Watershed Prioritization for Soil Conservation using Morphometric Parameters and GIS of Bend Watershed

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Abstract

Watershed prioritization for soil conservation is now needed to conserve the soil from erosion. The morphometric parameters are useful to prioritize sub-watershed to follow the soil conservation measures. These morphometric parameters are having influence on the soil erosion. The SoI toposheet, GIS technique and various morphometric parameters such as stream number, stream frequency, form factor, relief ratio of watershed, drainage density, bifurcation ratio and drainage texture are used to analyze compound parameter value obtained for prioritization of sub-watershed for soil conservation in Bend river watershed. The GIS technique is accurate and useful to carry the analysis. The results of sub- watershed prioritization categorized are into three classes as high priority, medium priority and low priority.

Keywords: Watershed Prioritization, Morphometric Analysis, GIS, Soil Conservation

Introduction

Land is important natural resource which supports plant for growth. The increasing population and changing methods of agriculture are having pressure on the land resources. The agricultural productivity is depends on the quality and fertility of soil. Many factor are controlling the soil erosion in which the surface runoff also one of the more influencing factor for the soil erosion. Upper layer of soil removed by streams and transported to another location and it reduces the soil fertility. The morphometric parameters are having direct and indirect influence on soil erosion. Quantitative description of a watershed is provided by the morphometric analysis, as it is the mathematical measurement and analysis of the shape of the earth's surface and its landform dimension, which is an important aspect of characterization of a basin (Strahler 1964; Clarke 1996; Agarwal 1998). The morphometric analysis is an important aspect to analyze flood condition and soil erosion (Chavare and Potdar, 2014, Chavare, 2011, Chavare and Shinde, 2013). The stream order, stream number, stream length, form factor, stream frequency, elongation ratio, relief ratio, circulatory ratio, drainage density, drainage texture and bifurcation ratio these all parameters are used to calculate compound parameter value and on that basis the sub-watershed prioritization is assigned for soil conservation.

Study Area

The bend river is tributary of the Seena River in Solapur district. The area of the watershed is 307 Km^2 and extended between 17^0 58' to 18^0 9' North Latitude and 75^0 16' to 75^0 34'East Longitude. Bend river originate in Karmala tahsil and flows eastward direction and confluence in Sultanpur to Seena River (Fig.1). The bend river is having up to 5th order stream network. The bend watershed is divided into 4 sub-watersheds to study the soil conservation priority on the basin of stream order.

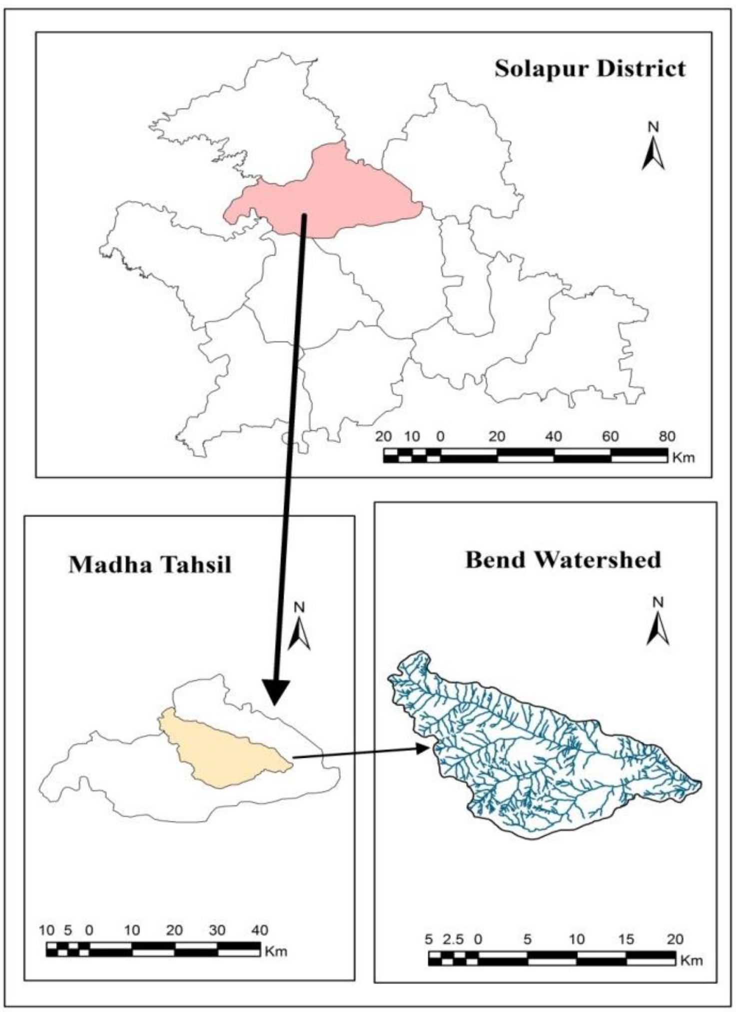

Fig.1 Location of Study Area

Materials and Methods

The watershed prioritization prepared using the SoI India toposheet 1:50000 scale. The bend watershed is prepared using SoI toposheet 47 O/5, 47 N/12 and 47 N/8, this toposheet is georeferenced and rectified with UTM projection system. The stream order is digitized from the toposheet and morphometric parameters calculated using various formulas (Table 1). The stream order, stream number, stream length, form factor, stream frequency, elongation ratio, relief ratio, circulatory ratio, drainage density, drainage texture and bifurcation ratio these all parameters are calculated for the 4 sub-watersheds. The compound parameter value is derived from the ranking each parameter in all sub-watershed using influence of factor and then priority is suggested for the soil conservation. Shuttle Radar Topography Mission (SRTM) elevation data of 90 m resolution is also used to analyzes the slope and aspect of the Bend river watershed. From the analysis of slope and aspect of area we can determine the drainage network and drainage pattern.

Table 1 Formula for calculating morphometric parameters

Sr.No.	Morphometric Parameter	Formula	Reference
	Stream Order(Su)	Hierarchical Rank	Strahler (1952)
	Stream Number (Nu)	Nu= N1+ N2+…Nn	Horton (1945)
	Stream Length(Lu) in Kms	Lu=L1+ L2…Ln	Strahler (1964)
	Stream Length Ratio(Lur)	---	Strahler (1964)
	Bifurcation Ratio(Rb)	---	Strahler (1964)
	Basin Perimeter (P) Kms	---	Schumm(1956)
	Basin Area (A) Sq Kms	---	Schumm(1956)
	Basin Length (Lb) Kms	---	Schumm(1956)
	Form Factor Ratio (Rf)	$Rf = A / Lb^2$	Horton (1932)
	Elongation Ratio (Re)	$Re = 2 / Lb * (A / \pi)^{0.5}$	Schumm(1956)
	Texture Ratio (Rt)	$Rt = N1 / P$	Schumm(1965)
	Circularity Ratio (Rc)	$Rc = 12.57 * (A / P^2)$	Miller (1953)
	Stream Frequency (Fs)	$Fs = Nu / A$	Horton (1932)
	Drainage Density (Dd) Km / Kms^2	$Dd = Lu / A$	Horton (1932)
	Relief Ratio (Rhl)	$Rhl = H / Lb$	Schumm(1956)

Results and Discussion

The Bend river watershed covers an area of 307 Km^2 and total length of basin is 32.94 Kms, highest elevation is 580 m above sea level and perimeter is 91Kms. The watershed is divided into four sub-watersheds for the purpose of prioritization for soil conservation. The morphometric parameter was calculated for individual sub-watershed and compound parameter value is obtained, according to this value the priority is assigned.

Stream Order (Su)

The preliminary step is stream ordering to understand the drainage basin characteristics followed by calculation of stream number and stream length (Horton 1945; Strahler 1952). Stream network is digitized from the SoI toposheet and stream ordering is done (Fig.2). The bend watershed is having 5th order stream network. The sub-watershed is demarcated on the basis of stream order and all are having 4th order stream network.

Table 2: Stream Analysis of Sub-watershed

Sub watershed	Stream numbers in different orders				Stream length in different orders (Km)			
	1	2	3	4	1	2	3	4
SW1	102	27	5	1	78.11	34.89	9.22	14.67
SW2	44	14	2	1	31.95	18.52	4.17	7.28
SW3	88	23	4	1	55.74	22.81	9.93	10.21
SW4	63	14	3	1	45.47	22.45	12.02	11.64

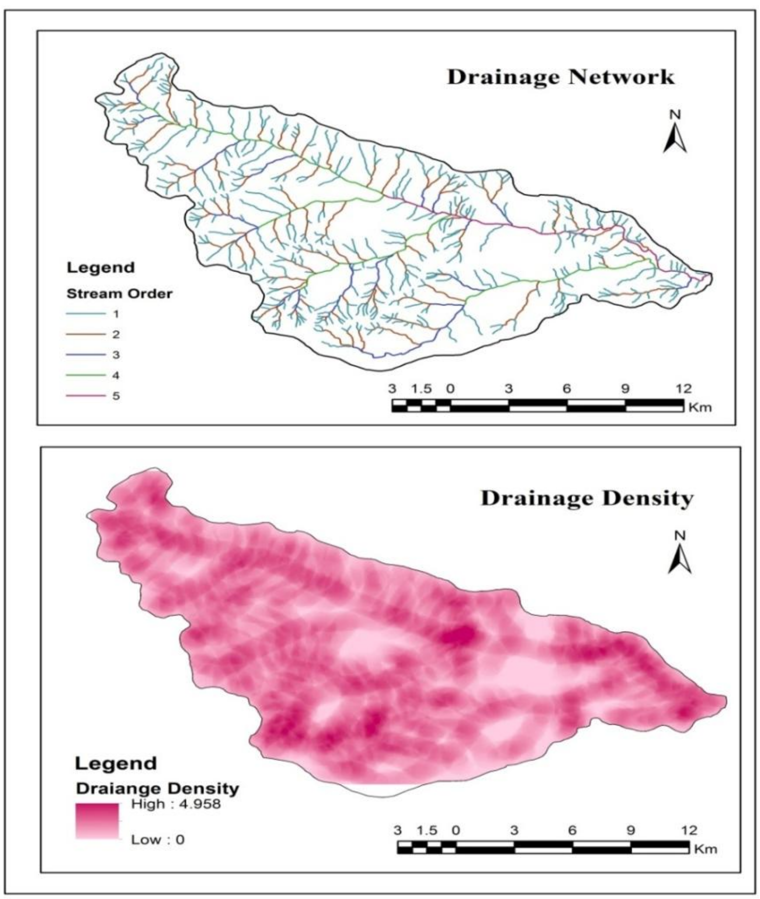

Fig.2 Drainage Netowrk and Drainage Density

ISSN: 2278-4632
Vol-10 Issue-5 No. 16 May 2020

Stream Number (Nu)

The count of stream channels obtained from stream orders is known as stream number (Strahler 1952). Number of streams is having direct influence on the soil erosion. High number of stream reflects the permeability of soil and it leads to flow and flowing water induce more erosion. The 394 total streams are digitized from the basin in which 297 stream are 1st order streams (Table 2).

Stream Length

Stream length is length of all stream networks in the basin. The 1st and 2nd order stream are having more length. The total stream length is 398.34 Kms (Table 2).

Drainage Density (Dd)

Drainage density is calculated as the total length of streams of all orders by the area of drainage basin which express as the closeness or spacing of channels within a basin over the basin area (Horton 1932, 1945; Strahler 1964). The drainage density is calculated for all sub-watershed and prepared map using line density (Fig. 2). The SW3 sub-watershed is having higher drainage density which is 2.03km/Km^2 and SW4 is having lowest which is 1.29 km/Km^2 (Table 3).

Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) is the ratio of number of streams of given order (Nu) to the streams number of next higher order (Nu + 1) (Schumm 1956; Strahler 1957, 1964). Mean bifurcation ratio is calculated for all sub-watersheds and SW1 is having highest and SW2 sub-watershed is having 4.05 (Table 3). Bifurcation ratio indicates the control of geological structure on drainage network.

Table 3: Values of drainage density, texture and bifurcation ratios for Sub- watershed

Sub-watershed	Perimeter (Km)	Drainage Density (Dd)	Drainage Texture (T)	Bifurcation Ratio (Rb)			Mean Bifurcation Ratio
				1/2	2/3	3/4	
SW1	46.15	1.68	2.93	3.78	5.40	5.00	4.73
SW2	27.82	1.65	2.19	3.14	7.00	2.00	4.05
SW3	31.88	2.03	3.64	3.83	5.75	4.00	4.53
SW4	45.06	1.29	1.80	4.50	4.67	3.00	4.06

Drainage Texture (T)

Drainage texture derived from drainage density and stream frequency. It is a measure of total stream of all orders per unit perimeter (Horton 1945; Smith 1950). In the present study the range between 1.80 per Km to 3.64 per Km. The drainage texture is related to infiltration capacity, soil, and geological structure of area and land use (Table 3).

Stream Frequency (Fs)

Stream frequency is ratio between number of streams of all order and the basin area (Horton 1932, 1945). Higher is the stream frequency greater the surface runoff. The computed stream frequency for all sub-watersheds and SW3 is having highest which is 2.38 Km^2 and SW4 is having lowest which is 1.14 Km^2 .

Form Factor (Rf)

Form factor expressed as the ratio of basin area to the square value of length of basin (Horton 1932, 1945). High form factor value resulting high flow in short duration and low form factor value resulting lower the flow. So high form factor value is responsible for higher erosion. The value of form factor in bend watershed is range between 0.20 (SW4) to 0.36 (SW2).

Table 4: Morphometric parameters of Sub-watershed

Sub-watershed	Area (Sq.km)	Stream Frequency (Fs)	Basin Length (Km)	Farm Factor (Rf)	Elongation Ratio (Re)	Circulatory Ratio (Rc)	Relief Ratio (Rhl)
SW1	81.41	1.66	15.77	0.33	0.65	0.48	2.54
SW2	37.45	1.63	10.26	0.36	0.67	0.61	3.90
SW3	48.64	2.38	12.20	0.33	0.65	0.60	4.92
SW4	71.23	1.14	19.11	0.20	0.50	0.44	3.14

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). In the Bend river sub-watershed elongation ratio is ranges between 0.50 to 0.67 (Table 4).

Circulatory Ratio (Rc)

This is ratio between basin's area and a circle's area with same circumference as basin perimeter (P) has represented as circularity ratio (Miller 1953; Strahler 1964). This variation resulted due to the variation in topography, relief, slope and other structural conditions (Hemanta Sutradhar, 2020). The computed circulatory ratio for the all sub-watershed is range between 0.44 to 0.61 which indicate the elongated shape and homogeneity in surface.

Relief Ratio (Rhl)

Relief Ratio is important indicator to determine slope of the basin. It is measured between total relief of a basin and longest basin length parallel to the principal drainage line

(Schumm, 1956). Steeper the slope is increase relief and resulting higher the soil erosion. In bend watershed in all sub-watersheds it ranges between 2.54 to 4.92 (Table 4).

Slope

Slope is one of the determining factors of soil erosion. The steep slope leads to fast runoff and ultimately higher the soil erosion. Slope is derived from SRTM data and it ranges from 0.79 degree to 6.17 degree (Fig.3).

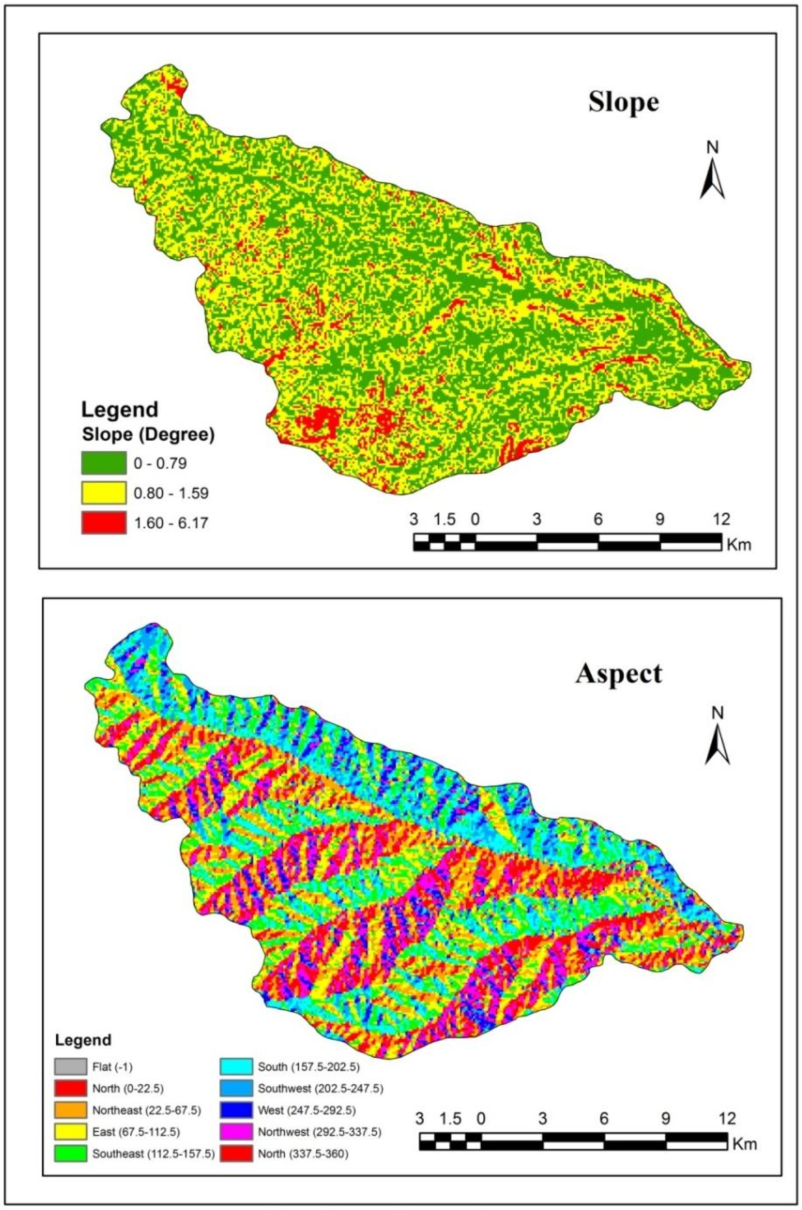

Fig.3 Slope and Aspect Map

Prioritization of Sub-watershed

One or two parameters are not having more influence on soil erosion. For comprehensive analysis of each sub-watershed, aerial, linear and relief parameters are taken into consideration for prioritization of sub-watershed. The morphometric parameters i.e. stream number, stream

ISSN: 2278-4632
Vol-10 Issue-5 No. 16 May 2020

length, stream frequency, bifurcation ratio, drainage density, drainage texture, relief ratio, form factor, elongation ratio, circulatory ratio, basin relief, basin length and basin perimeter, are having direct and indirect influence for soil erosion. The ranks are assigned for each sub-watershed according to influence of individual morphometric parameters and compound parameters values obtained. On the basis of compound parameter values 4 sub-watersheds are categorized into three class's namely high priority with lowest compound parameter value, medium priority with medium value and low priority with highest compound parameter value (Table 5). The priority is assigned for treatment for soil conservation to the bend river watershed (Fig.4). Result shows the SW3 is high priority for soil conservation and SW2 and SW4 having low priority.

Table 5: Prioritization of Sub-watershed using Morphometric Analysis

Sub-watershed	Rb	Dd	Rc	Re	Fs	T	Rf	Rhl	Compound Parameter Value	Priority
SW1	4.73	1.68	0.48	0.65	1.66	2.93	0.33	2.54	2.13	Medium
SW2	4.05	1.65	0.61	0.67	1.63	2.19	0.36	3.90	2.88	Low
SW3	4.53	2.03	0.60	0.65	2.38	3.64	0.33	4.92	1.63	High
SW4	4.06	1.29	0.44	0.50	1.14	1.80	0.20	3.14	2.88	Low

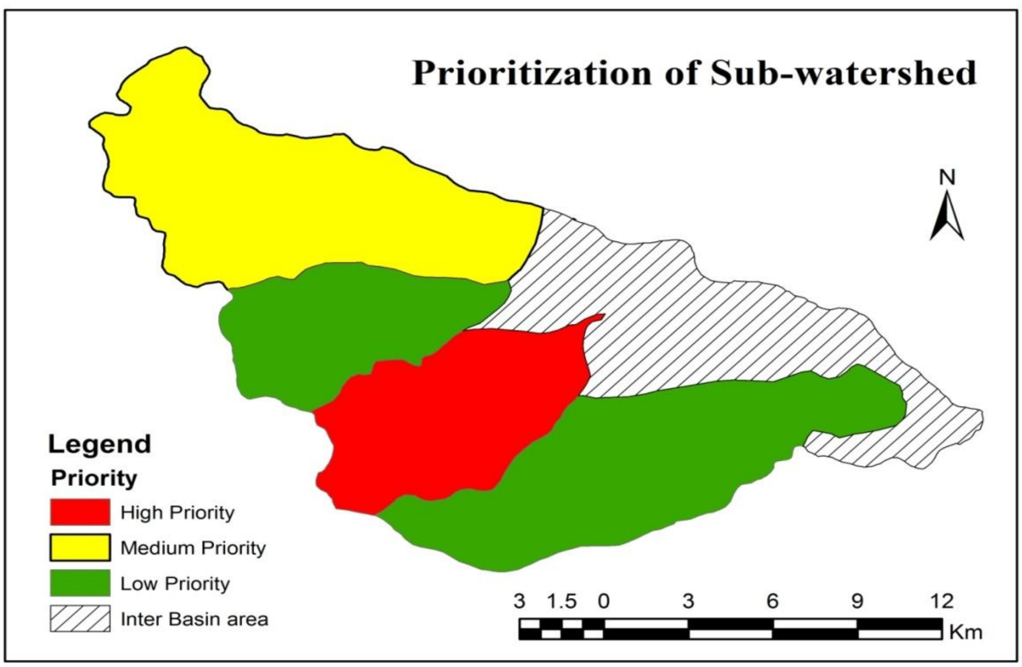

Fig.4 Prioritization of Sub-watershed

Conclusion

The prioritization of sub-watersheds of Bend river watershed based on morphometric parameters shows the usefulness of drainage morphometry in planning and management of soil from erosion and soil conservation strategy. Result shows the SW3 is need to give high priority for soil conservation among 4 sub-watersheds, SW1 sub-watershed covering part of origin of streams having medium priority for soil conservation and SW2 and SW4 having low priority for soil conservation. The SW3 sub-watershed required highest attention and immediate action for soil conservation measures. So soil conservation required to maintain the fertility and increase the crop production.

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