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CHECK DAM POSITIONING BY PRIORITIZATION OF MICRO-WATERSHEDS USING SYI MODEL AND MORPHOMETRIC ANALYSIS - REMOTE SENSING AND GIS PERSPECTIVE

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ABSTRACT

Sediment Yield Index (SYI) model and results of morphometric analysis have been used to prioritize watersheds and to locate sites for checkdam positioning in Tarafeni watershed in Midnapur district, West Bengal. Various thematic maps such as land use/land cover, slope, drainage, soil etc. were prepared from IRS 1D LISS III digital data, SOI toposheets of 1:50,000 scale and other reference maps. Morphometric parameters such as bifurcation ratio (R_b), drainage density (D_d), texture ratio (T), length of overland flow (L_0), stream frequency (F_u), compactness coefficient (C_c), circularity ratio (R_c), elongation ratio (E_r), shape factor (B_s) and form factor (R_f) were computed. Automated demarcation of prioritization of micro-watersheds was done by using GIS overlaying technique by assigning weight factors to all the identified features in each thematic map and ranks were assigned to the morphometric parameters. Five categories of priority viz., very high, high, medium, low and very low, were given to all the watersheds in both the methods. Sixty-two micro-watersheds using SYI method and twenty-three micro-watersheds using morphometric have been prioritized as very high priority. Final priority map was prepared by considering the commonly occurred very high-prioritized micro-watersheds in both SYI model and morphometric analysis. Twenty-four suitable sites were identified for check dam construction in 21 highly prioritized watersheds. It is proved that integrated study of SYI model and morphometric analysis yield good result in prioritization of watersheds.

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Introduction

A watershed is an ideal unit for management of natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The significant factors for the planning and development of a watershed are its physiography, drainage, geomorphology, soil, land use/land cover and available water resources. Remote sensing and GIS are the most advanced tools for watershed development, management and studies on prioritization of micro-watersheds for development. Morphometric analysis could be used for prioritization of micro-watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas *et al.*, 1999).

Several scientists worked using Remote Sensing, GIS techniques and SYI model, to prioritize the watersheds and to find appropriate location for check dam construction in different areas of entire watershed. Prioritization of watersheds using remote sensing data by sediment yield prediction has been carried out by Chakraborti (1991a). Site location for checkdam construction by studying run-off in part of Mahi river has been carried out by Durbude *et al.* (2001). GIS overlaying techniques has been used to locate the potential zones of groundwater (Murthy, 2000). Chinnamani (1991) estimated sediment yield using remote sensing data. Mani *et al.* (2003) carried out soil erosion studies of part of the world's largest river island, Majuli River –Island, using remote sensing data and ILWIS software.

The present study aims at for identification of suitable sites for check dam construction based on micro-watershed prioritization by using remote sensing data, GIS techniques and also through morphometric studies. The region is prone to soil erosion and it has scarce irrigation facilities. This attempt can help to increase the water potential for irrigation as well as drinking purpose.

Study Area

The study area, a part of Tarafeni River Basin in Binpur block of Paschim Midnapur District in the southwestern part of West Bengal, is located between $22^0\,31^1$ and $22^0\,47^1$ North Latitudes and $86^0 33^1$ and $86^0\,56^1$ East Longitudes, covering an area of 599.98 km^2 (Fig.1). The Western part of the study area is deeply corrugated with valleys and hills with an altitude approximately 1200m, the northwestern part is ridged with sparse vegetation. The eastern half is more or less plain and predominantly agrarian. The major irrigation facilities are Tarafeni barrage and Rangamataia irrigation project, which are contiguous to agricultural land.

Methodolgy

Remote Sensing and GIS have been applied considering sediment yield index (SYI) model and morphometric analysis for check dam positioning by prioritization of watersheds. The methodology is given in the flow chart (Fig. 2). The study area is covered in the Survey of India toposheets 73J/9, 73J/10 and 73J/14 on 1:50,000 scale. Base map of the study area was prepared from reference maps collected from district authorities. IRS ID LISS III satellite imagery with 23.5m resolution acquired on January 6, 1999 with path/row of 107/56 was used as source data.

The remotely sensed data was geometrically corrected and re-sampled taking toposheets as reference. Image enhancement techniques were applied to extract the drainage layer from FCC for better interpretation of the stream order. The drainage layer was digitized using ARC/INFO tools. The ordering was given to each stream, by following Strahler (1952a) stream ordering technique (Fig. 3). The study area was divided into 25 sub-watersheds of area ranging from 25 to 30 km^2 from the drainage map, and each sub-watershed is further divided into micro-watersheds with an area ranging from 5 to 10 km^2. Thus, a total of 82 micro-watersheds were delineated for the present study.

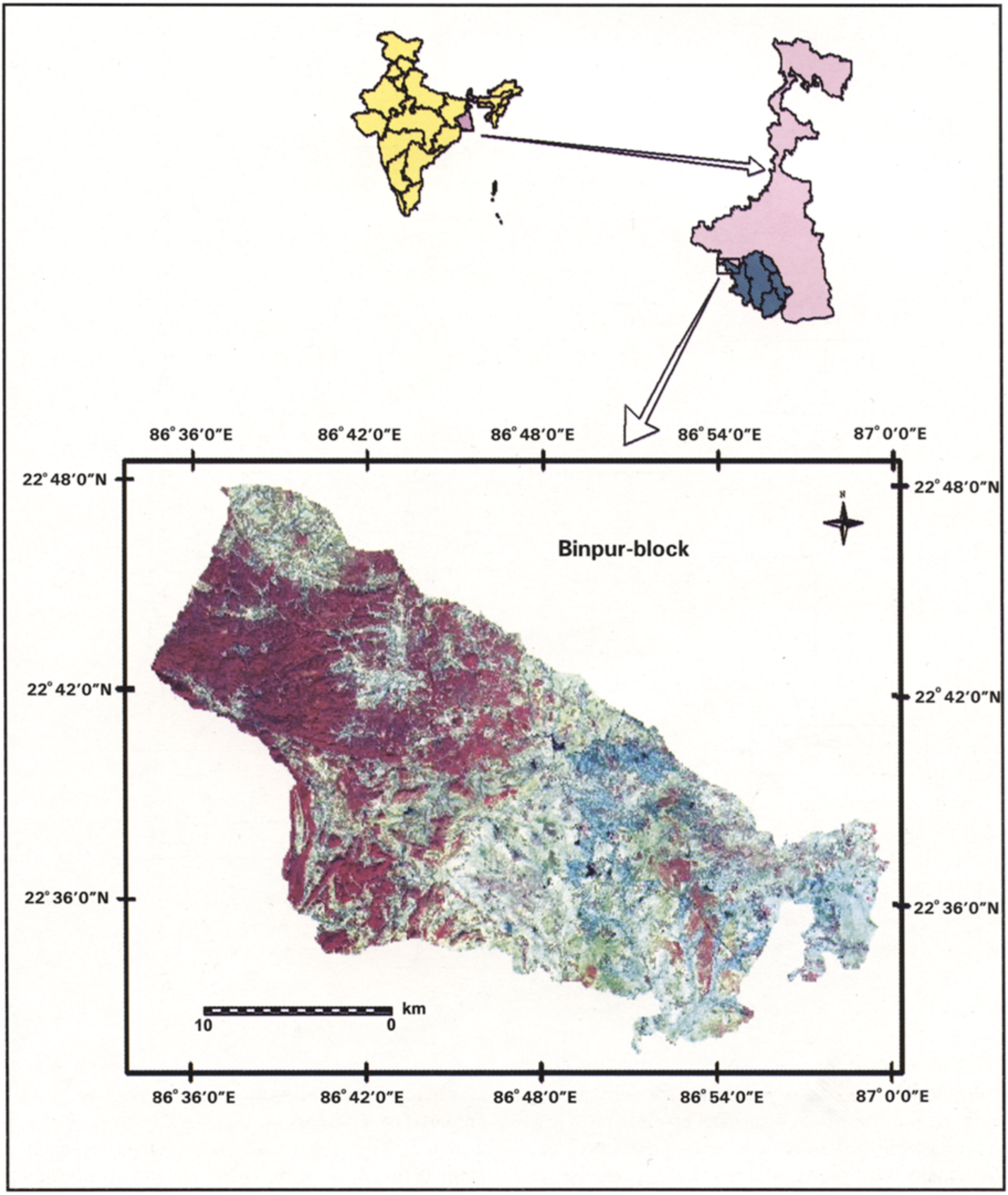

Fig. 1. Location map of the Study Area

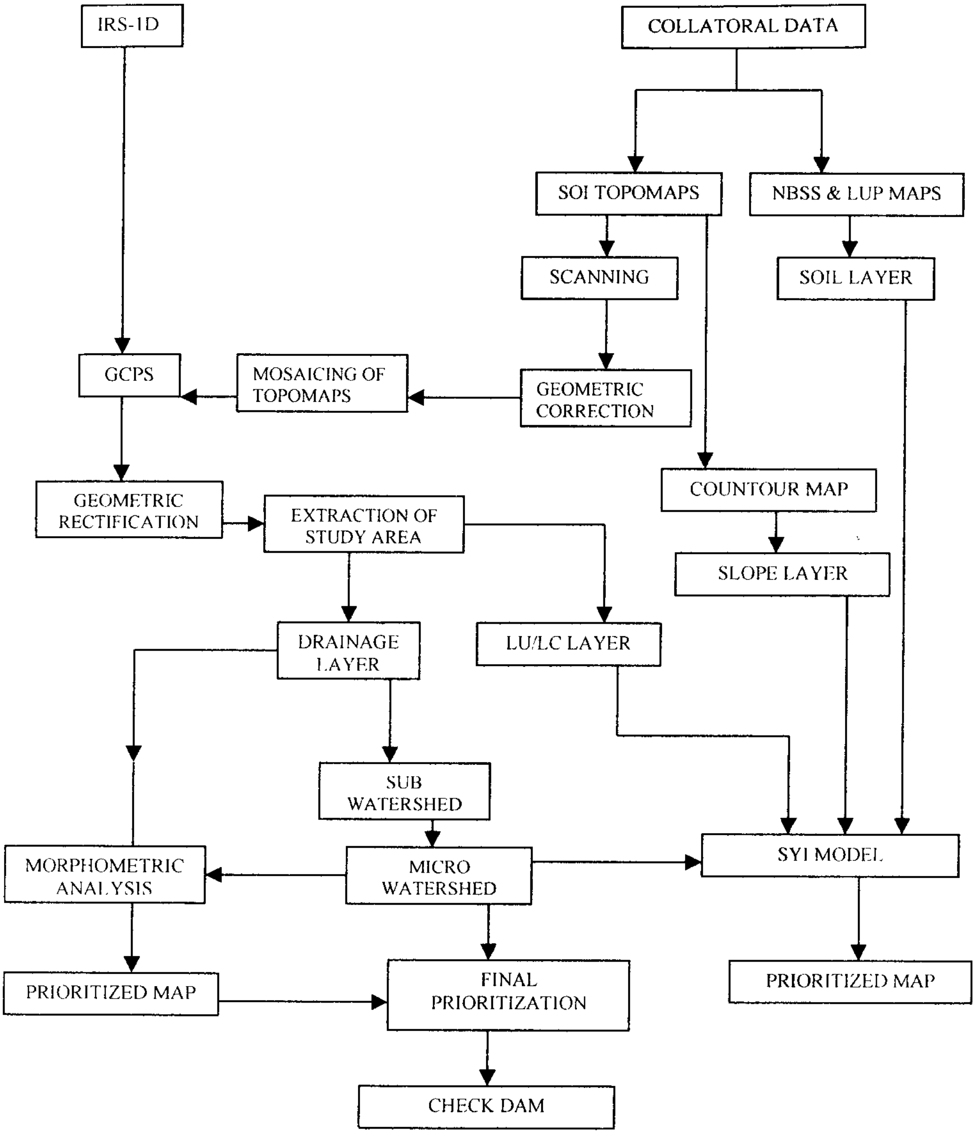

Fig. 2. Flow chart describes methodology for checkdam location

The thematic, layers such as land use/land cover, soil and slope are necessary for determining the susceptibility to erosion and erosion intensity, were mapped from the remote sensing data. Soil and slope maps were prepared form National Bureau of Soil Survey maps and Survey of India toposheets respectively. A total of thirteen land use/land cover features were identified using supervised classification technique (Fig. 4). Soil map was prepared on 1:50,000 scale and 9 categories of soils were identified (Fig. 5). Six slope categories ranging from 0 to 35 were derived from the slope map generated from SOI toposheets of 20m contour interval (Fig. 6).

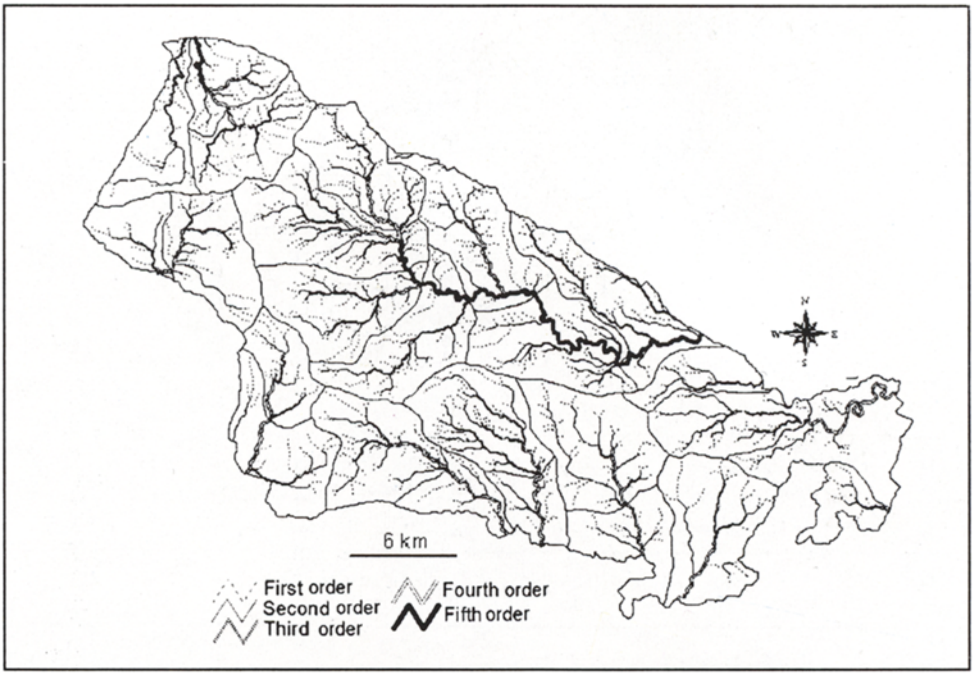

Fig. 3. Drainage with sub-watershed boundary

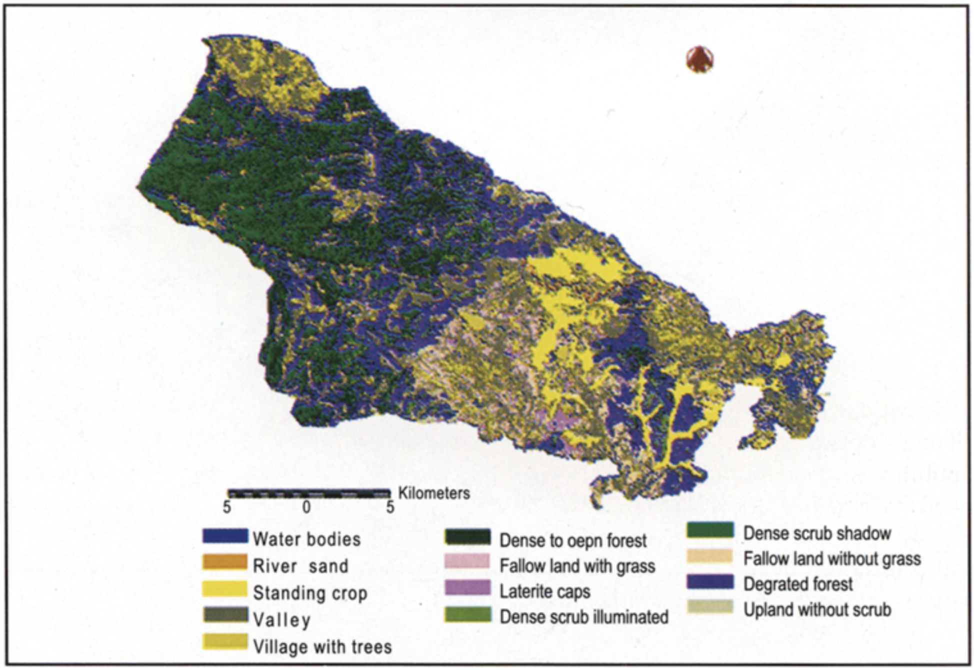

Fig. 4. Land Use/Land Cover map

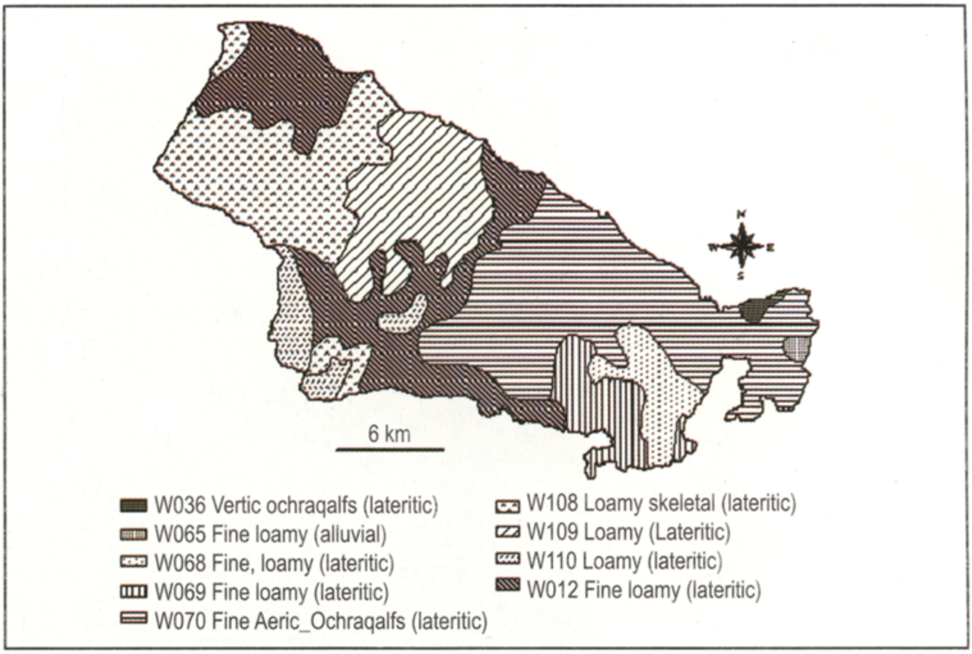

Fig. 5. Type of soils in the study area

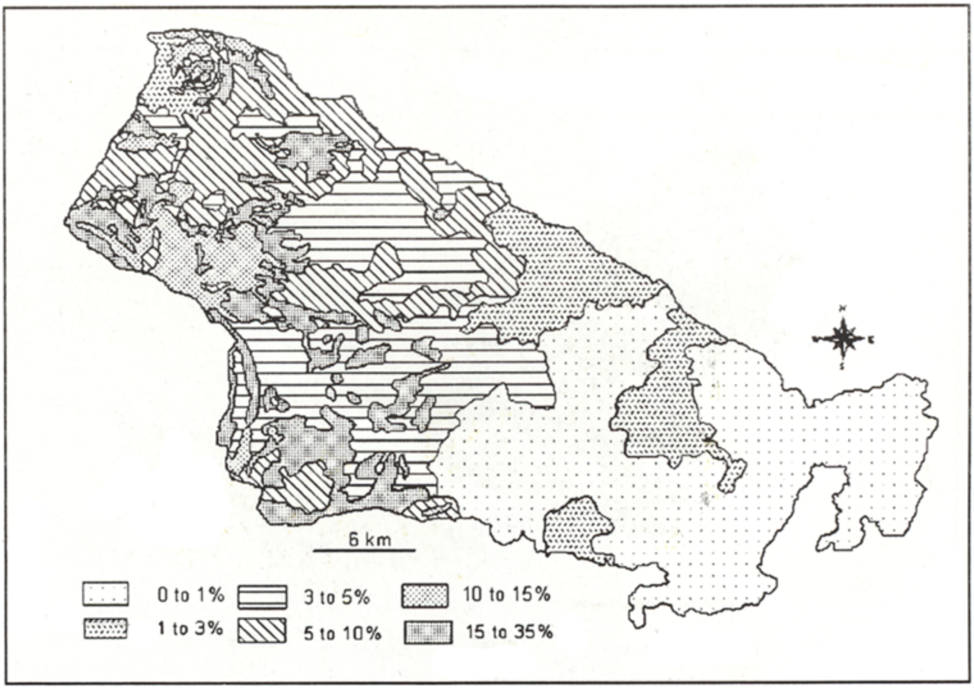

Fig. 6. Slope map

Weightage Factor Designation

Land use/ land cover plays a very important role in surface soil detachment. Canopy cover and root network system of different plant types mitigates the effect of rainfall and thus affect surface soil detachment. Hence, considering land use/land cover classes and their probability of erosion, all land use/land cover classes were arranged from minimum to maximum erosion. A proportionality factor ranging between 0.7 - 1.3 was designed. Land use/land cover class having maximum erosion mitigation has been assigned a value of 0.7 and land use/land cover class having least mitigation impact has been assigned weightage factor 1.3. The median of land use/land cover class gets unit factor 1 and either side there is increase and decrease of + - 0.05.

There are several soil properties which influence soil erodability and transportability during run-off, such as particle size, organic matter content, structure, soil depth, texture and mineralogy. There are 16 soil categories in the district out of which 9 are falling in the study area. Weightage factors have been assigned based on the soil properties and soil-bearing capacity (K + - n) where n gets +1,+2 ......+ n depending on probability of the extent of soil - bearing and n gets -1, -2...... –n depending on the plausibility of the extent of deposition in particular soil unit. Factor K is equal to 10 when particular soil unit has no loss - no gain situation (Pal, 2000).

Slope of a terrain generates velocity of the run-off water which effects surface soil detachment. Gentle slope condition may generate less velocity where as steep slope condition may generate high velocity of the run-off water. Thus terrain having gentle slope condition ranging between 0-1% has been assigned weightage factor 1 and steep sloping condition ranging between 15-35% has been assigned weightage factor 1.25. Thus all the features in the each thematic maps were assigned weight factors arbitrarily depending upon their influence on erosion (Table 1). All the thematic maps were overlaid through GIS analysis and the sediment yield index value was arrived at.

Table 1: Identified Categories and their weightage factors

Land Use/ Land Cover	Type factor (L_K)	Soil type	Weightage factor (W_J)	Delivery Ratio (D_J)	Slope Category (%)	Weightage factor (SI_J)
Water body	0.7	W036	11	0.50	0 – 1	1
River Sand	0.75	W065	13	0.60	1 – 3	1.05
Standing crop	0.8	W068	16	0.75	3 – 5	1.1
Valley	0.85	W069	14	0.65	5 – 10	1.15
Village with trees	0.9	W070	12	0.70	10 – 15	1.2
Dense to open forest	0.95	W108	17	0.90	15 – 35	1.25
Fallow with grass	1	W109	20	0.90		
Laterite caps	1.05	W110	19	0.90		
Dense scrub illuminated	1.1	W112	16	0.90		
Dense scrub shadow	1.15					
Fallow without grass	1.2					
Degraded forest	1.25					
Upland without scrub	1.3					

Priority Fixation of Micro-watershed

(1) Sediment Yield Index (SYI) method

The integrated study of SYI method is a very significant for prioritization of micro-watersheds. SYI model, which is an integration of the above discussed basin characteristics is used for automated demarcation of micro-watersheds for their priority. Valuable parameters considered in the present study are, (a) land use/land cover, a very significant primary map for an integrated approach, (b) soil, mainly purporting erosion study, and (c) slope a significant map for terrain study. Estimation of sediment yield is the main factor for study and development of the watershed, and it is useful for the automated demarcation for prioritization of watersheds, even without knowing of the rainfall data. GIS facilitates an integration of multi thematic layers as well as criteria, also evaluate the possible out come through the knowledge based querying. The automation process gives the end results for SYI model. Two vital input parameters 'erosivity' (weightage) and 'delivery ratio' (plausibility of the detached material to reach the sink) for soil types, type factor for the land use/land cover categories and weightage to slope categories were assigned for the GIS analysis. The micro-watershed areas were computed using erosivity and delivery ratios obtained by overlaying the thematic inputs. These ratios were used in obtaining SYI values for each micro-watershed. Incorporation of SYI values of a micro-watershed would determine quantitative priority value of that micro-watershed. The micro watersheds were arranged in the descending order of the SYI values and graded in order of priority into 5 categories as, very high($\geq$ 1500), high($\geq$1200 < 1500), medium($\geq$900 <1200), low($\geq$600 <900) and very low($\leq$600). The algorithm for sediment yield index model (Pal, 2000) and morphometric formulae are shown in Table 2.

(2) Morphometric analysis

The morphometric analysis is a significant tool for prioritization of micro-watersheds even without considering the soil map (Biswas *et al.*, 1999). Drainage patterns refer to spatial relationship among streams or rivers, which may be influenced in their erosion by inequalities of slope, soils, rock resistance, structure and geologic history of a region. For the prioritization of micro-watersheds, morphometric analysis was done using the linear parameters such as bifurcation ratio (R_b), drainage density (D_d), texture ratio (T), length of overland flow (L_o), stream frequency (F_u), and the shape factors are compactness coefficient (C_c), circularity ratio (R_c), elongation ratio (E_r), shape factor (B_s) and form factor (R_f). Linear parameters have a direct relationship with erodability. Higher the value, more is the erodability. The values of the morphometric parameters of all the 82 watersheds are shown in Table 3. The highest value of the linear parameter was rated as rank1, the second highest value as rank 2 and so on. On the contrary, as the shape parameters have an inverse relation with erodability. The lower their value, more is the erodability. Thus the value of the parameter was rated as rank 1 and the second lowest as rank 2 and so on. The ranks of all morphometric parameters were added up for each of the 82 watersheds to arrive at a compound parameter (Cp) (Biswas *et al.*, 1999). Table 4 shows the ranks and compound parameters values for high priority watersheds. All these micro-watersheds were categorized into very high ($\leq$ 30), high (>30 $\leq$35), medium (>35 $\leq$40), low (>40 $\leq$45) and very low (>45) based on the range of the compounded value (Cp). Thus, 23 micro-watersheds out of 82, were given very high priority, as they have very low compound value (Cp), 22 micro-watersheds were given high priority, with low Cp values. Eighteen micro watersheds fall under medium, having moderate Cp values, 17 micro-watersheds fall under low with high Cp values, and the remaining 2 micro-

Table 2: The SYI algorithm and morphometric parameters used

SYI – Model	Morphometric Analysis
$S_i = \dfrac{\sum_{J=1}^{n_1} [(\sum_{k=1}^{n_2} A_{LK} * L_K) * W_j * D_j * Sl_j * 100] * F_i}{M}$ Where, S_i Silt Load Index for ith micro watershed A_{LK} Area under erosion mapping unit for kth land use L_K Type factor for kth land use W_j Weightage of the jth erosion mapping unit D_j Delivery ratio of the jth erosion mapping unit Sl_j Slope factor of the jth erosion mapping unit F_i Proportion factor of the ith micro watershed M Area of the micro watershed n_1 Number of erosion mapping units under a micro watershed n_2 Number of land use class under an erosion mapping unit	1. $L_b=1.312A^{0\,568}$ (basin length) 2. $D_d = L/A$ (drainage density) 3. $F_u = N/A$ (stream frequency) 4. $L_o = ½ D_d$ (Length of overland flow) 5. $R_b = N_u/N_{u+1}$ (Bifurcation ratio) 6. $R_f = A/L_b^2$ (Form Factor) 7. $B_s = L_b^2/A$ (Shape factor) 8. $R_e = (2/L_b)*\sqrt{(A/P)} = 1.128\,A^{0\,5}/L_b$ (Elongation ratio) 9. $R_c = 4PA/P^2 = 12.57A/P^2$ (Circularity Ratio) 10. $C_c = 0.2821P/A^{0\,5}$ (Compactness Coefficient) 11. T=N1/P (T Texture ratio) Where L_b basin length is in km A area of the basin in km^2 P Perimeter in km D_d is the drainage density L is the total length of all channels of all order in the drainage basin N Total number of streams N_1 Total number of first order streams L_o Length of overland flow in Km R_b Bifurcation ratio N_u No. of streams of order u N_{u+1} No. of streams of next higher order u R_f Form Factor ($R_f < 1$) B_s Shape factor ($B_s > 1$) R_e Elongation ratio ($R_e \leq 1$) Rc Circularity Ratio ($Rc \leq 1$) C_c Compactness Coefficient ($C_c \geq 1$)

watersheds were given very low priority which have very high Cp value. Finally, the common watersheds, in SYI model and morphometric analysis that fall in very high category of prioritization were identified. After conducting intensive field visits, understanding the soils properties, and also the quantity and velocity of run-off water, suitable sites for check dam construction were identified and marked (Fig. 7). The priority watersheds obtained from SYI model and morphometric analyses were shown in Table 5.

Results and Discussion

Prioritization of watersheds has been done using SYI values by SYI method and using compound values by morphometric analysis, the latter is an integration of these two prioritized attributes. Out of 82 watersheds presently under study, on the basis of SYI values, 62 watersheds were found to be under top priority (very high), as they have very high value of SYI. Three micro-watersheds were under second priority (high

Table 3: Results of morphometric of all the watersheds

Watershed ID	A	P	L	N	N1	Lb	Rb	Dd	Fu	T	Lo	Rf	Bs	Re	Cc	Rc
1	6.17	14.34	13.65	13	12	3.69	1.00	2.21	2.11	0.84	0.23	0.45	2.20	0.76	1.62	0.37
2	10.30	16.60	21.56	22	15	4.94	2.88	2.09	2.14	0.90	0.24	0.42	2.36	0.73	1.45	0.47
3	6.35	10.97	12.01	20	13	3.75	2.63	1.89	3.13	1.19	0.26	0.45	2.21	0.76	1.22	0.66
4	5.90	10.88	13.50	14	10	3.60	3.17	2.29	2.37	0.92	0.22	0.46	2.19	0.76	1.26	0.62
5	8.97	14.11	19.41	21	13	4.56	2.53	2.17	2.34	0.92	0.23	0.43	2.32	0.74	1.32	0.56
6	7.40	11.22	11.26	13	10	4.09	3.50	1.52	1.76	0.89	0.33	0.44	2.26	0.75	1.16	0.73
7	6.64	15.14	13.54	17	11	3.85	2.39	2.04	2.56	0.73	0.25	0.45	2.23	0.76	1.66	0.36
8	7.42	13.95	13.26	17	12	4.10	2.75	1.79	2.29	0.86	0.28	0.44	2.26	0.75	1.44	0.48
9	9.00	13.00	12.14	12	9	4.57	3.25	1.35	1.33	0.69	0.37	0.43	2.32	0.74	1.22	0.67
10	7.99	16.76	13.71	20	14	4.27	3.90	1.72	2.50	0.84	0.29	0.44	2.28	0.75	1.67	0.36
11	6.56	13.02	12.30	16	10	3.82	2.28	1.87	2.44	0.77	0.27	0.45	2.22	0.76	1.43	0.49
12	4.39	10.85	9.11	13	9	3.04	2.50	2.08	2.96	0.83	0.24	0.48	2.10	0.78	1.46	0.47
13	7.15	12.45	12.82	19	13	4.01	2.61	1.79	2.66	1.05	0.28	0.44	2.25	0.75	1.31	0.58
14	5.62	14.16	8.03	7	6	3.50	6.00	1.43	1.25	0.42	0.39	0.46	2.18	0.76	1.68	0.35
15	7.55	13.26	17.76	16	13	4.14	6.50	2.35	2.12	0.98	0.21	0.44	2.27	0.75	1.36	0.54
16	9.11	12.64	16.59	19	14	4.60	3.75	1.82	2.09	1.11	0.27	0.43	2.32	0.74	1.18	0.72
17	9.46	14.25	16.24	25	16	4.70	2.56	1.72	2.64	1.12	0.29	0.43	2.34	0.74	1.31	0.59
18	6.81	14.41	8.72	8	5	3.90	2.33	1.28	1.17	0.35	0.39	0.45	2.23	0.75	1.56	0.41
19	5.43	10.22	4.28	7	4	3.43	3.00	0.79	1.29	0.39	0.64	0.46	2.17	0.74	1.24	0.65
20	5.06	12.89	14.07	13	7	3.29	1.94	2.78	2.57	0.54	0.18	0.47	2.14	0.77	1.62	0.38
21	6.60	14.15	10.01	6	4	3.83	4.00	2.77	0.91	0.28	0.18	0.45	2.22	0.76	1.55	0.41
22	9.54	14.52	16.32	16	10	4.72	2.00	1.71	1.68	0.69	0.29	0.43	2.34	0.74	1.33	0.57
23	9.63	14.98	19.56	25	20	4.75	4.50	2.03	2.60	1.34	0.25	0.43	2.34	0.74	1.36	0.54
24	5.96	10.21	15.95	20	12	3.62	2.38	2.68	3.36	1.18	0.19	0.46	2.19	0.76	1.18	0.72
25	5.65	12.24	6.54	8	5	3.51	2.25	1.16	1.42	0.41	0.43	0.46	2.18	0.77	1.45	0.47
26	9.17	13.60	17.01	16	11	4.62	2.33	1.86	1.75	0.81	0.27	0.43	2.33	0.74	1.27	0.62
27	4.22	9.17	8.90	10	6	2.97	2.50	2.11	2.37	0.65	0.24	0.48	2.09	0.78	1.26	0.63
28	5.26	12.42	10.12	8	6	3.37	6.00	1.92	1.52	0.48	0.26	0.46	2.16	0.77	1.53	0.43
29	6.23	11.04	6.39	5	4	3.71	4.00	1.03	0.80	0.36	0.49	0.45	2.21	0.76	1.25	0.64
30	5.63	14.61	11.20	13	10	3.50	3.50	1.99	2.31	0.68	0.25	0.46	2.18	0.77	1.74	0.33
31	7.55	12.97	18.15	21	14	4.14	2.29	0.55	2.78	1.08	0.91	0.44	2.27	0.75	1.33	0.56
32	8.02	12.23	9.08	13	9	4.28	3.00	1.13	1.62	0.74	0.44	0.44	2.28	0.75	1.22	0.67
33	8.62	14.48	11.59	9	6	4.46	3.50	1.34	1.04	0.41	0.37	0.43	2.31	0.74	1.39	0.52
34	4.21	9.35	7.87	12	9	2.97	3.25	1.87	2.85	0.96	0.27	0.48	2.09	0.78	1.29	0.60
35	9.69	16.42	15.84	10	8	4.76	8.00	1.64	1.03	0.49	0.31	0.43	2.34	0.74	1.49	0.45

Watershed ID	A	P	L	N	N1	Lb	Rb	Dd	Fu	T	Lo	Rf	Bs	Re	Cc	Rc
36	7.13	16.25	12.41	10	6	4.00	2.50	1.74	1.40	0.37	0.29	0.44	2.25	0.75	1.72	0.34
37	6.10	16.59	7.09	5	3	3.66	3.00	1.16	0.82	0.18	0.43	0.45	2.20	0.76	1.89	0.28
38	8.10	13.29	15.01	12	6	4.31	1.75	1.85	1.48	0.45	0.27	0.44	2.29	0.75	1.32	0.58
39	9.42	14.48	18.71	16	12	4.69	3.50	1.99	1.70	0.83	0.25	0.43	2.34	0.74	1.33	0.56
40	9.36	13.13	15.57	22	15	4.67	3.00	1.66	2.35	1.14	0.30	0.43	2.33	0.74	1.21	0.68
41	10.90	14.24	21.73	22	17	5.10	4.13	1.99	2.02	1.19	0.25	0.42	2.38	0.73	1.22	0.68
42	6.83	11.54	9.33	15	10	3.91	3.25	1.37	2.20	0.87	0.37	0.45	2.23	0.75	1.25	0.64
43	5.08	10.79	7.54	10	7	3.30	2.75	1.49	1.97	0.65	0.34	0.47	2.15	0.77	1.35	0.55
44	8.83	14.36	9.85	6	4	4.52	2.50	1.12	0.68	0.28	0.45	0.43	2.31	0.74	1.36	0.54
45	5.74	12.84	6.87	4	3	3.54	3.00	1.20	0.70	0.23	0.42	0.46	2.18	0.76	1.51	0.44
46	7.98	13.45	17.48	27	18	4.27	3.00	2.19	3.38	1.34	0.23	0.44	2.29	0.75	1.34	0.55
47	3.97	9.79	7.12	11	8	2.87	3.00	1.79	2.77	0.82	0.28	0.48	2.07	0.78	1.39	0.52
48	10.10	16.43	18.72	15	11	4.88	3.33	1.85	1.49	0.67	0.27	0.42	2.36	0.74	1.46	0.47
49	5.46	10.88	6.59	8	4	3.44	1.67	1.21	1.47	0.37	0.41	0.46	2.17	0.77	1.31	0.58
50	10.44	16.24	12.09	7	5	4.97	5.00	1.16	0.67	0.31	0.43	0.42	2.37	0.73	1.42	0.50
51	7.43	13.54	11.25	11	10	4.10	10.00	1.51	1.48	0.74	0.33	0.44	2.26	0.75	1.40	0.51
52	6.18	10.70	6.69	10	7	3.69	2.75	1.08	1.62	0.65	0.46	0.45	2.21	0.76	1.21	0.68
53	6.19	10.18	8.22	10	7	3.69	2.75	1.33	1.62	0.69	0.38	0.45	2.20	0.76	1.15	0.75
54	5.10	13.61	11.82	16	10	3.31	2.28	2.32	3.16	0.73	0.22	0.47	2.15	0.77	1.70	0.35
55	8.13	13.36	6.55	11	8	4.31	3.00	0.80	1.35	0.60	0.62	0.44	2.29	0.75	1.32	0.57
56	5.61	12.69	4.46	7	3	3.49	1.83	0.80	1.25	0.24	0.63	0.46	2.18	0.77	1.51	0.44
57	7.67	12.87	17.92	25	19	4.17	4.40	2.34	3.26	1.48	0.21	0.44	2.27	0.75	1.31	0.58
58	6.16	11.44	4.57	9	4	3.69	1.67	0.74	1.46	0.35	0.67	0.45	2.21	0.76	1.30	0.59
59	6.68	11.92	9.97	14	8	3.86	2.06	1.49	2.10	0.67	0.34	0.45	2.23	0.76	1.30	0.59
60	8.60	15.11	14.04	12	8	4.45	2.33	1.63	1.40	0.53	0.31	0.43	2.31	0.74	1.45	0.47
61	9.02	17.20	13.26	14	11	4.58	5.50	1.47	1.55	0.64	0.34	0.45	2.20	0.74	1.62	0.38
62	8.25	15.73	7.32	3	1	4.35	1.00	0.89	0.36	0.06	0.56	0.44	2.29	0.75	1.54	0.42
63	10.82	14.52	13.26	13	9	5.07	3.00	1.23	1.20	0.62	0.41	0.42	2.38	0.73	1.25	0.64
64	4.47	9.43	8.59	13	9	3.07	3.00	1.92	2.91	0.95	0.26	0.47	2.11	0.78	1.26	0.63
65	4.56	9.47	10.09	13	9	3.11	3.00	2.21	2.85	0.95	0.23	0.47	2.12	0.78	1.25	0.64
66	9.59	16.82	3.87	6	5	4.74	5.00	0.40	0.63	0.30	1.24	0.43	2.34	0.74	1.53	0.43
67	6.47	11.25	10.10	16	10	3.79	2.50	1.56	2.47	0.89	0.32	0.45	2.22	0.76	1.25	0.64
68	7.22	13.03	13.27	15	11	4.03	3.33	1.84	2.08	0.84	0.27	0.44	2.25	0.75	1.37	0.53
69	5.66	10.90	9.63	10	6	3.51	2.00	1.70	1.77	0.55	0.29	0.46	2.18	0.76	1.29	0.60
70	5.31	14.63	10.13	9	6	3.39	3.00	1.91	1.69	0.41	0.26	0.46	2.16	0.77	1.79	0.32
71	7.98	13.07	10.50	9	5	4.27	1.83	1.32	1.13	0.38	0.38	0.44	2.28	0.75	1.31	0.59

Watershed ID	A	P	L	N	N1	Lb	Rb	Dd	Fu	T	Lo	Rf	Bs	Re	Cc	Rc
72	6.97	10.76	5.24	4	3	3.95	3.00	0.75	0.57	0.28	0.67	0.45	2.24	0.75	1.15	0.76
73	11.00	17.16	16.42	15	10	5.12	2.44	1.49	1.36	0.58	0.33	0.42	2.38	0.73	1.46	0.47
74	5.91	11.89	7.47	9	4	3.60	1.67	1.26	1.52	0.34	0.40	0.46	2.19	0.76	1.38	0.53
75	6.81	12.12	8.48	7	5	3.90	5.00	1.25	1.03	0.41	0.40	0.45	2.23	0.76	1.31	0.58
76	10.17	19.91	9.80	11	8	4.90	3.00	0.96	1.08	0.40	0.52	0.42	2.36	0.73	1.76	0.32
77	5.10	9.96	6.70	8	5	3.31	2.25	1.31	1.57	0.50	0.38	0.47	2.15	0.77	1.24	0.65
78	8.07	20.10	3.45	5	4	4.30	4.00	0.43	0.62	0.20	1.17	0.44	2.29	0.75	2.00	0.25
79	6.78	12.24	10.72	10	6	3.89	2.00	1.58	1.47	0.49	0.32	0.45	2.23	0.76	1.33	0.57
80	4.36	9.42	2.39	4	3	3.03	3.00	0.55	0.92	0.32	0.91	0.48	2.10	0.78	1.27	0.62
81	9.29	16.20	6.43	2	0	4.64	0.00	0.69	0.22	0.00	0.72	0.43	2.33	0.74	1.50	0.44
82	6.01	11.56	6.94	8	4	3.63	1.67	1.15	1.33	0.35	0.43	0.46	2.20	0.76	1.33	0.57

Table 4: Compound Values and priorities depending upon the morphometric ranks

Watershed No.	Priority										
	Bs	Cc	Dd	Fu	Lo	Rb	Rc	Re	Rf	T	Cp value	Final priority
1	24	69	8	29	68	41	11	30	27	24	30.18	1
2	66	53	12	27	64	21	24	4	4	18	26.81	1
3	28	10	22	5	55	23	64	28	26	5	24.45	1
4	18	20	7	20	69	19	55	32	30	17	26.45	1
5	53	33	10	23	66	26	40	11	11	16	26.72	1
6	40	3	43	36	37	16	72	21	2	19	28.45	1
7	32	70	14	16	62	29	10	26	25	34	29.54	1
8	40	52	32	25	47	22	27	20	19	22	28.54	1
11	30	51	23	19	54	33	28	26	25	30	30.00	1
12	4	58	13	6	63	27	22	43	40	26	28.54	1
13	38	30	31	12	47	24	47	22	21	11	26.91	1
15	42	42	4	28	72	3	37	19	18	12	26.54	1
16	55	5	29	31	49	15	70	11	10	9	27.27	1
17	60	28	35	13	45	25	49	9	7	8	26.91	1
23	62	43	15	14	61	10	36	7	7	3	25.54	1
24	20	4	3	2	73	30	71	31	29	6	26.63	1
31	42	39	78	10	4	32	41	29	18	10	29.45	1
34	2	23	24	8	53	18	53	44	41	13	28.45	1
40	58	6	38	22	42	20	69	9	8	7	29.00	1
41	69	8	16	33	60	12	67	2	1	4	28.45	1
57	43	29	5	3	71	11	48	18	17	1	27.54	1

Table 5: Priority wise categorized watersheds

Priority	Watersheds categorised from SYI models	Watersheds categorised from Morphometric Analysis	Watershed categorised through integration of SYI and morphometric Analysis
Very high	1 to 9, 11 to 25, 27 to 35, 39 to 41, 43, 45,47,49,53 to57, 59,60,62 to 65, 67 to 70, 72 to 75,77,80 and 82	1 to 8,10 to 13, 15 to 17, 23, 24, 31, 34, 40, 41, 46 and 57	1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 15, 16, 17, 23, 24, 31, 34, 40, 41, 57
High	10,37 and 48	9,14,19,20,22,26 to 28, 30, 32, 39, 42,43,47,48,51,54,61, 64,65, 67 and 68	48
Medium	26,42,52 and 58	18,21,25,29,33,35,36,38,50,52, 53,55, 59, 60, 63, 69,70 and 73	52
Low	36,44,51,61,76,79 and 81	37,44,45,49,56,58,66,71,72, 74 to 80 and 82	44, 76, 79
Very low	38,46,50,66,71 and 78	62 and 81	nil

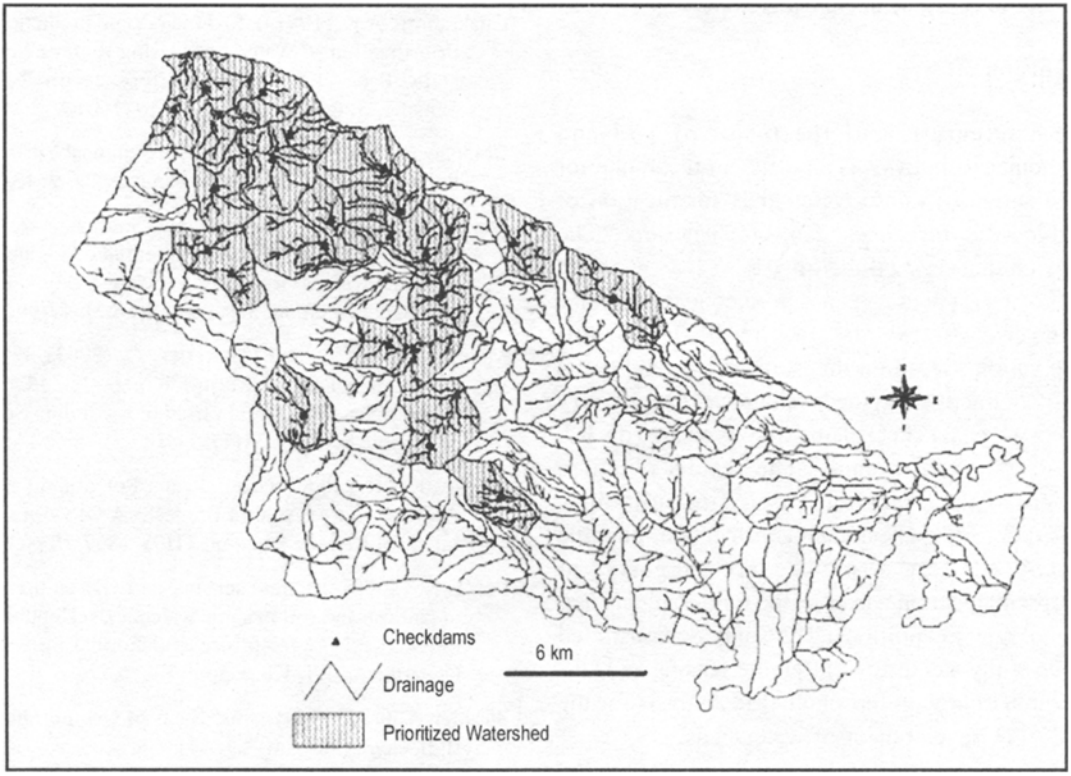

Fig. 7. Prioritized watersheds with Proposed checkdam location

category) with high value SYI, another 4 micro-watersheds comes under 3rd priority (medium category) with moderate SYI, 7 micro-watersheds with the low SYI under low priority and the remaining 6 watersheds fall under 5th priority with very low SYI. From the integrated study of SYI model and morphometric analysis, 21 micro-watersheds were identified as very high prioritized micro-watersheds. These have very high sediment yield value and have excellent drainage density with value greater than 1.5 indicating high erosion. Texture ratio values of these basins are also indicating high runoff. The low bifurcation ratio values, indicates stable geological structures underneath. None of the prioritized watersheds falls in the eastern half of the study area, probably because of the area in plains and it has comparatively well developed water resources in the form of Rangamatia irrigation project and Tarafeni river barrage. The prioritization of micro watersheds decreases from the western side to eastern side probably because of decreasing slope.

Conclusion

An integration of the result of SYI and morphometric analysis is an efficient technique for prioritization of micro-watersheds for location of suitable sites for check dam construction. The comprehensive evaluation of SYI as well as morphometric parameters has been done to prioritize the micro-watersheds on the basis of soil conservation. Based on this study it is found that a total of 21 micro-watersheds fall under category very high, in which 24 check dams were proposed on 3rd, 4th and 5th order streams. The results obtained showcased the precision-based site suitability evaluation for the check dam construction. Suitable soil conservation structures are suggested at appropriate location based on the topographical and morphological conditions. The study demonstrated the versatility and utility of Remote sensing and GIS in combination with morphometric analysis for the sustainable development of watersheds.

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