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Morphometric analysis for prioritization of watershed using GIS technique

■ NIVEDITA SINGH, PRIYANKA TIWARI, PRABHAT KUMAR GURU AND DHIRAJ KHALKHO

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See end of the Paper for authors' affiliation

Correspondence to :

DHIRAJ KHALKHO
Department of Soil and Water Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, RAIPUR (C.G.) INDIA

■ **ABSTRACT :** GIS technique can serve as vital tool in generating water resources action plan, drainage pattern and geomorphic indicator for location of recharge and discharge area analysis. The study has been undertaken in Kawali river watershed which is located at Giri river, in district Sirmaur and Solan of Himachal Pradesh. Kawali river is situated between $77^0$03'12'' to $77^0$39'10''E longitude and $30^0$36'51'' to $31^0$15'23''N latitude covering total area of 157.92 sq km. The altitude of the district Sirmaur varied from 630 to 3626 m above mean sea level. The present study area has been divided in 5 sub-watersheds. The maximum and minimum drainage density (D_d) has been found as 3.72 and 2.77 km/km^2 for sub-watershed 5 and 4, respectively, which confirms the recognition that the study area is underlain by impermeable sub-surface material having sparse vegetation and mountainous relief. This was the result of weak or impermeable subsurface material, sparse vegetation and mountain's relief. It leads to fine drainage texture. The top priority should be given to sub-watershed 5 and least to sub-watershed 4 to take up the soil and water conservation work in Kawali river watershed.

■ **KEY WORDS :** Watershed, Morphometry, Prioritization, GIS

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India has to support 16 per cent world population on 2.42 per cent of the global land area (Manorama year book 2000). About 175Mha land in India suffers from the effect of soil erosion and other land degradation problems and approximately 150 Mha natural resources land is affected by wind and water erosion. So for efficient and sustainable management, one has to look for sustainable geographical unit like watershed. The conventional methods of measuring morphological parameters of hydrology behavior of various basins particularly ungauged once has been very old art which is very time consuming, high labor work and also money investment affair.

Soil erosion is the degradation of fertile layer of the earth crust due to action of wind, water and air. About 175Mha land of total geographical area of the world suffers from soil erosion and other land degradation problems. India accounts 5300 million tons of soil eroded by the effect of wind and water erosion which severely affects the crop productivity and about 25Mha of productive land have lost in the form of ravines, gullies, shift cultivation and salinity/ alkalinity. The vulnerable natural resource need to focus on sustainable management, planning and implementation of land development programme.

The basic management schemes of land development deals with the degraded lands as a hydrological unit known as watershed. Watershed is an area which drained by streams in such a way that all flow is safely disposed to a single outlet. An accurate understanding of hydrological behavior of the watershed need study of the watersheds divides in to several sub-watershed as the pattern of drainage networks in the environment of GIS. In this research paper all morphological parameters are calculated using GIS for the accuracy of the case study of the Kawali river watershed. The watershed is dividing in to five sub-watersheds for their planning and management.

■ METHODOLOGY

This section deals with general description of the study area, watershed delineation, morphometric analysis of study area and prioritization of sub-watersheds based on morphometric analysis.

Study area:

Kawali river watershed which lies within the Giri river catchment is situated between $77^0 03' 12''$ to $77^0 39' 10''$. Kawali river watershed situated in Sirmaur district of Himachal Pradesh was delineated with the help of Arc GIS 9.3 software and different thematic maps of the study area for the calculation of different geo-morphometric parameters and characteristics of the Kawali river watershed was prepared.

Data base design–creation of database scanning in ArcCatalog:

Base map was prepared using survey of India (SOI) toposheet of 1:50,000 scale (Bali and Karale, 1978). Base map for watershed boundary and drainage network was prepared by digitizing toposheet with GIS based software ARC-GIS. The delineated watershed boundary was further subdivided into 5 sub-watersheds. This process was done in Arc GIS using following steps.

– Creating a folder for the project and subfolder for input and output.

– Creating a personal geo-database in input subfolder.

– Creating a personal geo-database in output subfolder.

– Creating the feature datasets and feature classes in the input folder.

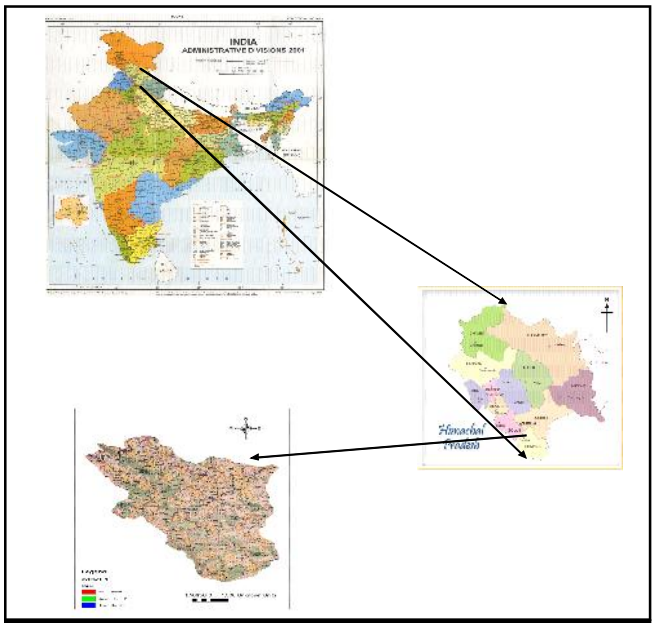

Fig. A : Kawali river watershed

Formulae and quantitative analysis of Kawali river sub-watersheds :

Morphometric analysis was carried out for five sub-watersheds. The parameters computed in present studies using GIS technique included stream order, stream length(L_a), bifurcation ratio(R_b), form factor(R_f), circulatory ratio(C_c), elongation ratio(R_e) drainage density(D_d),relief ratio(R_h), relative relief (R_r), constant of channel maintenance (C_m), texture ratio(T_r), drainage frequency (D_f) and ruggedness number(R_n) and discussed in Table A. The input parameters for morphometric analysis for the case study such as area of the sub-watersheds, perimeter, maximum and minimum elevation, stream length etc. were obtained from digitized coverage of drainage network map in GIS environment

■ RESULTS AND DISCUSSION

Table 1 deals with the results of the study on detailed account of different thematic maps of the study area, different geo-morphometric (Asthana, 1967) characteristics of the

Table A : Formulae of morphometric parameters

Sr. No.	Morphometric parameters	Formula/Definition
1.	Stream order	Hierarchical rank
2.	Bifurcation ratio (R_b)	$Rb = N_u / N_{u+1}$, where, N_u=Number of stream segments present in the given order, N_{u+1}= Number of segments of the next higher order
3.	Stream length (L_u)	Length of the Stream (km)
4.	Mean stream length (L_{sm})	$L_{sm} = L_u / N_u$, km, where, Lu=Mean stream length of a given order (km), N_u= Number of stream segments
5.	Drainage density (D_d)	$D= \Sigma L_u / A_u$) km/km^2, where, L_u=Total stream length of all orders (km), A_u=Area of the basin (km^2)
6.	Texture ratio (T_r)	$R_t = \Sigma N_u/P$, where, Nu= Stream Number, P = Perimeter (km)
7.	Stream frequency (D_f)	$D_f = \Sigma N_u / A_u$, where, N_u=Total number of streams in the basin, A_u= Basin area (km^2)
8.	Length of over land flow (L_g)	$L_g = 1/ D \times 2$ km, where, D = Drainage density (km/km^2)
9.	Form factor (R_f)	$R_f = A_u / L_b^2$, where, A_u=Area of the basin (km^2), L_b=Maximum basin length (km)
10.	Circularity ratio (R_c)	$R_c = 4\pi A_u / P^2$, where, A_u= Basin area (km^2), P= Perimeter of the basin (km) $\Pi = 3.14$
11.	Elongation ratio (R_e)	$R_e = \sqrt{Au}/\pi / L_b$, where, A_u= Area of the basin (km^2), L_b=Maximum basin length (km) $\Pi = 3.14$
12.	Relief ratio (R_h)	$R_h = H / L_{bmax}$, where, H = Maximum basin relief (km), L_{bmax}= Maximum basin length (km)
13.	Ruggedness number (R_n)	$R_n = H \times D_d$, where, H= Maximum basin relief, D_d= Drainage density
14.	Relative relief (Rr)	$Rr = H \times (100) / P$, where, H = Maximum basin relief, P = Perimeter of the basin (km)

Kawali river sub-basin of Himachal Pradesh. After the drainage network (Agrawal, 1998) digitization of the study area,6 order stream was found and for the accurate study of watershed area has been divided in five sub-watersheds, namely as one, two, three, fourth and fifth and the basic physical parameters numeric values of study area discussed in the Table A after the digitization of drainage network of the sub-watershed wise. And the Table 1 discussed, detail numeric values of the drainage network of the study area sub-watershed wise one by one, which is important to calculate geo-morphometric parameters of the Kawali river watershed.

With the help of Table A and Table 1 were computed sub-watershed wise morphometric parameters which is discussed in Table 1 and computed parameters are the base of the case study of GIS technique for the prioritization of sub-watershed.

Prioritization of sub-watersheds based on morphometric analysis:

The priorities of the sub-watershed were determined by carrying out the ranking of the basin. The ranking of the sub-watershed was done by assigning the highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameter (Table 2).

After the rating have been done based on every single parameter these were averaged to arrive to compound value for each watershed. Based on the average value of these parameter a watershed having least rating value was assigned the highest priority number of 1, the next highest value was assigned priority no. of 2 and so on. The watershed that has

Table 1 : Sub-watershed wise morphometric parameters of study area

Sub- watershed No.	Area (km^2)	Perimeter (km)	Elevation		Total relief (m)	No. of streams	Max. length of watershed (m)	Total streams length (m)
			Maximum	Minimum				
1	27036.76	27.52	1891	1400	491	167	7698	94990
2	26171.43	24.63	1981	1260	621	154	7724	93280
3	8889.02	12.94	1491	1100	391	50	5474	29381
4	59154.44	33.11	1840	1128	712	274	13137	164210
5	36676.89	27.78	1788	1000	788	221	8451	136496

Table 2 : Stream analysis of sub-watershed of study area

Sub-watershed	Stream order					
	1	2	3	4	5	6
Sub-watershed No. 1						
Stream no.	122	39	4	2		
Stream length	65113	17566	9152	3159		
Cumulative stream length	65113	82679	91831	94990		
Sub-watershed No. 2						
Stream no.	119	29	5	1		
Stream length	62678	17316	8851	4435		
Cumulative stream length	62678	79994	88845	93280		
Sub-watershed No. 3						
Stream no.	40	8	1		1	
Stream length	18454	4534	919		5474	
Cumulative stream length	18454	22988	23907		29381	
Sub-watershed No. 4						
Stream no.	223	36	11	3	1	
Stream length	106241	28876	15269	6323	7501	
Cumulative stream length	106241	135117	150386	156709	164210	
Sub-watershed No.-5						
Stream No.	175	36	7	2		1
Stream length	90471	21243	10539	5792		8451
Cumulative stream length	90471	111714	122253	128045		136496

Table 3 : Sub-watershed wise computed morphometric parameters of study area

Sub-watershed No.	R_r	R_h	R_n	C_m	R_b	D_d	T_r	D_f	R_c	R_f	C_c	R_e
1	0.063	1.78	1.71	0.284	5.9	3.51	4.51	6.17	0.44	0.456	0.09	0.78
2	0.08	2.52	2.21	0.280	4.1	3.56	4.54	5.88	0.66	0.438	0.06	1.12
3	0.071	3.02	1.29	0.303	5.0	3.30	4.49	5.62	0.64	0.296	0.01	0.61
4	0.05	2.15	1.97	0.361	6.2	2.77	3.76	4.63	0.54	0.342	0.08	0.43
5	0.093	2.83	2.91	0.268	4.8	3.72	4.77	6.02	0.59	0.513	0.07	0.8

Table 4 : Prioritization of Sub-watersheds based on morphometeric parameters of study area

Sub-watershed No.	R_b	D_d	T_r	D_f	R_c	R_f	C_c	R_e	Compound parameter	Final priority
1	3	3	2	1	1	4	5	3	2.750	2
2	1	2	3	3	5	3	2	5	3.000	3
3	4	4	4	4	4	1	1	3	3.125	4
4	5	5	5	5	2	2	4	1	3.625	5
5	2	1	1	2	3	5	3	4	2.625	1

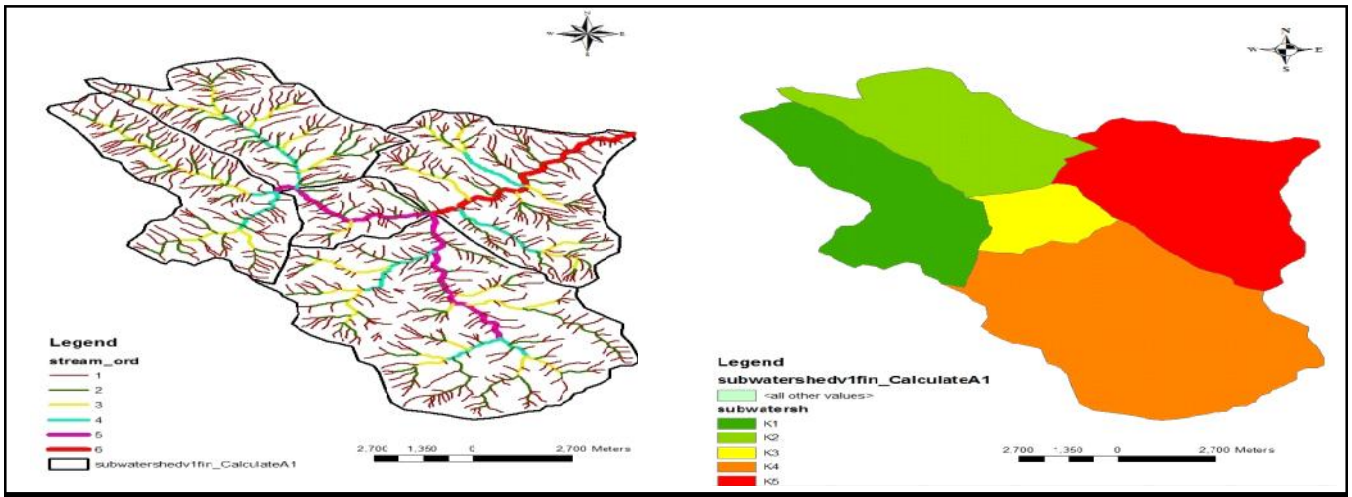

Fig. 1 : Sub-watersheds boundary and stream network of study area

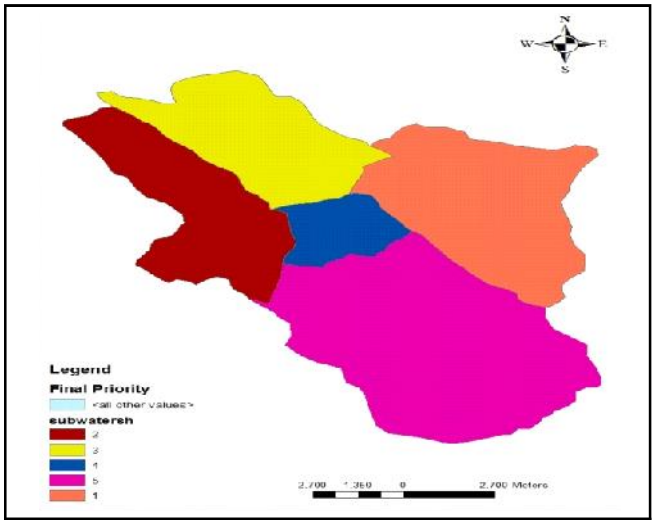

Fig. 2 : Final priority map of the study area

got the highest value was assigned the last priority number. The results of prioritization of sub-watersheds by GIS approach are presented in Table 4. It shows that sub-watershed 5 with a compound parameter value of 2.625 received highest priority 1 with the next in the priority was sub-watershed 1 having the compound parameter value of 2.750.The final priority map of study area is presented in Fig. 2.

Conclusion:

On the basis of study, conclusion has been drawn that GIS technique allows reliable accurate and update database on morphometric parameter of Kawali river watershed it is also drawn that the morphometric analysis of different sub-watershed shown their relative characteristics with respect to hydrological respose. The top priority should be given to sub-watershed 1 and least to sub-watershed 2 to take up the soil and water conservation work in Kawali river watershed.

Authors' affiliations:

NIVEDITA SINGH AND PRIYANKA TIWARI, Department of Civil Engineering, National Institute of Technology, KURUKSHETRA (HARYANA) INDIA

PRABHAT KUMAR GURU, Department of Farm Machinery and Power, Indira Gandhi Krishi Vishwavidyalaya, RAIPUR (C.G.) INDIA

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