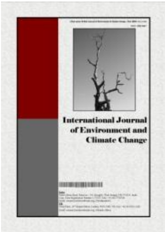

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Characterisation and Prioritization of Micro Watersheds Using Geospatial Techniques: A Case Study on river Bharathapuzha, Kerala

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Watershed based interventions are essential for the sustainable land and water management of any region. Watershed prioritisation is a must for the efficient utilisation of available monetary and human resources. One of the most common means of prioritisation is through morphometric analysis as hydrological processes or watershed responses depend on morphometric characteristics of the watersheds. The study contains morphometric analysis of a few number of micro watersheds of river Bharathapuzha of Kerala state. With the help of ArcGIS software and SRTM DEM, all the basic morphometric characteristics and derived morphometric characteristics of 10 micro watersheds are determined and then scores are assigned to the parameters. Finally, combined parameter scores are determined and ranking of each micro watershed is done. The priority scores between watersheds show considerable variation which is an indication of the efficacy of the methods employed. Once the ranking of the micro watersheds are done objectively and scientifically it would be a great support to the soil and water conservationist and planners. This study gives an insight into the applicability of the method to a mid land region in the state of Kerala, India.

Keywords: Watershed; morphometric analysis; prioritisation and geospatial techniques.

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1. INTRODUCTION

Soil erosion is considered as one of the major problems, which very adversely affect the environment and agriculture, in the midland area of Kerala. Erosion of the top soil leads to continuous land degradation and decline of soil fertility, overall quality and crop productivity. The main objective of watershed development is conserving land and water. The other economic and social development of the watershed follows as a consequence to the better management of land and water. Any natural resource (land and water) management programme must be started at the micro watershed level, which is the primary starting point of all processes of hydrology.

Morphometric analysis is a qualitative measurement and mathematical analysis of landforms. It plays a significant role in understanding the geohydrological characteristics of a drainage basin in relation to the terrain feature and its flow patterns. It also helps to estimate the process of infiltration and runoff, and other hydrological characters of a watershed like erosion and sediment transport which have strong implications for natural resource conservation. Morphometric analysis is the measurement of three dimensional geometry of landforms and has traditionally been applied to watershed, drainages, hill slopes, and other group of terrain features [1].

Prioritization of watershed on the basis of quantitative analysis of morphometric parameters is very important in order to decide on sustainable watershed development. Further, the quantitative analysis of morphometric parameters is of immense utility in river basin evaluation and watershed prioritization for soil and water conservation at micro watershed scale [2]. Morphometric characterization is essential to recognize the hydrological behaviour of the basin for carrying out management strategies [3]. Recently with the advancement of remote sensing and spatial technology, computation of various hydro-morphometric characters of drainage basins has been simplified [4]. For quantitative analysis of the watershed, various parameters such as basin perimeter, basin area, elevation difference, stream segments, slope and profile of land has to be determined [5].

Prioritization of small-watersheds for initiating soil and water conservation is carried out very effectively in several geographical areas. Such studies confirm the role of geospatial technology, and morphometric analysis as efficient tools in ranking different small-watersheds according to the order in which they have to be taken up for soil conservation measures [6]. At an early stage of morphometric analysis, application in prioritization of small-watersheds employ ten morphometric parameters, three of them are basin geometric parameters such as area (km^2), perimeter (km), and basin length (km), four linear parameters (bifurcation ratio, drainage density (km/km^2), stream frequency (no/km^2), and texture ratio [7]. Similarly, [8] utilized six morphometric parameters viz., two linear parameters (bifurcation ratio, drainage density; two shape parameters (circularity ratio, elongation ratio; and two relief parameters (ruggedness number, and relief ratio).

Watershed prioritization is the process of ranking different sensitive micro watersheds of a larger basin, to be taken up for various interventions for its natural resources management. The ranking of micro watersheds could be done depending on drainage pattern of the micro watersheds. In the state of Kerala, majority of the watersheds in the mid land and high land requires interventions to conserve land and water. Prioritisation of watershed is a necessary measure to identify the most vulnerable micro watersheds needing immediate attention. Hence, through this study, an attempt has been made to study the feasibility of prioritisation of micro watersheds through morphometric analysis using geospatial techniques and for which two sub watersheds of Bharathapuzha river basin has been chosen.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Two small sub watersheds of the river Bharthapuzha, the largest river of Kerala, which are located near to Valanchery town of Malappuram District, Kerala State has been chosen for the study. The first sub watershed (W1) geographically lies between $10^0 51^{'}$ North latitude, $76^0 02^{'}$East longitude and $10^0 56^{"}$ North latitude, $76^0 04^{"}$East longitude. The second sub-watershed (W2) lies between $10^0 54"$ North latitude, $76^0 04'$East longitude and $10^0 56'$ North latitude $76^0 06'$ East longitude. Using SRTM DEM watershed boundary and stream channels are extracted and then used to calculate morphometric parameters. The range of elevations of the sub-watersheds W1 and W2 are 11 to 164 m and 23 to 140 m above mean sea level respectively. The main streams flow nearly along the centre of the watersheds and play important roles in the socio economic development of the society of that area. The main streams feed water to agriculture and other activities of both of the watersheds.

Watershed boundary and drainage network was delineated by using the software Arc GIS 10.4 version. Shuttle Radar Topography Mission (SRTM) 1 arc-second resolution of National Aeronautics and Space Administration (NASA) was used for delineating sub watersheds and micro watersheds within them. For determination of the basic parameters of the watershed such as area, perimeter, stream order, stream length, stream number and elevation of each micro watershed was carried out separately. Finally, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio and compactness ratio have been quantified with the help of standard equations. The flow chart of the methodology is presented in Fig 2.

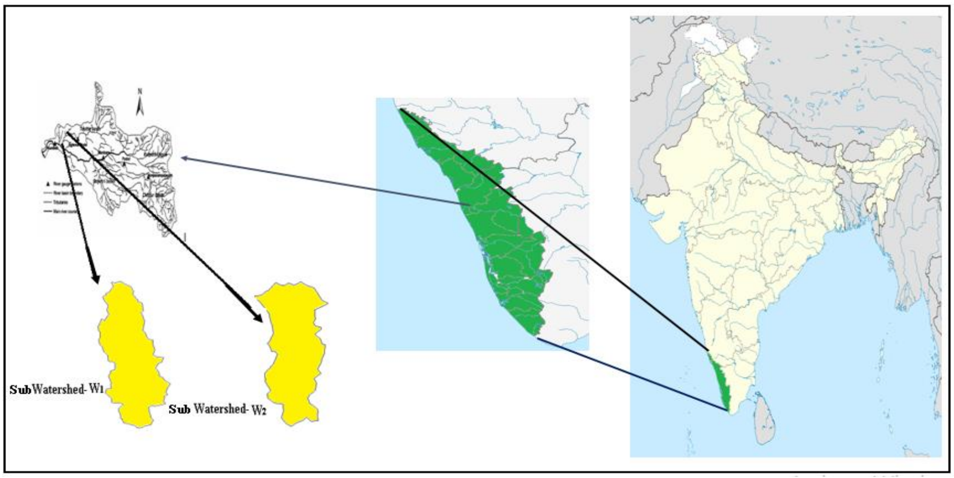


Fig. 1. Location Map of Study Area

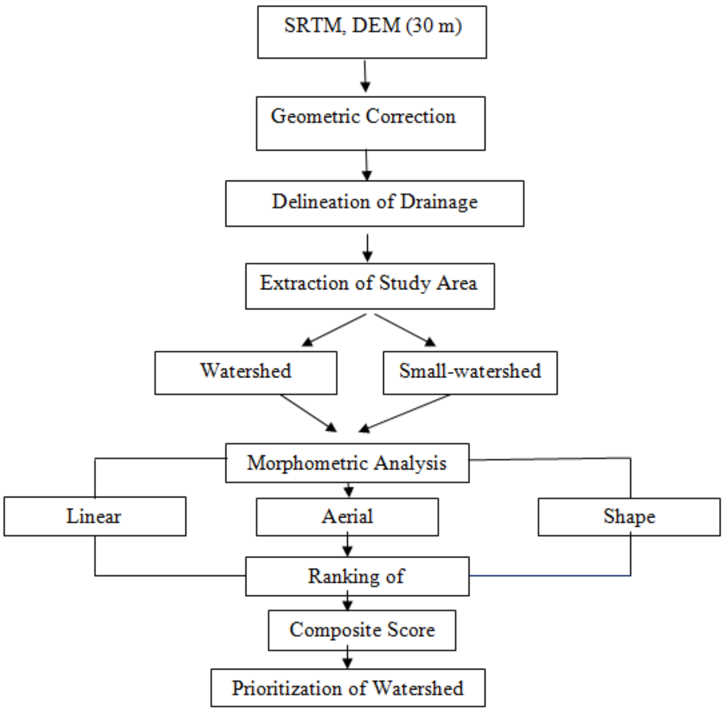


Fig. 2. Flow Chart of Prioritization of Sub watershed by Morphometric Analysis

2.2 Derivation of Thematic Maps

Drainage Map: The drainage map was prepared from the SRTM, DEM using the spatial analyst tool in Arc GIS Filling of the isolated grids, flow direction, flow accumulation are done by the software.

Slope Map: The slope map was also prepared from SRTM DEM and making use of the appropriate tools of Arc tool box. The whole watershed area was classified using guidelines laid down by the soil survey manual of United States Department of Agriculture (USDA). The slope categories was measured from the map scale and was used for preparing the slope map that gives various groups categories of Slope of the watershed area.

It was found that most of the terrain on the western part was characterized by a higher altitude and higher degree of slope in the case of W1 sub watershed and in the case of W2 it was in the northern region. These regions are considered to be responsible for higher runoff. The southern parts of both the watersheds come under lower altitude and gentle slope category. The range of the slope varies from nearly level (0–1 %) , very gentle sloping (1–4 %) moderate sloping (4-10%), high sloping (20-45%) and steep sloping (20-45%).

Soil map: Soil map prepared by the Directorate of soil survey and soil conservation is used for the study. Hydrological responses to rainfall strongly depend on the characteristics of the soil, such as water storage capacity and infiltration rates [9]. The major soil texture class of the both sub-watersheds are sandy clay loam followed by sandy clay and clay loam. Majority of these soils belongs to the laterite type.

2.3 Morphometric Analysis of Watersheds

Stream order: The stream order represents the degree of stream branching within a watershed. Each reach of stream is designated by its order. Stream order is a dimensionless term. Accordingly, the 1st order streams are those, which have no tributaries. The 2nd order streams are those, which have tributaries only of 1st order streams, where two 2nd order streams join, a segment of 3rd order is formed. When two 3rd order segments join, a 4th order stream is formed and so on [10].

Stream number (N_u) : The number of the stream segments of a particular order is designated by the term stream number. The number of the stream segments decreases as the order increases. Stream number is directly proportional to the size of the contributing watershed and channel dimensions.

Total stream length: The length of the stream channel is a dimensional property, which reveals the size of the component of drainage lines. It is the total length of stream in a particular order [5].

Mean stream length ($\bar{L}_u$) : Mean stream length is the ratio of total stream length of particular order to the total number of same ordered stream.

Basin length(L_b): It is defined as the distance measured along the main channel from the watershed outlet to the ridge. Since the channel does not extend to the basin-divide, it is necessary to extend a line from the end of the channel to the basin divide following a path where the greatest volume of water would travel. Thus, the length is measured along the principal flow path. Basin length is the basic input parameter to count the major shape parameters.

Watershed perimeter (P_r) : It is the total length of outer boundary of the watershed.

Stream length ratio (R_L) : It is defined as the ratio of mean length of stream segment ($\bar{L}_u$) of order 'u' to the mean length of stream segment of next lower order ($\bar{L}_{u-1}$) and is expressed as,

$$R_L = \frac{\bar{L}_u}{\bar{L}_{u-1}}$$

Bifurcation ratio (R_b): The bifurcation ratio [11] is the ratio of the number of stream segments of a given order N_u to the number of segments of the next higher order N_{u+1}.

The bifurcation ratio reflects the geological as well as tectonic characteristics of the watershed. Lower value of R_b indicates the partially disturbed watershed without any distortion in drainage pattern (Nag 1998). High value of R_b indicates the severe over land flow and low recharge for the small watershed.

Form factor (R_f): It is the ratio of the watershed area to the square of watershed length [5]. It is used as a quantitative expression of the shape of watershed. The value of the form factor would always be less than 0.79 (for a perfectly circular basin) [12]. In watershed, the smaller value of the form factor shows maximum elongation of the basin. The high value of form factor shows high peak in short duration and vice versa.

$$R_f = \frac{A}{(L_b)^2}$$

Elongation ratio (R_e): According to Schumm, 1956, elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The values of elongation ratio (E_l) generally lie between 0.6 and 1.0 which is depends on climate and geological properties. The values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are followed with high relief and steep ground slope [10]. These values can be grouped into three categories, namely circular (>0.9), oval (0.9–0.8) and less elongated (<0.7).

$$R_e = \frac{1}{L_b}\sqrt{\frac{A}{\pi}}$$

Circulatory ratio (R_c): Miller [13] defined circulatory ratio (R_c) as the ratio of watershed area to the area of a circle having the same perimeter as the watershed. It is influenced by the length and frequency of the stream, geological structures, land use land cover (LULC), climatic variability, relief and slope of the small-watersheds [14].

$$R_c = \frac{4\Pi A}{(A_C)^2}$$

Drainage density (D_d): Drainage density is the total length of streams of all order in the watershed to the area of whole watershed [15]. In general, low drainage density is seen in regions of highly resistant or highly permeable small soil materials, under dense vegetation cover and where relief is low.

High drainage density indicates well developed network and torrential runoff resulting intense floods which is seen in regions of weak or impermeable surface materials, sparse vegetation and mountainous relief. A high value of the drainage density would indicate a relatively high density of streams and thus a rapid storm response [16]. The equation is expressed below,

$$D_d = \frac{L}{A}$$

Stream frequency (F): It is another measure to describe the capacity of stream network to carry the discharge and is derived as number of stream segments per unit area [5]. It indicates the close correlation with drainage density value of the watershed. Higher the value of stream frequency, lower the permeability of the area and higher is the runoff and vice versa.

$$F = \frac{N}{A}$$

Texture ratio (R_t): It is the number of first order streams (N_1) per unit perimeter of of the drainage basin [15]. It is calculated by using the following formula. It depends upon properties of lithology of the watershed, infiltration of the soil and relief aspect of the terrain [17].

$$R_t = \frac{N_1}{P}$$

Maximum watershed relief (H): Basin relief is the maximum elevation difference between highest and lowest point of the watershed.

Compactness coefficient (C_c): It is measured as the ratio of the perimeter of watershed (P_b) to the circumference of a circle (P'_b) equivalent to the area of the watershed [5]. It is expressed as

$$C_C = \frac{P_b}{P_b'}$$

Lower values of this parameter indicate more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion. Compactness coefficient of a circular basin is the most hazardous from a drainage stand point, because it will yield the shortest time of concentration before peak flow occurs in the basin [18].

Length of overland flow (L_g): It refers to the flow of precipitated water which moves over the land surface leading to the stream channels. The overland flow is significant in the smaller watersheds. The shorter the length of overland flow, the quicker the surface runoff from the streams. The length of overland flow is calculated as half of the reciprocal of the drainage density [5]. This factor relates inversely to the average slope of the channel and is synonymous with the length of sheet flow.

$$L_g = \frac{1}{2D_d}$$

2.4 Prioritization of Sub-watersheds

For prioritization of watersheds their linear, areal and relief parameters have to be considered. These parameters have a direct relationship with erodibility. In view of prioritization of micro watersheds the highest value of linear parameters was assigned as rank 1 followed second highest value was assigned as rank 2 and so on. The least value has been assigned as last in rank. Shape parameters such as circularity ratio, form factor, elongation ratio and compactness coefficient have an inverse relationship with erodibility [18]. The least value of shape parameter has been shown as a measure of more erodibility. Thus, the lowest value of shape parameters was assigned as rank 1, next lowest value was assigned as rank 2 and so on and the highest value was rated as last in the case of shape parameter rank. Hence, the ranking of the small-watersheds has been determined by assigning the priority/rank (Table 7 & 8)

At last, the compound parameter have been calculated by averaging all the parameter ranks, known as compound parameter value in a particular sub watershed. However, the final priority has been assigned as the least compound parameter value as highest priority, next higher value was assigned second priority and so on. Finally, the highest score of compound parameter was assigned as last rank.

3. RESULTS AND DISCUSSION

In this study, morphometric analysis of the watershed parameters, such as stream order, stream length, bifurcation ratio, drainage density, stream frequency, circulatory ratio, form factor, elongation ratio, texture ratio, compactness coefficient, length of over land flow and area, perimeter, elevation difference, basin length, maximum relief, number of stream and total stream length of the six Micro watersheds of W1 sub watershed and four Micro watersheds of W2 sub watershed has been carried out and their results are shown in The watershed area (A) is most important watershed characteristic for hydrological design and reflects the volume of water that can be generated from rainfall [19]. The results shows that in the case of sub watershed W1, the third micro watershed in it (W1-3) covers the highest area of 3.82 km^2, while W1- 4 has lowest area of 1.62 km^2. While for the sub watershed W2, micro watershed W2-2 has highest area of 1.65 km^2, while W2-3 possesses the lowest area of 1.08 km^2 . The basin perimeters of the micro watersheds of W1 sub watershed are presented in Table 3. W1-3 has highest perimeter of 10.18 km and W1-4 has lowest perimeter of 5.94 km. The counterpart results of W2 sub watersheds are presented in Table 4. A highest perimeter of 7.55 m has been obtained for W2-2 micro watershed.

Stream order (u) and Stream length(L): The stream order is one of the crucial linear morphometric parameter and it is based on the delineated streams and their branching. As shown in Table Table 1&2, out of the six micro watersheds in W1 sub watershed W1-1, W1-3, and W1-5 has fourth order and remaining three has third order streams. In W2 watershed W2-1 and W2-3 has fourth order stream and W2-2 and W2-4 has third order stream.

Total number of streams and stream lengths of sub watershed W1 of all order is 602 and 69.81 km respectively. Similarly, total number of streams and stream length of W2 sub watershed is 243 and 27.68 km respectively.

Bifurcation ratio (R_b): Bifurcation ratio depends on stream order and stream number. In this study, the mean value of bifurcation ratio of micro watersheds of W1 sub watershed varies between 2 and 10.46. The corresponding variation for sub watershed W2 is 4.84 and 15.68. The variation of bifurcation ratio is shown in Tables 5 & 6.

Drainage density (D_d): Drainage density of six micro watersheds of W1 sub watershed varies from 3.95 to 7.19 and four micro watersheds of W2 Sub watershed varies from 2.93 and 9.85.

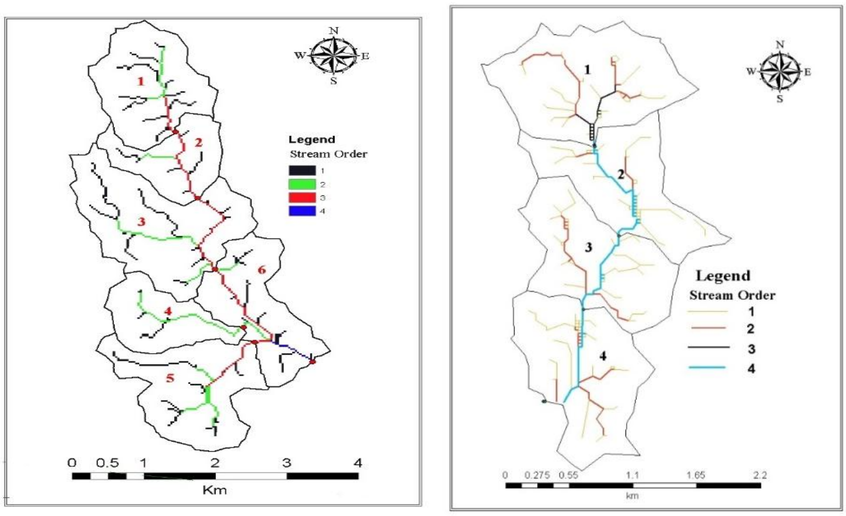
Stream frequency: Stream frequency of all Micro watersheds have been determined and is presented in Table 5 and 6. Prioritization wise ranking of the stream frequency of the all micro watershed is summarized in Tables 7 & 8. W1-5 will produce more runoff compared to other micro watersheds of W1 sub watershed. Their stream frequency values ranges from 34.35 (W1-2) to

55.46 (W1-5). Similarly, stream frequency of Micro watersheds of W2 sub watershed vary from 24.24 (W2-2) to 62.96 (W2-3).

Circulatory ratio (R_c): The results shows that the circulatory ratio of micro watersheds of W1 sub watershed varies from 0.45 for (W1-4) to 0.67 for (W1-3). In the case of sub watershed W2 the circulatory ratio varies from 0.36 for (W2-2) to 0.67 for (W2-1).

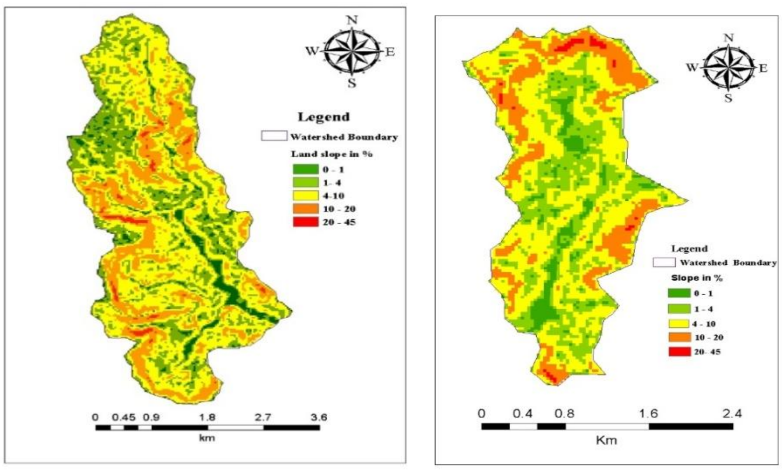
Form factor: It was found that the value of form factor varies from 0.42 for W1-4 to 0.56 for W1-1 which indicates that W1-1 is more elongated as compared to W1-4. Similarly, form factors of micro watersheds of W2 sub watershed varies from 0.70 for W2-3 to 1.20 for W2-4 which indicates that W2-4 is considerably more elongated than SW-3.

Elongation ratio (E_l): The study showed that the elongation ratio of different micro watersheds of W1 sub watershed varies from 0.36 to 0.42. In the case of sub watershed W2, the elongation ratio varies from 0.47 to 0.62. Elongation ratio micro watersheds of W1 sub watershed were 0.42 (W-1) and 0.36 (W-4). In case of micro watersheds of W2 sub watershed, the lowest and highest values were 0.47 (W2-3) and 0.62 (W2-4). The results of form factor and elongation ratio are seen in conformity to each other.



(a) (b)

Fig. 3. (a) Stream order of Micro watersheds of W1 Sub watershed, (b) Stream order of Micro watersheds of W2 Sub watershed



(a) (b)

Fig. 4. (a) Slope map of sub watershed W1, (b) Slope map of sub watershed W2

Texture ratio: The texture ratio of the micro watersheds of sub watershed W1 lies between 8.69 (W1-2) and 16.66 (W1-5). In the case of micro watersheds of sub watershed W2 it between 5.29 (W2-2) and 14.20 (W2- 4). In both of the watersheds, these values are high ranges. The higher values of texture ratio indicate that the basin has got high degree of slopes.

Compactness coefficient: The highest value (1.46) was found in micro watershed W1-3 while the lowest value (1.21) in W1-1 in sub watershed W1. In the case of micro watersheds in sub watershed W2, the highest value (3.1) was found in W2-1 and lowest value (1.21) in W2-4. The variations in compactness coefficient across the micro watersheds are given in Tables 5& 6.

Relief ratio: The values of relief ratio are given in Tables (5 & 6) which ranges from 0.029 for W1-6 to 0.066 for W1-2 in sub watershed W1. Similarly, it varies from 0.071 for W2-3 to 0.096 for W2-1 in W2 sub watershed. It is certain that high relief ratio of the basin will lead to high run off and erosion [20].

Length of overland flow (L_f**):** The values of length of overland flow varies from 0.069 in W1-5 to 0.126 in W1-2 for the first group of micro watershed and from 0.050 in W2-4 to 0.17 in W2-2 for the second group of micro watersheds.

3.1 Prioritisation of Micro Watersheds

This study gives special importance to the prioritization of micro watersheds of a midland region with undulating topography at Valanchery in Malappuram district, a typical land form of the state of Kerala. All the 10 micro watershed coming under two sub watersheds viz. W1 and W2 have been analysed morphometrically and have been ranked as per the procedure described in methodology. The final priority rank score of the six micro watersheds of W1 sub watershed and the four micro watersheds of W2 sub watershed and their ranking are shown in Tables. 7 and 8.

The minimum and maximum prioritized score of micro watersheds is 2.9 and 4.1 for W1 sub watershed. These scores vary in the range of 2.3 and 2.9 for the micro watersheds of W2 sub watershed. Lower value of the priority score refers to higher priority rank and vice versa. For example, the lowest value of priority score 2.1 of the first group of micro watershed is given rank I in the priority category. High priority indicates the potential for higher surface runoff and greater degree of erosion. In the present study, linear parameters such as bifurcation ratio, drainage density, texture ratio, length of overland flow, stream frequency, and the shape parameters viz. circulatory ratio, form factor, elongation ratio, compactness coefficient and are the relief parameters considered for compound priority value ranking. Therefore, it is necessary to adopt the required kinds of the soil and water conservation measures as per the priority rank in the micro watershed.

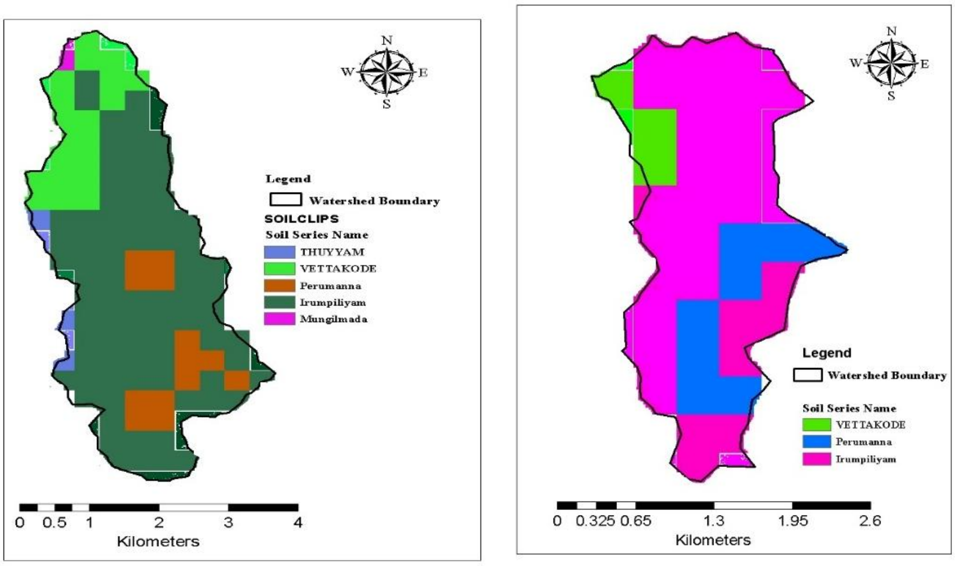
Further, the micro watersheds are classified based on the basis of priority score. For the micro watersheds of sub watershed W1, three classes of priority have been defined as high (2.9-3.3), medium (3.4-3.7) and low (3.8 - 4.1) priority on the basis of compound parameter value. For the sub watershed W2, the micro watersheds have been categorized into two classes as high (2.1-2.5) and low (2.6-3) priority on the basis of compound parameter value. Accordingly, micro watersheds W1-3, W1-4 and W1-5 fall in the high priority; W1-6 falls in medium priority and W1-1 and W1-2 in the low priority category (Table 7). [21]. For the micro watersheds of W2 sub watershed, W2-1, W2-3 and W2-4 fall in the high priority, W2-2 fall in the low priority category (Table 8).

Table 1. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W1

Sl. No.	Micro Watershed Name	Area In Km^2	Number of Streams(N_u)				Stream Length (L_u) in km			
			I	II	III	IV	I	II	III	IV
1	**W1-1**	2.65	55	32	14	1	6.84	3.66	1.33	0.77
2	**W1-2**	1.63	36	19	1	-	3.03	2.54	0.87	-
3	**W1-3**	3.82	76	36	28	1	7.81	4.74	2.72	0.45
4	**W1-4**	1.62	53	13	1	-	4.00	0.82	2.13	-
5	**W1-5**	2.47	62	47	27	1	6.76	2.74	6.96	1.32
6	**W1-6**	2.98	70	28	1	-	6.08	4.18	1.6	-

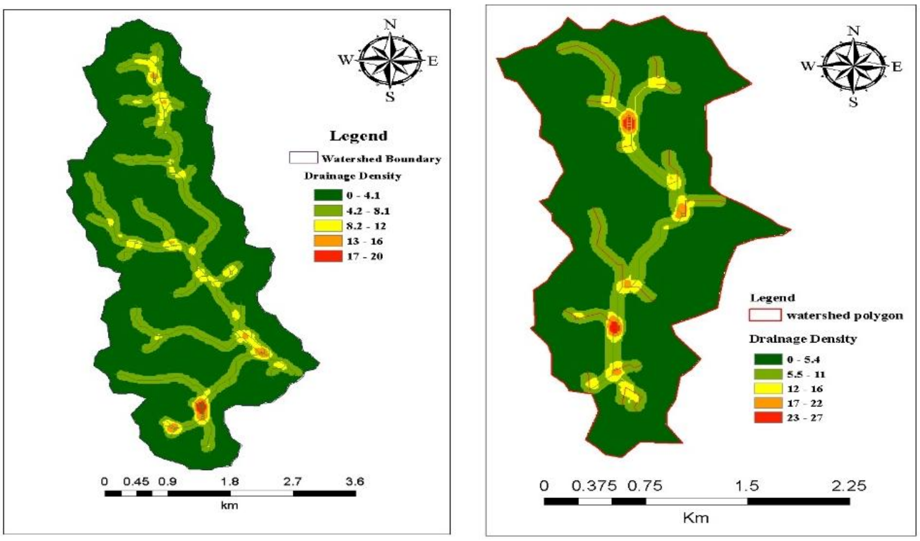
Table 2. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W2

Sl. No.	Micro Watershed Name	Area In Km^2	Number of Streams (N_u)				Stream Length in km (L_u)			
			I	II	III	IV	I	II	III	IV
1	**W-1**	1.32	34	17	11	1	2.88	1.91	0.8	0.042
2	**W-2**	1.65	32	7	1	-	3.07	1.02	0.756	-
3	**W-3**	1.08	38	19	10	1	3.4	1.13	0.78	0.067
4	**W-4**	1.20	41	30	1	-	6.84	3.66	1.33	-



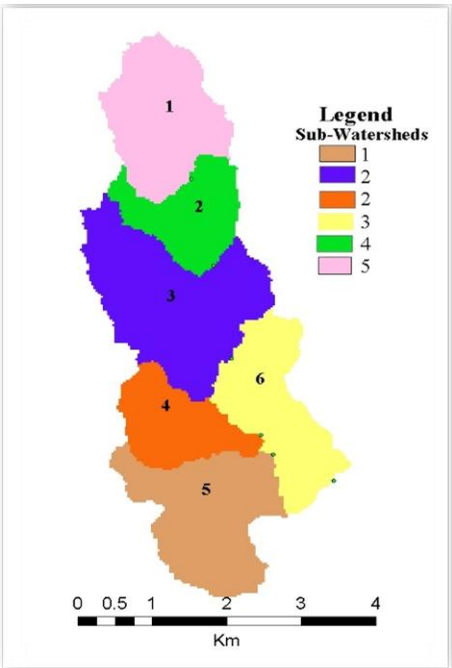
(a) **(b)**

Fig. 5. (a) Soil map of sub watershed W1, (b) Soil map of sub watershed W2

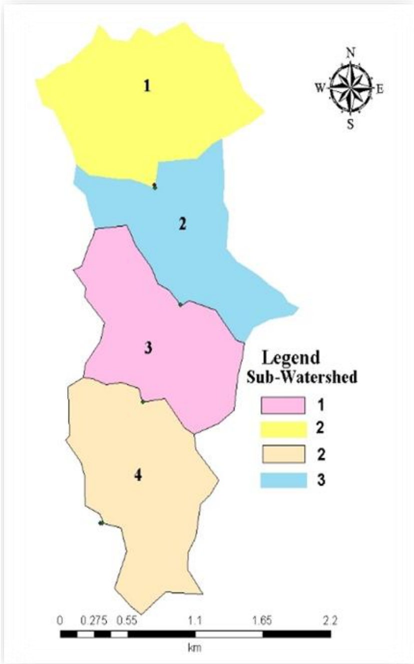


(a) **(b)**

Fig. 6. (a) Drainage density map of sub watershed W1, (b) Drainage density map of sub watershed W2



(a)



(b)

Fig. 7. (a) Final priority map of Sub watersheds W1, (b) Final priority map of Sub watersheds W2

Table 3. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W1

Sl. No.	Micro Watershed Name	Area (km^2)	Perimeter in (km)	Elevation (m)		Basin Length(km)	Maximum Relief(m)	No. of Stream	Total Stream Length(km)
				Max	Min				
1	W1-1	2.65	7.01	164	60	2.16	104	102	12.6
2	W1-2	1.63	6.40	139	24	1.73	115	56	6.44
3	W1-3	3.82	10.18	133	15	2.79	118	141	15.72
4	W1-4	1.62	5.94	115	18	1.95	97	67	6.94
5	W1-5	2.47	8.22	116	3	2.17	113	137	17.78
6	W1-6	2.98	8.91	88	11	2.59	77	115	11.86

Table 4. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W2

Sl. No.	Micro Watershed Name	Area (km^2)	Perimeter in (km)	Elevation (m)		Basin Length(km)	Maximum Relief(m)	No. of Stream	Total Stream Length(km)
				Max	Min				
1	W2-1	1.32	4.94	139	24	1.19	115	63	5.63
2	W2-2	1.65	7.55	124	26	1.22	98	40	4.84
3	W2-3	1.08	4.87	112	23	1.24	89	68	5.38
4	W2-4	1.20	5.07	109	23	0.99	86	72	11.83

Table 5. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W1

Micro Watershed Name	Bifurcation Ratio	Drainage Density	Stream Frequency	Circulatory Ratio	Form factor	Elongation Ratio	Texture Ratio	Compactness coefficient	Relief Ratio	Length of Overland flow
W1-1	6.00	4.75	38.49	0.67	0.56	0.42	14.55	1.21	0.048	0.105
W1-2	10.44	3.95	34.35	0.49	0.54	0.41	8.69	1.42	0.066	0.126
W1-3	10.46	4.11	36.91	0.46	0.49	0.39	13.85	1.46	0.046	0.121
W1-4	8.43	4.29	41.35	0.57	0.42	0.36	11.27	1.31	0.049	0.116
W1-5	10.01	7.19	55.46	0.45	0.52	0.40	16.66	1.47	0.050	0.069
W1-6	2.07	3.97	38.59	0.47	0.44	0.37	12.90	1.45	0.029	0.125

Table 6. Results of morphometric characteristics of micro watersheds of Valanchery sub watershed W2

Micro Watershed Name	Bifurcation Ratio	Drainage Density	Stream Frequency	Circulatory Ratio	Farm factor	Elongation Ratio	Texture Ratio	Compactness coefficient	Relief Ratio	Length of Overland flow
W2-1	4.84	4.26	47.72	0.67	0.93	0.54	12.75	1.21	0.096	0.11
W2-2	5.78	2.93	24.24	0.36	1.10	0.59	5.29	1.65	0.080	0.17
W2-3	4.63	4.98	62.96	0.57	0.70	0.47	13.96	1.32	0.071	0.10
W2-4	15.68	9.85	60	0.58	1.20	0.62	14.20	1.30	0.086	0.050

Table 7. Prioritized rank of micro watersheds of Valanchery sub watershed W1 using the morphometric parameters

Micro Watershed Name	Bifurcation Ratio	Drainage Density	Stream Frequency	Circulatory Ratio	Form factor	Elongation Ratio	Texture Ratio	Compactness coefficient	Relief Ratio n	Length of Overland flow	Compound parameter	Priority rank
W1-1	5	2	4	6	6	6	2	1	4	5	4.1	V
W1-2	2	5	6	4	5	5	6	3	1	1	3.8	IV
W1-3	1	3	5	2	3	3	3	5	5	3	3.3	II
W1-4	4	6	2	5	1	1	5	2	3	4	3.3	II
W1-5	3	1	1	1	4	4	1	6	2	6	2.9	I
W1-6	6	4	3	3	2	2	4	4	6	2	3.6	III

Table 8. Prioritized rank of micro watersheds of Valanchery sub watershed W2 using the morphometric parameters

Micro Watershed Name	Bifurcation Ratio	Drainage Density	Stream Frequency	Circulatory Ratio	Form factor	Elongation Ratio	Texture Ratio	Compactness coefficient	Relief Ration	Length of Overland flow	Compound parameter	Priority rank
W2-1	3	3	3	4	2	2	3	1	1	2	2.4	II
W2-2	2	4	4	1	3	3	4	4	3	1	2.9	III
W2-3	4	2	1	2	1	1	2	3	4	3	2.3	I
W2-4	1	1	2	3	4	4	1	2	2	4	2.4	II

4. CONCLUSION

Appropriate soil and water conservation interventions at micro watershed scale are very important for the sustainable development of any region. At the same time, watershed development measures are costly, time consuming and human resources intensive. Therefore, watershed interventions need to be carried out on priority basis starting from the most priority micro watershed. Morphometric analysis is one of the most commonly adopted technique of watershed prioritisation which involves the linear, areal and relief aspects of the individual micro watersheds. Morphometric analysis by manual means is very cumbersome. At the same time, remote sensing and GIS techniques have made a paradigm shift in the approach of morphometric analysis. In this context, a study has been taken up to prioritise the micro watersheds of two small sub watersheds of river Bharathapuzha near Valanchery municipal town in Kerala.

For the study, two small sub watersheds of river Bharathpuzha have been delineated from the SRTM DEM using ArcGIS 10.4 software. The sub watersheds W1 and W2 are further divided into micro watersheds of six and four numbers respectively in the former and latter. All these 10 micro watersheds are subjected to morphometric analysis and for which their basic linear, area and relief parameters are determined. From these basic parameters, 10 secondary parameters are quantitatively computed and ranks are assigned to these parameters and then, compound rank is determined. From the compound rank, priority rank numbers are assigned such that rank I is assigned to the micro watershed with least value of compound rank; rank II to the next compound rank and so on. Micro watershed with rank I will have to be taken up with utmost priority then with rank II and so on. It is seen that the combined priority parameter value varies considerably among the micro watersheds and it makes ranking more objectively with less ambiguity. If micro watersheds are prioritised based on scientific morphometric analysis, it would be a great boon to the soil and water conservation agencies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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