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Morphometric Analysis using Remote Sensing and GIS

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Abstract—*The objective of this paper is to demonstrate the capabilities of Remote Sensing (RS) and Geographic Information System (GIS) techniques for the morphometric analysis of any ungauged as well as gauged watershed. Remote sensing and GIS have emerged as most powerful tools for morphometric analysis for the development of the regional hydrological models for solving various hydrological problems of the ungauged watershed in inadequate data situations especially for the developing countries like India. The study area is one of the sub-basin of Dwarakeshwar River covering four block of Bankura district of West Bengal. The Gandeshwari watershed expands approximately over 391.7624 Km^2 and it has been divided into 24 micro-watershed (MWS). The morphometric parameters divided into four categories: basic parameter, relief characteristics, drainage network and drainage texture analysis. Basic parameter deals with basin area, basin perimeter, basin length, elongation ratio, form factor and recirculatory ratio. Relief characteristics consists of maximum height of watershed, minimum height of watershed, basin relief, relief ratio, biffurcation ratio and ruggedness number. The third category which is drainage network deals with stream order, stream length and mean stream length. The last category is drainage texture analysis which consists of stream frequency, drainage density, drainage intensity, constant channel of maintenance, length of overland flow and drainage intensity.*

Index Terms*: Remote sensing, GIS, morphometric analysis, Gandeshwari watershed.*

1. INTRODUCTION

In recent years, there has been a marked increase in the level of interest towards watershed management for which we have to understand the morphology of the catchment for better understanding. Morphology factors depends only on the topography of the land forms of which the drainage basin is composed and on the form and extent of the stream-system or drainage net within it [1] .Remote sensing has the ability of obtaining synoptic view of large area and very useful in analyzing the drainage morphometric parameter [2].Many works have been carried out on morphometric analysing using RS and GIS. Sarita et al. (2013) presented their work prioritizing erosion-prone area through morphometric analysis of the Narmada catchment up to Manot is located in Mandla district of Madhya Pradesh having length of River Narmada 269 km and drainage area of 4,884 km^2 [3]. Rajat et al. (2013) have used remote sensing and GIS for identification of artificial recharge sites of Loni watershed having area 1,166 km^2 in the Unnao and Rae Bareli districts of Uttar Pradesh and calculate parameters, namely the bifurcation ratio, elongatin ratio, drainage density, ruggedness number, relief ratio and circulatory ratio were considered as guiding tools for identifying the necessity of selecting a particular type of soil and water conservation structures sub-watershed [4]. Shrudha et al. (2013) uses RS and GIS for estimation of morphometric parameters and runoff of Yagachi catchment situated in Chickamaglur and Hassan district having area 559.493 Km^2 and sub-divided into 20 micro-watershed. He observed the bifurcation ratio is less than 5 indicating that the catchment is structurally controlled and presence of low drainage density suggests that it has it has highly permeable sub-soil and moderate to coarse drainage texture [5].

2. DESCRIPTION OF STUDY AREA

The study of Gandeswari watershed of Bankura district of West Bengal state lies geographically at a latitude 23°30'0"N to 23°32'30"N and longitude 86°54'30"E to 87°07'30"E.It covers the areas about 391.7624 km^2 having perimeter of 128.70568 Km. Fig.1 shows the location map of study area and drainage pattern to understand morphometric process of the catchment at the watershed level. Gandeshwari river is 32 Km of stretch which is flowing south-west of Sushunia hill and north Bankuraand joins Dwarakeshwar river near Bhutsahar. The whole study area is under the Drought Prone Area Programme (DPAP) of the government of India which effects the cultivation of paddy which is major kharif crop of this region due to scarcity of water.

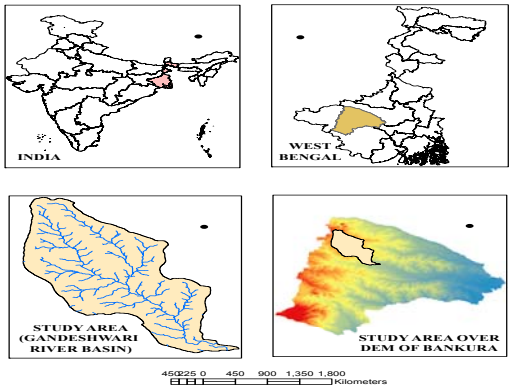

Fig. 1: Location of study area

3. DATA AND METHOD USED

The Gandeshwari watershed is found to be severely afflicted with water scarcity. In the present study, the satellite remote sensing data has been used for updating of drainage and the updated drainages used for morphometric analysis. Topographical map 73I/14, 73 I/15,73 M/3 and 73 M/4 of scale factor 1:50,000 from Survey of India which cover entire study area.

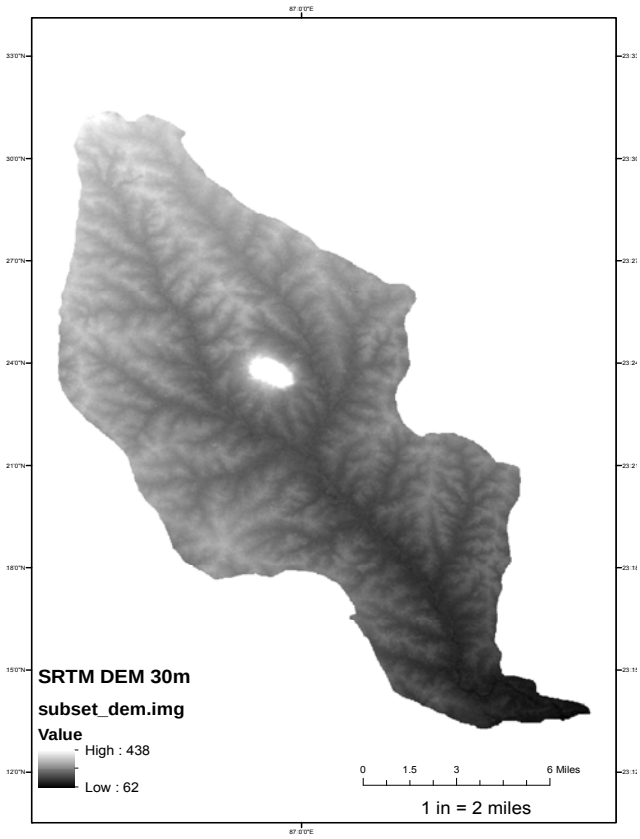

Fig. 2 SRTM 30m DEM of Gandeshwari watershed

The toposheet are geometrically rectified and mosaic. After mosaicking we extract study area by joining first order stream to the outlet of the river. Shuttle Radar Topographic Mission (SRTM) having resolution of 30 m Digital Elevation Model (DEM) is used for morphometric analysis see Fg.2.The software used is TNT mips and ArcGIS for the computation of various morphometric parameters and layout of map. The variation in the elevation of DEM from 62m to 438m.

4. RESULTS AND ANALYSIS

Most of the morphometric parameters are dimensionless which is helpful in analysing the result regardless of scale and also shows the nature of effect on other morphometric parameter. The complete Gandeshwari watershed is divided into 24 micro-watershed for the analysis purpose shows in Fig.3.

Table 1: Formulae for calculation of various morphometric parameter

Sl. No	Parameter	Symbol	Units	Formulae	Reference
1.	Basin Area	A	Km^2	Software analysis	Schumm (1956) [6]
2.	Basin perimeter	P	Km	Software analysis	Schumm (1956) [6]
3.	Basin length	Lb	Km	Software analysis	Schumm (1956) [6]
4.	Elongation Ratio	Re	Dimensionless	Re=2{(A/π) ½}/Lb	Schumm (1956) [6]
5.	Form factor	Ff	Dimensionless	$Ff=A/Lb^2$	Horton (1932) [1]
6.	Circulatory ratio	Rc	Dimensionless	Rc= $4\pi A/(P)^2$	Miller (1953) & Schumm (1956) [7-6]
7.	Maximum height of watershed	Z	m	Software analysis	From DEM
8.	Minimum height of watershed	z	m	Software analysis	From DEM
9.	Basin relief	H	m	H=Z-z	Strahler (1957) [8]
10.	Relief ratio	Rh	Dimensionless	Rh=H/Lb	Schumm (1956) [6]
11.	Biffurcation ratio	Rb	Dimensionless	Rb=Nu/Nu+1	Horton (1945) & Strahler (1964) [9-10]
12.	Ruggedness number	Rn	Dimensionless	Rn=D*H	Melton (1957) [11]
13.	Stream Order	Su	Dimensionless	Hierarchical rank	Strahler (1957) [8]

14.	Stream Length	Lu	Km	Lu=L1+L2+…Ln	Horton (1932) [1]
15.	Mean stream length	Lū	Dimensionless	Lū Lū =Lu/Nu	Strahler (1964) [10]
16	Stream frequency	Fs	Km^{-2}	$\sum \boldsymbol{Nu}/A$	Horton (1932) [1]
17	Drainage density	D	Km/Km^2	$\sum \boldsymbol{Lu}/A$	Horton (1932) [1]
18	Constant channel of maintenance	C	Km^2/Km	C=1/D	Schumm (1956) [6]
19	Length of overland flow	Lg	Km	Lg=A/2* $\sum \boldsymbol{Lu}$	Horton (1945) [9]
20	Drainage intensity	Di	Km^{-1}	Di=Fs/D	Faniran (1968) [12]

a. Basic Parameter

Basin Area (A)

The total drainage area of Gandeshwari watershed is 391.7624 Km^2 and the areas of each watershed are shown in table 2.MWS2 having the smallest watershed area 3.785 Km^2 and MWS1 having largest area 57.01 Km^2.

Basin Perimeter (P)

The perimeter is the total length of the drainage basin boundary [2].The perimeter of Gandeshwari watershed is found to be 128.70568 Km. The length of individual basin boundary is given in table 1.The perimeter varies from 74.153 km to 9.3124 km.

Basin Length (Lb)

The basin length corresponds to the maximum length of the basin and sub-basin measured parallel to the main drainage line [2] .The basin length for each watershed is presented in table 2. MWS3 having maximum basin length and MWS15 having the minimum.

Elongation Ratio (Re)

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 value of Re varies from 0 to 1 i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5) [6].The obtained values of individual MWS is shown in table 2.The values which obtained is less than 0.5 in maximum MWS which means the MWS are elongated which leads to delay in runoff.

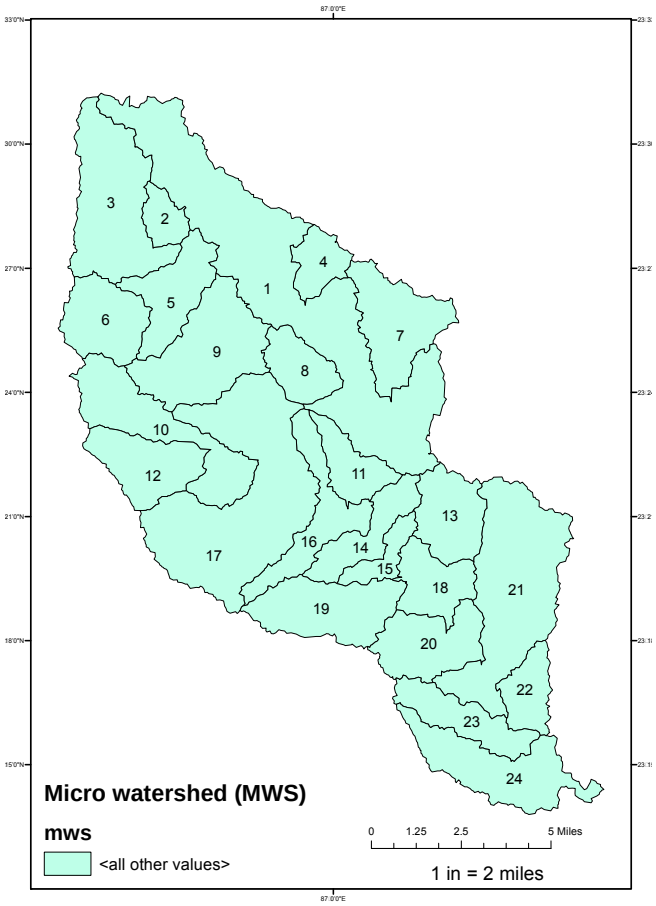

Fig. 3 Micro-watershed (MWS) of Gandeshwari watershed

Table 2: Basic parameter of Gandeshwari watershed

MWS	A (km^2)	P (km)	Lb (Km)	Re	Ff	Rc
1	57.01	74.153	8.811	0.141	0.037	0.13
2	3.785	9.3124	13.73	0.049	0.002	0.548
3	21.72	26.643	16.11	0.044	0.002	0.384
4	5.179	11.537	7.188	0.121	0.022	0.489
5	10.57	19.598	11.21	0.061	0.004	0.346
6	10.68	14.732	12.91	0.056	0.003	0.618
7	13.87	21.799	10.54	0.091	0.017	0.367
8	7.095	12.099	5.269	0.209	0.049	0.609
9	18.79	23.643	9.184	0.092	0.009	0.422
10	16.25	28.571	9.613	0.091	0.009	0.25
11	6.642	14.732	3.738	0.328	0.114	0.384
12	10.93	15.642	9.426	0.076	0.006	0.561
13	9.945	14.933	6.181	0.14	0.028	0.56
14	7.994	18.49	3.681	0.228	0.059	0.294
15	3.843	13.189	3.343	0.25	0.057	0.277
16	11	28.963	5.18	0.232	0.069	0.165
17	39.86	40.517	6.694	0.126	0.017	0.305
18	8.219	16.371	4.454	0.231	0.066	0.385
19	14.23	19.629	7.232	0.111	0.015	0.464
20	11.49	18.704	6.384	0.17	0.031	0.412

21	29.11	34.09	9.334	0.199	0.073	0.315
22	6.107	12.763	12.98	0.06	0.006	0.471
23	8.773	18.908	11.8	0.069	0.006	0.308
24	15.25	28.434	13.43	0.071	0.009	0.237

Form Factor (Ff)

Form factor may be defined as the ratio of basin area to square of the basin length [1].It is dimensionless quantity which is used to describe the different shape of basin. The basins with high form factors 0.114 (MWS11) have high peak flows of shorter duration, whereas, elongated drainage basin with low form factors 0.002 (MWS2 & MWS3) have lower peak flow of longer duration. For individual MWS Ff see table 2.

Recirculatory Ratio (Rc)

Rc is the ratio of area of basin to the area of circle having same circumference as the perimeter of the basin [7]. When Rc value is equal 1.0 shows the basin is perfectly circular in shape having quick runoff and shows narrow peak hydrograph [7]. Rc values varies from 0.13 (MWS1) to 0.618 (MWS6) for different MWS computed in table 2.

b. Relief Characteristics

Maximum and Minimum Height (Z,z)

The maximum and minimum height shows the elevation or nature of the terrain of Gandeshwari watershed. It ranges from 62m to 438m at the top of Shusunia hill and individual watershed height is given in table 3.

Basin Relief (H)

Basin relief is defined as the difference in height between the highest and the lowest points (summit and the mouth) of the basin. The total basin relief is found to be 373m and individual MWS basin relief is given in table 3.

Relief Ratio (Rh)

The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line [6].

The high value of Rh shows the steep slope which indicate high surface run-off , producing more peaked basin discharges and potential erosion effect. For individual MWS see table 3.

Biffurcation Ratio (Rb)

Bifurcation ratio may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order [6].Rb is a dimensionless parameter which also indicate the relief and dissections [9] .The Rb of a river basin is low which is less than 2 ,there is a higher chance of flooding, as the water will be concentrated in one channel rather than spread out. For different MWS Rb values are given see table 3.Lower values of Rb shows there is less structural disturbances which is due to the region is under Chota Nagpur plateau.

Ruggedness number (Rn)

Ruggedness number as the product of maximum basin relief and drainage density [10] .Rn may be based on standard deviation elevation, slope and variability of contour. MWS 18 having low ruggedness value implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density. For individual value of Rn see table 3.The minimum value of Rn suggests that there is low chances of soil erosion.

c. Drainage Network

Stream Order (Su)

The stream order is a dimensionless number, which can be used for comparison of geometry for drainage networks on different linear scale [2].The main stream through which all the discharge of water passes is of order 7^{th}, therefore considered as the stream of highest order. Stream ordering is done for the proper planning of conservation measures in terms of water storage and capacity [2].The stream order is shown in Fig. 4.

Table 3: Relief characteristics of Gandeshwari watershed

MWS	Z	Z	H	Rh	Rb	Rn
1	418	101	317	0.007	1.298	0.125
2	172	132	40	0.002	1.491	0.091
3	196	126	70	0.001	1.251	0.093
4	166	121	45	0.004	1.222	0.104
5	162	119	43	0.002	1.266	0.098
6	169	126	43	0.002	1.424	0.105
7	161	109	52	0.003	1.188	0.095
8	438	109	329	0.03	1.197	0.617
9	163	106	57	0.003	1.285	0.114
10	164	104	60	0.003	1.601	0.113
11	383	98	285	0.021	1.295	0.186
12	161	108	53	0.002	1.342	0.123
13	144	99	45	0.004	1.229	0.53
14	135	88	47	0.007	1.362	0.085
15	126	91	35	0.007	1.491	0.089
16	395	93	302	0.013	1.574	0.197
17	438	96	342	0.008	1.479	0.188
18	130	86	44	0.007	1.382	0.058
19	152	92	60	0.003	1.514	0.097
20	131	82	49	0.005	1.259	0.097
21	139	80	59	0.006	1.387	0.093
22	121	78	43	0.002	1.384	0.073
23	126	76	50	0.002	1.602	0.095
24	122	70	52	0.002	1.374	0.14

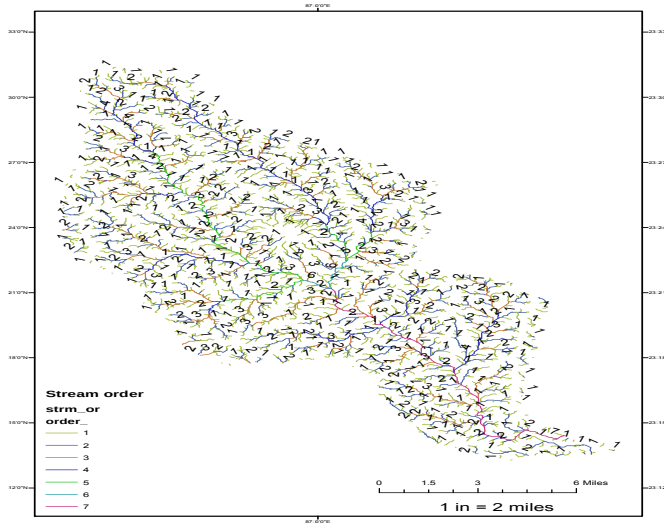

Fig. 4: Stream order map of Gandeshwari watershed

Stream Length (Lu)

It is the length of all streams having order Su [3].The stream length is a dimensional property to understand the characteristic size component of a drainage network. It is noticed that lower stream order having high stream length and higher order stream have low stream length or vice-versa. Stream length of individual stream order is given in table 4.

Mean Stream Length (Lū)

The mean stream length is characteristics property related to the drainage network and its surface feature [10].The lengths of stream segments of up to 7th order are measured and the total length as well as mean stream length (Lū) of each order is computed in table 4.

d. Drainage Texture Analysis

Stream Frequency (Fs)

The analysis of Fs is more important in morphometric parameter calculation. Stream frequency is defined as the number of stream segment per unit area [9].Stream frequency is also referred as channel frequency or drainage frequency. MWS3, MWS9, MWS16, MWS17, MWS22 having moderate stream frequency and the rest are having high stream frequency.

Drainage Density (D)

Drainage density is defined as the ratio of total stream lengths of all orders to area of the basin [1].D is effected by geology, lithology and density of vegetation. Permeable rocks with a high infiltration rate have low drainage density and vice-versa. The difference between very low and very high drainage density is very high which shows there is huge spatial variation. MWS9 having low drainage density which shows there is high permeability and low runoff. MWS24 having high runoff and low permeability which leads to flood due to high drainage density.

Drainage Intensity (Di)

Drainage intensity is defined as the ratio of the stream frequency to the drainage density [12]. With the low values of drainage density, stream frequency and drainage intensity, surface runoff is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides.

For individual MWS see table 5.

Constant channel of maintenance (C)

The reciprocal of drainage density is called constant channel of maintenance [6]. When C=1 basin behaves like circular whereas C>1 indicates more deviation from the circular nature of the basin [13]. Higher value of C shows strong control of lithology with a surface of high permeability.

Table 4: Drainage network characteristics for individual MWS

Drainage Network									
Stream Order (Su) wise stream length (Lu) in km									
MWS	1	2	3	4	5	6	7	Total (Km)	Lū
1	86.12	38.33	21.81	18.29	7.555	0.033		172.1	563.1
2	4.668	2.623	2.485	0.47	0.002			10.25	463.4
3	28.83	12.55	9.837	8.33	1.208			60.75	523.1
4	9.551	3.066	3.563	0.001				16.18	509.2
5	15.4	7.38	2.226	2.282	3.419			30.7	574.6
6	15.91	7.213	7.746	0.408				31.27	534.2
7	22.27	10.5	5.331	3.411	0.003			41.52	527.6
8	15.37	5.608	2.253	0.949	0.003			24.18	560.2
9	26.39	14.4	8.188		4.502			53.48	557
10	21.9	12.32	8.259	2.974	0.002			45.46	456.5
11	10.51	3.999	2.039			3.293	0.002	19.84	617.4
12	13.8	2.254	3.473	4.275				23.8	544.4
13	13.28	7.132	3.803	2.778				26.99	520.7
14	9.37	3.804	5.54				2.205	20.92	499.1
15	4.106	2.934	2.227	0.002			1.554	10.82	584.6

16	17.24	5.128	7.923			1.515	1.132	32.94	563.2
17	65.76	27.16	15.61	1.816	13.05	0.018		123.4	578.1
18	11.55	6.078	1.208	1.842			3.576	24.25	598.7
19	19.85	10.93	5.28	5.51			0.005	41.57	508.7
20	15.39	9.93	5.332	0.559			2.332	33.54	553.1
21	37.97	23.77	10.63	6.691			3.004	82.06	556.6
22	8.408	4.557	3.086				0.619	16.67	527.6
23	13.74	6.011	4.312				1.657	25.72	540.9
24	21.55	13.87	4.355				6.325	46.1	495.6

Length of Overland Flow (Lg)

Horton (1945) used this term to refer to the length of the run off the rainwater on the ground surface before it is localized into definite channels [9]. Lg is one of the most important independent variable hydrologic, hydrographic as well as water required to a certain threshold of erosion. High value of Lg represents long time of flow in the basin. For individual value of Lg see table 5.

Table 5: Drainage texture analysis of Gandeshwari watershed

MWS	Fs	D	Di	C	Lg
1	25.76	17.99	1.43	0.27	0.13
2	10.19	4.45	2.29	0.26	0.13
3	9.46	4.97	1.9	0.3	0.15
4	38.34	28.21	1.36	0.23	0.12
5	10.01	4.51	2.22	0.28	0.14
6	13.49	5.05	2.67	0.49	0.24
7	28.63	10.2	2.81	0.3	0.15
8	10.84	4.88	2.22	0.24	0.12
9	8.62	4.21	2.05	0.28	0.14
10	10.48	4.27	2.45	0.27	0.14
11	11.09	5.02	2.21	0.31	0.16
12	13.67	5.67	2.41	0.47	0.23
13	708.6	228.1	3.11	0.56	0.28
14	18.49	6.97	2.65	0.3	0.15
15	18.18	7.32	2.49	0.26	0.13
16	9.11	4.46	2.04	0.24	0.12
17	9.22	4.34	2.12	0.26	0.13
18	46.24	13.1	3.53	0.24	0.12
19	12.86	5.2	2.48	0.29	0.15
20	14.9	5.69	2.62	0.33	0.17
21	28	12.49	2.24	0.28	0.14
22	9.74	4.6	2.12	0.29	0.14
23	12.83	5.82	2.2	0.26	0.13
24	178.6	73.63	2.43	0.61	0.31

5. CONCLUSION

Remote sensing and GIS technique shows an efficient tools for analysisng morphometric parameter. The study area is under the Chotta Nagpur Plateau therefore the morphometric parameters calculated showing the wide range of variation due to geologically as well as structurally. It is found that the bifurcation ratio is less than 5 which shows the structural disturbance is less. The presence of high drainage density suggests that it has low soil permeability and high surface runoff. Here stream order is found to be 7th order. Minimum stream order have maximum stream length whereas maximum stream order have minimum length.

6. ACKNOWLEDGEMENT

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REFRENCES

[1] R. E. Horton, "Drainage basin characteristics," *Transactions American Geophysical Union*, vol. 13, pp. 350–361, 1932.

[2] Rabu, P. P., & Askaran, R. B. (2013). Drainage Morphometry of Upper Vaigai River Sub-basin , Western Ghats , South India Using Remote Sensing and GIS, *82*(November), 519–528.

[3] Gajbhiye, S., & Ashish, S. K. M. (2014). Prioritizing erosion-prone area through morphometric analysis : an RS and GIS perspective, 51–61. http://doi.org/10.1007/s13201-013-0129-7

[4] Agarwal, R., Garg, P. K., & Garg, R. D. (2013). Remote Sensing and GIS Based Approach for Identification of Artificial Recharge Sites, 2671–2689. http://doi.org/10.1007/s11269-013-0310-7

[5] Shrudha, V. K. (2013). ESTIMATION OF MORPHOMETRIC PARAMETERS AND RUNOFF USING RS & GIS TECHNIQUES, 449–455.

[6] S. A. Schumms, "Evolution of drainage systems and slopes in Badlands at Perth Amboy,New Jersey," *Bulletin of the Geological Society of America*, vol. 67, pp. 597–646, 1956.

[7] Miller VG (1953) A quantitative geomorphic study of the drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Colombia University, Geology Dept., Project NR 389-042, Technical Report No. (3):30

[8] A. Strahler, "Quantitative analysis of watershed geomorphology," *Transactions AmericanGeophysicalUnion*, vol. 38,pp. 913–920, 1957.

[9] R. E. Horton, "Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology," *Geological Society ofAmerica Bulletin*, vol. 56,pp. 275–370, 1945.

[10] A. N. Strahler, "Quantitative geomorphology of drainage basins and channel networks," in *Handbook of Applied Hydrology*, V. T. Chow, Ed., section 4–11, McGraw-Hill, New York, NY, USA, 1964.

[11] Melton MA (1957) An analysis of the relation among elements of climate, surface properties and geomorphology. Technical Office of National Research, project NR Columbia University. 389–642

[12] Faniran, A. *The Index of Drainage Intensity - A Provisional New Drainage Factor.* Australian Journal of Science. 1968. 31; 328-330.