Prioritization of sub-basins of Jharol river basin in Rajasthan using Remote Sensing and Geographical information system (GIS) Techniques.

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ABSTRACT

Land resource development programmes are applied generally on a watershed basis. Delineation of watersheds or sub-basins within a large drainage basin and their prioritization is required for proper planning and management of natural resources for sustainable crop production. Morphometric analysis is commonly applied to prioritization of watersheds or sub-basins. The present study attempts to prioritize sub-basins based on morphometric analysis using remote sensing and GIS techniques in Jharol river basin of Udaipur district, Rajasthan, India. Various morphometric parameters, namely linear and shape have been determined for each sub-basins and assigned ranks on the basis of value/relationship, so as to arrive at a compound parameter values for a final ranking of the sub-basins and prioritization rating of five sub-basin of Jharol river basin is carried out. The sub-basin with the lowest compound parameter value is given the highest priority. The prioritization results reveal that sub-basin 4 rank highest, which compound parameter value is lowest as 2.375 and are considered as high priority for conservation measures by planners and decision makers, hence it should be provided with immediate soil and water conservation measures.

Keyword: prioritization, jharol river basin, morphometric analysis, remote sensing and GIS techniques.

Introduction:

Drainage basins, catchments and sub-catchments are the fundamental units for the management of land and water resources. Soil and water conservation are key issues in watershed management in India behind demarcating the priority watersheds. Watershed management is the process of formulation and carrying out a course of action involving modification of the natural system of watershed to achieve specified objectives. It implies the proper use of land and water resources of a watershed for optimum production with minimum hazard to natural resources. Remote Sensing and G1S techniques have emerged as powerful tools for watershed management programmes. The quantitative analysis of drainage system is an important aspect of characterization of watershed (strahler, 1964). Earlier studies indicated a relationship between cumulative stream length and stream order and also bifurcation ratio, drainage density, texture ratio and relief ratio for assessing the level of soil erosion (Nautiyal, 1994, Chaudhary and Sharma, 1998). Misra et al. (1984) studied the effect of different topo elements such as area, drainage density, form factor etc. with the sediment production rate of the sub watersheds in the upper Damodar valley and concluded that the increase of from factor reduces sediment production rate. Morisawa (1958) analyzed effect of different shape parameters on runoff rainfall ratios. It has been observed that the shape parameters showed a negative correlation with runoff-rainfall ratio. Now a days GIS techniques are used for assessing various terrain and morphometric parameters of the basin, as they provide a flexible and powerful tool for the manipulation and analysis of spatial information (Pareta and Pareta 2011). Ali et. al. (2013) studied morphometric analysis of Banas river basin using remote sensing and GIS technology. The morphometric characteristics of drainage and its effect on hydrology of watershed by using SRTM data and GIS were studied and concluded that the study of these aspects were useful for rainwater harvesting and watershed management plans (Sreedevi et al. 2009). Rudraiah et. al. (2008) has carried out morphometric analysis using Remote Sensing and GIS techniques in the Sub-Basin of Kagna River Basin, Gulburga District, Karnataka, India. Ali et. al. (2010) and Meshesha et. al. (2014) studied the landuse/ landcover change to determine the socio- environmental impact in Ethiopia highland with the help of remote sensing and GIS technique. Sharma et al. (2010) studied the morphometric analysis and prioritization of eight sub watersheds of Uttala river watershed, which is a tributary of Son River. Vittala et al. (2008) prioritize the sub-watersheds for sustainable development and management of natural resources using remote sensing, GIS and socio-economic data. In the present study the objective is to characterize and prioritize, the sub-basins enveloping in Jharol river basin of Udaipur district, Rajasthan, India on the basis of morphometric characteristics**.**

Study area:

Jharol river is one of the tributary of Mansi-Wakal river. In this study, the Jharol river basin was divided into five sub-basins. This river basin lies between the latitudes of $24^0$11'40.429" to $24^0$23'3.455"N and the longitudes of $73^0$19'44.778" to $73^0$27'11.053"E in the Udaipur district of Rajasthan, India. The total catchments area of the basin is 177.85 km^2. The area is characterized by sub-humid climate with an average annual rainfall of 630 mm. The general topography of the area is hilly and undulating. Most of the cultivated lands are located in the valleys. Surface drainage of the area is generally good due to slight undulations in the topography. Water flows through seasonal nala with high velocity, which is a main cause of erosion in the area. Small and scattered land holding situated on varying slope gradient is also a measure cause of soil erosion in the area. The drainage map of the Jharol river basin is shown in Fig.1.

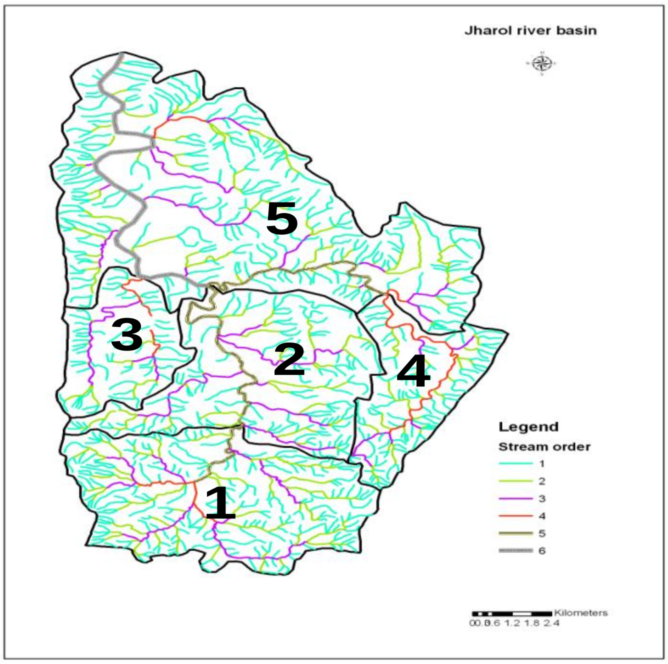

Fig.1. Drainage map of Jharol River Basin.

Methodology:

In the present study, morphometric analysis and prioritization of sub-basins of Jharol river is based on the integrated use of remote sensing and GIS techniques. The map showing drainage details of Jharol river have been prepared from digital data of LISS III and extracted by digitizing boundary of the basin from the geometrically rectified toposheet. The Jharol river basin was divided into five sub-basins designated as sub-basin 1 to sub-basin 5. The smallest (sub-basin 3) and the largest (sub-basin 5) sub-basin measure 14.86 and 74.30 km^2 respectively. The drainage map of sub-basins of Jharol river basin is shown in Fig.2. The figure also shows digitized stream network. The stream ordering was carried out using hierarchical ranking of stream proposed by Strahler (1964). The drainage pattern for delineated five sub-basins of Jharol river was exported to ARC/INFO GIS software for morphometric analysis. The fundamental parameters namely; stream length, area, perimeter, number of streams and basin length were derived from the drainage layer. The morphometric parameters for the delineated watershed area were calculated based on the formula suggested by Horton (1945), Strahler (1964), Schumn (1956) and Miller (1953) as given in Table 1.

Morphometric analysis is a significant tool for prioritization of sub basins. The morphometric parameters i.e., bifurcation ratio (R_b), drainage density (D_d), stream frequency (F_s), drainage texture (T), form factor (R_f), elongation ratio (R_e), circularity ratio (R_c) and compactness coefficient (C_c) are also termed as erosion risk assessment parameters and have been used for prioritizing sub-basins for treatment and conservation measures (Biswas et al., 1999). The linear parameters such as drainage density, stream frequency, bifurcation ratio, texture ratio have a direct relationship with erodibility, higher the value, more is the erodibility. Hence, for prioritization of sub basins, the highest value of these linear parameters was rated as rank 1, second highest value was rated as rank 2 and so on, and the least value was rated last in rank. Shape parameters such as elongation ratio, circularity ratio, form factor and compactness coefficient have an inverse relationship with erodibility (Nooka Ratnam et al., 2005), lower the value, more is the erodibility. Thus the lowest value of these shape parameters was rated as rank 1, next lower value was rated as rank 2 and so on and the highest value was rated last in rank. Hence, the ranking of the sub basins have been determined by assigning the highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters. After the rating has been done based on every single parameter, the rating values for every sub-basins were averaged to arrive at a compound value. Based on average value of these parameters, the sub-basin having the least rating value was assigned highest priority number of 1, next higher value was assigned priority number 2 and so on. The sub-basin which got the highest value was assigned the last priority number.

Table 1: Formula for computation of Morphometric Parameters.

Morphometric parameters	Formula	Reference
Stream order (u)	Hierarchical rank	Strahler (1964)
Stream length (L_u)	Length of stream	Horton (1945)
Mean stream length(L_{sm})	$L_{sm} = L_u / N_u$ Where, L_u = Total stream length of order u N_u = Total number of stream segments of order u	Strahler (1964)
Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ Where, N_u =Total number of stream segments of order u N_{u+1} = Number of stream segment of next higher order	Schumn (1956)
Mean bifurcation ratio (R_{bm})	R_{bm} = Average of bifurcation ratio of all orders.	Strahler (1964)
Drainage density (D_d)	$D_d = L_u / A$ Where, L_u = Total stream length of all order (km) A = Area of basin (km ^{2}).	Horton (1945)
Stream frequency (F_s)	$F_s = \Sigma N_u / A$	Horton (1945)

	Where, ΣN_u = Total number of stream of all order. A = Area of basin (km ^{2}).	
Texture ratio (T)	$T = \Sigma N_u / P$ Where, ΣN_u = Total number of stream of all order. P = Perimeter of basin (km).	Horton (1945)
Form factor (R_f)	$R_f = A / L_b^{\ 2}$ Where, A = Area of basin (km ^{2}). L_b = Length of basin (km).	Horton (1945)
Circularity ratio (R_c)	$R_c = 4 \pi A / P^2$ Where, A = Area of basin (km ^{2}). P = Perimeter of basin (km).	Miller (1953)
Elongation ratio (R_e)	$R_e = (2 / L_b) * (A / \pi)^{0.5}$ Where, L_b = Length of basin (km) . A = Area of basin (km ^{2}).	Schumn (1956)
Compactness constant (C_c)	$C_c = 0.2821 P / A^{0.5}$ Where, A = Area of basin (km ^{2}). P = Perimeter of basin (km).	Horton (1945)

Results and Discussion:

The study emphasizes on prioritization of sub-basins for their development and management on a sustainable basis, based on morphometric analysis of the sub-basins. The morphometric parameters of sub–basins of Jharol river were calculated in GIS environment and are presented in Table 2 & 3. The designation of stream order is the first step in morphometric analysis of a drainage basin, based on the hierarchic ranking of streams proposed by Strahler (1964). The highest stream order for the study area is six. In this study the sub-basin 1, sub-basin 2, sub-basin 3 and sub-basin 4 are of fifth order where as, sub-basin 5 is of sixth order basin. The fundamental parameters namely stream length, area, perimeter, basin length and number of stream for each of the sub-basins are calculated and shown in Table 2. The stream morphometric parameters namely bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio and compactness constant are calculated and are shown in Table 3. Jharol river basin shows a dendritic to sub dendritic drainage pattern. The highest bifurcation ratio is 4.66 for sub-basin 2 and minimum is 3.63 for sub-basin 4. The drainage density indicates the closeness of spacing of channels. More the drainage density, higher would be the run-off (Vittala et al. 2008). The drainage density in the study area varies from 3.18 to 4.23 km/km^2. Based on the priority factor the highest priority has been given to sub-basin 1 as they had high drainage density compared to the remaining sub-basins (Table 4). The stream frequency (Fs) values of sub-basins of the study area are varies from 4.04 to 7.65 (Table 3). The highest stream frequency for sub-basin 4 and minimum for the sub-basin 5. The highest circularity ratio is 0.57 for sub-basin 3. The form factor values are in range of 0.30 to 0.60. The sub-basin 3 has the highest elongation ratio (0.87) indicating possibility of less erosion. The compound parameter values of five sub-basins of Jharol river basin are calculated and prioritization rating is shown in Table 4. Sub-basin number 4 with a compound parameter value of 2.25 receives the highest priority (one) with the next in the priority list is sub-basin 1, sub-basin 2, sub-basin 5 and sub-basin 3 respectively. Thus soil conservation measures can first be applied to sub-basin 4 and then to the other sub-basins depending upon their priority.

Table 2: Sub- Basin Parameters of Jharol River Basin.

Sub-basin No	Area (km2)	Perimeter (km)	Number of stream Oder wise						Total No. of Streams	Total Stream Length (km)	Max. length of the basin (km)
			1	2	3	4	5	6			
Sub-basin-1	37.59	28.95	199	63	7	2	1		272	158.93	9.43
Sub-basin-2	34.23	30.78	124	34	6	0	1		165	114.71	9.26
Sub-basin-3	14.86	18.03	58	16	3	1			78	47.32	4.98
Sub-basin-4	16.87	22.46	93	28	6	1	1		129	70.27	7.47
Sub-basin-5	74.3	49.76	216	65	15	2	1	1	300	237.27	15.04

Table 3: Stream Morphometric Parameters of Jharol River Basin.

Sub-basin No.	Mean Bifurcation Ratio	Drainage Density	Stream Frequency	Texture Ratio	Circularity Ratio	Form Factor	Elongation Ratio	Compactness Constant
Sub-basin-1	4.41	4.23	7.24	9.40	0.56	0.42	0.73	1.33
Sub-basin-2	4.66	3.35	4.82	5.36	0.45	0.40	0.71	1.48
Sub-basin-3	3.99	3.18	5.25	4.33	0.57	0.60	0.87	1.32
Sub-basin-4	3.75	4.17	7.65	5.74	0.42	0.30	0.62	1.54
Sub-basin-5	3.63	3.19	4.04	6.03	0.38	0.33	0.65	1.63

Table 4: Prioritization Result of Sub- Basins of Jharol River Basin.

Sub-basin No.	Bifurcation Ratio	Drainage Density	Stream Frequency	Texture Ratio	Circularity Ratio	Form Factor	Elongation Ratio	Compactness Constant	Compound Parameter	Final Priority
Sub-basin-1	2	1	2	1	4	4	4	2	2.5	2
Sub-basin-2	1	3	4	4	3	3	3	3	3.0	3
Sub-basin-3	3	5	3	5	5	5	5	1	4.0	5
Sub-basin-4	4	2	1	3	2	1	1	4	2.25	1
Sub-basin-5	5	4	5	2	1	2	2	5	3.25	4

Conclusions

The present study demonstrates the utility of remote sensing and GIS techniques in prioritizing sub-basins of Jharol river basin of Udaipur district based on morphometric analysis. The morphometric analysis of different sub-basins of Jharol river shows their relative characteristics with respect to hydrologic response of the basin. The results of morphometric analysis show that sub-basin 4 is prone to relatively higher erosion and soil loss than other sub-basins. Hence, planners and decision makers may take this first priority for conservation measures to locate specific planning and development. The next priority is given to sub-basin 1, sub-basin 2, sub-basin 5 and sub-basin 3 respectively.

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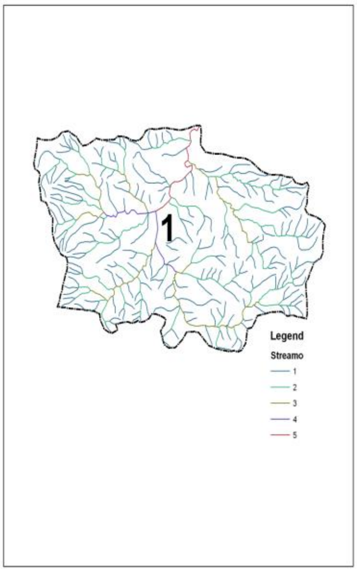
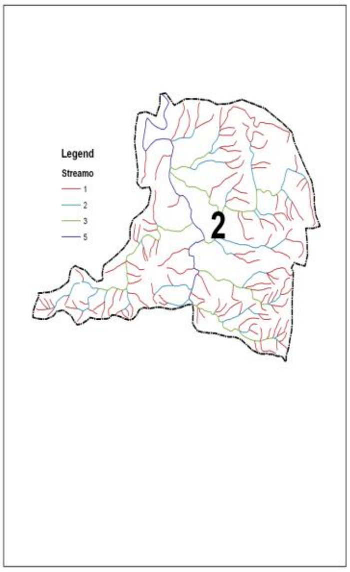
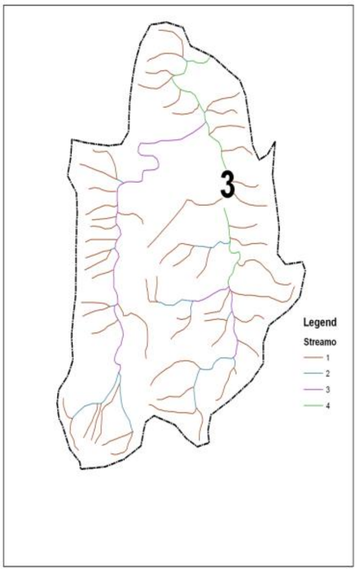
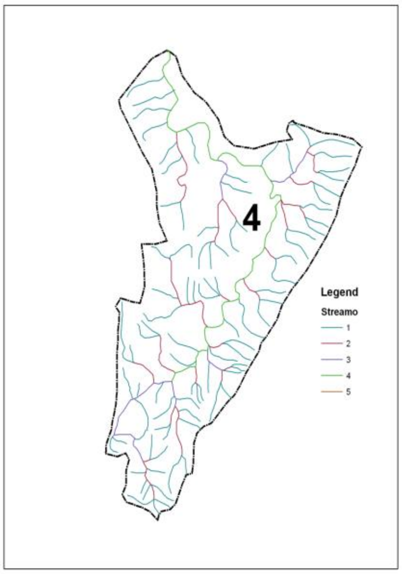
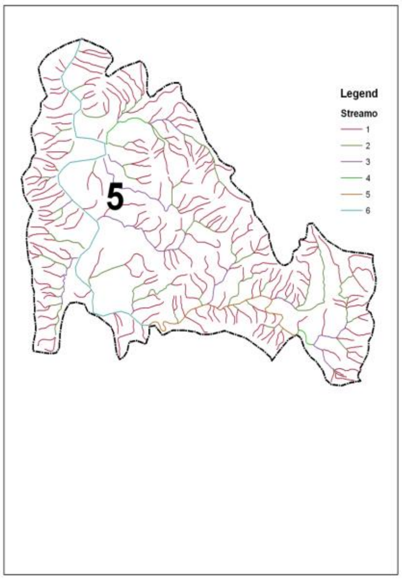






Sub-Basin 1 Sub-Basin 2 Sub-Basin 3





Sub-Basin 4 Sub-Basin 5

Fig. 2: Drainage map of sub-basins of Jharol River Basin.