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PRIORITIZATION BASED ON MORPHOMETRIC ANALYSIS OF BHILANGANA WATERSHED USING SPATIAL TECHNOLOGY

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Abstract

Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management. Marphometric analysis has been commonly applied to prioritization of watershed. In the present study, prioritization and morphometric analysis of micro watersheds have been perform for the Bhilangana watershed of Uttarakhand. Various morphometric parameters, namely linear and shape have been determined for each micro-watersheds and assigned ranks on the basis of value/relationship so as to arrive at a compound value for a final ranking of the watershed. For the study stream network along with their order was extracted from ASTER DEM 30 m in geospatial environment. The stream order up to 6 has been analysed. This watershed comprises of 20 micro watersheds named MW1 to MW20 with geographical area in the range of 5.08 km^2 for MW 19 to 341.56 km^2 for MW 1. Based on morphometric analysis, the watershed has been classified into three categories as high medium and low in terms of priority for conservation and management of natural resources.

Keywords: Watershed, prioritization, DEM, morphometric.

Introduction

A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape. 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 watershed management concept recognizes the interrelationships among the linkages between uplands, low lands, land use, geomorphology, slope and soil. Soil and water conservation is the key issue in watershed management while demarcating watersheds. 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). Morphometric analysis refers to the quantitative analysis of form, a concept that encompasses size and shape. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper 2008). The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams, etc. (Chorley 1969, Gregory and Walling 1973). Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms (Clarke 1996). The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992). This analysis can be achieved through measurement of linear, aerial and relief aspects of basins by using the approach of remote sensing and GIS.

Remote sensing and GIS techniques are currently used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. Satellite remote sensing has the ability of obtaining synoptic view of large area at one time and very useful in analyzing the drainage Morphometry.

Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. 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).

However, while considering watershed conservation work, it is not feasible to take the whole area at once. Thus the whole basin is divided into several smaller units, as sub watersheds or micro watersheds, by considering its drainage system.

Study Area

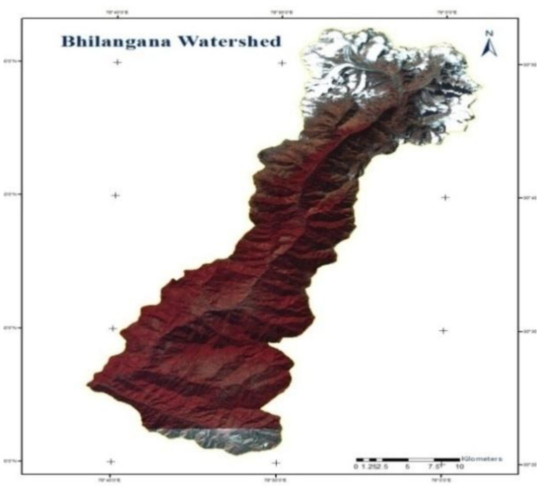

Figure 1:-Study area map of Bhilangana watershed

The Bhilangana watershed located between 30˚ 51’ 32.33” to 30˚ 20’ 27.88” N latitude and 78˚ 59’ 47.15” to 78˚ 47’ 34.58” E longitude (shown in fig 1.). The topography of the upper catchment of the Bhilangana River consists of U-shaped valley, moraines, eskers, cirques and high ridges. Permanent pockets of snow occur in moist shady depressions. In its upper course the Bhilangana flows past alpine meadows and thickest of sub alpine forests. Coniferous and broad-leaved forests are found in Bhilanagana valley. Bhilangana River is an important tributary of Bhagirathi River near Tehri. It flows from the khatling glacier (elevation 3,717 m (12,195 ft), approximately 50 km (31 mi) south of Gaumukh and north of Ghuttu in Tehri district of Grahwal region. The river flows along a SW direction to join the Bhagirathi River at Tehri in the Bhagirathi valley. A number of glacial lakes occur in the upper catchment of this river. Small streams emanate from these water bodies and merge with the main stream. The river flows from its source for 205 km (127 mi) before meeting the Alaknanda River at an elevation of 475 m (1,558 ft) in the town of Devprayag.

The study area Topography is mountainous with flowering valleys and small grasslands complementing it. At one point of time the forests of Tehri Garhwal were teeming with many exotic and rare species but now they are critically endangered. A pleasant weather all through the year but sometimes it does get extremely chilly due to occasional snowing. The forests of Tehri Garhwal are literally a storehouse of health since many medicinal herbs, shrubs and trees are found here. The areas under forests have a great importance not only in the ecology but also in the economy of the district.

Methodology

Morphometric analysis of a drainage system requires delineation of all existing streams. The stream delineation was done in GIS environment using ASTER 30 m DEM. Stream order upto 6 have been delineated for the study. The various morphometric parameters such as area, perimeter, stream order, 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, compactness coefficient, shape factor, texture ratio were computed based on the formula suggested by (Horton, 1945), (Strahler, 1964), (Schumm, 1956), (Nookaratnam et al., 2005) and (Miller, 1953) given in table 1(Page No.49).

The linear parameters such as drainage density, stream frequency, bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility, higher the value, more is the erodibility. Hence for prioritization of sub-watersheds, the highest value of 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, compactness coefficient, circularity ratio, basin shape and form factor have an inverse relationship with erodibility (Nooka Ratnam et al., 2005), lower the value, more is the erodibility. Thus the lowest value of 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 micro watersheds has 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

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. Thus an index of high, medium and low priority was produced. The various indicators which have been used in the prioritization of watershed are described in table 2(Page No. 50).

Result and Discussion

Land Use/Land Cover analysis

Land use/land cover mapping was carried out using LISS-III geocoded FCC of 2008. The visual interpretation of the LISS-III data led to the identification and delineation of land use/land cover categories.

Table 3: Land use/land cover analysis

Class	Area (Sq. Km.)
Agricultural Land-Crop Land-Kharif Crop	0.91
Agricultural Land-Crop Land-Rabi Crop	0.09
Agricultural Land-Crop Land-Two crop area	2.79
Agricultural Land-Crop Land-Zaid Crop	0.10
Agricultural Land-Fallow-Current Fallow	0.20
Forest-Deciduous (Dry/Moist/Thorn)-Open	0.18
Forest-Evergreen / Semi Evergreen-Dense/Closed	15.29
Forest-Evergreen / Semi Evergreen-Open	0.07
Forest-Forest Blank	0.19
Forest-Scrub Forest	4.22
Natural/Semi natural grassland & Grazing land-Alpine/Sub alpine	0.53
Natural/Semi natural grassland & Grazing land-Temperate/Sub tropical	0.59
Snow covered - Permanent	3409.05
Snow covered/Glacial area	22.95
Tree Clad Area/Dense	0.48
Tree Clad Area/Open	2.05
Wastelands-Barren Rocky/Stony waste	1.20
Water bodies-River/Stream-Dry	0.30
Water bodies-River/Stream-Perennial	3.96

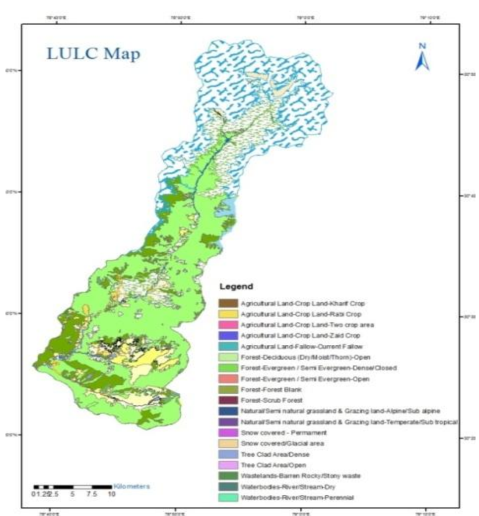

Figure 2:-Land use/land cover map

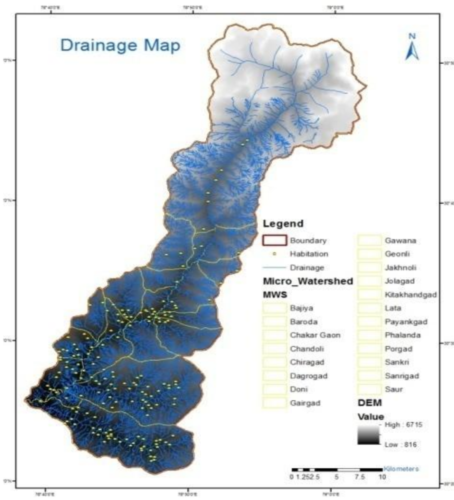

Figure 3:-Drainage map

Morphometry analysis

The study carried out has been divided into three sections, the first section deals with delineation of stream numbers, stream order and stream lengths in the study area using ASTER DEM (30m) along with delineation of watershed area, perimeter and length in GIS environment shown in table 3. The second section deals with the various linear and shape morphometric parameters and the third section deals with the prioritization of watersheds on the basis of these linear and shape morphometric parameters.

Table 3: Area, Perimeter and Basin length of micro watersheds

Micro watershed code	Area (km^2)	Perimeter (km)	Basin length (km)
MW 1	341.56	94	39.26
MW 2	24.92	23	9.95
MW 3	19.56	21	6.64
MW 4	7.11	14	3.37
MW 5	10.63	15	5.94
MW 6	24.47	25	9.34
MW 7	11.30	16	5.42
MW 8	20.59	19	8.18
MW 9	10.83	17	7.20
MW 10	14.38	19	8.21
MW 11	8.55	16	7.53
MW 12	12.89	19	8.28
MW 13	23.85	22	8.88
MW 14	19.47	21	7.92
MW 15	13.94	15	4.79
MW 16	19.75	23	4.88
MW 17	93.32	42	20.89
MW 18	18.57	25	4.81
MW 19	5.08	13	4.25
MW 20	91.10	51	22.40

Stream Number and Order

This is the most important parameter for drainage basin analysis ,in the study area total number of streams found is 1700 out of which 1334 is of first order,250 of second order,81 of third order,20 of fourth,3 and 1 are of fifth and sixth order respectively. The watershed wise number, order and length given in table 4 .it reveals that maximum number of streams is found in MW1(701) and minimum number for MW 19(17),it is also noted that first order streams are highest in number in all micro watersheds while highest order has the lowest number.

Stream length

Stream length analysis is shown in table 4(Page No. 51).It can be noted from the table that in each micro watershed stream length decreases as the stream order increases (Horton,1945) except MW 4,5,6,7,12,14,15,20 this may be due to flowing of streams from high altitude, lithological variations and moderately steep slopes. Figure 3 showing different stream order in the study area.

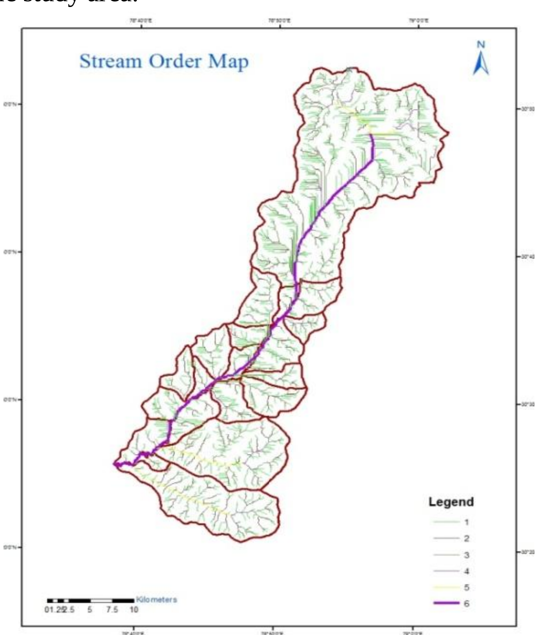

Figure 4:-Stream orders map

Stream length ratio

Change in stream length ratio shown in table 5. noted from one order to another in maximum micro watersheds indicating the late youth stage of geomorphic development of streams in the inter basin area, except MW 8,9,11,12,13,15,17,20 where increasing trend in length ratio noted from lower order to higher order which indicates their mature geomorphic stage.

Table 5: Stream length ratio of different order streams in study area

Microwatershed code	2/1	3/2	4/3	5/4
MW 1	0.36	0.50	0.29	0.43
MW 2	0.31	0.85	0.44	-
MW 3	0.42	0.32	0.37	-
MW 4	0.27	0.09	2.29	-
MW 5	0.44	0.08	7.32	-
MW 6	0.18	1.32	0.14	-
MW 7	0.11	2.14	0.06	-
MW 8	0.39	0.67	-	-
MW 9	0.26	0.47	-	-
MW 10	0.59	0.40	-	-
MW 11	0.42	0.19	0.75	-
MW 12	0.19	1.62	-	-
MW 13	0.39	0.61	-	-
MW 14	0.31	1.22	0.33	-
MW 15	0.08	3.75	-	-
MW 16	0.34	0.51	0.09	-
MW 17	0.36	0.48	0.34	1.90
MW 18	0.37	0.26	-	-
MW 19	0.50	-	-	-
MW 20	0.58	0.22	0.47	2.92

Liner parameters

Stream frequency

stream frequency of all micro watershed shown in table 6,indicating high stream frequency is indicative of high relief and low infiltration capacity of the bedrock pointing towards the increase in stream population with respect to increase in drainage density. The watersheds having large area under dense forest have low stream frequency and the area having more agricultural land have high stream frequency. High value of drainage frequency produces more runoff in comparison to others. Highest value of stream frequency noted for MW 9 (3.34 km/km^2) and lowest value for MW 10 (1.52 km/km^2).

Drainage density

Drainage density value lies in the range of 1.48 to 2.8, maximum value noted for MW 7 and minimum for MW 10 (table 6).It has been observed that low drainage density found to be associated with regions having highly permeable subsoil material under dense vegetative cover, and where relief is low and high value noted for the regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief.

Drainage texture

Drainage texture for the study area (table 6, Page No. 51) found to be very coarse to coarse, value ranges from 7.45 (MW 1) to 1.15 (MW 10).

Shape parameters

Form factor

Form factor values in the study area (table 7, Page No. 52) found maximum for MW 16 (0.82) and minimum for MW 11(0.15). High value of form factor stating the circular shape of the basin while low one indicates elongated shape and states that the basin will have a flatter peak flow for longer duration. Flood flows of such elongated basins are easier to manage than from the circular basin.

Elongation ratio

Value of the elongation ratio in the study area (table 7, Page No. 52) found in the range of 0.43-1.02 indicating high relief and steep ground slope. Shape of the micro watersheds found to be elongated (low elongation ratio) to less elongated (high elongation ratio).

Circulatory ratio

Circulatory ratio in the study area (table 7, Page No. 52) found in the range of 0.37-0.77.High value of circulatory ratio indicates the maturity stage of topography. This anomaly is due to diversity of slope, relief and structural conditions prevailing in this micro watershed.

Compactness Constant

Compactness constant value for the whole study area is shown in table 7(Page No. 52). Highest value found for MW 17 (1.29) while lowest value for MW 1 (0.2).

Watershed prioritization

The compound parameter values of all twenty micro watersheds of Bhilangana watershed are calculated and prioritization rating is shown in Table 8(Page No. 52)The Watersheds have been broadly classified into three priority zones according to their compound value (Cp) - High (<8.0), Medium (8.0-10) and Low (10 and above).

Watersheds falling under high priority are under very severe erosion susceptibility zone. Thus need immediate attention to take up mechanical soil conservation measures gully control structures and grass waterways to protect the topsoil loss. While watersheds falling under low priority have very slight erosion susceptibility zone and may need agronomical measures to protect the sheet and rill erosion. Figure 5 showing prioritized micro watershed map of Bhilangana watershed.

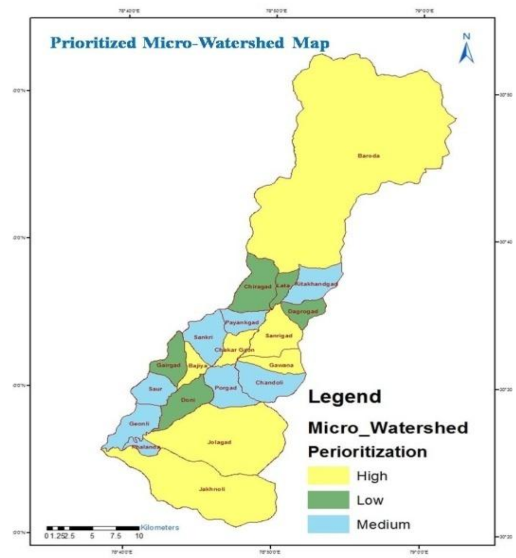

Figure 5:-Prioritized micro watershed map

Conclusion

The study depicts the utility of Remote Sensing and GIS technique in prioritizing micro-watershed based on morphometric and land use/land cover analysis which could be valuable for watershed management practices. Drainage density in the study area varies from 1.67 to 3.01 km/km^2, along with coarse to very coarse drainage texture. Mean bifurcation ratio for the area varies from 7.41 to 2.76 high values clearly indicating the structural control on the drainage pattern. Form factor value ranges from 0.21 for MW 8 to 0.82 for MW 15 indicating MW 15 is circular in shape while remaining are elongated. Circulatory ratio varies from 0.37 for MW 9 and 18 to 0.77 for MW 11 high value for MW 11 clearly indicating the late maturity stage of topography. Minimum compound parameter value 6 noted for the MW 13 clearly indicating that it is subjected to maximum soil erosion and natural hazards. Hence these may be taken for conservation measures by planners and decision makers for local-specific planning and development.

References

1. Chavare S., 2011, Morphometric Analysis using GIS Techniques: a case study of Valheri River basin, tributary of Tapi River in Nandurbar District (M.S.).

2. International Referred Research Journal August, 2011. ISSN- 0974-2832, RNI-RAJBIL 2009/29954; VoL.III *ISSUE-31.
3. Kanth T.A., Hassan Zahoor ul.,2012, Morphometric Analysis and Prioritization of watersheds for soil and water resource management in Wular catchment using Geo-Spatial tools. International Journal of Geology, Earth and Environmental Sciences Vol. 2 (1) January-April, pp.30-41/Kanth and Hassan.
4. Mishra .S Sangita, Nagarajan.R., 2010, Morphometric analysis and prioritization of subwatersheds using GIS and Remote Sensing techniques: a case study of Odisha, India. International Journal of Geomatics and Geoscience Volume 1, No 3.
5. M. Imran Malik, M. Sultan Bhat and Nissar A. Kuchay., 2011, Watershed based drainage Morphometric Analysis of Lidder catchment in Kashmir Valley using Geographical Information System. Recent Research in Science and Technology 2011, 3(4): 118-126.
6. Pareta K., Pareta U.,2011, Quantitative Morphometric Analysis of a Watershed of Yamuna Basin, India using ASTER (DEM) Data and GIS. International Journal of Geomatics and Geoscience Volume 2, No 1.
7. Sethupathi A.S, Lakshmi Narasimhan C, Vasanthamohan V , Mohan S.P .,2011, Prioritization of miniwatersheds based on Morphometric Analysis using Remote Sensing and GIS techniques in a draught prone Bargur – Mathur subwatersheds, Ponnaiyar River basin, India. International Journal of Geomatics and Geoscience Volume 2, No 2.

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Table 1: Formulae for the Computation of Morphometric Parameters

Morphometric Parameter	Method	Reference
Stream Order	Hirerachial 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 (RL)	RL = Lu/Lu1 where Lu = Total stream length of order ‘u’, Lu1 = The total stream length of its next lower order	Horton (1945)
Bifurcation ratio (Rb)	Rb = 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 (Dd)	Dd=Lu/A where Dd = drainage density, Lu = total stream length of all orders, A = area of the basin(km^2)	Horton (1945)
Stream frequency (Fs)	Fs=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, π = π 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/ π) 0.5 /Lb where Re = elongation ratio, A = area of the basin, km ^{2},π = π value i.e., 3.141, Lb = basin length, m	Miller (1953)
Form factor (Ff)	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)
Compactness constant (Cc)	Cc = 0.2821 P/ A 0.5 Where Cc = Compactness Ratio, A = Area of the basin , km ^{2},P = basin perimeter, km	Horton (1945)

Table 2: Description of Indicators of Prioritization

Parameter	**Characteristics**
Linear	
Stream Order	It is defined as a measure of the position of a stream in the hierarchy of tributaries.
Mean Stream Length (Lsm)	The mean stream length is the characteristic property related to the drainage network and its associated surfaces. Generally higher the order, longer the length of streams is noticed in nature.
Drainage Texture (T)	It is the total number of stream segments of all orders per perimeter of the area
Bifurcation Ratio (Rb)	Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern.
Drainage Density (Dd)	Drainage density (Dd) shows the landscape dissection, runoff potential, infiltration capacity of the land, climatic conditions and vegetation cover of the basin. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture.
Stream Frequency (Fs)	Stream Frequency is the total number of stream segments of all orders per unit area. Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity.
Shape	
Form Factor (Ff)	Form factor is defined as ratio of basin area to the square of basin length The value of form factor would always be less than 0.7854 (for a perfectly circular basin) Smaller the value of form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated watershed with low form factors have lower peak flow of longer duration.
Circulatory Ratio (Rc)	It is defined as the ratio of basin area to the area of circle having the same perimeter as the basin and is dimensionless. Circulatory Ratio is helpful for assessment of flood hazard. Higher the Rc value, higher is the flood hazard at the peak time at the outlet point.
Elongation Ratio (Re)	Elongation ratio (Re) is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Values near to 1.0 are typical of regions of very low relief
Compactness Co efficient (Cc)	Compactness Co efficient (Cc) is used to express the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin.

Table 4: Stream Analysis of micro watersheds

Micro watershed code	1st order		2nd order		3rd order		4th order		5th order	
	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length
MW 1	559	453.84	106	164.76	28	83.97	7	24.72	1	10.74
MW 2	38	29.92	7	9.35	3	7.98	1	3.54	-	-
MW 3	38	20.26	8	8.60	1	2.81	1	1.04	-	
MW 4	13	9.68	3	2.65	1	0.24	1	0.55	-	
MW 5	15	11.41	5	5.13	1	0.42	1	3.09	-	
MW 6	51	37.07	9	7.00	6	9.25	2	1.38	-	
MW 7	22	23.19	2	2.58	3	5.54	1	0.37	-	
MW 8	37	19.68	6	7.70	1	5.20	-		-	
MW 9	26	20.17	4	5.30	3	2.50	-		-	
MW 10	19	11.57	2	6.92	1	2.82	-		-	
MW 11	18	8.43	1	3.61	4	0.72	1	0.54	-	
MW 12	23	18.87	3	3.72	1	6.05	-		-	
MW 13	44	25.64	5	10.05	2	6.23	-		-	
MW 14	35	22.55	9	7.13	3	8.72	1	2.94	-	
MW 15	31	19.09	4	1.65	4	6.19	-		-	
MW 16	33	23.49	5	8.20	4	4.19	1	0.41	-	
MW 17	154	98.37	31	35.98	8	17.52	2	5.99	1	1.50
MW 18	34	21.44	7	8.05	1	2.11	-		-	
MW 19	13	5.65	4	2.88	-		-		-	
MW 20	131	76.66	29	45.05	6	10.07	1	4.76	1	13.93

Table 6: Linear morphometric parameters of study area

Micro watershed code	Stream frequency	Drainage density	Drainage texture	Mean Bifurcation ratio
MW 1	2.05	2.16	7.45	5.01
MW 2	1.96	2.03	2.13	3.57
MW 3	2.45	1.67	2.28	4.58
MW 4	2.53	1.84	1.28	2.76
MW 5	2.06	1.88	1.46	3.00
MW 6	2.77	2.23	2.72	3.36
MW 7	2.47	2.80	1.75	4.86
MW 8	2.13	1.58	2.31	6.05
MW 9	3.04	2.58	1.94	3.90
MW 10	1.52	1.48	1.15	5.75
MW 11	2.80	1.55	1.50	7.41
MW 12	2.09	2.22	1.42	5.30
MW 13	2.13	1.77	2.31	5.60
MW 14	2.46	2.12	2.28	3.26
MW 15	2.79	1.93	2.60	4.37
MW 16	2.07	1.53	1.78	3.95
MW 17	2.10	1.70	4.66	3.68
MW 18	2.26	1.70	1.78	5.90
MW 19	3.34	1.67	1.30	3.25
MW 20	1.84	1.65	3.29	4.07

Table 7: Shape morphometric parametrs

Microwatershed code	Form factor	Elongation ratio	Circulatory ratio	Compactness Constant
MW 1	0.22	0.53	0.48	0.27
MW 2	0.25	0.56	0.59	1.29
MW 3	0.44	0.51	0.55	0.55
MW 4	0.62	0.89	0.45	0.74
MW 5	0.29	0.61	0.59	0.19
MW 6	0.28	0.59	0.49	0.53
MW 7	0.38	0.69	0.55	0.63
MW 8	0.30	0.62	0.71	0.51
MW 9	0.16	0.51	0.47	0.66
MW 10	0.21	0.52	0.50	0.61
MW 11	0.15	0.43	0.41	0.72
MW 12	0.18	0.48	0.44	0.64
MW 13	0.30	0.62	0.61	0.51
MW 14	0.31	0.62	0.55	0.55
MW 15	0.60	0.87	0.77	0.60
MW 16	0.82	1.02	0.46	0.57
MW 17	0.21	0.52	0.66	0.35
MW 18	0.80	1.01	0.37	0.61
MW 19	0.28	0.59	0.37	0.84
MW 20	0.18	0.48	0.44	0.39

Table 8: Prioritization results of Morphometric analysis

Microwatershed code	Rb	Dd	Fs	T	Ff	Rc	Cc	Re	Compound parameter (Cp)	Final Priority
MW 1	7	5	16	1	5	5	7	2	6	High
MW 2	15	7	17	8	6	6	11	17	10.88	Low
MW 3	9	13	9	7	12	3	10	7	8.75	Medium
MW 4	20	10	6	17	14	12	4	15	12.25	Low
MW 5	19	9	15	14	8	8	11	1	10.63	Low
MW 6	16	3	5	4	7	7	8	6	7.00	High
MW 7	8	1	7	11	11	10	10	11	8.63	Medium
MW 8	2	15	11	6	9	9	14	5	8.88	Medium
MW 9	13	2	2	9	2	3	6	13	6.25	High
MW 10	4	18	19	18	4	4	9	10	10.75	Low
MW 11	1	16	3	13	1	1	2	14	6.38	High
MW 12	6	4	13	15	3	2	3	12	7.25	High
MW 13	5	11	11	6	9	9	12	5	8.50	Medium
MW 14	17	6	8	7	10	9	10	7	9.25	Medium
MW 15	10	8	4	5	13	11	15	9	9.38	Medium
MW 16	12	17	14	10	16	14	5	8	12.00	Low
MW 17	14	12	12	2	4	4	13	3	8.00	High
MW 18	3	12	10	12	15	13	1	10	9.50	Medium
MW 19	18	13	1	16	7	7	1	16	9.88	Medium
MW 20	11	14	18	3	3	2	3	4	7.25	High