GIS-Based Approach in Drainage Morphometric analysis of Bharathapuzha river basin, India

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ABSTRACT

Aims: The paper aims in study about the river basin morphometry for the quantitative evaluation of the the for characteristics of the basin and study about composition of stream system is done quantitatively with Physical, Linear and Areal parameters for the basin

Study design: The Study has been carried out with the help of Geospatial techniques and statistical formulas

Place and duration of study: Bharathapuzha river basin, Kerala,India between January 2018 to July 2018

Methodology: The Study of River morphometry of Bharathapuzha River basin has been analyzed with the help of SRTM satellite data. The downloaded data has been analyzed with the help of ARC GIS Software. The morphometric analysis has been carried out by dividing the basin into nine watersheds based on water shed atlas of India Prepared by Soil and Land Use board of India. Relief, Linear and areal parameters of the basin is calculated with the help of statistical formulas.

Results: Based on the analysis it is noted that there is not much difference in morphometric values except in some watersheds. Watershed number 5A2B5, 5A2B6 and 5A2B7 has highest drainage density, stream frequency, relief, relief ratio and ruggedness number, stream length ratio and lowest bifurcation ratio. These watersheds are characterized by highest surface runoff and erosion. The values of form factor, circulatory ratio and elongation ratio suggests that most of the watersheds are elongated and has high basin relief. The maximum stream order frequency is observed in case of first order streams and then for second order streams. Hence it is noted that there is decrease in stream frequency as stream order increases.

Conclusion: The mean bifurcation ratio of the Bharathapuza basin is 1.52 which indicates the whole basin is less effected by structural control. This present study is valuable for the erosion control, watershed management land and water resource planning and future prospective related to runoff study.

Keywords: Morphometry, Physical linear and areal parameters,

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1.INTRODUCTION

Morphometric analysis refers to the quantitative evaluation of form characteristics of the earth surface and any landform unit. This is the most common technique in basin analysis, As morphometry form an ideal areal unit for interpretation and analysis of fluvial originated landforms where they exhibits an example of open system of operation. The analysis will help to manage water resources in the area and proper planning can be adopted for sustainable use of water resources. The composition of the stream system of drainage basin is expressed quantitatively with stream order, Drainage density, Bifurcation ratio and stream length ratio (Horton 1945). It incorporates quantitative study of the various components such as stream segments, basin length, basin parameters, basin area, altitude, slope , which indicates the nature of the development of basin.

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2.STUDY AREA

The Bharathapuzha River (10°25' to 11°15' N and 75°50' to 76°55' E) is the second longest (209 km) and largest (annual discharge 3.94 km^3) among the west flowing perennial rivers (41 in number) in the state of Kerala of India . The river basin covers 1/9 of the total geographical area of the state. The flow regime of the river covers highlands (>76 m above MSL), midlands (8 - 76 m above MSL) and the low lands (<8 m above MSL). The river has a well-developed flood plain and fluvial terrace of recent origin. The river is the life line water resource for more than 4.5 million people residing in four administrative districts, namely Malappuram, Trissur and Palakkad districts of Kerala, and Coimbatore district of Tamil Nadu. There are eleven dams and irrigation projects in the river basin catering to 493,064 ha area under cultivation. In recent years, the basin is facing severe dearth of water and drought like situations, perhaps for the increasing anthropogenic pressures and development works that grossly neglect the hydrologic flow regime of the basin. Unsustainable exploitation of water, in stream sand mining and clay mining for brick kilns are among the striking threats to flow of the river.

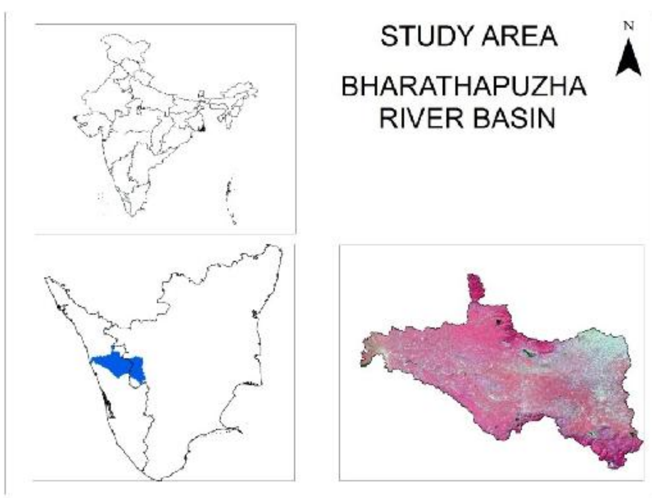

Fig1: Study area map of the Bharathapuzha river basin

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3.METHODOLOGY

Manual extraction of drainage network and finding out the stream order from Survey of India Toposheets for such a large area is a time taking tedious task. To overcome this problem, an automatic extraction technique have been used for evaluating the morphometric parameters of the basin. The satellite data for the study has been taken from Shuttle Radar Topographic Mission (SRTM) with a pixel size of 90 m. ARC GIS 10.3 software has been used for preparation of various thematic layers and estimation of morphometric parameters. The Bharathapuzha basin is divided into 9 watersheds naming 5A2B1 to 5A2B9 .The numbering and delineation of watershed was based on the Watershed Atlas of India prepared by Soil and Land use Survey of India .The River basin is automatically extracted from DEM data with the help of various geo processing techniques in ARC GIS 10.3.The DEM and the Pour point are two input parameters required for the extraction purpose. A pour point is a user- supplied point to the cells of highest flow accumulation (Magesh et al 2013). The drainage of the Bharathapuzha river basin is extracted with help of hydro tools in ARC GIS 10.3 from the SRTM DEM data of the study Area. The flow direction raster has been extracted from the SRTM DEM data. The flow accumulation and streams have been derived from the flow direction raster. The extracted stream has been given stream order by using Strahler method. Stream length, Number of stream, Area and perimeter of each watershed was calculated. The other parameters for morphometry analysis was calculated with the help of mathematical formulas (table 1)

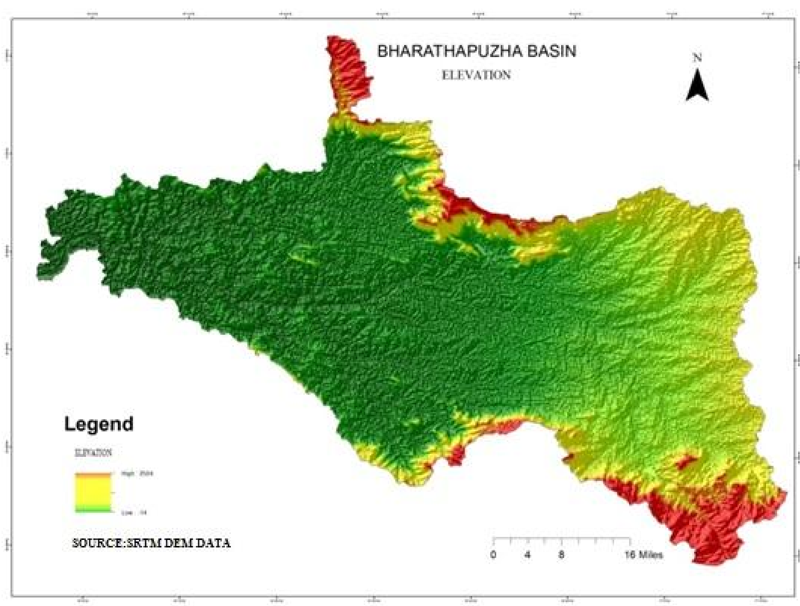

Fig 2-: Digital Elevation Model of the River basin

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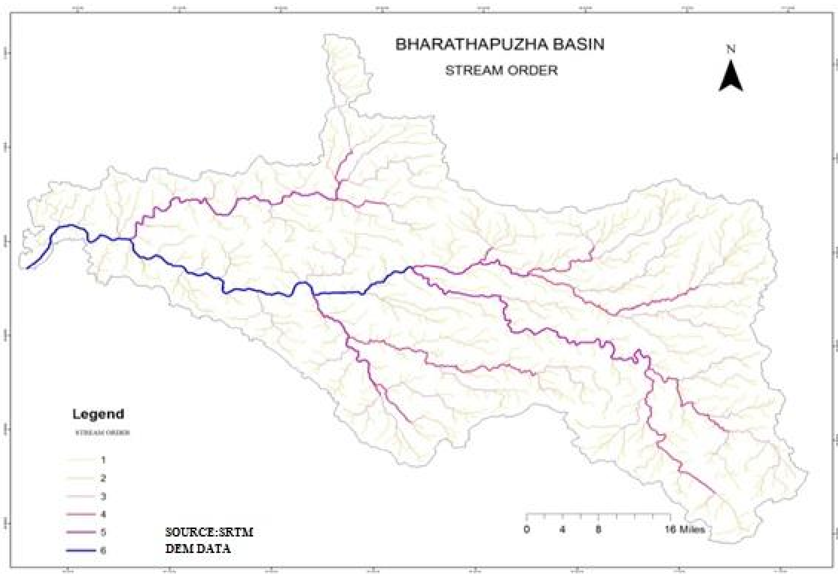

Fig 3: Drainage map of the Bharathapuzha River basin

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Sl No	Morphometric Parameters	Formula/Definition/Methods	Reference
1	Stream Order	Hierarchical Order	Strahler 1964
2	Stream Length(Lu)	Length of stream (Km)	Horton 1945
3	Mean Stream Length(Lsm)	Lsm = Lu / Nu, Where, Lu=Total Stream length of order ‘U’, Nu=Stream length of next higher stream order.	Horton 1945
4	Stream Length Ratio(Rl)	Rl=Lu/Lu-1; where, Lu= Total stream length of order‘U’, Lu-1=Stream length of next lower order.	Horton 1945
5	Bifurcation Ratio (Rb)	Rb=Nu/Nu+1,Where, Nu=Total Number of stream segments of order ‘U’,Nu+1= Number of segments of the next higher order.	Schumm 1956
6	Drainage Density(Dd)	Dd=L/A Where L=Total length Of stream,A=Area of watershed	Horton 1945
7	Stream Frequency(Fs)	Fs=N/A Where N= Total Number of Stream,A=Area of the watershed	Horton 1945

8	Texture Ratio(T)	T=N/P Where N= Total Number of stream,P=Perimeter of watershed	Horton 1945
9	Form Factor(Rf)	$Rf=A(Lb)^2$ Where,A=Area of the watershed,Lb= Maximum Basin length	Horton 1932
10	Circulatory ratio(Rc)	$Rc=4\pi A/P^2$ .Where,A=Area of Watershed,P=Perimeter of the basin,π=3.14	Miller 1953
11	Elongation ratio(Re)	$Re=2\sqrt{(A/\pi)}/Lb$.Where, A=Area of Watershed,Lb=Maximum Basin Length,π=3.14	Schumm 1956
12	Length of overland flow(Lof)	Lof=1/2Dd.Where Dd=Drainage density	Horton 1945
13	Constant channel maintenance	1/Dd.Where,Dd=drainage Density	Horton 1945
14	Basin Relief(Bh)	Vertical distance between the lowest and highest point of watershed	Schumm1956
15	Relief Ratio(Rh)	Rh=Bh/Lb,Where,Bh=Basin Relief,Lb=Basin length	Schumm1956
16	Ruggedness number(Rn)	Rn=Bh*Dd,where Bh=Basin Relief,Dd=Drainage density	Schumm1956
17	Rho Co efficient	Mean Stream length ratio/Mean bifurcation ratio	Horton 1945
18	Relative Relief	Bh/P Where Bh= basin relief,P=Perimeter of watershed	Hamnowd 1954??check spelling

Table 1: List of river morphometric parameters and its calculation

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4.RESULTS AND DISCUSSION

4.1 linear parameters

Morphometric parameters considered under this domain are the stream order, stream length , mean stream length, stream length ratio, and bifurcation ratio.

4.1.1Stream order

Stream ordering is the first step taken in any drainage basin analysis where it is done on a hierarchical way. Stream order was computed based on the Strahler's Method. Stream that originates at a source is defined as first order stream. When two streams of first order join, an order two streams is created and so on and it provide information about topography, runoff and drainage network. Bharathapuzha river basin is found to be of the 6th order with 9 Watersheds. The total number of streams in the basin is 1982 . Out of the 9 watershed Two (5A2B1 &5A2B4) are of 6 th order watershed. 5A2B2 5A2B3, 5A2B5, 5A2B8, 5A2B9 are the 5 th order watersheds in the basin. Rest of the watershed comes under fourth order. Watersheds with higher number of lower order streams yield more water .In this basin watershed number with 5A2B7 and 5A2B1 have higher number of first order streams. Watersheds numbered 5A2B2 have less number of first order streams. The maximum and minimum of total stream is observed in water shed number 5A2B7 (315) &5A2B2 (154). Details of stream order in each water shed are shown in table 2. It is observed that maximum frequency is seen in case of first order stream and it decreases as the stream order increases.

4.1.2Stream length (lu)

According to Horton (1945), stream length delineate the total lengths of stream segment of each of the successive orders in a basin and tend to approximate a direct geometric series in which the first term is the average length of the stream of the first order. The stream length is a measure of hydrological characteristics of the bedrock and the drainage extent. Wherever the bedrock and formation is permeable, only a small number of relatively longer streams are formed in well drained watershed, a large number of streams of smaller length are developed where bedrock and formations are less permeable (Sethupathi 2011). Smaller length of streams are prominent in hilly areas with larger slopes where as longer streams are generally indicative of flat areas with lesser slope. The number of streams of various orders in the basin is counted and their length is measured using GIS technique. The result of order wise stream length of each watershed in Bharathapuzha basin is shown in table 2. It is clearly identified that the cumulative stream length is higher in first order streams and decreases as the stream order increases. Major share of the stream length is constituted by first and second order streams. The total stream length of first order stream for the basin is 1660 km and the highest stream order has a length of 94 km .The length of stream in each watershed is shown in table 2.

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4.1.3 Mean stream length(Lsm)

According to Strahler (1964), the stream length is a characteristic property related to the drainage network components and its associated basins. Mean Stream length reveals the characteristic size of components of a drainage network and its contributing surfaces. In a drainage basin mean stream length of a given order is higher than that of the lower order and less than that of its next higher order (Deepak Khare 2014).The mean stream length value differ with respect to different basins as it is directly proportion to the size of the drainage network and its associated surfaces (Strahler 1964).The values of Lsm of 1 to 6 order in the river basin are as follows 1.98,3.28,1.2,4.8 and 4.12 (table 1). Lsm has a highest significant association with the surface flow discharge and erosional stage of the basin (Girish Gopinath 2016). Low Lsm shows high surface flow and erosion.

4.1.4Stream length ratio(Rl)

Stream length ration is defined as the ratio between the mean stream length of one order with that of the next lower order stream segments. The stream length ratio between the streams does not follow any trend in the whole basin. This change may be attributed to the variation in slope and topography, indicating the late youth stage of geomorphic development in the streams of the study area (vittala et al 2004). The Rl varies with difference of slope and topographic conditions, surface flow discharge and erosional stage of the basin (Sreedevi et al 2005). In most of the watershed, the ratio fall within a range between 0.3 to 0.7 but watershed number 3 and 7 have comparatively higher values that is 1.3 and 1 which is due to the higher relief of the area. Stream length ratio for each order is calculated separately and is shown in table 2.

Table 2: Results of the morphometric parameters of the River basin

Parameter		Stream order	Watershed 5A2B1	5A2B2	5A2B3	5A2B4	5A2B5	5A2B6	5A2B7	5A2B8	5A2B9	Bharathapzha River basin
Area(Sq km)			752.42	461.28	593	698.37	544.7	728	944.99	675.7	563.49	5961.93
perimeter			203.77	122.95	149.69	172.91	121.2	125.9	168.41	184.2	137.74	1386.78
Basin length			56.46	42.76	49.32	54.122	47	55.41	64.26	53.12	47.911	470.37
Total Stream length of Order In km		1	196.44	128.14	170.41	202.24	167.1	205.1	263.87	173.4	153.9	1660.60
		2	116.52	52.93	73.71	104.66	103.3	105.1	119.86	113.1	69.27	858.49
		3	43.922	41.70	32.89	11.65	32.91	75.98	60.823	16.6	64.15	380.64
		4	0	14.49	45.15	0	32.91	31.21	63.432	0	22.13	209.32
		5		13.25	10.33	87.436	11.86	0	0	54.46	2.95	180.30
		6	72.845	0	0	21.188	0	0	0	0	0	94.03
			429.73	250.54	332.5	427.17	348.1	417.4	507.99	357.6	312.39	3383.4
Mean Stream length in Km		1/2	1.68	2.42	2.31	1.93	1.62	1.95	2.20	1.53	2.22	1.98
		2/3	2.65	1.26	2.24	8.98	3.14	1.38	1.97	6.81	1.08	3.28
		3/4	0	0	0.72	0	1	2.43	0.96	0	0	1.28
		4/5	0	0	4.36	0	2.77	0	0	0	7.5079	4.88
		5/6	0	0	0	4.13	0	0	0	0	0	4.12
Number of streams of different Order		N1	134	80	103	121	91	115	162	114	85	1005
		N2	71	37	44	54	51	52	76	60	39	484
	Linear parameters	N3	30	24	19	7	19	42	36	11	29	217
		N4	0	6	28	0	14	14	41	0	13	116
		N5	0	7	10	47	8	0	0	31	3	106
		N6	39	0	0	15	0	0	0	0	0	54
			274	154	204	244	183	223	315	216	169	1982
Bifurcation Ratio		1/2	1.88	2.16	2.34	2.24	1.784	2.212	2.1316	1.9	2.17	2.09
		2/3	2.36	1.54	2.31	7.71	2.684	1.238	2.1111	5.455	1.34	2.97
		3/4	0	4	0.67	0	1.357	3	0.878	0	0	1.10
		4/5	0	0.86	2.8	0	1.75	0	0	0	4.33	1.08
		5/6	0	0	0	3.133	0	0	0	0	0	0.34
		Mean	0.85	1.71	1.63	2.62	1.515	1.29	1.0241	1.471	1.57	1.51
stream length Ratio		2/1	0.5931	0.41	0.43	0.5175	0.618	0.513	0.4542	0.652	0.45	0.51
		3/2	0.377	0.78	0.44	0.1113	0.319	0.723	0.5074	0.147	0.92	0.48
		4/3	0	0.34	1.37	0	1	0.411	1.0429	0	0.34	0.75
		5/4	0	0.91	0.22	0	0.361	0	0	0	0	0.50
		6/5	0	0	0	0.2423	0	0	0	0	0	0.24
		Mean	0.194	0.49	0.496	0.1742	0.459	0.329	0.4009	0.16	0.3442	0.33
Ruggedness number			290.13	797.88	878.64	582.31	1247	180.1	1224.6	272	1281.8	750.45
Relief			508	1469	1567	952	1951	314	2278	514	2312	1318.33
Relief ratio	Relief parameters		8.9971	34.352	31.77	17.59	41.51	5.667	35.447	9.677	48.256	25.91
relative relief			2.493	122.95	10.46	5.50	16.09	125.9	13.527	2.791	16.785	35.17
RHO co efficient			0.228	0.28	0.30	0.0666	0.303	0.255	0.3915	0.109	0.219	0.24
Drainage Density			0.57	0.54	0.56	0.61	0.639	0.573	0.53	0.529	0.55	0.56
Texture ratio			1.34	1.25	1.3628	1.41	1.509	1.771	1.87	1.173	1.22	1.43
Stream Frequency			0.36	0.33	0.344	0.34	0.336	0.306	0.33	0.32	0.29	0.33
Form factor			0.23	0.25	0.2438	0.23	0.247	0.237	0.22	0.239	0.24	0.24
Circulatory Ratio			0.23	0.38	0.3324	0.29	0.465	0.577	0.41	0.25	0.373	0.36
Elongation Ratio			0.54	0.56	0.5573	0.55	0.56	0.55	0.53	0.552	0.55	0.55
Length of overland flow	Areal Parameters		0.28	0.27	0.2804	0.30	0.32	0.287	0.26	0.265	0.27	0.28
Constant of channel Maintenance			1.7509	1.8411	1.7834	1.6349	1.565	1.744	1.8603	1.89	1.8038	1.76

~~Table 2: Results of the morphometric parameters of the River basin~~

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4.1.5 Bifurcation ratio(Rb)

Bifurcation ratio describes the branching pattern of a drainage network and is defined as ratio between the total number of stream segments of a given order to that of the next higher order in the basin(Schumm1956). Bifurcation ratio generally ranges from 3.0 to 5.0 for basins in which geologic structures do not distort the drainage pattern (Strahler 1964). The ratio varies from 0.6 to 3.9 indicating that all the watershed are falling under normal basin category .The bifurcation ratio is also an indication of shape of the basin. Elongated basin is likely to have higher ratio where as circular basin is likely to have a lower ratio. The mean ratio is highest in watershed number four and less in watershed number one (table 2). In the study area, the higher values of ratio indicates a strong structural control in the drainage pattern where as the lower values indicates that the watersheds are less affected by structural disturbances(Strahler 1964).

4.2 Relief parameters

Morphologic parameters included under this domain include basin relief, relief ratio, and relative relief and Ruggedness number

4.2.1 Basin relief(Bh)

The Bharathapuzha river is generally having dentritic pattern of drainage throughout the basin. Watersheds of 5A2B6 have low relief in the basin where as watershed of 5A2B7 AND 5A2B9 have high relief in the basin. Basin relief is calculated by vertical distance between the lowest and highest point of watershed (Schuman 1956). The Digital Elevation Model (DEM) derived from SRTM data reveal that Northern and South Eastern part of the basin is having higher elevation regions where the elevation goes beyond the 1900 meters above mean sea level. Low basin relief indicates low runoff, low sediment transport and spreading of water basin .High relief tends to enhance the flood peaks of the drainage system (Girish gopinath 2016). Basin relief for the study area ranges between 314 for 6th watershed to 2312 to 9 th watershed.

4.2.2 Relief ratio(Rh)

Schumm (1956) states that the maximum relief to horizontal distances along the longest dimensions of the basin parallel to the principal drainage line is termed as relief ratio. Difference in the elevation between the highest point of basin and lowest point on the valley floor is termed as total relief of that river basin. Schumm (1963) also stated that it is dimensionless height-length ratio equal to the tangent of angle formed by two planes intersecting at the mouth of the basin, one representing the horizontal and other passing through the highest point of the basin. Low value of the relief ratio is mainly due to the resistant basement rocks of the basin and low degree of slope (Mahadevaswamy et al 2011). The ratio normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk 1964). Relief ratio for each watershed is shown in table.2

4.2.3 Relative relief

Relative Relief (Hamnowd 1954and Thaver 1955) also termed as amplitude of relief or local relief which represents actual variation of attitude in a unit area with respect to its local base level..The values of relative relief for the 9 watersheds calculated are shown in table2. The low relative relief is observed in watershed number one and it is high in watershed number 6.

4.2.4 Ruggedness number(Rn)

Ruggedness Number is an indication of efficiency for peak discharge of the basin and indicates the structural complexity of the terrain (Ozdemir and bird 2009). The susceptibility of the area to soil erosion can also be inferred from this number (Rashid et al 2011). High Values are expected on mountainous region with high rainfall (Ritter at al 1995). Rn values are high in fifth, seventh and ninth watershed of the basin.

4.3 Areal Parameter

Drainage density, Stream frequency, Texture ratio ,form Factor, Circulatory Ratio, Elongation ratio Length of overland flow and constant channel maintenance are grouped under areal parameters

4.3.1 Drainage density(Dd)

It is defined as the total length of streams of all orders per drainage area. It is an expression to describe the existing channel closeness in a basin, thus providing a quantitative measure of travel time of water in the whole basin(Horton 1932). The measurement of Dd is a useful numerical measure of landscape dissection, runoff potential, infiltration capacity of the area, vegetation cover and climatic conditions (Chorley 1969). Areas with sparse vegetation are characterized by high drainage density and have large flood peaks and volume. Preferences for sub watershed are based on their decreasing order of drainage density. Regions with highly resistant and permeable surface material, and low relief show low drainage density where as region underlain by weak and less permeable material and with high relief show high drainage density (Girish 2016). Drainage density of watershed varies between 5 to 7. Watersheds number four and five have high Dd which indicates that these regions are having high flood peak and high water yield.

4.3.2 Rho Coefficient

The Rho Coefficient is an important parameter relating to drainage density for the physiographic development of watershed which facilitate evaluation of storage capacity of drainage network and hence ,a determinant of ultimate degree of drainage development in given watershed(Horton 1945).The climatic, geologic, Biologic ,Geomorphologic and anthropogenic factors determine the changes in parameter. The Minimum Rho value is observed in Fourth watershed (0.06) and maximum in seventh watershed (0.39).

4.3.3 Stream frequency (Fs)

Stream Frequency(Fs) is the total number of stream segment of all orders per unit area (Horton 1952). Reddy (2004) stated that low values of stream frequency indicate presence of permeable subsurface material and low relief. Stream frequency for the full river basin is 0.33, watershed wise stream frequency is shown in table1 .Stream frequency mainly depends on the lithology of the basin and reflects the texture of the drainage network. The value of stream frequency for the basin exhibits positive correlation with the drainage density value of the area, indicating the increase in stream population with respect to increase in drainage density (Parveen kumar 2017). Channel frequency density serves as tool in establishing the erosional processes operating over an area to be more specific. Stream orders and their characteristics provides data which can throw light in even on the sequences of relief developments and the degree of ruggedness in the area.

4.3.4 Texture ratio (T)

Texture ratio is an important factor in the drainage morphometric analysis which is depended on the underlying lithology, infiltration capacity and relief aspect of the terrain. It signifies the relative spacing of drainage lines. It is considered as number of streams of basin present per perimeter of that area (Horton 1945). Classification of drainage density into five different textures has been done by Smith (1950). The drainage density of less than 2 indicates very coarse texture, 2 to 4 indicates coarse ,4 to 6 stands for moderate, 6 to 8 is considered as fine and greater than 8 is taken as very fine drainage texture. It is observed that that all the watersheds comes under very coarse texture since all the values of the watershed are below 2(table2). The ratio ranges from 1.2 to 1.8 in watersheds of the basin.

4.3.5Form factor (Rf)

It is the ratio of basin area , to the square of maximum length of the basin (Schumm 1956). It is a dimensionless property and is used as quantitative expression of the shape of the basin (S.K sharma 2017). The form factor value should be always greater than 0.78 to have a perfectly elongated basin. The smaller values will give more elongated basin (Deepak Khare 2014). All the watershed in the basin is having a similar value ranging from 0.2 to 0.3(table 1), which shows that all watersheds in the basin is having a similar shape. Hence all are elongated watersheds.

4.3.6Circulatory ratio (Rc)

Miller (1953) introduced the circulatory ratio to quantify the basin shape. It is the ratio of the watershed area and the area of circle of watershed perimeter. Circulatory ratio is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. The values for circulatory ration for each watershed are given in the table separately. The value ranges from 0.2 to 0.6 . According to the miller range, the watersheds are elongated in shape

4.3.7 Elongation ratio (Re)

According to Schumn(1956), the elongation ratio is an indication of the shape of the basin. Elongation ratio is defined as the ratio of the diameter of a circle having the same area as basin and the maximum basin length. The values of elongation ratio generally varies from 0.6 to 1 over a wide variety of climatic and geologic types. Values close to 1 are typical regions of very low relief whereas values in the range between 0.6 to 0.8 are generally associated with high relief and steep slope (Strahler 1964). It is very a significant index in the analysis of the shape of the basin which helps to give an idea about the hydrological character of the drainage basin. A circular basin is more efficient in the discharge of runoff than an elongated basin. The elongation ratio of 9 watersheds is given in table 2. All the watersheds in the basin is following a similar trend. The values of the watershed are near to 0.6 and hence almost all the watersheds have high relief and steep slope.

4.3.8 Length of overland flow (Lof)

The overland flow and surface runoff are quite different. The overland flow refers to that flow of precipitated water, which moves over land surface leading to the stream channels, while the channel flow reaching the outlet of watershed is referred as surface runoff. The overland flow is dominant smaller watersheds instead of larger watershed (Horton 1945). Watershed number 4 and 5 have maximum (.31) length of overland flow for other watersheds have been calculated and it is given in table 2.

4.3.9 Constant of channel maintenance(C)

Constant of channel maintenance (C) depends on the lithology, permeability, climatic regime, vegetation cover and relief as well as the duration of the erosion. Generally higher the C values of the basin, the higher the permeability of the rocks and vice versa (Subha 2009 ,pakmode 2003). The C values of basin ranges from 1.5 to 1.9 Square/Km. Low C values suggests that the area is associated with lesser length of overland flow and thus water drains quickly as channel flow.

5.CONCLUSION

Morphometric analysis of drainage system is important for doing any hydrological studies. Determination of stream networks behavior and their interrelation with each other is of great importance. Remote sensing data and GIS techniques has proved to be an effective tool in creation of drainage and delineation of basins and watersheds.In the present study morphometric analysis of watersheds of the Bharathapuzha river basin is calculated separately and basin morphometry is derived from that. The morphometric analysis is carried out by measurement of linear, areal and relief aspect of the basin.

- Based on the analysis it is noted that there is not much difference in morphometric values except in some watersheds. Watershed number 5A2B5, 5A2B6 and 5A2B7 ~~has~~ have the highest drainage density, stream frequency, relief, relief ratio and ruggedness number, stream length ratio and lowest bifurcation ratio. These watersheds are characterized by highest surface runoff and erosion.
- The values of form factor, circulatory ratio and elongation ratio suggests that most of the watersheds are elongated and has high basin relief. The maximum stream order frequency is observed in case of first order streams and then for second order streams. Hence it is noted that there is decrease in stream frequency as stream order increases.
- The mean bifurcation ratio of the Bharathapuza basin is 1.52 which indicate the whole basin is less effected by structural control.
- The drainage density value of Bharathapuzha river basin value is around five which reveals that basin is having coarse drainage which reveals that sub surface area is permeable.
- The stream length ratio varies for each area. It may be because of differences in slope and /gradients. The basin has an elongation value of about 0.55.
- Higher values of elongation ratio show high infiltration capacity and low runoff. This present study is valuable for the erosion control, watershed management land and water resource planning and future prospective related to runoff study.

Comment [u9]: The grammatical expressions used in this study still needs to be improved across the paper

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