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Morphometric Analysis for Flood Vulnerability

Sruthy N M[1], Anjana C Jain [2], Feby Martin[3], Anjana Anilkumar[4], Jaito Johnson[5], Gokul Krishna P G[6]

Assistant Professor, Nirmala College of Engineering, Kerala, India[1,2]

B.Tech Students, Nirmala College of Engineering, Kerala, India[3,4,5,6]

sruthy.n.m@gmail.com, anjanajain017@gmail.com, anjanaanilkumar099@gmaill.com, febymartin2001@gmaill.com, jaitojohnson012@gmail.com, gokulkrishnapg@2001@gmail.com

Abstract*: Morphometric analysis is a quantitative analysis which is mainly relies on the geographical parameters of the earth. The morphometric parameters are differentiated as linear, areal and relief and comprises of thirteen distinctive parameters. The values of these parameters are calculated and based on the values; ranks are assigned to these parameters. Theses ranks are added to find out the total ranking of sub watersheds. Based on the ranks sub watersheds are prioritized.Flood is a natural disaster which occurred in Kerala in consecutive 3 years of time. During the months of July and August the monsoon strengthens and rivers overflow. Two days of torrential rain had filled all upstream dams on Chalakudyriver on August 15, 2018. As the flood gates of four dams (Thoonakadavu, Upper Sholayar, Lower Sholayar, Neerar Dam in Tamil Nadu) water came gushing to Peringalkuthu dam which started overflowing at 4.30am on August 16. All the streams, low-lying areas and agricultural fields in the river's proximity was flooded. All the towns and villages within 5 km of the river were flooded except the slightly high hill tops. It was the worst flood in Chalakudy in nearly a century. The Indian government had declared it a Level 3 Calamity, or "calamity of a severe nature". In this paper the study area is divided in to 4 sub watersheds and the thirteen morphometric parameters of each sub watersheds and prioritized.*

Keywords: Morphometric parameters, Prioritization, Ranking,

I. INTRODUCTION

1.1 General

Morphometric analysis is a quantitative measurement and mathematical analysis of landforms.Objectives of morphometric analysis is to understand the hydrological and morphological characteristics from morphometric parameters and compare the morphometric characteristics in two different morpho-climatic settings.

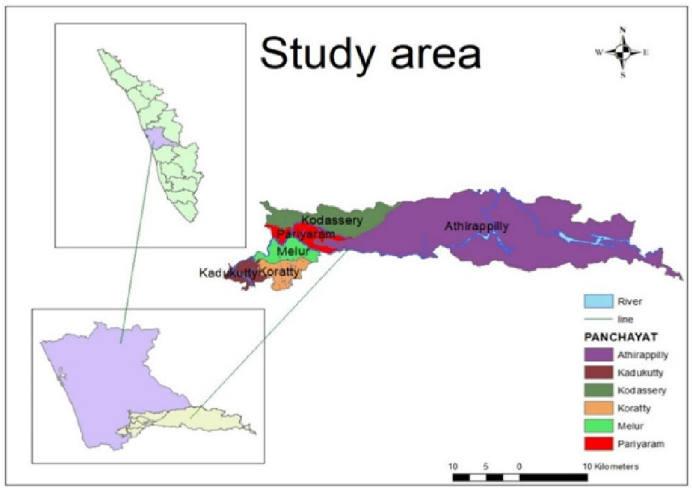
A systematic analysis is essential for the configuration of a catchment, and its stream courses involve relief aspects, linear aspects, and aerial or shape aspects of the catchment. Linear aspects involve the stream length, the number of streams, the bifurcation ratio, the mean stream length ratio, the stream frequency, the stream length ratio, the stream density, the drainage texture, the drainage intensity, the length of the overland flow, and the RHO coefficient. Relief features contain watershed relief, relief ratio, relief relative, ruggedness number, maximum elevation, and minimum elevation. Also, the areal features consist of circulation ratio, watershed area, perimeter, form factor ratio, basin length, elongation ratio, and compactness coefficient.

The linear parameters have a direct association with flooding, hence for prioritization of sub watersheds, the highest value of linear parameters have assigned first rank, second highest value given second rank and so on, the lowest value. It seems that higher the value of linear parameters, more susceptibility of flooding. The areal aspects such as form factor, elongation ratio and circulatory ratio have an inverse connection with flooding, it means lower the value more the vulnerability and vice versa. Hence the lowest value of aerial parameters has assigned as first rank, next lower value as second and so on. After the ranking of all linear and aerial parameters in all sub watersheds the values of each watershed are summing up in order to obtain compound value and its average. Based on the average value the priority criteria have decided i.e., High Priority, Medium priority and low priority. The sub watershed having lowest average weightage belongs to High priority and the watershed having lowest average weightage concerned to low priority.

1.2.Study area

Chalakudy is a municipal town situated on the banks of Chalakudy River in Thrissur District of the Kerala State in India. The block covering an area of 522 sqkms divided into 6 panchayaths.Kadukutty, Meloor, Pariyaram, Kodassery, Koratty, Athirappily are the panchayaths situated in Chalakudy block. Chalakudy is a Midland region. The Chalakudyriver flows through the southern part of the town.Chalakudy is at a distance of 35 km from Thrissur. Chalakudyriver is the fifth largest river in Kerala with length of 144 km. The river basin is bounded by the Karuvannur sub-basin on the north and the Periyar sub-basin on the south. The total drainage area of the river is 1704 sq.km and out of this 1404 sq.km lies in Kerala and the rest 300 sq.km in Tamil Nadu.

Fig 1: Location map of study area



II. MORPHOMETRIC PARAMETERS

2.1 Basic parameters

Basin area is a very significant hydrological feature as it determines water quantity that could result from rainfall.

Perimeter can be used as an indicator of the sub watershed shape and size. A strong correlation was found between the sub-watershed area and the perimeter.

Basin length is an indicator of surface runoff characteristic, where longer streams indicate flatter gradients.

2.2 Linear parameters

2.2.1 Stream order

Stream order refers to the way a stream develops and connects to other streams. It's also known as a stream hierarchy position measurement (Horton, 1945; Strahler, 1957).

2.2.2 Stream length

Larger stream lengths imply a flatter river plain, whereas shorter stream lengths reveal a steeper gradient with fine texture (Strahler, 1964).

2.2.3 Mean Stream length

It demonstrates that a higher stream order results in a longer stream length, while a lower stream order results in a shortening stream length.

2.2.4 Stream length ratio

It was computed by dividing the mean stream length of a given order by the mean stream length of the next lower order in a given order.

2.2.5 Bifurcation ratio

The bifurcation ratio, which characterizes the branching pattern of a drainage network, is defined as the ratio between the total number of stream segments of a particular order and the total number of stream segments of the next higher order in a drainage system (Schumm, 1956).Less bifurcation indicates circular basins that are more likely to form (Chow, 1964).

2.2.6 Length of overland flow

The length of water flow across land before it reaches the main river is known as the overland flow

2.3 Areal parameters

2.3.1 Drainage frequency

The frequency of streams is calculated by dividing the total number of stream segments in all given orders by the river basin's entire area (Horton, 1945). The lower the stream frequency, the slower the surface runoff, and hence the less prone the basin is to floods.

2.3.2 Drainage frequency

The total length of streams per unit area is known as drainage density (Horton, 1945).

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The total length of streams per unit area is known as drainage density (Horton, 1945).

2.3.3 Drainage texture

Drainage texture of a basin is calculated by dividing total number of stream segments to its basin perimeter (Horton, 1945).

2.3.4 Circulatory ratio

It is defined as the ratio of basin area to that of a circle with the same perimeter as that basin (Miller, 1953). The circulatory ratio varies from 0 to 1.

2.3.5 Elongation ratio

It is defined as the relationship between the diameter of a circle covering the same area as the watershed and the maximum length of the watershed.

2.3.6 Form factor

It is the ratio of basin area to the square of river basin length that is known as the form factor.

A river basin with a form factor of 1 is completely circular, whereas a basin with a form factor of 0 is very elongated.

2.3.7 Compactness coefficient

The compactness coefficient (Cc) is defined as the ratio of the perimeter of a watershed to the circumference of an equivalent circular area of the watershed (in square kilometres) (Horton, 1945).

2.4 Relief parameters

2.4.1 Basin relief

The maximum altitude difference between the basin's highest and lowest elevations is known as the basin relief.

2.4.2 Basin relief

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2.4.3 Relief ratio

The relief ratio is the relationship between the relief of a basin and the length of the basin.

2.4.4 Ruggedness ratio

The ruggedness number combines the slope steepness and length indicating the extent of the instability of land surface.

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Table 1: Morphometric parameters

Aspects	Morphometric parameters	Methods
Linear aspects	Stream order (Nu) Stream length (Lu) Mean stream length(Lm) Stream length ratio(R1) Bifurcation ratio(Rb) Length of overland flow(Lg)	Hierarchical ordering Length of the stream Lm=Lu/Nu R1 = Lu/L(-1), where Lu i stream segment length c Rb = Nu/N(u+1), where I order and N(u-1) is numl Lg=½Dd, Where Dd = Dra
Areal aspects	Stream frequency(Fs) Drainage density(Dd) Drainage texture(Dt) Circularity ratio(Rc) Elongation ratio(Re) Form factor (Ff) Compactness coefficient (Cc)	Fs = N/A where N is total watershed Dd =L/A, where L is total Dt = Nu/P Where Nu is N perimeter Rc = 4πA/P ² where A is a perimeter Re=2 √(A/π)/Lb. where A basin length Ff =A/Lb2 Cc =0.282×P/√A, where I watershed
Relief aspect	Basin relief (R) Relief ratio (Rr) Ruggedness number (Rn)	R=H-h, where H is maxin elevation within the basi Rr = R/Lb, Where R is ba Rn = R×Dd. Where R is b

III. RESULT AND DISCUSSIONS

3.1. Linear aspects

Linear factors also vary inversely with the flood. So that the highest value is ranked 4 and the lowest value is ranked 1.

3.1.1. Stream order

Streams of orders 1 – 4 are present on our watershed. Sub watersheds 1 and 3 are not having stream order 3. The number of stream orders of four sub watersheds are counted and summarized in the table.

Sl no	Sub watershed	Area (km^2)	Stream order (number of stream)				Total number of stream segments
			I	II	III	IV	
1	SW1	114.13	6	3	0	2	11
2	SW2	108.83	10	2	1	5	18
3	SW3	188.46	14	8	0	9	31
4	SW4	751.73	19	10	8	4	41

Table 2: Stream order

3.1.2. Stream length

The length of streams varies from 24.79 to 109.86 from sub watershed 1 to sub watershed 4 respectively. Sub watersheds 4 have the largest value of stream length because its area is larger. It is calculated from stream order in ArcGIS software.

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Table 3: Stream length

Sl no:	Sub watershed	Area (km^2)	Stream length (km)				Total length of stream segments
			I	II	III	IV	
1	SW1	114.13	12.22	6.72	0	5.85	24.79
2	SW2	108.83	25.50	13.47	0.59	20.98	60.56
3	SW3	188.46	18.31	22.52	0	20.88	61.71
4	SW4	114.13	42.85	16.55	38.93	11.53	109.86

3.1.3. Mean stream length

Mean stream length is the mean value of length of the streams of all orders on the basin. And the value varies from 2.92 to 4.19. The highest mean stream length value is obtained for sub watershed 2.

Table 4: Mean stream length

Sl no:	Sub watershed	Mean stream length (km)			
		I	II	III	IV
1	SW1	2.036	2.24	0	2.92
2	SW2	2.55	6.74	0.59	4.19
3	SW3	1.49	2.82	0	2.034
4	SW4	2.25	1.65	4.87	2.88

3.1.4. Stream length ratio

Stream length ratio varies from 0.29 to 35. 22 and the highest value of the stream length ratio is for sub watershed 2. As the stream length ratio is a linear parameter, highest rank of 4 is provided to the 4th sub watershed and rank 1 is provided to the 2nd sub watershed. Rank 2 and 3 are provided for 3rd and 1st sub watersheds respectively.

Table 5: Stream length ratio

Sl no:	Sub watershed	Stream length ratio (Ri)		
		II/I	III/II	IV/III
1	SW1	0.55	0	0.87
2	SW2	0.53	0.044	35.22
3	SW3	1.23	0	0.93
4	SW4	0.39	2.35	0.29

3.1.5. Bifurcation ratio

Bifurcation ratio value varies from 0.2 to 1.5 for sub watersheds 2 and 4 respectively. As this parameter also is a linear parameter, rank 4 is provided for sub watershed 2 and rank 1 is provided for sub watershed 4. Rank 2 and 3 are provided for 1st and 3rd sub watersheds respectively.

Table 6: Bifurcation ratio

Sl no:	Sub watershed	Bifurcation ratio (Rb)		
		Rb1	Rb2	Rb3
1	SW1	2	0	1.5

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2	SW2	5	2	0.2
3	SW3	1.75	0	0.89
4	SW4	1.9	1.25	2

3.2.Areal aspects

Areal factors also vary inversely with the flood. So that the highest value is ranked 4 and the lowest value is ranked 1.

Table 7: Areal aspects

Sl no	Sub watershed	Drainage density (Dd)	Drainage frequency (Fl)	Length of overland flow (Lo)	Drainage texture (Dt)	Circulatory ratio (Rc)	Form factor (Rf)	Elongation ratio (Re)	Compactness coefficient (Cc)
1	SW1	0.22	0.074	2.27	0.125	0.24	0.85	139.38	2.06
2	SW2	0.56	0.058	0.89	0.138	0.33	0.41	190.63	1.74
3	SW3	0.33	0.026	1.526	1.52	0.38	0.57	280.59	1.63
4	SW4	0.15	0.227	0.519	3.33	0.18	0.71	1003.89	2.38

3.3. Relief aspects

Relief factors vary inversely with flood and therefore the highest rank 4 is provided for the highest value. In this manner, for height difference, rank 1 is provided for 1st sub watershed and rank 4 is provided for 3rd sub watershed.

Table 8: Relief aspects

SW	Height difference	Relief ratio	Relative relief ratio	Basin slope	Ruggedness number
1	0.18	0.016	0.00280	0.00026	0.0024
2	0.52	0.032	0.00655	0.000535	0.0106
3	1.12	0.06	0.00484	0.00103	0.034
4	0.6	0.00184	0.0077	0.000308	0.004

3.4. Ranking of parameters

lowest value is the most vulnerable to the flood. The lowest rank is 28 and it's the value of sub watershed 1 and the highest rank of 38 for sub watershed 4. Therefore, the most prioritized sub watershed is 1 and then sub watershed 2 having rank of 31 and then the sub watershed 3 having rank of 33 and the least prioritized is sub watershed 4. The most prioritized sub watersheds are the most vulnerable towards flood.

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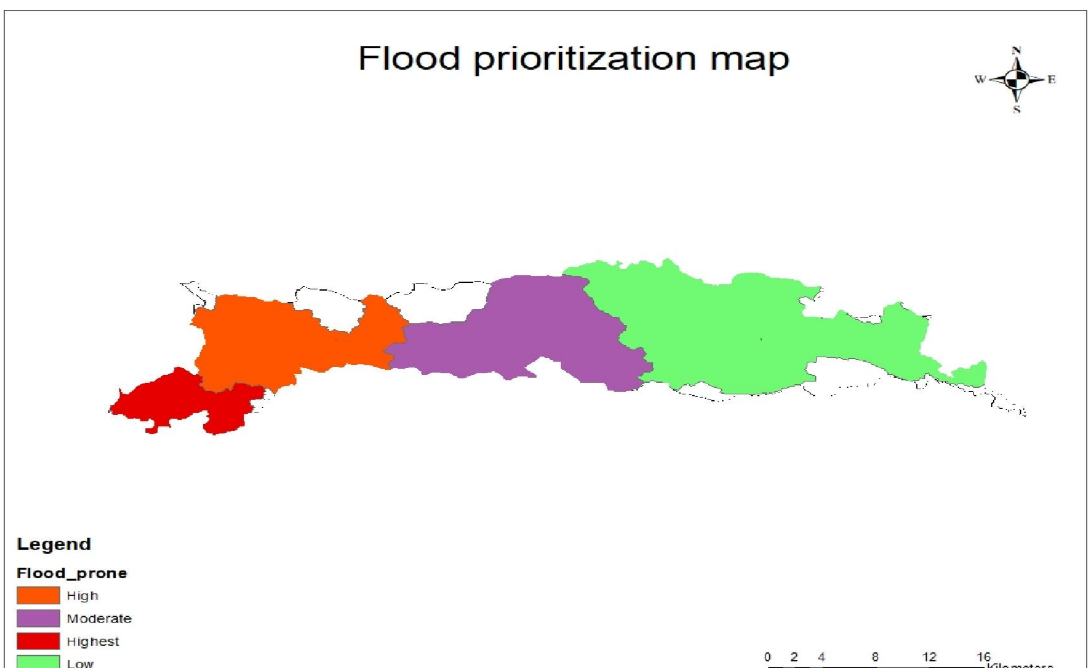
Table 9: Ranking of various aspects

Sub watershed	Length of stream segments (L_b)	Average bifurcation ratio (Rb_m)	Drainage density (Dd)	Drainage frequency	Length of overland flow (Lo)	Drainage texture (Dt)	Circulatory ratio (Rc)	Form factor (Rf)	Elongation ratio (Re)	Compactness coefficient (Cc)	Basin relief (R)	Relief Ratio (Rf)	Ruggedness number (Rn)	Total	Prioritized ranking
SW1	4	2	2	3	1	1	2	4	1	3	1	2	2	28	1
SW2	3	1	4	2	3	2	3	1	2	2	2	3	3	31	2
SW3	1	3	1	1	2	3	4	2	3	1	4	4	4	33	3
SW4	2	4	3	4	4	4	1	3	4	4	3	1	1	38	4

Fig 2: Flood prioritization map



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IV. RESULT OF MORPHOMETRIC ANALYSIS

Ranks were assigned to the morphometric features of 4 sub watersheds to determine their prioritization rank.According to the results of the study, sub-watershed 1, which is located in the lower catchment of the study area is very vulnerable to floods. SW1 with flat slopes, low altitudes, more population and significant amount of built-up area at downstream end are found to be more vulnerable for flood hazard. On the other hand, sub watersheds at u/s of the study area are least affected by flood due to steep topography and high altitudes.

V FLOOD CONTROL MEASURES

Peringalkuthu dam is situated at the upstream of Athirapilly which has a reservoir capacity of 32MCM. Water from Upper Sholayar, Lower Sholayar and Idamalayar flow to Peringalkuthu. It can cause overflowing of dam. Increasing the capacity of Peringalkuthu dam and thus contain more water in the dam can be done to avoid overflow.

A dam was proposed in Vazhachal which was not sanctioned due to biodiversity. By sanctioning that dam some water can be flowed towards Vazhachal dam which will reduce the amount of water in Peringalkuthu dam and thus the impact of overflowing due to opening of dam can be reduced.

Also a seven-meter canal is situated which flow from Vachumaram to Idamalayar which has a capacity of 1000MCM. Deepening the canal can increase its capacity. Some water can be deviated towards this canal to reduce the amount of water flowing towards Peringalkuthu

Also small scale watershed management techniques like rainwater harvesting, artificial recharge of ground water resource, check dams, dikes can be done. Also river bank protection works, widening of riverbank and construction of water flow channel in water stagnant areas can reduce the impact of flood.

Silting of reservoir causes the reduction of capacity in reservoir. Periodic silt removal can increase the reservoir capacity. Also proper drainage network facilitates proper water flow and thus inundation of water can be reduced.

VI. CONCLUSION

According to morphometric analysis, sub-watershed 1, which is located in the lower catchment of the study area is very vulnerable to floods. SW1 with flat slopes, low altitudes, more population and significant amount of built-up area at downstream end are found to be more vulnerable for flood hazard. On the other hand, sub watersheds at u/s of the study area are least affected by flood due to steep topography and high altitudes. Based on sub watershed prioritization using morphometric analysis, overall 40% of the overall study area is more prone to flooding.

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