QUANTITATIVE GEOMORPHOLOGICAL ANALYSIS OF MICRO WATERSHEDS OF GHATAPRABHA RIVER SUB BASIN

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ABSTRACT

The quantitative analysis of drainage system is an important aspect of prioritisation of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. In the present study, an attempt has been made to study the quantitative geomorphological analysis of micro watersheds of Ghataprabha river sub-basin in Karnataka, India. The study region lies between 16° 12' 16'' N to 16° 30' 1'' N latitude and 74° 45' 18'' E to 75° 44' 58'' E longitude of northern Karnataka. The twelve micro watersheds of sub basins (KSNU032 and KSNU033) have been prioritized using GIS by determining the areal, linear, and relief parameters based on morphometric analysis on the basis of Survey of India Toposheets at 1:50,000 scale, CARTOSAT-1 DEM data, and RESOURCESAT-2 LISS-III data. Each morphometric characteristic is considered as a single parameter and knowledge based weightage has been assigned. The compound parameter values are calculated and the micro watershed with lowest compound weight is given highest priority. The results of this analysis would be useful in determining the effect of watershed characteristics such as size, shape, slope of the watershed & distribution of stream network within the watershed which intern useful for planning watershed management.

Keywords: Geo-Morphology, Prioritisation, Micro-Watersheds, Remote Sensing, Ghataprabha River

I. INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke, 1966). The drainage basin is the landform commonly analysed in morphometry. 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, 2006). The quantitative analysis of drainage system is an important aspect of characteristics of watershed (Strahler, 1964) since they were made predominantly by surface fluvial runoff which has very important climatic, geologic and biologic effects e.g. Sharp and Malin, (1975), Laity and Malin (1985), Malin and Edgett (2000), Hynek and Phillips (2003), and Pareta (2004). Land and water resources are limited and their improper utilization without any conservation is the prime cause for the deterioration of watershed. In this context prioritization of watershed is gaining importance in natural resource management and conservation.

In the present study, an attempt has been made to quantitatively analyze the hydro-morphological features and prioritize the micro watersheds of Ghataprabha River sub Basin in Karnataka, India using the spatial datasets by RS & GIS Techniques. The study region lies between 16° 12' 16'' N to 16° 30' 1'' N latitude and 74° 45' 18'' E to 75° 44' 58'' E longitude of northern Karnataka. The spatial datasets namely, CARTOSAT-1 DEM data, RESOURCESAT -2 LISS III along with Survey of India (SOI) Toposheets at 1:50,000 scale have been used to determine the areal, linear, and relief morphometric parameters with the help of Erdas Imagine and ArcGIS software's for the study area. The prioritisation of watersheds has been done based on knowledge based weightage method by calculating the compound parameter values for each micro watershed. The result reveals that, based on prioritisation the necessary action should be taken for sustainable development of the watersheds by means of land and water conservation practices.

II. STUDY AREA

In this present study, parts of Ghataprabha River sub basin, Karnataka, India has been chosen as study area which extends from 16° 12' 16'' N to 16° 30' 1'' N latitude and from74° 45' 18'' E to 75° 44' 58'' E longitude and covers 4 Taluks in Belgaum and 3 Taluks of Bagalkot districts shown in Fig. 1. The area is well connected by road and rail to other parts of the state. The total length of Ghataprabha river up to the confluence with the Krishna river is about 260 kms. The climate is mostly temperate. Temperatures vary from a minimum of 7 degree in winter to about 41 degree Celsius in summer. Annual rainfall is a quite uniform between 550 and 500 mm on the North West and 500 mm up to 1200 mm on East- West which has a significant effect in the watersheds.

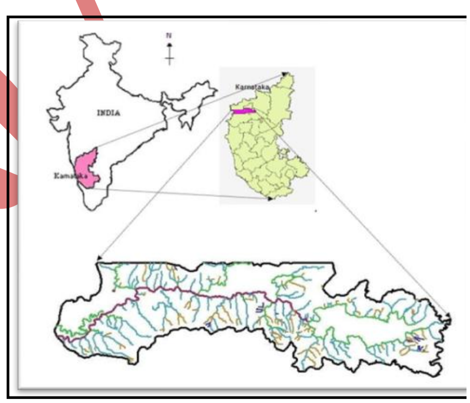


Figure 1. Map showing the study area boundary

III. MATERIALS AND METHODS USED

RESOURCESAT- 2 LISS III, Digital Elevation Model (DEM) from CARTOSAT-1 along with Survey of India Toposheets at 1:50,000 scale were used to derive the morphological parameters. ArcGIS and Erdas Imagine software's were used for digitization, processing and creation of maps.

3.1 Base maps Preparation

3.1.1 Landuse/ Landcover map generation

From the LISS III satellite image, landuse/ landcover map has been generated (shown in Fig. 2) by using supervised classification method.

3.1.2 Stream network generation

The topographical maps were used as a base map for digitizing the stream networks which has been done in Erdas Imagine software, shown in Fig.3.

3.1.2 Extraction of contours

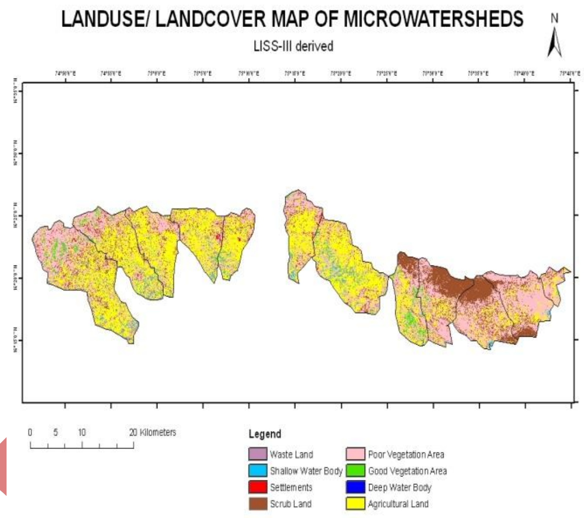


Fig. 2

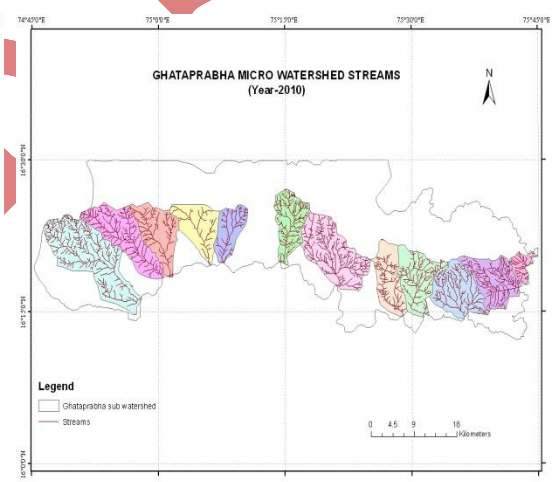


Fig. 3

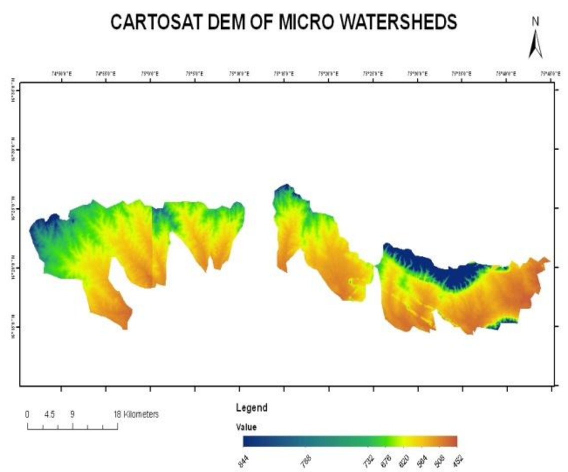
Figure 2. Landuse/ Landcover Map of the Study Area

Figure 3. Map Showing the Digitized Drainage Network of the Study Area

3.2 Parameters Estimation

The linear, aerial and relief morphometric parameters of the micro- watersheds were estimated based on the various formulae proposed by different authors which are tabulated in Table 1.

Fig. 4& 5 Shows The Extraction Of Contour Lines From CARTOSAT DEM Using Arcgis.



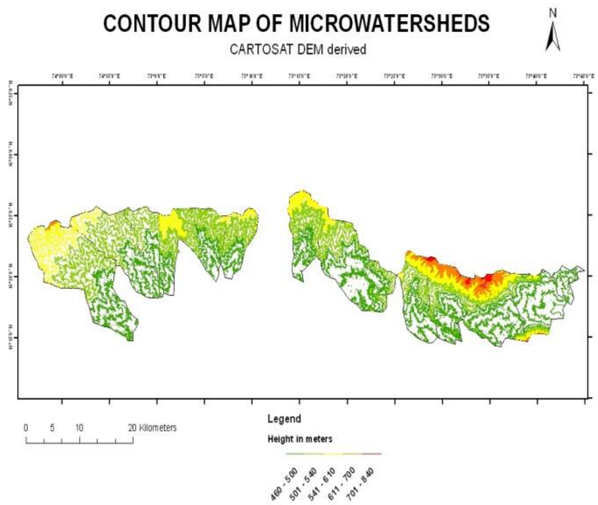


Figure 4. Map Showing the CARTOSAT DEM of The Study Area

Figure 5. Map Showing the Contours Extracted From CARTOSAT DEM Data

3.3 Watershed prioritization

The linear aspects have the direct relationship with soil erosion. Hence, the parameter of higher value indicates the possibility of soil erosion (High value- higher rank). Shape parameters like Const. of Channel Maintenance (kmsˆ2/km), Texture Ratio (Rt), Form Factor (Ff), Circulatory Ratio (Rc), Circulatory Ration (Rcn), Elongation Ratio (Re), RHO Coefficient have inverse relationship with soil erosion. Hence, lower value of shape parameter is an indication of higher risk of erodability.

As per the analysis, ranks have been given to each parameter, shown in Table 2. The compound parameter values are calculated (Average) and the micro watershed with lowest compound weight has been given highest priority. The final priority weightage have been divided into 3 major classes (High, Medium & Low Priority) shown in Table 3.The high priority indicates need of reclamation process and action plan for soil conservation.

IV. RESULTS AND DISCUSSIONS

The area, altitude, volume, shape and texture of the landforms comprise the principal parameters of investigation. Various formulae and methods for landform analysis have been applied and their results are presented in the form of maps and tables or statistical indices.

4.1 Linear Aspects

The stream ordering has been carried out based on the method proposed by Strahler (shown in Fig. 6) and it has been observed that maximum frequency is in the case of first order streams and it has also noticed that there is decrease in stream frequency as the stream order increases. Fifth order is the highest order of stream within the 12 micro-watersheds.

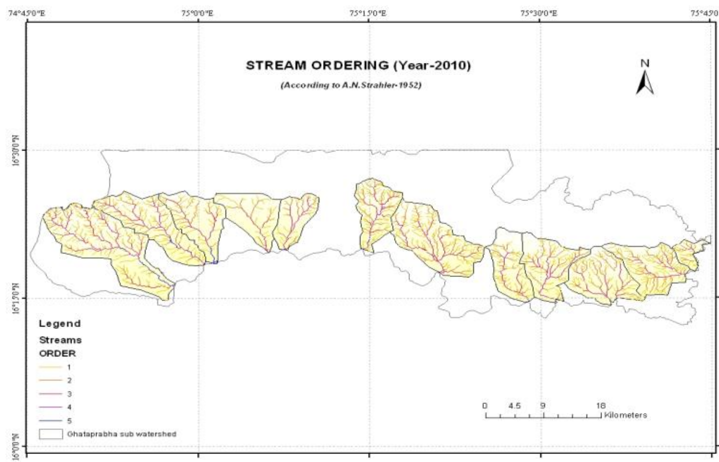


Figure 6. Map Showing The Digitized Drainage Network Of The Study Area

Table 1. Morphometric parameters with formula

S.No.	Morphometric Parameters	Formula	Reference
		Linear Aspects	
1	Stream order (Su)	-	Strahler(1964)
2	Stream Number(Nu)	-	Horton (1945)
3	Total stream length of order 'u' (Lu)	Average length of streams of each different orders	Horton (1945)
4	Mean stream length (Lsm)	Lsm=Lu/Nu	Strahler(1964)
5	Stream Length Ratio (RL)	RL= Lu/ Lu-1	Horton (1945)
6	Bifurcation ratio (Rb)	Rb= Nu/ Nu+1	Schumn (1956)
		Areal Aspects	
1	Area of the Basin (A) in km2	-	Schumn (1956)
2	Length of the basin (Lb) in km	-	Schumn (1956)
3	Perimeter of the basin (P) in km	-	Schumn (1956)
4	Mean Basin Width (Wb)	Wb= A/ Lb	Horton (1932)
5	Relative Perimeter(Pr)	Pr=A/P	Schumn (1956)
6	Length Area Relation (Lar)	Lar= 1.4* A ˆ0.6	Hack (1957)
7	Mean Bifurcation ratio (Rbm)	Rbm= Average of bifurcation ratios of all orders	Strahler(1964)
8	Drainage density (Dd) in km/kmsˆ2	D= Lu/ A	Horton (1932)

9	Drainage Intensity(Di)	Di= Fs/Dd	Faniran (1968)
10	Infiltration Number (If)	If= Fs*Dd	Faniran (1968)
11	Constant of Channel Maintenance (kms^2/ km)	C= 1/ Dd	Schumn (1956)
12	Stream frequency (Fs)	Fs= Nu/ A	Horton (1932)
13	Texture Ratio (Rt)	Rt= N1/ P	Schumn (1956)
14	Drainage Texture (Dt)	Dt= Nu/ P	Horton (1945)
15	Form factor ratio (Rf)	Rf= A/ Lb2	Horton (1932)
16	Lemniscate's (k)	k= Lb2/ A	Chorely (1957)
17	Circulatory ratio (Rc)	Rc= 4*∏*(A/ P^2)= 12.57*(A/P^2)	Miller (1960)
18	Circulatory ration (Rcn)	Rcn= A/ P	Strahler(1964)
19	Compactness Co-efficient (Cc)	Cc= (0.2841*P)/ A^ 0.5	Gravelius (1914)
20	Elongation ration (Re)	Re= 2* √(A/∏)/ Lb= 2/ Lb*(A/ ∏)^0.5	Schumn (1956)
21	RHO Co-efficient (RHO)	RHO= RL/ Rb	Horton (1945)
22	Length of overland flow (Lg)	Lg= 1/ D*2	Horton (1945)
Relief Aspects			
1	Height of the basin mouth (z) in m	-	
2	Maximum Height of the basin (Z) in m	-	
3	Total Basin Relief (H) in m	-	Strahler(1952)
4	Relief ratio (Rhl)	Rhl= H/ Lb	Schumn (1956)
5	Slope Angle (S)	S= tan-1 (H)/ Lb	Ahamed (2010)
6	Ruggedness index (Ri)	Ri= D* (H/1000)	Strahler(1968)

It is observed that number of stream segments of each order (Stream Number) forms an inverse geometric sequence with order number which follows the statement of Horton (1945) and MW1 is having highest 437 streams of all micro watersheds and it is given high priority. The stream length has been computed based on the law proposed by Horton (1945) that supports the theory that geometrical similarity is preserved generally in watersheds of increasing order. Bifurcation Ratio is considered as index of relief and dissertation. It is a dimensionless property and generally ranges from 3.0 to 7.0. The lower values of Rb are characteristics of the watersheds, which have suffered less structural disturbances (Strahler, 1964) and in which the drainage pattern has not been distorted. In the present study, MW 6 is having the highest value of Rbm indicates strong structural control on the drainage pattern (ranked as 1), while the MW 9 is having Rbm of 1.83 which is lowest value of all MWs indicates that the MW9 is not affected by structural disturbances.

4.2 Areal Aspects

Basin Area (A) and Perimeter (P) are other important parameters computed by ArcGIS-10 software shows that the MW1 is having highest area coverage and perimeter and MW12 is lowest among them. Length of the Basin (Lb) is defined as the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956) and it is computed for all MWs. MW1 is the longest watershed having 25.58 km of length. The lower value of Lemniscate’s

(k) of MW 12 indicates that the watershed occupies the maximum area in its region of inception with large number of streams of higher order, is given the least rank for prioritisation.The value of the Form factor ratio (Ff) would always be less than 0.754(perfectly circular area). MW 2 is having the lowest Ff value 0.21, which shows that the MW2 is more elongated and flow for longer duration.

Strahler states that the Elongation ratio (Re) runs between 0.6 to 1.0 (circular- 0.9 to 0.1, oval- 0.8 to 0.9, less elongated- 0.7 to 0.8, elongated- 0.5 to 0.7, and more elongated- less that 0.5) over a wide variety of climatic and geologic types. From the calculated Re values, MW 2 is having 0.51(more elongated) and MW12 is having 1.21(circular) which can also be verified by visual interpretation. Texture Ratio (Rt) is depending upon the underlying lithology, infiltration capacity and relief aspects of the terrain. The texture ratio of the micro-watersheds ranges from 0.8 to 3.37 and categorized as low in nature. Miller et al. (1960) has described the basin Circulatory Ratios (Rc) range 0.4- 0.7, which indicates strongly elongated and highly permeable homogeneous geologic materials. MW5 & 10 posses higher (0.66) value and MW 2 has lower (0.44) value of Rc. It gives the similar result of Elongation ratio (Re) that MW 2 is elongated in shape.

Drainage Texture (Dt) has classified into five different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). In this study, the drainage texture of MW 4 is (1.43) very coarse and of MW 7 is (7.13) fine in nature. Compact Coefficient (Cc) is independent of the size of watershed and dependent only on slope. For the study watersheds it ranges from 1.24 to 1.50. Stream frequency (Fs) of the micro- watersheds ranges from 0.79 to 3.54.

Drainage Density (Dd) is a better quantitative expression of the dissection and analysis of land form, although a function of climate, lithology and structures and relief history of the region can finally use as an indirect indicator to explain, those variables as well as the morphogenesis. It is calculated by using Spatial Analyst Tool in ArcGIS-10(shown in Fig. 7), which ranges from 0.83(MW4- high permeable soil) to 2.25(MW11- moderate permeable sub-soil with thick vegetative cover).

Lower value(<1) of Drainage intensity(Di) along with the lower drainage density and stream frequency values implies that the surface runoff is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides. In this study MW4 is having the lowest Dd. Fs and Di values which implies it is more prone to surface runoff and denudation. High Infiltration Number (If) indicates the high surface runoff. MW 6 is having If (7.60), posses high surface runoff potential. In the watershed, the Drainage Pattern (Dp) reflects the influence of slope, lithology and structure and helps in identifying the stage in the cycle of erosion.

It is possible to deduce the geology, strike and dip of depositional rocks, existence of faults, permeability of rocks, vegetation and relief, etc. Howard (1967) related the drainage pattern to geological information. In the study area, dendritic, radial and parallel patterns have been identified. Dendritic pattern is the most common pattern formed in a drainage basin composed of fairly homogeneous rock without control by the underlying geologic structure. The longer the time of formation of a drainage basin is, the more easily the dendritic pattern is formed.

RHO Coefficient (RHO) facilitates the evaluation of storage capacity of drainage network and hence, a determinant of ultimate degree of drainage development in a watershed. The higher RHO value (<0.85) indicates that the watershed is having higher hydrologic storage during floods and attenuates the erosion. Conversely, the study shows that the RHO value of the micro- watersheds are very less than 0.85 which reveals the watersheds are prone to severe erosion and suggest that there is an instant need of development of erosion control measures by the development authority.

4.3 Relief Aspects

Schumm found that the sediment loose per unit area is closely correlated with Relief ratio (Rhl). It has been observed that areas with low to moderate relief and slope are characterized by moderate value of relief ratios. Low Rhl values (MW7- 6.52) are mainly due to the resistant basement rocks of the basin and low degree of slope. As per the analysis, ranks have been given to each parameter (shown in Fig. 8and Table. 2) and Micro watersheds are prioritized on the basis of conservation of watersheds (soil erosion control) shown in Fig.9 and Table. 3.

The high priority of Micro watersheds 3, 4 5 and 12 indicates the high possibility of soil erosion and there is an immediate need for reclamation and action plan for soil conservation. Low prioritized Micro watersheds namely MW1, 2, 6 and 7 are having stabilized geological and morphological characteristic, hence there won't be of implementation of watershed conservation measures.

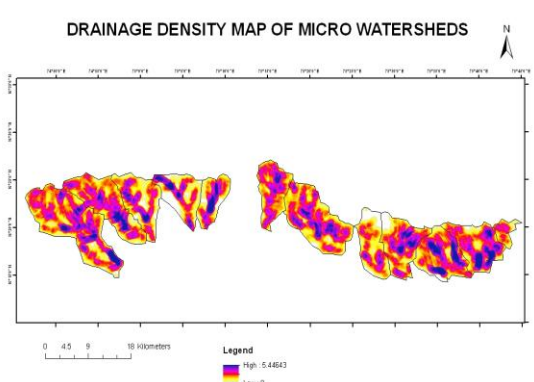


Figure 7. Map Showing the Variation in Drainage Density of the Study Area

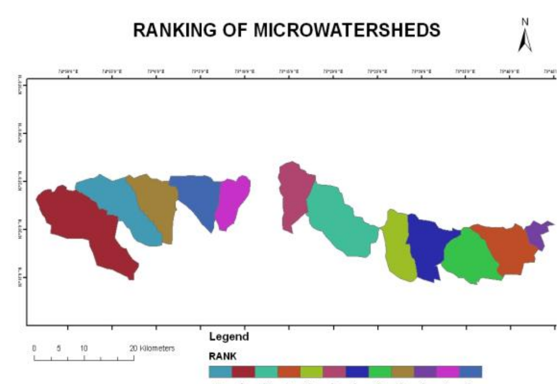


Figure 8. Map showing the ranking of Micro watersheds based on morphometric parameters

V. CONCLUSION

The study demonstrates that remote sensing data i.e., CARTOSET DEM, Toposheets and GIS techniques can be an efficient approach for prioritisation of watershed based on drainage morphometry and land use change analysis. It is not feasible to take the whole area at once for analyzing conservation and development studies of Watersheds. In that case prioritisation will help us to take decision for conservation of natural resources for their sustainable development. Based on this study, it has been observed that MW-3, MW-4, MW-5 and MW-12 fall under the category of high priority by considering morphometry. Hence, these micro-watersheds can be taken for conservation of soil and water resources compared to medium and low ranking sub-watersheds.

Table 2. Ranking of Micro Watersheds Based On the Calculated Morphometric Parameters

MICRO WATERSHED NO	1	2	3	4	5	6	7	8	9	10	11	12
LINEAR ASPECTS												
Sum of no. of streams(Nu)	1	3	7	11	8	12	9	4	2	6	10	5
Stream Order (Su)	1	1	1	2	1	1	1	2	2	1	2	2
Average Stream Length (Lsm)	6	9	4	11	1	7	3	8	2	10	5	12
Mean Stream Length Ratio (RL)	4	5	3	1	4	8	9	2	6	10	7	6
Avg. Bifurcation Ratio (Rbm)	6	7	9	11	2	1	4	8	12	3	10	5
AREAL ASPECTS												
Area of the Basin (A) in km2	1	3	7	8	11	10	2	9	5	4	6	12
Length of the Basin (Lb) in km	1	2	4	6	10	7	3	5	8	11	9	12
Perimeter of the Basin (P) in km	1	2	5	10	11	9	3	8	4	7	6	12
Mean Basin Width (Wb)	3	11	7	6	12	9	2	10	5	1	4	8
Relative Perimeter (Pr)	1	4	6	5	9	8	2	8	7	3	5	10
Length Area Relation (Lar)	1	3	7	8	11	10	2	9	5	4	6	12
Mean Bifurcation Ratio (Rbm)	6	7	9	11	2	1	4	8	12	3	10	5
Drainage Density (Dd) in km/kms^2	5	6	10	11	9	2	4	7	8	5	1	3
Stream Frequency (Fs)	7	6	11	12	10	1	4	3	8	9	5	2
Drainage Intensity(Di)	5	4	9	12	7	3	8	1	6	10	11	2
Infiltration Number (If)	7	6	11	12	10	1	4	5	8	9	3	2
Drainage Texture (Dt)	2	6	9	12	10	3	1	4	8	7	5	11
Lemniscate's (k)	2	1	3	6	7	5	8	4	9	11	10	12
Length of overland flow (Lg)	6	6	2	1	3	9	7	5	4	6	10	8
Const. of Channel Maintenance (kms^2/kKm)	5	6	10	11	9	2	4	7	8	6	1	3
Texture Ratio (Rt)	11	6	3	1	2	10	12	8	5	7	9	4
Form factor Ratio (Rf)	2	1	3	6	6	5	7	4	8	10	9	11
Circulatory Ratio (Rc)	3	1	5	9	10	8	9	7	4	10	6	2
Circulatory Ration (Rcn)	12	9	6	7	2	4	11	3	5	10	8	1
Compactness Co-efficient (Cc)	8	10	6	2	1	3	2	4	7	1	5	9

Elongation Ratio (Re)	2	1	3	6	6	5	7	4	8	10	9	11
RHO Co-efficient (RHO)	7	6	9	11	3	1	2	10	8	1	5	4
RELIEF ASPECTS												
Relief Ratio (Rhl)	7	10	12	3	4	1	11	2	8	9	5	6
Ruggedness Index (Ri)	4	6	8	10	9	5	7	3	1	2	1	11

Table 3. Prioritisation of Micro watersheds

Micro Watershed	Compound Parameter	Weightage	Priority
MWS4	7.66	1	High
MWS12	7	2	
MWS5	6.55	3	
MWS3	6.52	4	
MWS10	6.41	5	Medium
MWS9	6.31	6	
MWS11	6.31	6	
MWS8	5.59	7	
MWS7	5.24	8	Low
MWS6	5.21	9	
MWS2	5.1	10	
MWS1	4.38	11	

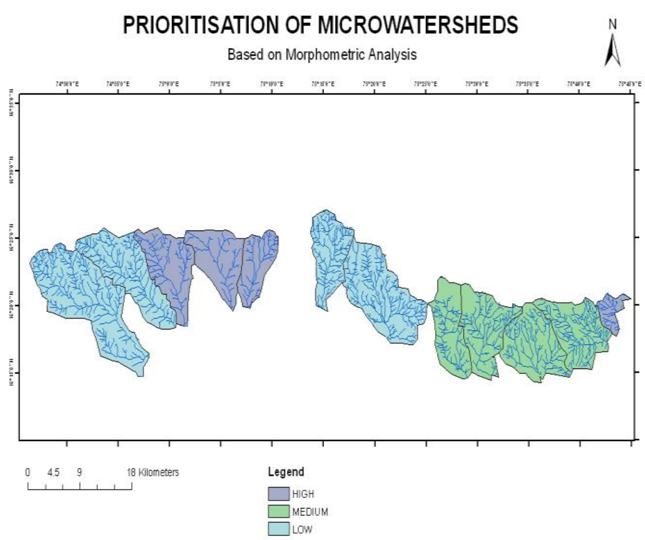


Figure 9. Map Showing the Prioritization of Micro Watersheds Based On Morphometric Analysis

VI. ACKNOWLEDGEMENT

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