**$Rc=4\pi A/ P^2$** Rc= Circularity Ratio, A= Area of the Basin (km^2), P = Perimeter of the Basin (km)	Miller (1953)
12	Elongation Ratio (Re)	**Re=2 v(A/π) /Lb** Re=Elongation ratio Lb= Length of basin (km), A = Area of the basin (km^2)	Schumm (1956)
13	From Factor (Rf)	**$Rf = A/Lb^2$** A = Area of the basin (km^2) Lb^2 = Square of the basin length	Horton (1945)
14	Compactness Constant (Cc)	**$Cc = 0.2821\ P/A^{0.5}$** A = Area of the basin (km^2) P = Perimeter of the basin (km)	Horton (1945)

Table No. I

STUDY REGION:

The study region selected for present study is Yerala river basin of west part of Maharashtra. It covers total area of 3041 km2 and lies between in 160 55' to 170 28' North and 740 20' to 740 40' East Longitude in Satara and Sangli districts. Twenty three sub-basins are identified in Yerala river basin. Minimum and maximum elevation of the area is 458 meter and 1004 meter respectively. The average annual rainfall increases from 1900 mm in the western side to 600 mm in the east side. (Zende A. M, 2011)



Map 1

YERALA RIVER BASIN: MORPHOMETRIC PARAMETERS

	Basic Parameters			Stream Analysis	
Sub-watershed	Area (Km^2)	Perimeter (Km)	Basin Length (Km)	Total number of stream order	Total Stream Length (Km)
Y_01	393	150.537	39.044	272	290.29
Y_02	77	60.239	15.469	50	66.56
Y_03	130	85.762	20.828	79	112.82
Y_04	140	87.697	21.724	96	108.58
Y_05	186	90.359	25.528	99	156.21
Y_06	174	99.249	24.579	113	137.68
Y_07	265	112.918	31.213	162	216.25
Y_08	71	68.162	14.772	31	58.36
Y_09	186	96.346	25.528	129	148.44
Y_10	232	138.018	28.942	130	171.66
Y_11	137	89.028	21.458	100	108.45
Y_12	87	67.678	16.580	67	74.39
Y_13	33	40.704	9.560	18	28.07
Y_14	82	70.702	16.032	45	65.17
Y_15	12	24.616	5.382	14	13.6
Y_16	105	68.646	18.449	72	86.04
Y_17	148	94.229	22.420	99	127.03
Y_18	246	140.316	29.922	169	199.92
Y_19	116	77.113	19.523	75	89.86
Y_20	29	44.272	8.883	21	23.7
Y_21	87	61.509	16.580	60	69.03
Y_22	55	54.796	12.778	36	45.79
Y_23	50	71.791	12.105	32	40.96
Yerala Basin	3041	481.540	124.821	1969	2438.86

	Linear Parameter				Shape Parameter			
Sub-watershed	Drainage Density (Dd)	Stream Frequency (F)	Mean Bifurcation Ratio (Rbm)	Texture Ratio (T)	Form Factor (Rf)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Compactness Constant (Cc)
Y_01	0.74	0.69	1.74	1.81	0.258	0.573	0.218	2.142
Y_02	0.86	0.65	1.74	0.83	0.322	0.640	0.267	1.937
Y_03	0.87	0.61	2.05	0.92	0.300	0.618	0.222	2.122
Y_04	0.78	0.69	7.82	1.09	0.297	0.615	0.229	2.091
Y_05	0.84	0.53	3.59	1.10	0.285	0.603	0.286	1.869
Y_06	0.79	0.65	1.89	1.14	0.288	0.606	0.222	2.123
Y_07	0.82	0.61	1.8	1.43	0.272	0.589	0.261	1.957
Y_08	0.82	0.44	1.85	0.45	0.325	0.644	0.192	2.282
Y_09	0.80	0.69	1.73	1.34	0.285	0.603	0.252	1.993
Y_10	0.74	0.56	1.67	0.94	0.277	0.594	0.153	2.556
Y_11	0.79	0.73	3.66	1.12	0.298	0.616	0.217	2.146
Y_12	0.86	0.77	4.56	0.99	0.316	0.635	0.239	2.047
Y_13	0.85	0.55	2.39	0.44	0.361	0.678	0.250	1.999
Y_14	0.79	0.55	1.72	0.64	0.319	0.638	0.206	2.203
Y_15	1.13	1.17	2.04	0.57	0.414	0.727	0.249	2.005
Y_16	0.82	0.69	4.42	1.05	0.308	0.627	0.280	1.890
Y_17	0.86	0.67	1.93	1.05	0.294	0.612	0.209	2.185
Y_18	0.81	0.69	4.98	1.20	0.275	0.592	0.157	2.524
Y_19	0.77	0.65	3.38	0.97	0.304	0.623	0.245	2.020
Y_20	0.82	0.72	1.85	0.47	0.367	0.684	0.186	2.319
Y_21	0.79	0.69	4.53	0.98	0.316	0.635	0.289	1.860
Y_22	0.83	0.65	2.64	0.66	0.337	0.655	0.230	2.084
Y_23	0.82	0.64	1.53	0.45	0.341	0.659	0.122	2.864
Yerala Basin	0.80	0.65	1.74	4.09	0.195	0.499	0.165	2.463

Table No. II Source: Computed by author

RESULT AND DISCUSSION:

A] Morphometric Analysis:

I) Basic Parameter:

Basic parameters include watershed area, perimeter and basin length.

a) Basin Area (A):

The drainage area (A) is probably the single most important watershed characteristic for hydrologic design and reflects the volume of water that can be generated from rainfall. Present study shows that the Yerala river basin covers an area about 3041 km2. The author has computed the twenty three sub watershed area by using ArcGIS-10 software, ranging from 12 km2 to 393 km2. (Table 2)

b) Basin Perimeter (P):

Basin perimeter is the outer boundary of the watershed that enclosed its area. It is measured along the divides between watersheds and may be used as an indicator of watershed size and shape. Perimeter of the watersheds is about 481.54 km. The author has computed the sub-watershed perimeter by using ArcGIS-10 software, ranging from 24.61 km to 150.53 km.
(Table 2)

c) Length of the Basin (Lb):

Basin length is usually defined as the distance measured along the main channel from the watershed outlet to the basin divide. Basin length is the basic input parameter to count the major shape parameters. In the result, Yerala river basin length is 124.82 km. The author has computed the sub-watershed basin length, ranging from 5.38 km to 39.04 km. (Table 2)

II) Linear Parameter:

The linear aspects of morphometric analysis of sub-watershed include stream order, stream length, mean stream length, stream length ratio, drainage density and bifurcation ratio.

a) Drainage Density: (Dd)

According to Horton (1932), Drainage density is the ratio of total stream length of all orders in drainage basin to the total area of the basin. Drainage density in the Yerala river basin is low and varies from 0.74 to 1.13 km/km2, thus indicates that the regions has permeable subsoil and low relief. (Table 2)

b) Bifurcation Ratio: (Rb)

The bifurcation ratio is the ratio of the number of stream segments of a given order to the number of stream segments of the next higher order (Schumn 1956). The lower values of bifurcation ratio are characteristics of the watersheds, which have suffered less structural disturbances and the drainage pattern is not distorted. (Strahler 1964). The mean bifurcation ratios of all orders, varies from 1.53 to 7.82 and entire basin is 1.74. The highest value of mean bifurcation ratio is found in sub-watershed Y_04 suggesting structural control in the area and low permeability whereas all other basins are geologically homogenous. (Table 2)

c) Stream Order (Su):

Stream ordering is the first step of quantitative analysis of the drainage basin. In the present study, stream ordering has been carried out using Strahler .The smallest stream is called as first order stream. A second order stream forms when two first order streams connect and a third order when two second order streams are connected and so on (Strahler, 1964).

d) Stream Number (Nu)

The total of order wise stream segments is known as stream number. In Yerala river basin the total number of streams is 1969, out of which 977 belong to first order, 435 are of second order, 274 are of third order, 136 are of fourth order, 76 of fifth and 71 is of sixth order. The sub-watershed wise total stream number is given in the table 1. It has been observed that, frequency of first order streams is highest and the number of stream segments decreases as the stream order increases.

e) Stream Length (Lu)

The total stream lengths of the various segments are computed with the help of Arc GIS software. In the Yerala river basin, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. This is a normal trend and indicates that the topography is gently sloping, low relief and homogenous lithology.

f) Texture ratio (T)

According to Horton (1945), It is the total number of stream segments of all orders per perimeter of that area and it depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. The value of texture ratio of Yerala river basin is 4.09 indicating moderate texture.

III) Shape Parameter:

a) Form factor (Ff)

Form factor is the ratio of the basin area to the square of basin length . It is used as a quantitative expression of the shape of basin form. If the watershed is narrow, the form factor will be low and wider watersheds have high form factor values. (Gregory & Walling, 1985). The elongated watershed with low form factors have lower peak flow of longer duration, whereas, high form factors have high peak flows of shorter duration. The Yerala river basin is having low value (0.19) of from factor. The form factor of sub-watersheds varies between 0.25 to 0.41. The analysis shows that the sub watersheds are more or less elongated.

b) Elongation ratio (Re)

According to Schumm (1965), elongation ratio is the ratio of diameter of a circle of the same area as the basin to the maximum basin length. According to Strahler (1964), Re value ranged between 0.6 and 0.8 are associated with high relief and steep ground slope. The lower value of the elongation ratio indicates that particular watershed is more elongate than others. The elongation ration of Yerala river basin is 0.49, which is represented the watershed is more elongated. In the Yerala river basin, The Re value for all sub watersheds also varies from 0.57 to 0.72 indicating high relief and steep ground slope.

c) Circulatory ratio: (Rc)

Circularity ratio is the ratio of the basin area to the area of a circle having the same circumference perimeter as the basin, which is dimensionless and expresses the degree of circularity of the basin (Miller, 1953). It is useful for flood hazard assessment. Higher the circularity value, higher is the flood hazard at the peak time at the outlet point. In the Yerala river basin the Circularity ratio varies from 0.12 to 0.28 indicating sub watersheds are elongated.

d) Compactness Constant: (Cc)

Compactness constant is the ratio between the area of the watershed and the perimeter of the watershed. It is dependent on the slope and independent of size. Lower values of this parameter indicate the less erosion and more elongation of the watershed. In this study the value of compactness constant is 2.46 of the Yerala river basin and all sub watersheds also varies from 1.86 to 2.86.

B] Watershed Prioritization

The morphometric parameters like drainage density, bifurcation ratio, stream frequency, elongation ratio, form factor, circularity ratio and compactness constant can be termed as erosion risk assessment parameters and have been used to prioritize watershed. (Biswas, et al. 1999). The sub-watersheds have been classified into three priority zones according to their compound value: High (<10.0), Medium (10-15) and Low (>15). The watershed wise prioritization ranks are given in table 3 and the final prioritized map of the study area is shown in Map 2.

The watersheds which fall in high priority category are Y_1, Y_5, Y_7, Y_9, Y_11, Y_12, Y_17 and Y_18. There are eleven watersheds falling in medium priority. These include Y_2, Y_3, Y_4, Y_6, Y_10, Y_15, Y_16, Y_19, Y_20, Y_21 and Y_22. Low Priority category has been attained by Y_8, Y_13, Y_14 and Y_23. Highest priority indicates the higher degree of soil erosion in the particular sub-watershed and it becomes potential area for applying soil conservation measures. Thus, soil management and conservation to be applied first to Y_1, Y_5, Y_7, Y_9, Y_11, Y_12, Y_17 and Y_18 sub-watersheds followed by other sub-watersheds.

CONCLUSION:

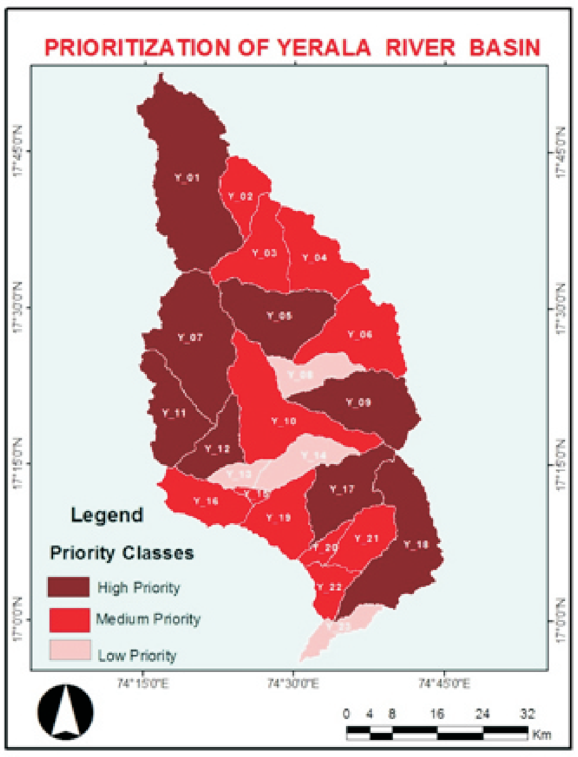
The morphometric analyses of the Yerala river basin were carried out through measurement of linear and areal aspects of the watershed. Drainage density shows that, moderate permeable sub-soil and low relief found in the Yerala river basin. The mean bifurcation ratio is indicating that, all basins are geologically homogenous. The value of circularity ratio and form factor suggests that the sub-watersheds are more or less elongated. In the Yerala river basin, the value of elongation ratio for all sub watersheds indicating that, high relief and steep ground slope.

Watershed prioritization is one of the most important aspects of planning for implementation of its development and management programs. A result of prioritization of sub-watersheds shows that, sub-watersheds Y_1, Y_5, Y_7, Y_9, Y_11, Y_12, Y_17 and Y_18 are fall in high priority category. High priority sub-watersheds are possibly having greater degree of soil erosion. Therefore, immediate attention towards soil conservation measures is required in these watersheds to preserve the land from further erosion.

Final Prioritization of Yerala River Basin.

Sub-watershed	Dd	F	Rbm	T	Rf	Re	Rc	Cc	Compound Parameter	Final Priority
Y_01	23	6	18	1	1	1	9	15	9.25	1
Y_02	3	14	19	16	17	17	20	4	13.75	2
Y_03	2	18	11	15	11	11	11	13	11.5	2
Y_04	20	10	1	8	9	9	12	12	10.125	2
Y_05	7	22	7	7	5	6	22	2	9.75	1
Y_06	19	13	14	5	7	7	10	14	11.125	2
Y_07	13	17	17	2	2	2	19	5	9.625	1
Y_08	9	23	16	21	18	18	5	19	16.125	3
Y_09	15	5	20	3	6	5	18	6	9.75	1
Y_10	22	19	22	14	4	4	2	22	13.625	2
Y_11	18	3	6	6	10	10	8	16	9.625	1
Y_12	5	2	3	11	14	14	14	10	9.125	1
Y_13	6	21	10	23	21	21	17	7	15.75	3
Y_14	16	20	21	18	16	16	6	18	16.375	3
Y_15	1	1	12	19	23	23	16	8	12.875	2
Y_16	10	9	5	10	13	13	21	3	10.5	2
Y_17	4	11	13	9	8	8	7	17	9.625	1
Y_18	14	8	2	4	3	3	3	21	7.25	1
Y_19	21	15	8	13	12	12	15	9	13.125	2
Y_20	12	4	15	20	22	22	4	20	14.875	2
Y_21	17	7	4	12	15	15	23	1	11.75	2
Y_22	8	12	9	17	19	19	13	11	13.5	2
Y_23	11	16	23	22	20	20	1	23	17	3

Table No: III   Source: Computed by author



Map 2

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