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MORPHOMETRIC ANALYSIS AND PRIORITIZATION OF PURINBAL SUB-WATERSHED OF SINDH CATCHMENT FOR SOIL AND WATER RESOURCE MANAGEMENT USING GEO-SPATIAL TOOL

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ABSTRACT

Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management and morphometric analysis has been commonly applied to prioritization of watersheds (Javed *et. al.*, 2009). The prioritization process identifies the highest priority watersheds in which to conduct management. Morphometric analysis has been commonly applied to prioritization of watersheds as watershed characteristics of a basin represent its physical and morphological attributes that are employed in synthesizing its hydrological response. The present study makes an attempt to prioritize micro-watersheds based on morphometric parameters and GIS techniques in Sindh Catchment of Ganderbal district, Jammu and Kashmir. Various morphometric parameters, namely linear parameters and shape parameters have been determined using Survey of India (SOI) toposheets at 1:50,000 scale for each micro-watershed and assigned ranks on the basis of value/relationship so as to arrive at a computed value for a final ranking of the micro-watersheds. The analysis has revealed that the total number as well as total length of stream segments is maximum in first order streams and decreases as the stream order increases. Horton‘s laws of stream numbers and stream lengths also hold good. The slope model for the study area was generated from the contours of Survey of India (SOI) topo sheets at 1:50,000 scale following a 40 m contour interval. Results of prioritization of micro-watersheds based on morphometric analysis show that micro-watershed SSM-1 fall under very severe erosion class and are more susceptible to soil erosion.

INTRODUCTION

A watershed is an area from which runoff resulting from precipitation flows past a single point into large stream, river, lake or ocean. In agricultural areas, draining of fields causes water to run off the land and into streams and lakes more quickly, bringing sediment, nutrients, and other pollutants along with it. This can lead to flooding and water quality problems. To reduce soil erosion, planning, conservation and management of the watershed is vital.

Morphometry is the measurement and mathematical analysis of the configuration of the earth’s surface, shape and dimension of its landforms (Agarwal, 1998). Using micro-watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The various studies indicate that morphometric attributes like bifurcation ratio, stream length, drainage density, drainage frequency etc substantially contribute to evaluate the hydrological characteristics of a basin and help in identification of overall terrain character of basin (Singh, 1980). Morphometric analysis requires measurement of linear features, areal aspects, gradient of channel network and contributing ground slopes of the drainage basin (Nautiyal, 1994). The morphometric parameters i.e., bifurcation ratio (Rb), shape factor(Bs), compactness coefficient (Cc), drainage density (D), stream frequency (Fs), drainage texture (Rt), length of overland flow (Lo), form factor (Rf), circularity ratio (Rc), and elongation ratio (Re) are also termed as erosion risk assessment parameters and have been used for prioritizing sub-watersheds (Biswas *et al.*, 1999).Remote sensing data provides accurate timely and real time information on various aspects such as size and shape of the watershed, land use/land cover, physiography, soil distribution, drainage characteristics etc.

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Objective of the Study

1. To study the morphometric parameters Purinbal sub-watershed of Sindh Catchment
2. To prioritize micro-watersheds of Purinbal sub-watershed to identify erosion susceptibility zones based on morphometric parameters.

Study Area

The study area is the Sindh river catchment Purnibal Sub-watershed which is situated between the geographical coordinates of 34^{o} 16\`-$34^{o}$ 19\`N latitude and 75^{o}4\`-$75^{o}$10\`E longitude. The catchment has an area of approx. 32.16 sq kms.

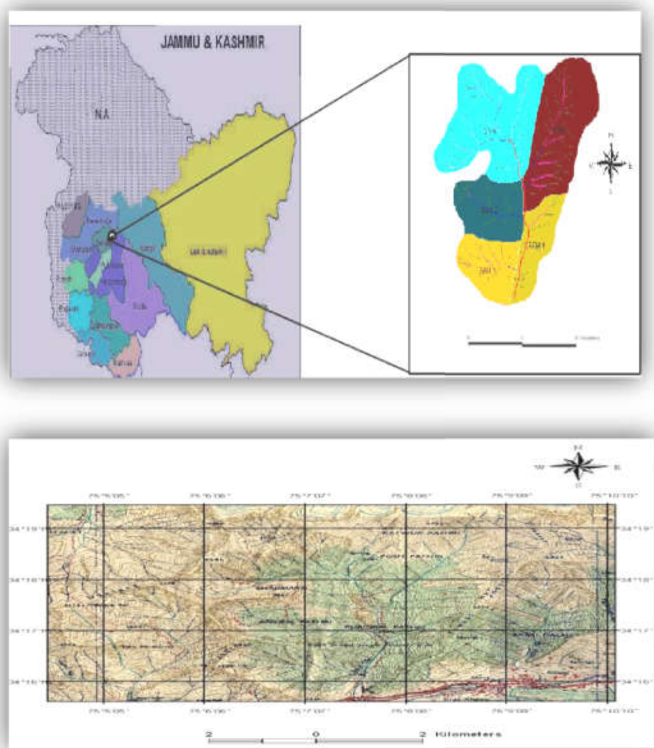

Fig 1 Location map of study area

METHODOLOGY

The methodology adopted for the current study can be best explained in terms of flow chart diagram shown below fig 2.

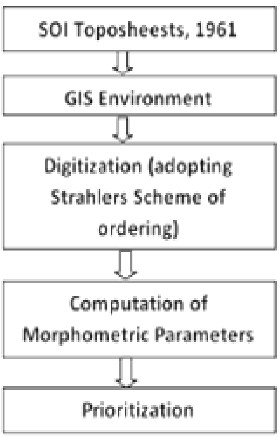

Fig 2 Steps of methodology

The Study was carried out on Micro-watershed level utilizing survey of india (SOI) toposheets. All the steams were digitized from Survey of India Toposheets, 1961 on a scale of 1:50,000 The morphometric analysis has been carried out for 5 micro-watersheds. The digitization was done in GIS system (Arcview 3.2a). Strahler‘s system of stream analysis is probably the simplest, most used system and same has been adopted for this study. Morphometric parameters namely perimeter, stream length, stream number, bifurcation ratio, drainage density, stream frequency, drainage texture, length of basin, form factor, circulatory ratio, elongation ratio, length of overland flow were computed using standard methods and formulae given in table: 1. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest CP were of low priority while those with lowest Cp were of high priority.

Table 1 Formula for computation of morphometric parameters

Morphometric Parameters	Formula	Reference
Stream order	Hierarchical rank	Strahler (1964)
Stream length (Lu)	Length of the stream	Horton (1945)
Mean stream length (Lsm)	Lsm = Lu / Nu Where, Lu = Total stream length of order ‘u’ Nu = Total number of stream segments of order ‘u’	Strahler (1964)
Stream length ratio (R_l)	Rl = Lu / Lu1 Where, Lu = Total stream length of order ‘u’ Lu-1 = The total stream length of its next lower order	Horton (1945)
Bifurcation ratio (R_b)	R_b = Nu / Nu + 1 Where, Nu = Total no. of stream segments of order ‘u’ Nu + 1 = Number of segments of the next higher order	Schumm (1956)
Drainage density (D_d)	D_d = Lu /A Where, D_d = drainage density Lu = total stream length of all orders A = area of the basin(km ^{2})	Horton (1945)
Stream frequency (F_s)	F_s = Nu/A Where Fs = stream frequency Nu = total number of streams of streams of all orders A = area of the basin, km 2	Horton (1945)
Circulatory ratio (Rc)	$Rc = 4 * \pi * A/P^2$ Where, Rc = circularity ratio $\pi = \pi$ value i.e., 3.141 A = area of the basin, km ^{2} P ^{2} = square of the perimeter, km	Miller (1953)
Elongation ratio (Re)	$Re = (4*A/ \pi)^{0.5} / Lb$ Where, Re = elongation ratio A = area of the basin, km ^{2} $\pi = \pi$ value i.e., 3.141 Lb = basin length, m	Miller (1953)
Form factor (F_f)	$Ff = A/Lb^2$ Where, Ff = form factor A = area of the basin, km ^{2} Lb = basin length	Schumm (1956)
Drainage texture (T)	T = Nu/P Where, Nu = total no. of streams of all orders P = basin perimeter, km	Horton (1945)

The micro watershed map of purinbal sub-watershed of Sindh catchment generated from Arc gis (3.2a), consists of five micro watersheds are shown in fig 3

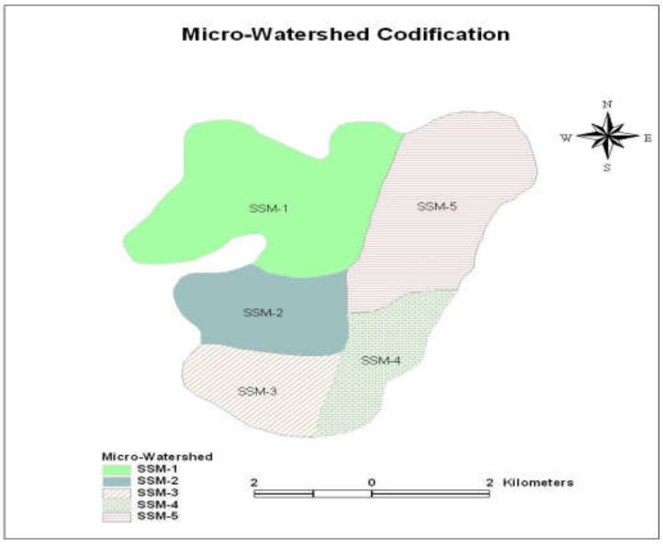

Fig 3 Micro-watershed map of purinbal sub-watershed

Drainage map

All the steams were digitized from Survey of India Toposheets, 1961 on a scale of 1:50,000. The digitization was done in GIS system (Arcview 3.2a). Strahler's system of stream analysis is probably the simplest, most used system and same has been adopted for this study. Following Strahler's scheme, it has been found that in Sindh Catchment , the total number of streams is 133 out of which 104 belong to 1st order, 23 are of 2nd order, 5, are of 3rd order, 1 are of 4th order shown in fig 4.

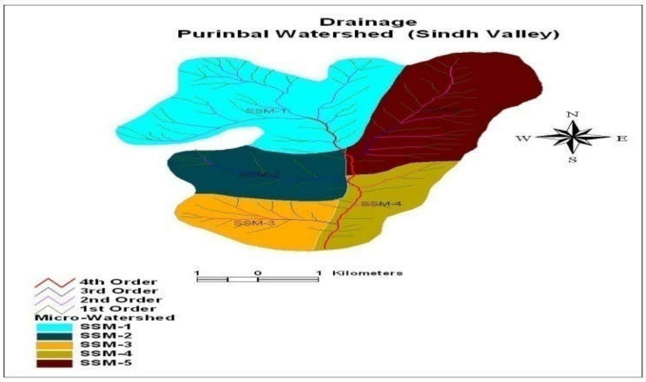

Fig 4 Drainage map of Purinbal sub-watershed

RESULTS

The results of the present investigation are divided into quantification and prioritization of micro-watershed using morphometric parameters

Quantification of morphometric parameters

The study carried out has been divided into three sections, the first section deals with applicability of Hortons laws of stream numbers and stream lengths in the study area. The second section deals with the various linear and shape morphometric characteristics and finally prioritization of watersheds is done on the basis of these linear and shape factors.

Linear parameters

Stream Number and Order

The watershed wise number and order is given in the Table 2. It reveals that the highest number of streams is found in SSM1 (55), followed by SSM5 (32) and SSM3 (19), where as the smallest number of streams is found in SSM2 (13) and SSM4 (13).

Stream Length

The Watershed wise length of streams in different orders, mean length of the streams is given in table 2. whereas their total length is given in table 3. It is revealed from the tables that the drainage network of the Sindh Catchment is characterized by total length of 95.34 km. The micro-watershed wise drainage length given in the table reveals that SSM-5 constitutes the highest proportion of drainage length of 30.40 km, followed by SSM-1 which is 22.25 km, and SSM-3 contributes 15.2 km, While the lowest contributors are SSM-2 and SSM -4 contributing 9.69 km and 9.7 km.

Bifurcation Ratio (Rb)

The mean bifurcation ratio in the Sindh Catchment comparatively registers a stable trend. It ranges from 4.70 (lowest) in SSM-1 to 6 (highest) in SSM-2. The mean bifurcation ratio of other micro-watersheds is in the range of 4-5 given in table 5.

Drainage density (D)

The drainage density values for all micro-watersheds in Sindh Catchment are given in the table 5. The drainage density exhibits a wide range in its values from 1.97 (lowest) in SSM-1 to 3.49 (highest) in SSM-5.

Stream frequency (Fs)

In Sindh Catchment the lowest drainage frequency is in SSM-2 (2.29), followed by SSM-5 (3.67). The highest drainage frequency is found in SSM-1 (4.9) followed by SSM-3 (4.19) are given in table 4.

Drainage texture (Rt)

The drainage density values of micro-watersheds range from 1.52 to 3.61 indicating very coarse and coarse drainage texture in the catchment. The watershed wise drainage texture is given in table 5.

Length of Overland flow (Lg)

The Lg values of the study area shows variation from 0.57 to 1.01. The values of Lg are higher in case of SSM-1, indicating low relief whereas the values of Lg are low in case 0.57 indicating high relief is given table 5.

Shape parameters

Form factor (Rf)

In the present case form factor values ranges from 0.15 to 0.37 indicating them to be elongated in shape and suggesting flatter peak flow for longer duration. Flood flows of such elongated basins are easier to manage than those of the circular basin are given in table 4.

Table 2 Order Wise, Stream Number, Stream Length and Mean Stream Length

Micro watershed code	First Order			Second Order			Third Order			Fourth Order			Fifth Order		
	No	Length	Mean	No	Length	Mean	No	Length	Mean	No	Length	Mean	No	Length	Mean
SSM 1	41	17.05	0.41	12	3.12	0.26	2	2.08	1.04	0	0	0	0	0	0
SSM 2	11	5.8	0.53	1	1.0	1.0	1	2.89	2.89	0	0	0	0	0	0
SSM 3	15	7.2	0.48	3	5	1.66	1	3	3	0	0	0	0	0	0
SSM 4	11	6.1	0.55	2	3.6	1.8	0	0	0	0	0	0	0	0	0
SSM 5	26	18.3	0.70	5	8.7	1.74	1	3.4	3.4	0	0	0	0	0	0
SWS-(Purinbal sub-watershed)	104	54.45	0.532	23	21.42	0.93	5	11.37	2.27	1	8.1	8.1	0	0	0
Cumulative mean length			0.532			1.46			3.73			6.43	0	0	0

Table 3 Total Length of Stream of all Orders

Micro-Watershed code	Stream Length of all Orders (Km)					Total Stream Length (Km)
	1	2	3	4	5	
SSM 1	17.05	3.12	2.08	0	0	22.25
SSM 2	5.8	1.0	2.89	0	0	9.69
SSM 3	7.2	5	3	0	0	15.2
SSM 4	6.1	3.6	0	0	0	9.7
SSM 5	18.3	8.7	3.4	0	0	30.4
SWS-(Purinbal sub-watershed)	54.45	21.42	11.37	8.1	0	95.34

Compactness coefficient (Cc)

The values of Cc in the study area vary from 1.014 to 1.40 showing wide variations across the micro-watersheds are given in table 5.

Prioritization of micro-watersheds based on morphometric analysis

In the study, morphometric analysis of the parameters, namely stream order, stream length, bifurcation ratio, relief ratio, drainage density, stream frequency, drainage texture, form factor, circulatory, compactness coefficient, elongation ratio, area, perimeter and length of the micro-watersheds has been carried out . Prioritization of watersheds has been done using compound values by morphometric analysis in table 6. The final priority/ranking was given by classifying the highest and lowest range of Cp value into four classes as very severe erosion class (1.7), severe erosion class (2.2), Moderate (3.2-3.6) and Slight erosion class (>4). Out of 5 micro-watersheds under study, one micro-watershed SSM-1 fall under the category of very severe erosion class. The micro-watershed SSM-2 fall under severe erosion class shown in fig 5. The micro-watersheds SSM-3 and SSM-5 fall under moderate erosion class. The micro-watershed SSM-4 fall under slight erosion class. Micro-watersheds under severe erosion class indicates the greater degree of erosion and these becomes potential zones after very severe erosion class for applying soil conservative measure. The soil and water conservation

Table 4 Results of Morphometric Analysis

Micro-watershed code	Area (A) Km^2	Perimeter (P) Km	Length of basin (L_b) Km	Stream Frequency (F_s)	Form Factor (R_f)	Elongation ratio (R_e)	Circulatory Ratio (R_c)
SSM 1	11.24	15.22	7.15	4.9	0.21	0.52	0.60
SSM 2	4.48	7.55	3.45	2.9	0.37	0.69	0.98
SSM 3	4.53	7.79	3.98	4.19	0.28	0.60	0.93
SSM 4	3.21	8.5	4.65	4.04	0.15	0.43	0.55
SSM 5	8.70	11.81	5.86	3.67	0.25	0.56	0.78
SWS-(Purinbal sub-watershed)	32.16	18.45	12.34	4.14	0.21	0.51	1.18

Table 5 Results of Morphometric Analysis

Micro-watershed code	Bifurcation Ratio (Rb)				Mean	Drainage Texture (R_t)	Length of overland flow(l_g)	Compactness coefficient (C_c)	Shape Factor (B_s)	Drainage density (D_d)
	(Rb1/2)	(Rb2/3)	(Rb3/4)	(Rb4/5)	(Rb)					
SSM 1	3.41	6	0	0	4.70	3.61	1.01	1.28	4.54	1.97
SSM 2	11	1	0	0	6	1.72	0.92	1.014	2.65	2.16
SSM 3	5	3	0	0	4	2.43	0.59	1.36	3.49	3.35
SSM 4	5.5	0	0	0	5.5	1.52	0.66	1.4	6.73	3.02
SSM 5	5.2	5	0	0	5.1	2.70	0.57	1.15	3.94	3.49
SWS-(Purinbal sub-watershed)	4.5	4.6	5	0	4.7	7.2	0.68	0.917	4.73	2.9

Shape factor(Bs)

Shape factor the ratio of the square of basin length (Lb) to the area of the basin (A). The Bs values of micro-watersheds ranges between 2.65 to 6.73 are given in table 5.

Circulatory Ratio (Rc)

Circulatory Ratio is helpful for assessment of flood hazard. Higher the Rc value, higher is the flood hazard at a peak time at the outlet point. Circulatory ratios of micro-watersheds under study range between 0.55to 0.98 given in table 4

Elongation ratio (Re)

Elongation ratio Re values of micro-watersheds indicate that all micro-watersheds and the whole of Sindh Catchment fall in the elongated category. The elongation ratio for all micro-watersheds varies from 1.01-1.15 given in table 4.

measures can also be applied to moderate priority micro-watersheds after serve priority micro-watersheds. The remaining micro-watersheds are under slight or low priority.

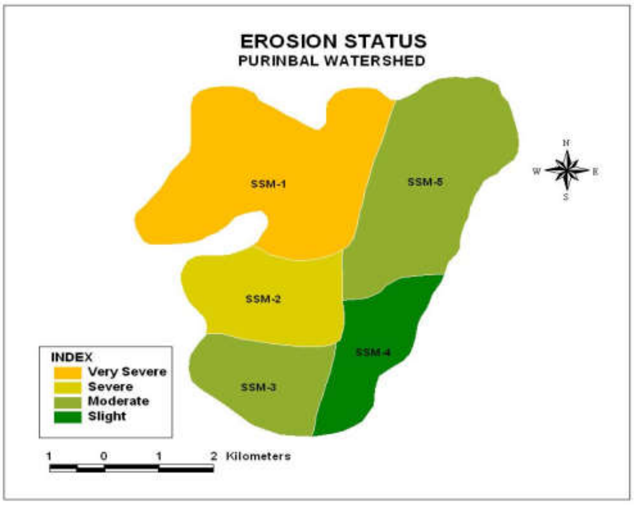

Fig 5 Prioritization of micro-watersheds

Table 6 Compound Values and Erosion Class depending upon the morphometric ranks

Micro-watershed code	Linear Parameters						Shape Parameters				C_p	Priority	Erosion Class
	R_b	F_s	R_t	L_g	D_d	R_c	R_e	R_f	C_c	B_s			
SSM 1	2	1	1	1	2	3	2	1	3	1	1.7	1	Very Severe
SSM 2	1	5	3	2	4	1	1	1	2	2	2.2	2	Severe
SSM 3	5	2	3	4	2	2	5	2	4	3	3.2	3	Moderate
SSM 4	5	3	4	5	3	5	4	3	4	5	4.1	4	Slight
SSM 5	3	4	2	5	4	3	3	3	5	4	3.6	3	Moderate

CONCLUSION

In total 5 micro-watersheds were identified for watershed prioritization study based on morphometric analysis out of which one micro-watershed SSM-1 falls under the category of very Severe erosion class, one micro-watershed viz.SSM-2 falls under severe erosion class, two SSM-3 and SSM-5 micro-watersheds falls under moderate erosion class and one watershed SSM-4 falls under slight erosion class respectively. The very Severe erosion class micro-watersheds have higher erosivity values due to their location in the hilly terrain with undulating topography. These are also nearer to the river body, therefore have better delivery ratio value considering the fluvial nature of hazards and need immediate attention. This study has found common area falling in the very severe category based on morphometric analysis; hence, these may be taken for conservation measures by planners and decision makers for locale-specific planning and development. The erosion susceptibility zone map will be helpful in identification of priority zones for the evaluation and suggestion of soil conservation measures based on the existing terrain conditions., GIS and remote sensing approach in prioritization of micro-watersheds and zone mapping based on ranks obtained from morphometric parameters. This approach will certainly help planners and decision makers in judicious allocation and utilization of available resources for treatment of small hydrologic units and effective checking of soil erosion.

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