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Research Paper

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Multivariate Geomorphometric Approach to Prioritize Erosion Prone Watershed of Upper Cauvery Karnataka

Mohammed Badiuddin Parvez[1]*, M Inayathulla[2]

[1,2]Dept. of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India

Corresponding Author: parvezuvce@gmail.com Tel.: +919060506390

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Abstract-Prioritization of watershed has Grabbed up significance in watershed management. Morphometic investigation is been usually applied to organize the watershed. In the present study upper cauvery of Karnataka with an area of 10874.65 km^2 and highest order stream of 8 was considered. The area was divided into Eight Watersheds. Various morphometric parameters namely Bifurcation ratio(Rb), Drainage density (Dd), Stream frequency(Ns), Texture ratio(T), Form factor(Rf), Circularity ratio(Rc), Elongation Ratio(Re), length of overland flow, shape factor(Bs), compactness ratio (Cc) has been determined for each watershed and allotted position on premise of relationship as to arrive at a Compound value for final ranking of watershed. The morphometric parameters ranges between Rb (3.416-5.0442), Dd (1.377-1.463), Ns (1.397-1.579), T (5.235-8.540), Rf (0.233-1.082), Rc (0.179-0.447), Re (0.545-1.173), Cc (1.496-2.365), Lof (0.341-0.363), and Bs (0.924-4.284). It is found that the 38.83 % of area falls under high priority category where as 42.12% of area falls under this Medium category and 19.05% of the area falls under low catergory.

Keywords: GIS, DEM, Morphometric analysis, Watershed, Priority, Compound Factor.

I. INTRODUCTION

Soil disintegration is viewed as one of the most significant corruption forms on the planet. The soil resource is limited and its wide use is of utmost importance; it sustains bio geochemical processes and is the habitat for a great diversity of microorganisms. Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). Morphometric analysis requires measurement of linear features, gradient of channel network and contributing ground slopes of the drainage basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms. A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945). Drainage basin examination based on morphometric parameters is very fundamental for watershed planning since it gives an thought regarding the basin characteristics in terms of slope, topography, soil condition, runoff characteristics, surface water potential etc. Geographic Information System techniques strategies described by an exceptionally high exactness of mapping and measurement prove to be a tool in morphometric analysis. One of the advantages of quantitative analysis is that many of the basin parameters derived are in the form of ratios, and dimensionless numbers, thus providing an effective comparison irrespective of the scale (Krishnamurthy et al. 1996).

II. MATERIALS AND METHODS

2.1 Study Area

The study area geographically lies between 75^0 29’ 19” E and 76^0 37’ 40” E longitude and 11^0 55’ 54” N and 13^0 23’ 12.8” N latitude, as shown in Fig 1, the study area has an area of 10874.65 Sq km. The maximum length and width of the study area is approximately equal to 143.73 km and 96.75 km respectively. The maximum and minimum elevation of the basin is 1867 m and 714 m above MSL, respectively. The study area covers five district of Karnataka state i.e., Chikmangalur, Hassan, Kodagu, Mandya and Mysore as shown in Fig 3. The maximum average annual rainfall in the catchment is 1072.66 mm has been recorded in the year 2005 and minimum average annual rainfall of 524.58 mm in 1998. June, July and August are the months with heavy rainfall and rainfall in July was the heaviest. The study area is divided into eight watershed as A1, A2, A3, A4, B1, B2, B3 and B4 as shown in Fig 2.

2.2 Methodology

By using SRTM DEM data, basin was delineated and the drainage network was extracted. Initially the sink or depression area in DEM is been filled to get rid of small uneveness in the data. Then on basis of relative slopes between pixels flow direction is determined. Flow accumulation grid has been prepared using this data. Stream order was generated using above data on the basis of drainage flow direction study area was divided into Eight Watersheds designated as (as A1, A2, A3, A4, B1, B2, B3 and B4). Morphometric aspects such as Bifurcation ratio(Rb), Drainage density(Dd), Stream frequency(Ns), Texture ratio(T), Form factor(Rf), Circularity ratio(Rc), Elongation Ratio(Re), length of overland flow, shape factor(Bs), drainage texture, compactness ratio(Cc) is calculated. Stream order Map is shown in Fig 4.

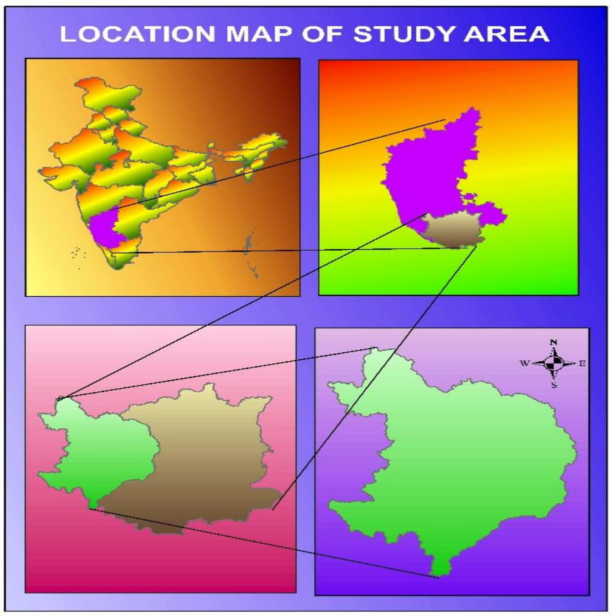


Fig 1 location map of study area

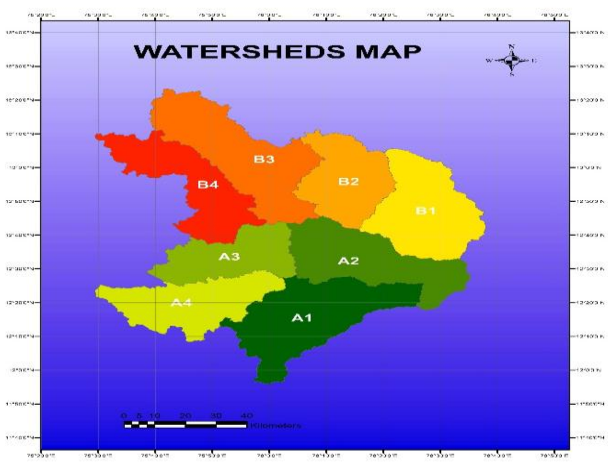


Fig 2 Watershed Map of Area

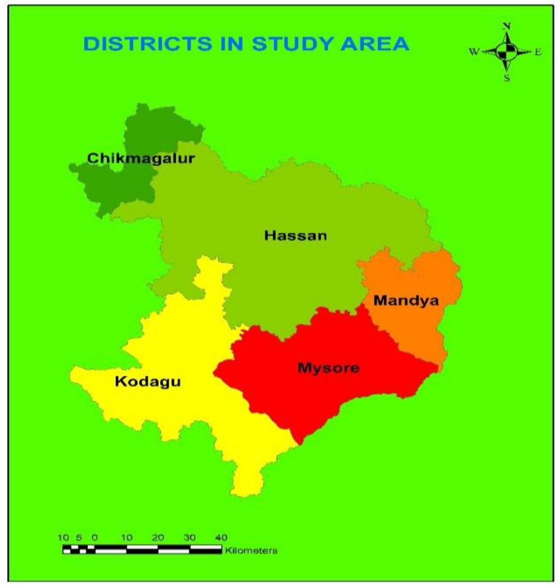


Fig 3 District map of study area

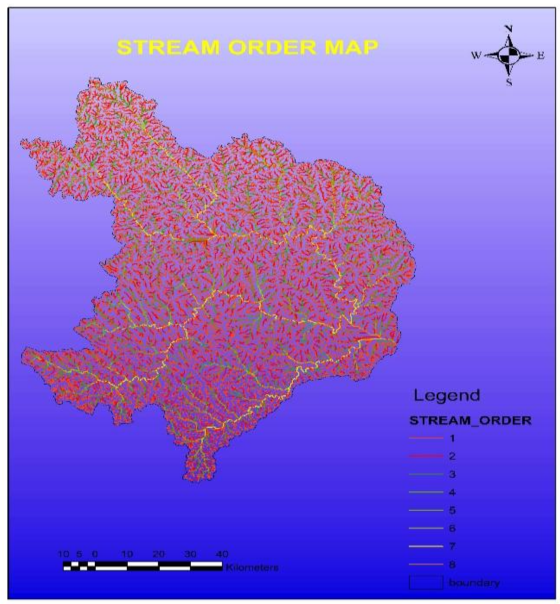


Fig 4 Stream order Map

The total Area (A), Perimeter (P) of Eight Watersheds is calculated using Arc GIS and values are tabulated in table 1.

III. RESULTS AND DISCUSSIONS

3.1 Morphometric analysis

Designation of Stream order is the basic step in morphometric analysis of a drainage basin, based on the hierarchic making of streams proposed by Strahler (1964). The highest order stream in the study area is 8^{th} order. The morphometric parameters were calculated it shows that Bifurcation ratio (Rb) ranges from 3.416-5.0442 A3 have low Rb whereas B2 have high Rb. Drainage density (Dd) is low in A3 and high in B1 its value ranges from 1.377-1.463. Stream frequency (Ns) varies from 1.397-1.579 with A1 having low and B4 has high value. Texture ratio (T) ranges from 5.23-8.54 with low in B4 and high in B1. Form factor (Rf) is low in B3 and high in B2 it ranges from 0.233 to 1.082. Length of overland flow varies from 0.341 to 0.363 with low in B1 and high in A3. Basin shape (Bs) is low in B2 and high in B3 it ranges from 0.921 to 4.284. Compactness coefficient (Cc) show wide variation across the watershed it is more in B4 and less in B1 it varies from 1.496 to 2.365. Elongation ratio(Re) varies from 0.545 to 1.173 with B2 has low and B2 has high value. Circularity ratio(Rc) of watersheds ranges from 0.179 to 0.447 with low in B4 and high in B1. The Tabulated results are shown in Table 3. Linear morphometric characteristics is shown in Table 2.

Table 1 : Watersheds of Upper Cauvery Catchment

Subwatersheds	Area(km^2)	Perimeter(km)	Length(km)	Width(km)
A1	1705.50	263.13	76.20	56.52
A2	1411.28	244.53	50.02	24.30
A3	973.81	201.52	38.50	22.84
A4	1205.17	222.98	52.17	22.21
B1	1463.36	202.94	38.75	24.87
B2	1097.97	193.21	31.85	30.40
B3	1759.84	315.76	86.83	21.3
B4	1257.72	297.45	65.26	15.22

Table 2: Linear Morphometric Characteristics of Watershed of Upper cauvery

Watershed	Stream order	No of Streams	Total length of Streams (km)	Cumulative Length(km)	Mean Stream Length(km)	Bifurcation Ratio	Length Ratio
A1	1	1857	1203.930	1203.930	0.648		
	2	387	618.430	1822.360	1.598	4.798	2.465
	3	83	271.300	2093.660	3.269	4.663	2.045
	4	19	137.110	2230.770	7.216	4.368	2.208
	5	6	49.050	2279.820	8.175	3.167	1.133
	6	1	97.200	2377.020	97.200	6.000	11.890
A2	1	1562	1022.530	1022.530	0.655		
	2	321	521.640	1544.170	1.625	4.866	2.482
	3	70	249.480	1793.650	3.564	4.586	2.193
	4	13	120.370	1914.020	9.259	5.385	2.598
	5	1	9.520	1923.540	9.520	13.000	1.028
	6	1	13.060	1936.600	13.060	1.000	1.372
	7	2	72.950	2009.550	36.475	0.500	2.793
	8	1	17.300	2026.850	17.300	2.000	0.474
A3	1	1090	680.950	680.950	0.625		
	2	238	341.090	1022.040	1.433	4.580	2.294
	3	51	152.990	1175.030	3.000	4.667	2.093
	4	12	79.430	1254.460	6.619	4.250	2.207
	5	4	40.190	1294.650	10.048	3.000	1.518
	6	2	20.830	1315.480	10.415	2.000	1.037
	7	1	26.110	1341.590	26.110	2.000	2.507
A4	1	1449	937.440	937.440	0.647		
	2	301	424.630	1362.070	1.411	4.814	2.181
	3	66	213.250	1575.320	3.231	4.561	2.290
	4	19	80.580	1655.900	4.241	3.474	1.313
	5	5	48.200	1704.100	9.640	3.800	2.273
	6	1	58.930	1763.030	58.930	5.000	6.113
	1	1734	1116.050	1116.050	0.644		

B1	2	374	535.540	1651.590	1.432	4.636	2.225
	3	79	223.030	1874.620	2.823	4.734	1.972
	4	21	130.550	2005.170	6.217	3.762	2.202
	5	5	68.420	2073.590	13.684	4.200	2.201
	6	2	6.990	2080.580	3.495	2.500	0.255
	7	1	60.730	2141.310	60.730	2.000	17.376
B2	1	1286	828.930	828.930	0.645		
	2	266	400.140	1229.070	1.504	4.835	2.334
	3	58	194.150	1423.220	3.347	4.586	2.225
	4	10	77.300	1500.520	7.730	5.800	2.309
	5	1	48.460	1548.980	48.460	10.000	6.269
	6	0	0.000	1548.980	-	-	-
	7	1	36.170	1585.150	36.170	-	-
B3	1	2022	1308.330	1308.330	0.647		
	2	421	627.240	1935.570	1.490	4.803	2.303
	3	86	290.350	2225.920	3.376	4.895	2.266
	4	22	162.740	2388.660	7.397	3.909	2.191
	5	5	40.270	2428.930	8.054	4.400	1.089
	6	2	76.490	2505.420	38.245	2.500	4.749
	7	1	11.470	2516.890	11.470	2.000	0.300
B4	1	1557	922.450	922.450	0.592		
	2	340	478.000	1400.450	1.406	4.579	2.373
	3	68	207.300	1607.750	3.049	5.000	2.168
	4	16	126.390	1734.140	7.899	4.250	2.591
	5	4	29.550	1763.690	7.388	4.000	0.935
	6	1	50.700	1814.390	50.700	4.000	6.863

3.2 Priortization of Watershed

Morphometric aspects such as Drainage density (Dd), Stream frequency (Ns), Texture ratio (T), Form factor (Rf), Bifurcation ratio (Rb), Circularity ratio (Rc), Elongation Ratio (Re), length of overland flow, Basin Shape (Bs), compactness ratio(Cc) are also termed as erosin risk assessment parameters and have been used for prioritizing Watersheds [3]. The preliminary priority ranking of Watersheds was done on the basis of morphological characteristics the parameters such as Bifurcation ratio(Rb), Stream frequency (Ns), Drainage density(Dd), Texture ratio(T), have a direct relationship with erodibility higher values of all these have been have been given rank 1 second largest is rated as rank 2 and so on with the least ranked last in each of the mini watersheds. Parameters such as Form factor (Rf), Circularity ratio (Rc), Elongation Ratio (Re), Basin Shape (Bs) have inverse relationship with the erodibility higher the value less is erosion lower the value high is erodibility [5]. In this manner least estimations of this is appraised as rank 1 and second least been rated as rank 2 and so on and the highest values is given last rank. The final priority ranking and related categorization were made on the basis of the compound factor value, which was computed by multiplying the ranks from morphometric analysis and their weights obtained using cross-correlation analysis of these parameters to give compound factor for final prioritization of sub-watersheds[5]. The compound factor is calculated using equation 1.

$CF= PPR_{mp} \times W_{mp}$ (1) Where CF is compound factor, PPR_{mp} is the preliminary priority rank based on morphometric parameter, and W_{mp} is the weight of morphometric parameter obtained using cross correlation analysis. Based on final value of compound factor Watershed with least rating was assigned highest rank next value was assigned second rank and so on and the Watershed with highest compound value was assigned last rank.

3.2.1 Prioritization of sub-watershed based on weighted sum approach

The cross-correlation analysis among various morphometric parameters (Table 5) was performed and tested at 5% level of significance. The priority ranks of Watersheds were determined on the basis of compound factor (Table 4), which was calculated using Eq.1.The value of weights assigned to a morphometric parameter was calculated by dividing the sum of correlation coefficient of each parameter by the grand total of correlations (Table 5)[5]. By assigning the weights to different parameters, a model was formulated to assess the final priority ranking. The compound factor for Watershed A1 prioritization was computed as follows:

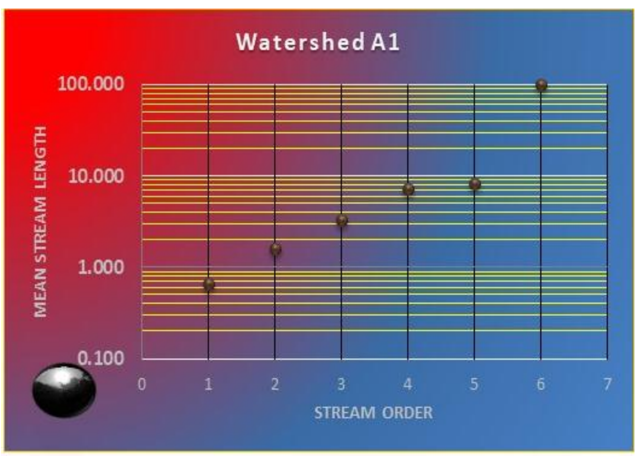
Compound factor =(0.185*PPR of Rbm)+(0.297*PPR of Dd)-(0.277*PPR of LOF)- (0.193*PPR of Cc)+(0.244*PPR of Rc)+(0.181*PPR of Ns)+(0.268*PPR of Rf)-(0.189*PPR of Bs)+(0.249*PPR of Re)+(0.255*PPR of T) .

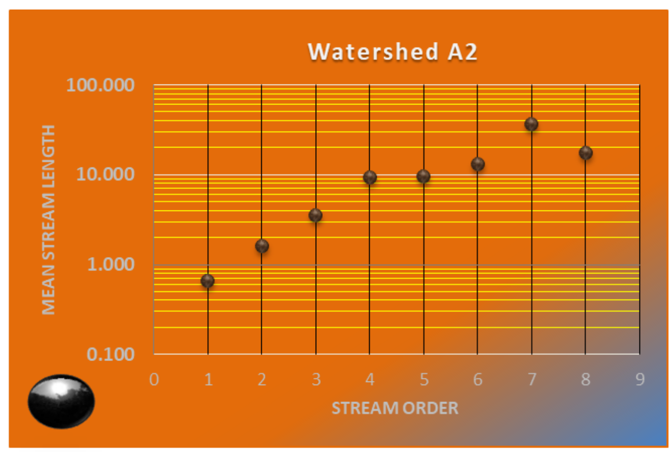
The final priority ranking was made in such a way that the lowest value of compound factor was given the priority rank of 1, the next lower value was given priority rank of 2, and so on for all the Watersheds. Figure 8 shows the final priority ranking map of Eight watershed under study.

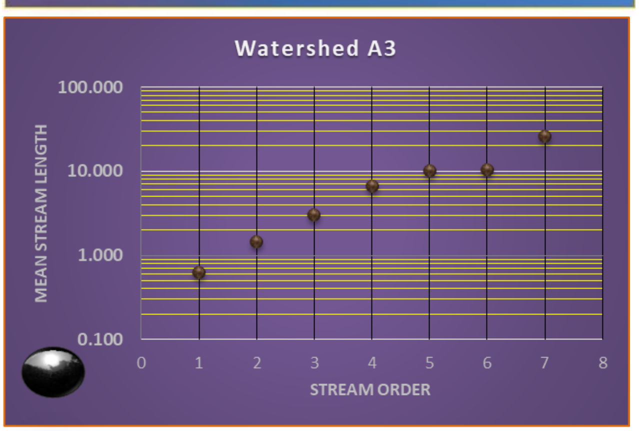
Based on the compound factor value, all the Watersheds were classified into Three priority categories such as (i) High (0 to 3), (ii) Medium (3.0 to 6.0), (iii) Low (6.0 to 9.0), as given in Table 6 and 7. It was observed from Table 11 that the three Watersheds (A4, B3 and B4) were under very high category, Three Watershed (A1, A2 and B1) under medium, and Two Watershed (A3 and B2) was under low category.

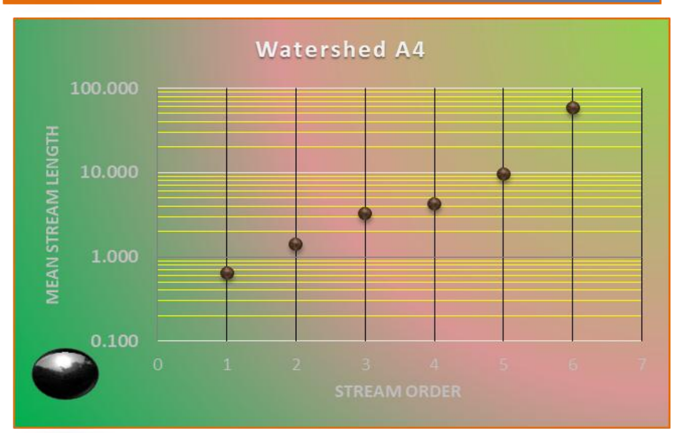
Table 3 Morphometric Parameters of Watershed of Upper Cauvery

Watershed	Bifurcation Ratio Mean	Drainage Density	Length Of Overland Flow	Compactness Coefficient	Circularity Ratio	Stream Frequency	Form Factor	Elongation Ratio	Shape Factor	Texture Ratio
A1	4.5990	1.3937	0.3587	1.7970	0.3099	1.3797	0.2937	0.6112	3.4045	7.0573
A2	4.4770	1.4362	0.3481	1.8358	0.2969	1.3966	0.5641	0.8470	1.7729	6.3878
A3	3.4160	1.3777	0.3629	1.8213	0.3017	1.4356	0.6570	0.9141	1.5221	5.4089
A4	4.3300	1.4629	0.3418	1.8115	0.3049	1.5276	0.4428	0.7505	2.2584	6.4983
B1	3.6387	1.4633	0.3417	1.4962	0.4470	1.5143	0.9746	1.1133	1.0261	8.5444
B2	5.0442	1.4437	0.3463	1.6445	0.3700	1.4773	1.0824	1.1733	0.9239	6.6560
B3	3.7512	1.4302	0.3496	2.1228	0.2220	1.4541	0.2334	0.5449	4.2842	6.4036
B4	4.3659	1.4426	0.3466	2.3655	0.1788	1.5790	0.2953	0.6129	3.3862	5.2345









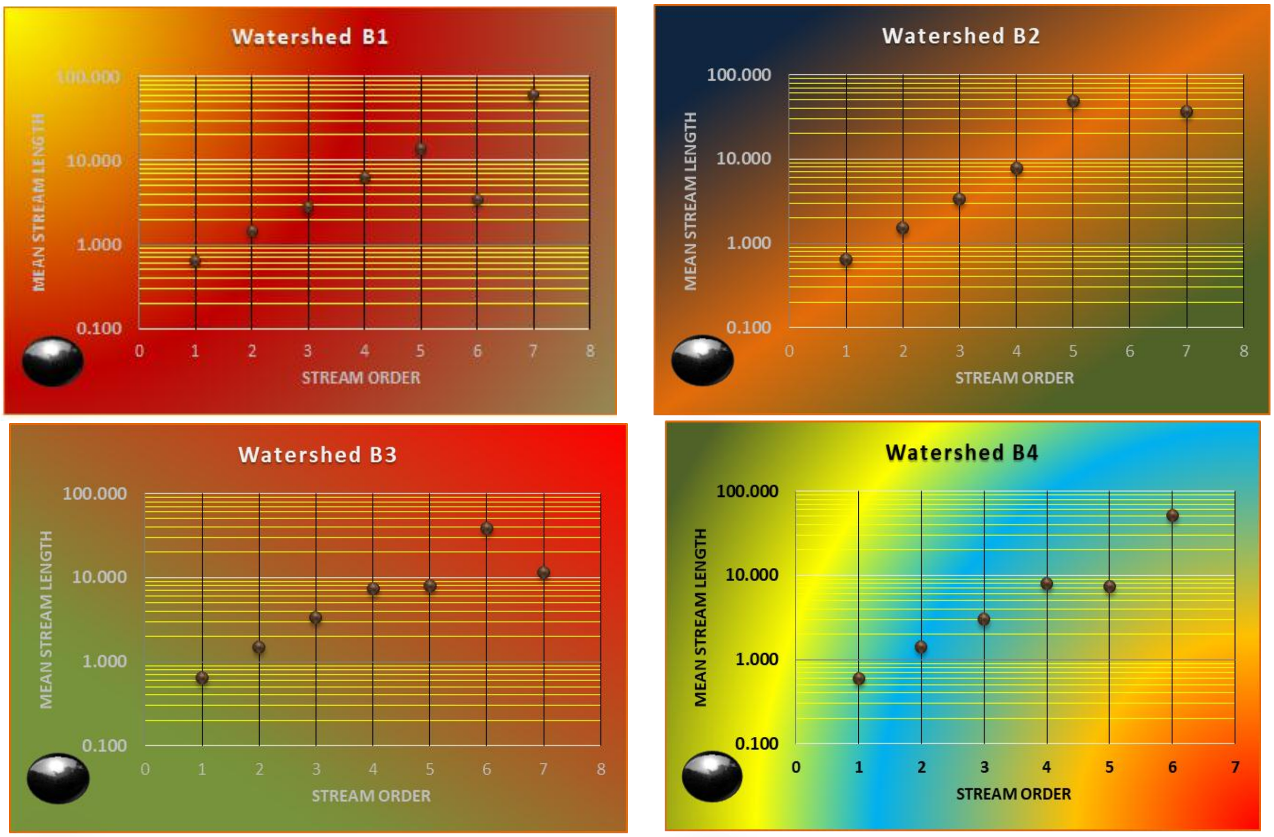
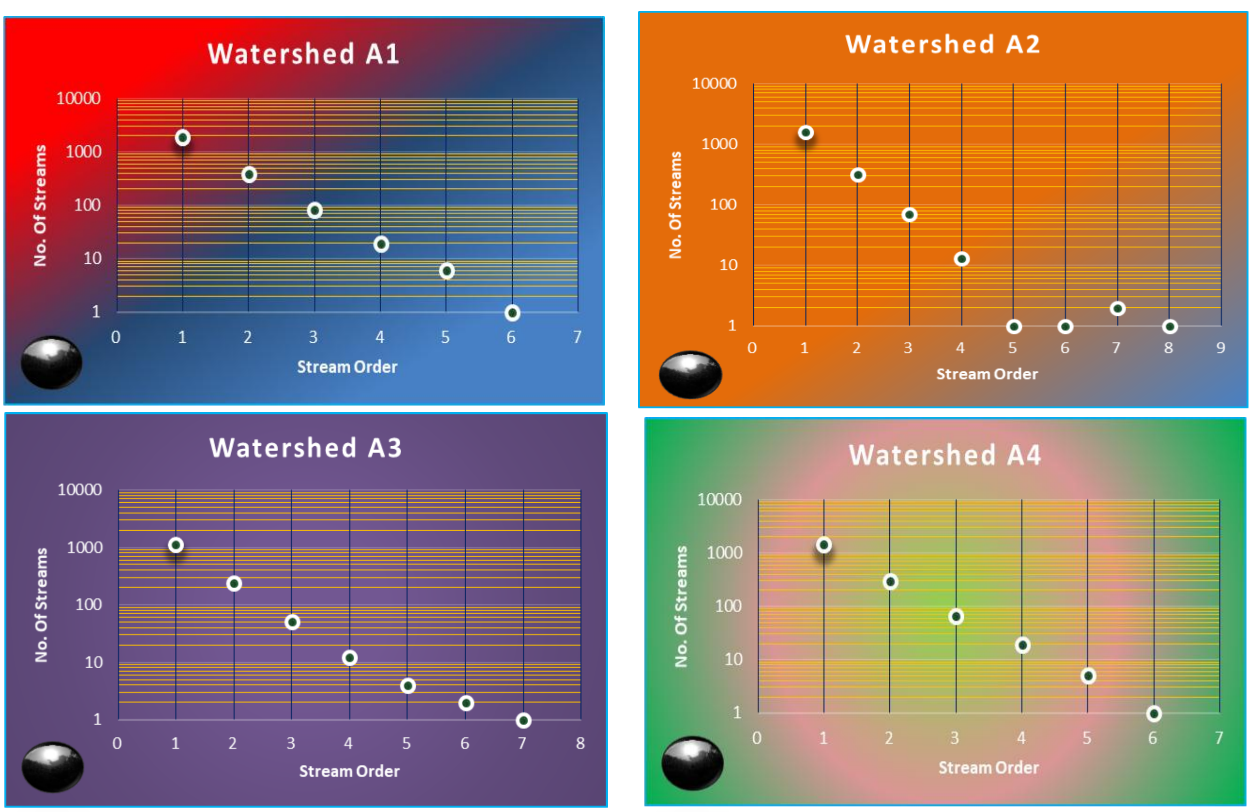


Figure 5 Regression of stream order vs No of Streams



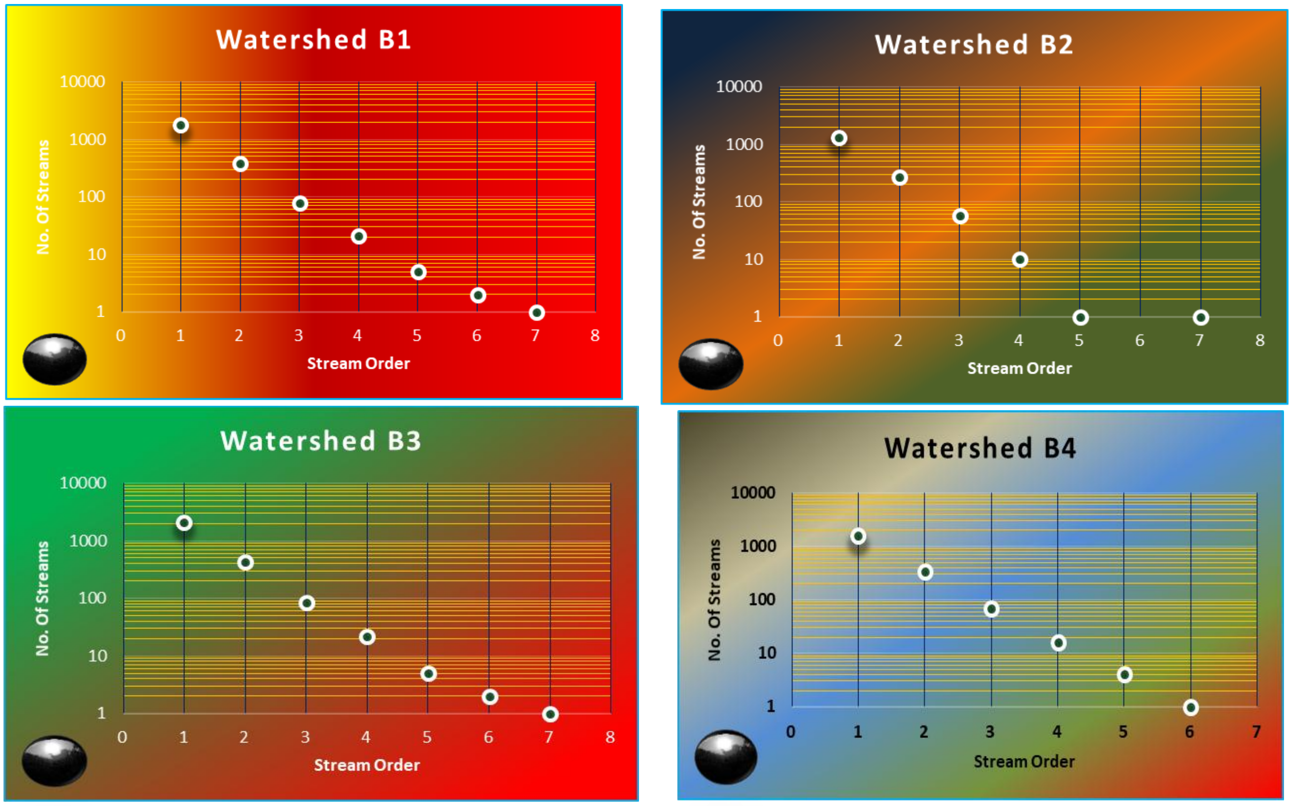
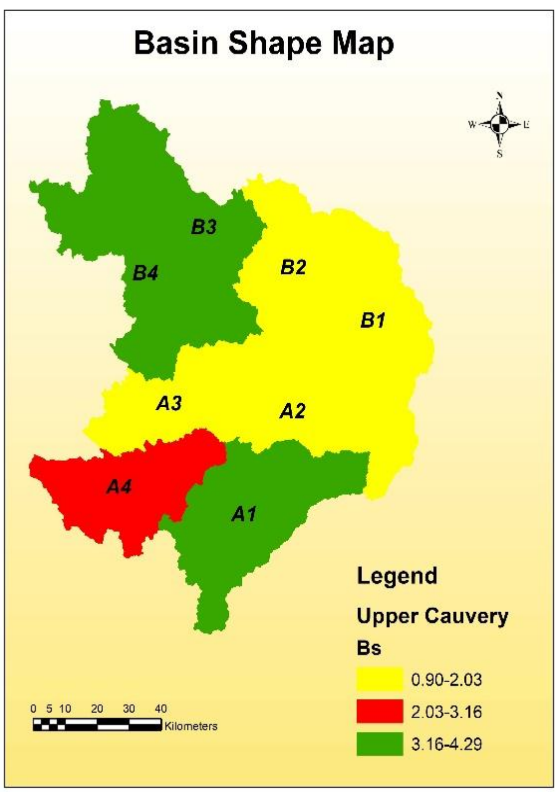
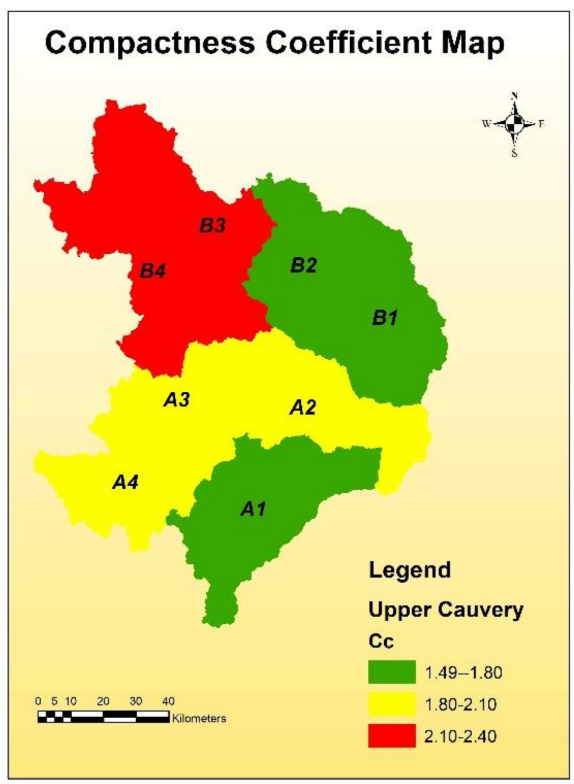
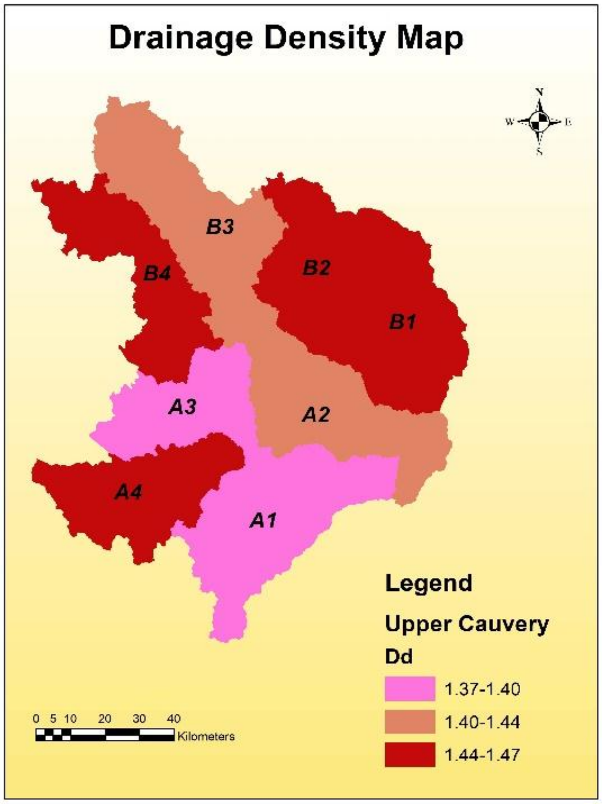
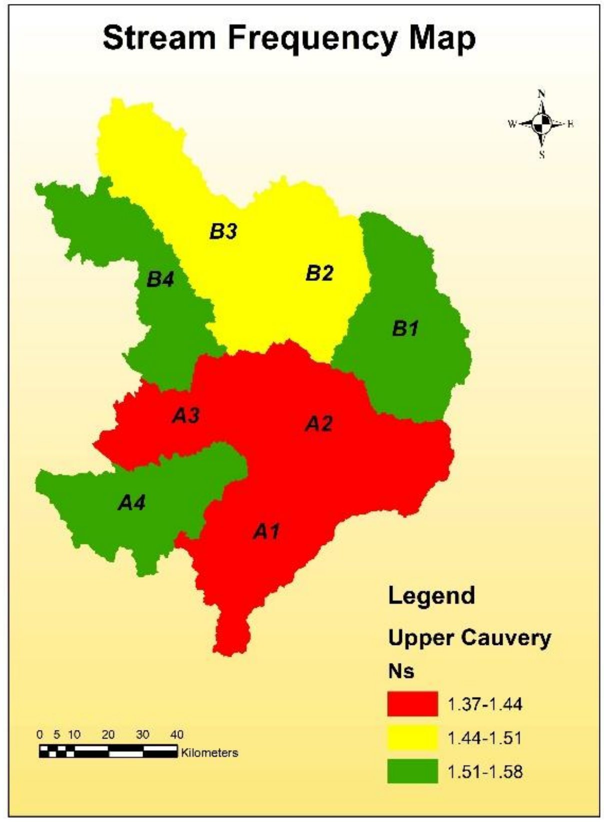


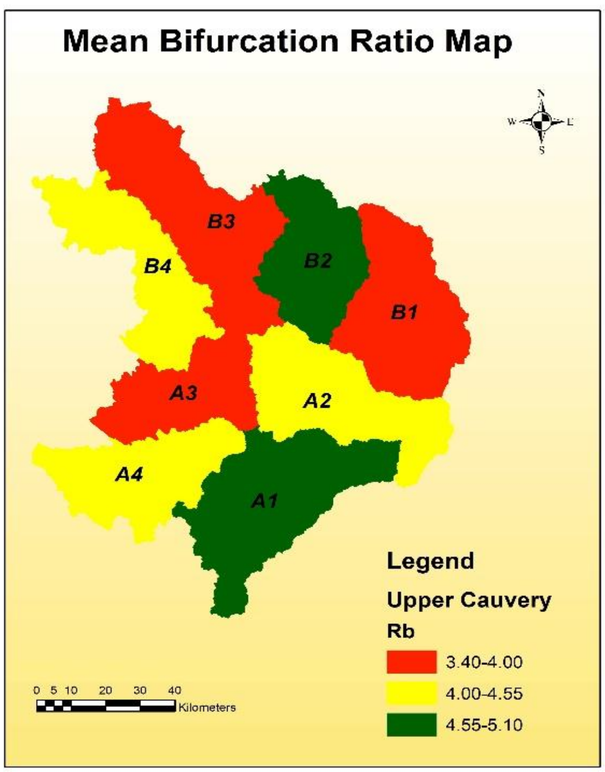
Figure 6 Regression of stream order vs mean stream length

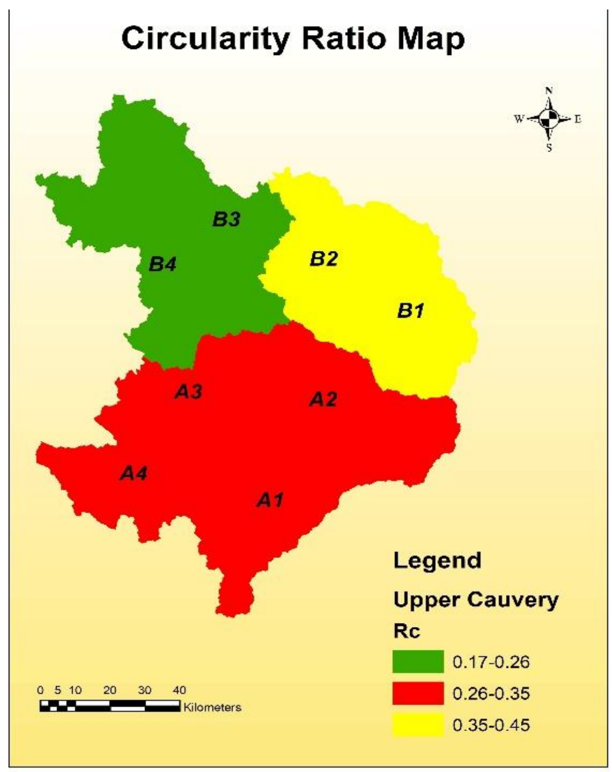





Drainage Density Map
B3
B4
B2
B1
A3
A2
A4
A1
Legend
Upper Cauvery
Dd
1.37-1.40
1.40-1.44
1.44-1.47
0 5 10 20 30 40
Kilometers


Stream Frequency Map
B3
B2
B4
B1
A3
A2
A4
A1
Legend
Upper Cauvery
Ns
1.37-1.44
1.44-1.51
1.51-1.58
0 5 10 20 30 40
Kilometers


Mean Bifurcation Ratio Map
B3
B2
B4
B1
A3
A2
A4
A1
Legend
Upper Cauvery
Rb
3.40-4.00
4.00-4.55
4.55-5.10
0 5 10 20 30 40
Kilometers


Circularity Ratio Map
B3
B4
B2
B1
A3
A2
A4
A1
Legend
Upper Cauvery
Rc
0.17-0.26
0.26-0.35
0.35-0.45
0 5 10 20 30 40
Kilometers

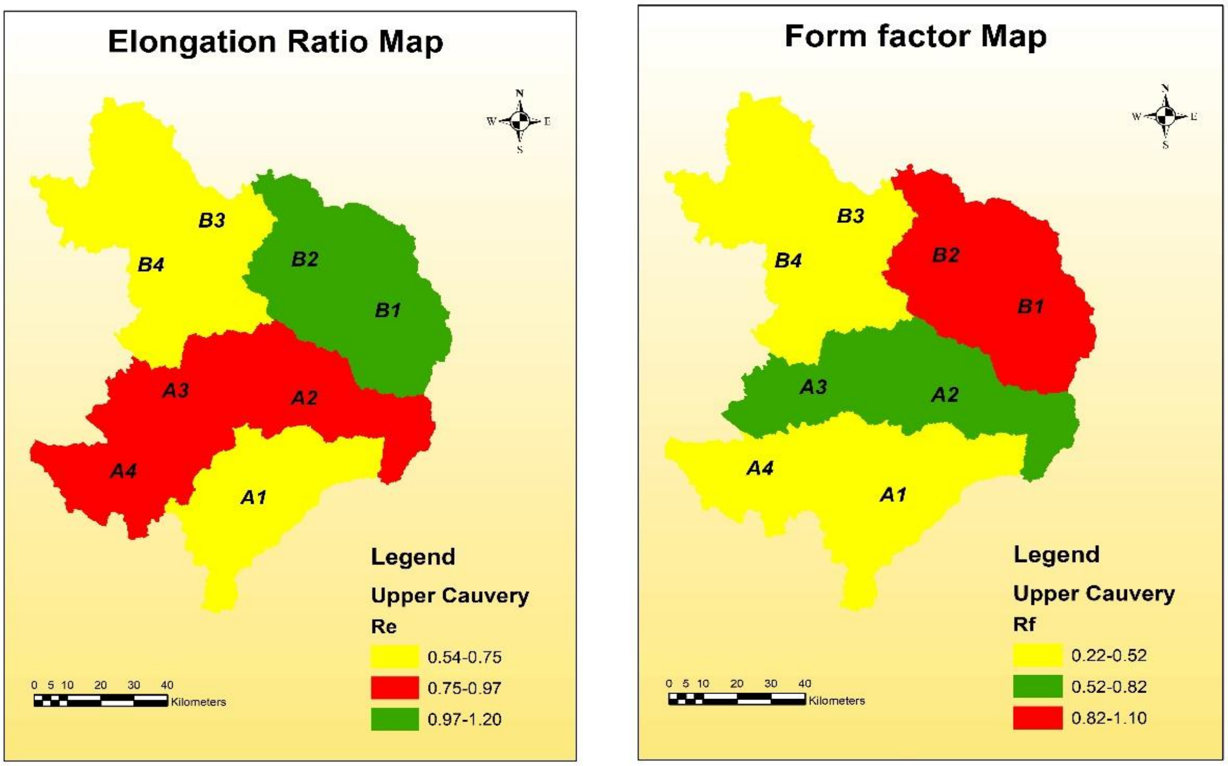


Figure 7: Spatial Distribution of Morphometric Parameter

Table 4: Preliminary priority ranking of Watersheds

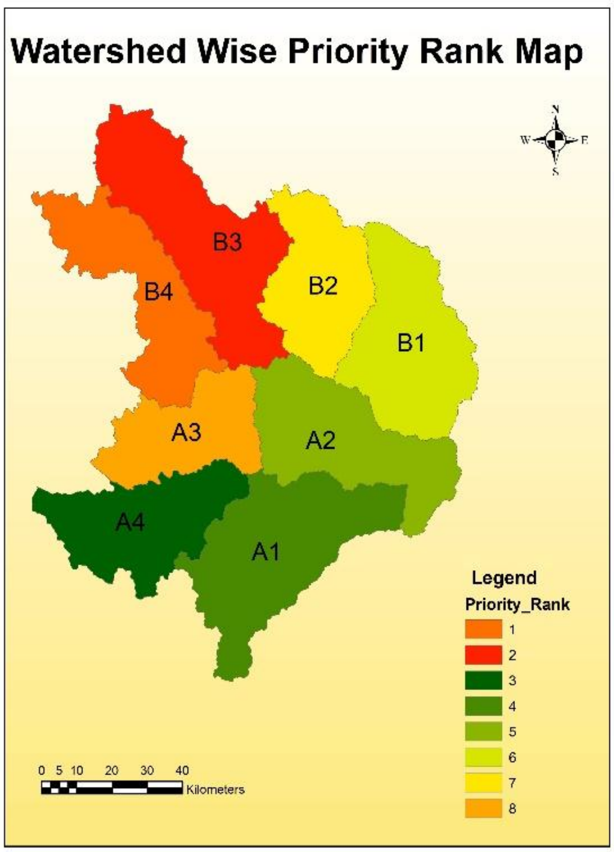
Wateshed	Bifurcation Ratio Mean	DRAINAGE DENSITY	LENGTH OF OVERLAND FLOW	COMPACTNESS COEFFICIENT	CIRCULARITY RATIO	Stream Frequency	Form Factor	ELONGATION RATIO	Shape Factor	Texture Ratio
A1	2	7	2	3	6	8	2	2	7	2
A2	3	5	4	6	3	7	5	5	4	6
A3	8	8	1	5	4	6	6	6	3	7
A4	5	2	7	4	5	2	4	4	5	4
B1	7	1	8	1	8	3	7	7	2	1
B2	1	3	6	2	7	4	8	8	1	3
B3	6	6	3	7	2	5	1	1	8	5
B4	4	4	5	8	1	1	3	3	6	8

Table 5: Cross-correlation matrix between various parameters of Watersheds

	Rbm	Dd	LOF	Cc	Rc	Ns	Rf	Re	Bf	T
Rbm	1.0000	0.4503	-0.4590	0.0097	-0.0293	0.1221	0.2157	0.1964	-0.1751	-0.1025
Dd	0.4503	1.0000	-0.9998	-0.1763	0.2748	0.5208	0.1153	0.0844	-0.0230	0.6039
LOF	-0.4590	-0.9998	1.0000	0.1658	-0.2641	-0.5158	-0.1086	-0.0767	0.0130	-0.5976
Cc	0.0097	-0.1763	0.1658	1.0000	-0.9743	0.3027	-0.8585	-0.8784	0.8640	-0.7397
Rc	-0.0293	0.2748	-0.2641	-0.9743	1.0000	-0.1459	0.8910	0.8990	-0.8510	0.8208
Ns	0.1221	0.5208	-0.5158	0.3027	-0.1459	1.0000	-0.1365	-0.1687	0.2076	0.0148
Rf	0.2157	0.1153	-0.1086	-0.8585	0.8910	-0.1365	1.0000	0.9945	-0.9097	0.5751
Re	0.1964	0.0844	-0.0767	-0.8784	0.8990	-0.1687	0.9945	1.0000	-0.9476	0.5527
Bf	-0.1751	-0.0230	0.0130	0.8640	-0.8510	0.2076	-0.9097	-0.9476	1.0000	-0.4348
T	-0.1025	0.6039	-0.5976	-0.7397	0.8208	0.0148	0.5751	0.5527	-0.4348	1.0000
Sum	1.2284	1.8504	-1.8429	-1.2849	1.6211	1.2010	1.7783	1.6556	-1.2564	1.6927
Grand Total	6.6432	6.6432	6.6432	6.6432	6.6432	6.6432	6.6432	6.6432	6.6432	6.6432
Weight	0.185	0.279	-0.277	-0.193	0.244	0.181	0.268	0.249	-0.189	0.255

Table 6 : Final Priority Ranking		
Watershed Name	Compound factor	Rank
A1	4.323	4
A2	5.042	5
A3	8.852	8
A4	2.497	3
B1	5.156	6
B2	6.118	7
B3	2.275	2
B4	1.809	1

Table 7: Priority category based on compound factor for mini-watershed 1				
Sl No	Priority Level	Priority Category	Watershed name	% Area
1	0.0-2.5	High	A4, B3, B4	38.83
2	2.5-5.0	Medium	A1, A2, B1	42.12
3	5.0-7.5	Low	A3, B2	19.05



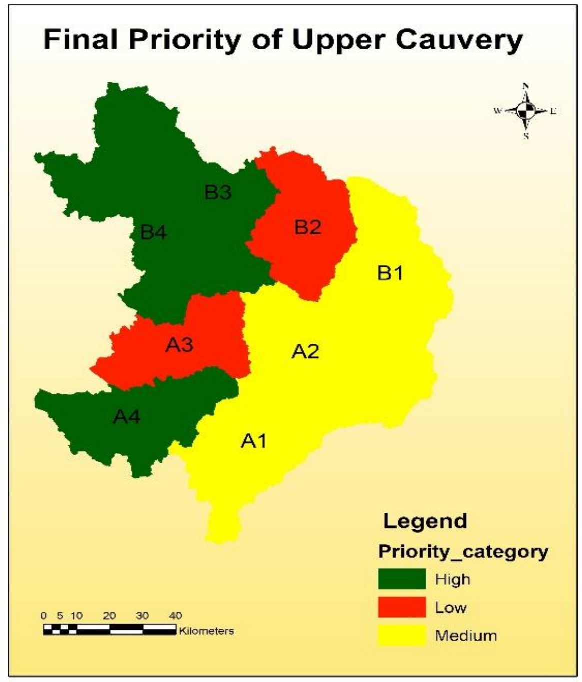


Figure 8 Priority Map

IV. CONCLUSIONS

The length of overland flow (lof) for all the Watersheds in the present study is more than 0.30 hence they have longer flow paths associated with more infiltration and reduced runoff. Stream frequency (Ns) for present study is low demonstrating relatively a low runoff. Higher value of form factor (Rf) indicates wider basin and lower value indicates narrow basin. Drainage density varies from1.377 km/km^2 to 1.463 km/km^2 indicating watersheds fall under coarse and very coarse texture. From Table 6 and 7 it can be found that the 38.83 % of area falls under high priority category where as 42.12% of area falls under this Medium category and 19.05% of the area falls under low catergory. We can also conclude that in case of unavailability of soil maps this type of study could be used in selecting area for soil conservation measure.

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AUTHORS PROFILE

Mohammed Badiuddin Parvez Is a life member of Indian Water Resources Society, ASCE Born in Gangavathi, Obtained his BE in Civil Engineering in the year 2009-2013 from UVCE, Banagalore and M.E with specialization in Water Resources Engineering during 2013-2015 from UVCE, Bangalore University and Pursuing Ph.D from Bangalore University. And has 3 years of teaching experience. Till date, has presented and published several technical papers in many National and International seminars, Journals and conferences.

M Inayathulla Is a life member of Environmental and Water Resources Engineering (EWRI), ASCE, WWI, ASTEE, ASFPM. Born in Karnataka, Obtained his BE in Civil Engineering in the year 1987-1991 from UBDT, Davanagere and M.E with specialization on Water Resources Engineering during 1992-1994 from UVCE, Bangalore University and got Doctorate from Bangalore University. Presently working as Professor at UVCE, Bangalore University, India. And has more than 25 years of teaching experience. Till date, has presented and published several technical papers in many National and International seminars and conferences

