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Application of morphometric analysis of third order basin for geo-hydrological studies using geospatial techniques: A case study of upper catchment of Kumari drainage basin

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Abstract
The study has been carried out in the upper catchment area of Kumari river basin in the eastern part of India. The main aspiration of the study was to examine the linear, areal, and relief aspect of morphometric parameter of third order sub-basin for geo-hydrological studies, with the help of geospatial technology. Here 64 third order basin has been considered for morphometric analysis. Analysis of morphometry of drainage basin plays a significant role to understand the geo-hydrological behaviour of that particular drainage basin. The result has revealed that maximum sub-basin has highest first order stream and it decreases as order increases. Also similar result we show on stream length. From the shape parameters it was revealed that maximum sub-basins were more elongated where value was > 0.5 (R_e = 0.25 to 0.49). The areal and relief parameters have been shown that maximum sub basin has high discharge of runoff in short span of time and impermeable sub-soil, hard rock material condition, moderate to low infiltration capacity, poor groundwater resource. The study exposed that morphometric analysis upon integrated RS & GIS technique is a capable tool for geo-hydrological studies. Also this type of work very useful for planning of groundwater potential areas, watershed management and environmental assessment.

Keywords: morphometric analysis, geo-hydrological, geospatial, kumara river

1. Introduction

Morphometry refers to the mathematical-statistical analysis of configuration of the earth's surface, shape and dimension of its landforms [1, 2]. A basin of morphometric characteristic is fundamental to understand the various hydrological behaviour or process [3]. A river basin is a natural hydrological unit [1]. Therefore, morphometric analysis of a basin is a useful and prefers to get to know the hydrological condition of that particular place. The morphometric analysis of a particular drainage basin is paramount important for hydrological investigation like groundwater management, assessment of groundwater potential and environmental assessment [4]. Geospatial techniques are being increasingly used for analysis of spatial information and morphometric parameters [5] of the drainage basin. Because in recent times this technology known as efficient, rapid tools and provide a flexible environment [5].

The objective of the present study was to examine the linear, areal and relief aspect of morphometric parameter of third order sub-basin of upper catchment area of Kumari river basin in eastern part of India using geo-spatial technology. Here morphometric analysis and GIS give us sagacity of different geo-hydrological characteristics of the third order drainage basin.

2. Materials and Methods

For the fulfilment of present study, we have used topographic maps which nos. were 73 I/4, I/8, I/12 and 73 J/1, J/5, J/9 on the scale 1: 50000. Topographic maps were rectified geographically and whole study area was delineated in GIS environment with the help of ArcGIS 10.2.1 software assigning Universal Transverse Mercator (UTM), World Geodetic System (WGS 1984) and 45N Zone Projection system. We have used conventional techniques of morphometric analysis of different aspects i.e. linear aspect, areal aspect, relief aspect. The drainage network of the basins was digitised from scanned SOI Topographical sheets (refer to above said topographic sheet nos.) and after the digitisation, it was updated from LISS IV MX image and all works done in GIS platform. Here 64th 3rd order basins have been carried out for morphometric analysis using standard mathematical formulae given in the table 1. Present day advance Geographic Information System and current computer technology has been used for assessment of the drainage basin morphometry (See Flow Chart in Fig 1).

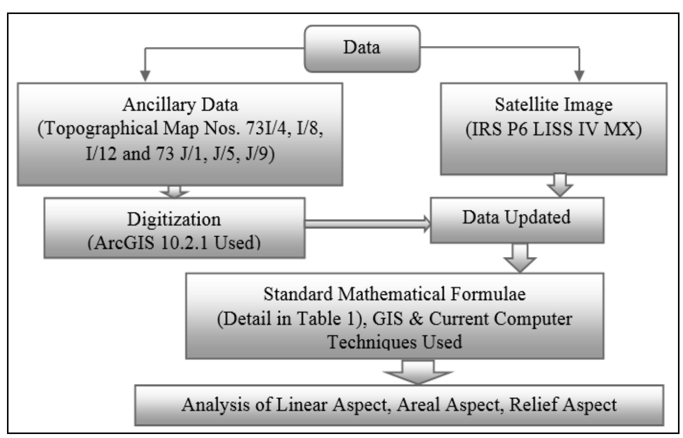

Fig 1: Flow Chart of Methodology (Modified after Mondal, 2013 [6])

2.1 Study Area

The study area was a part of Chhotanagpur plateau [7] and situated in the upper catchment of Kumari River basin which located in part of Baghmundi, Balarampur, Barabazar, Manbazar I, Purulia I blocks of Purulia District, West Bengal and part of Borma and Patmda blocks of Singhbhum District, Jharkhand. The upper catchment of Kumari river basin surrounded by 22° 52' 13.7" N to 23° 14' 7.83" N latitude and 86° 9' 42.46" E to 86° 31' 13.68" E longitude (Fig. 2) and it is covered in the SOI Topographical sheet numbers 73 I/4, 73I/8, 73 I/12 and 73 J/1, 73 J/5, 73J/9 on 1:50000 scale. Total area of the present study is 833sq. km and the perimeter is 157 km.

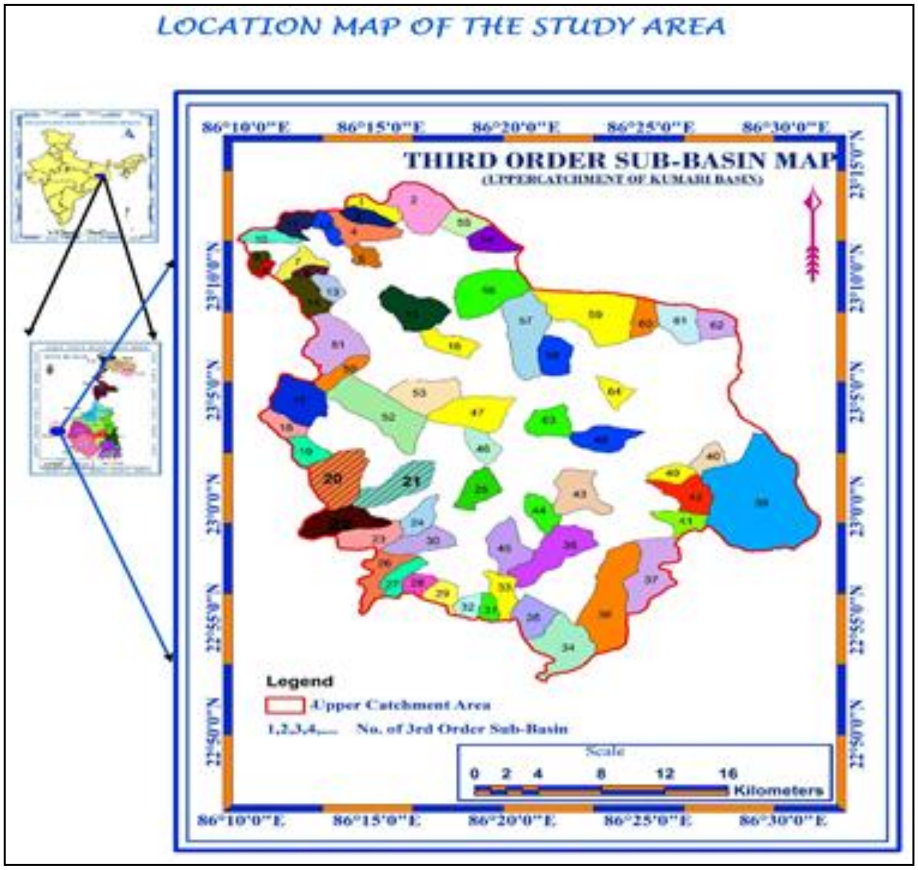

Fig 2: Location Map of the Study Area

Table 1: Morphometric Parameters

Morphometric Parameter	Formula / Definition	Reference
LINEAR ASPECT		
Stream Order (Su)	Hierarchical Rank	[8]
Stream Number (Nu)	Nu =N1+N2....Nn	[9]
Bifurcation Ratio (Rb)	Rb=Nu / Nu+1 Where, Nu denote Number of stream segments present in the given order, Nu+1 denote Number of segments of the next higher order	[8, 10]
Weighted Mean Bifurcation Ratio (Rbw)	Rbw = Rb1 × n1 + Rb2 × n2 + …/ n1 +n2 + …..	[9]
Stream Length (Lu)	Length of the all streams	[8]
Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu denote Mean stream length of a given order (km), Nu denote Number of stream segment.	[9]
Stream lengthRatio (RL)	RL=Lsm/Lsm-1, Lsm denotes mean stream length of one order (u), Lsm-1 denotes the stream length of its next lower order.	[9]
AREAL ASPECT		
Dranage Density (Dd)	Dd= Total length of streams/ Area of basin	[9]
Drainage Frequency (Df)	Df= Total number of stream segment / Area of basin	[9]
Drainage Texture (Dt)	Dt= Number of stream in a given order/perimeter	[9]
Infiltration Number (Dn)	Dn= Drainage Density × Drainage Frequency	[11]
Drainage Intensity (Di)	Di= Drainage Frequency / Drainage Density	[11]
Length of Overland Flow (Lof)	Lof=A/2×Lu or 1/2Dd where, Dd=Drainage density	[9]
Elongation Ratio (R_e)	$R_e= \sqrt{(A/\pi)}/Lb$, where, A=Basin Area, Lb=Maximum basin length	[10]

Circularity Ratio (R_c)	$R_c=4\pi A/P^2$ where, A = Basin area (Km²) and P= Perimeter of the basin(Km)	[12]
Form Factor (R_f)	$R_f = A/Lb^2$ Where, A = Area of the basin and Lb = Maximum basin length	[9]
Shape Index (S_w)	$S_w = Lb^2/A$; where, Lb=Basin length; A=Area of basin	[9]
RELIEF ASPECT		
Relative Relief (H)	Relative Relief=Maximum Altitude − Minimum Altitude	[10]
Relief ratio (Rh)	Rh =H / Lb Where, H=Basin relief, Lb=Max. Basin length	[10]
Ruggedness Number (Rn)	Rn= (Relative Relief × Drainage Density)/K where, K=1000 for km/km²	[10]
Dissection Index (DI)	DI=Relative Relief/Maximum Altitude	[12, 13]
Area	Calculated in GIS	833 km^2
Perimeter	Calculated in GIS	157

3. Results & Discussion

3.1 Linear Aspects

3.1.1 Stream Order (Su) and Stream Length (Lu)

In the present study, hierarchical ranking of stream that means stream order (Su) has been carried out and it was based on the method proposed by Strahler (1964) [8] and stream length (Lu) has been calculated on the method proposed by Horton (1945) and both are delineated with the help of ArcGIS 10.2.1 software. Stream ordering is the first step of the basin morphometry. The study brought out that upper catchment of Kumari river has 7th order river (Fig 4). After field verification and update from LISS IV MX image upper catchment of Kumari basin has 64th third order river. The stream order of the upper catchment of Kumari basin have been calculated according to the stream ordering system by Strahler (1964) [8]. The number of stream segment of the order presented in the table 2. And this table show that the all sub basin has maximum first order stream and it decreases as order increases. Out of the 64th third order basin 39th third order basin has largest stream number (55) and maximum stream length 22.22 km. 18th, 49th, 62nd, 64th (Fig. 3) number sub basin has lowest number of stream. Stream length is a sequential development of stream segments including tectonic trouble [2, 5]. In the 8th number of sub basin has lowest length of stream which was 3.45 km.

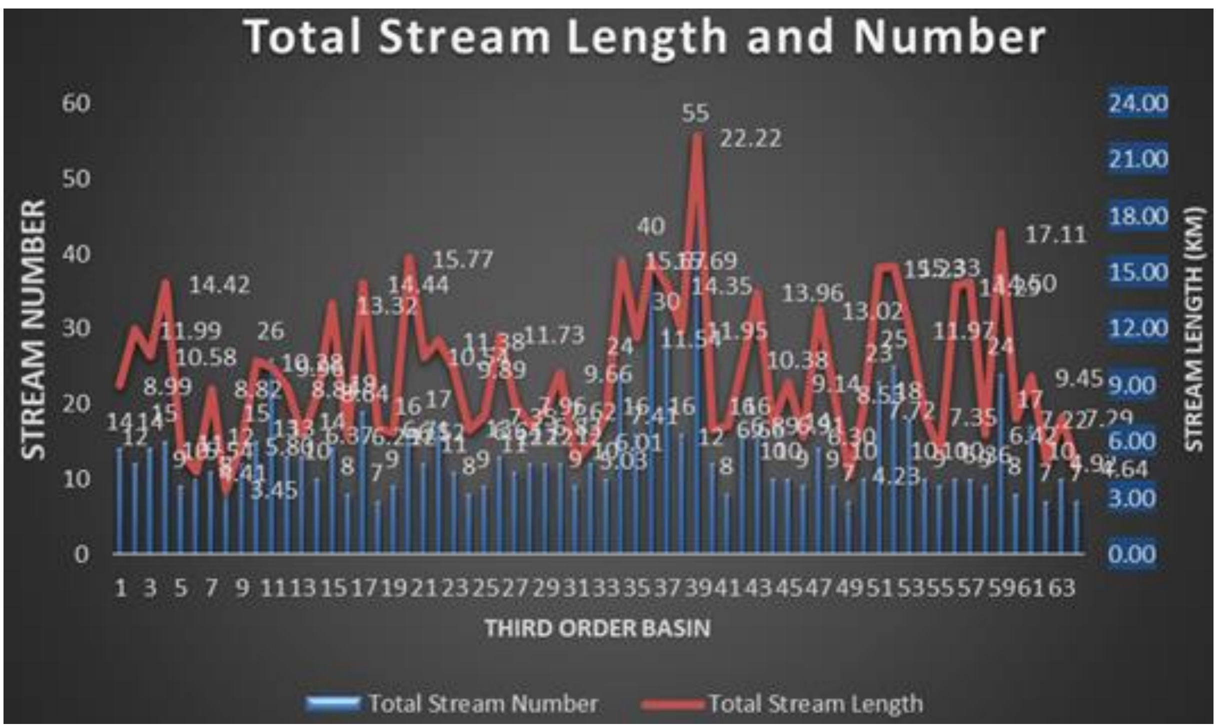

Fig 3: Total stream length and total number of stream of each 3rd order sub basin

3.1.2 Mean stream length (Ls_m)

The mean stream length of a stream has a dimensional aspect which reveals the characteristic size of a drainage network and shape of basin [2, 5, 8, 14]. Mean stream length of Kumari river basin reveals an increasing trend with increasing stream order (Fig. 5). 39th and 36th third order basin has highest value respectively 0.15 to 10.87 and 0.13 to 10.9. Lower value of mean stream length reveals that the higher number of stream segment in that particular order and vice versa. Drainage pattern of the basin area is chiefly dendritic to sub-dendritic.

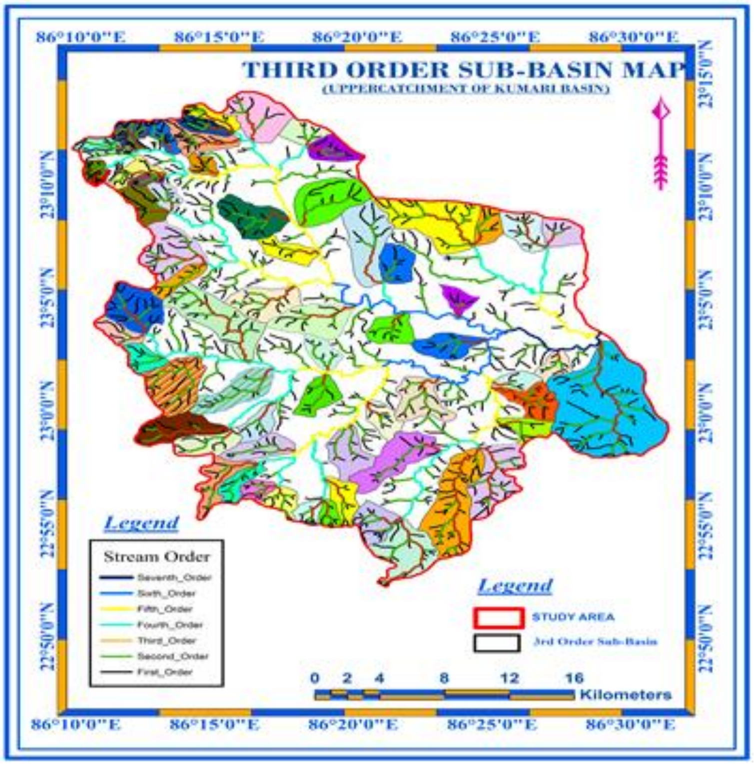

Fig 4: 3rd Order Basin with Drainage Order

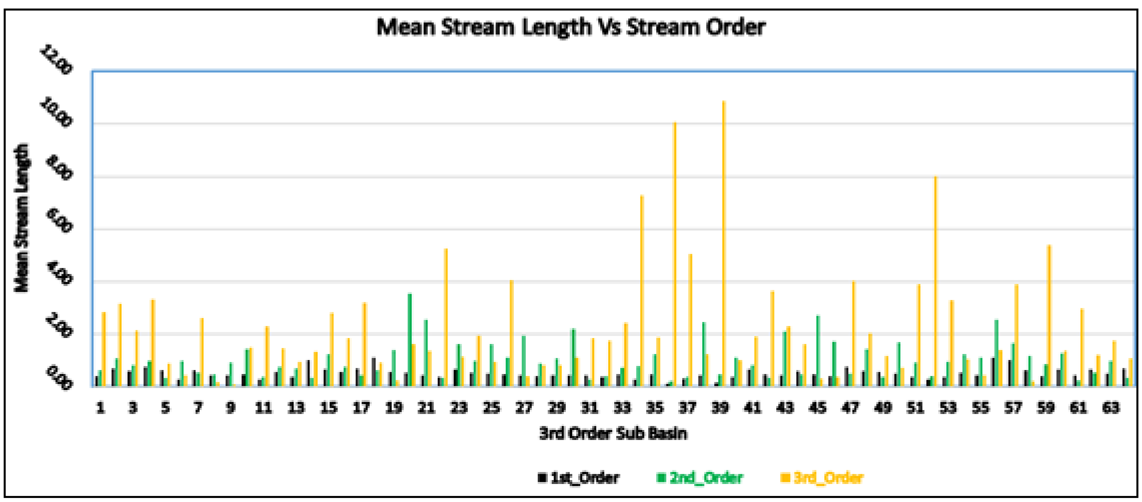

Fig 5: Mean Stream Length Vs Stream Order

3.1.3 Stream Length Ratio (RL)

Stream length ratio is the ratio of the mean stream length of a given order to the mean stream length of next lower order. Stream length ratio has been paramount important relationship with water discharge erosion stage of basin and surface flow [2]. The values of stream length ratio of 64th third order basin was very chaotically. 20th, 30th, 39th, 52th, and 61st number of third order sub basin was high value respectively 6.57 to 0.46, 4.76 to 0.51, 3.05 to 23.42, 1.48 to 19.63, 0.58 to 11.47.

3.1.4 Bifurcation Ratio (Rb) and Weighted Bifurcation Ratio (Rb_w)

Bifurcation ratio is interrelated to the branching pattern of a drainage network. It can be defined as the ratio between the total numbers of stream segment of one order to that of the next higher order in a drainage basin [10]. Low Rb value points out that poor structural disturbance and where the drainage patterns have not been misshapen, where high Rb values point out that high structural complexity and low permeability of the topography [15]. Here different sub basins have different values and maximum third order basin has high Rb value, which indicates that there was potential for flash flood during heavy rainfall. Among the 64th third order sub basin 4th, 7th, 10th, 11th, 17th, 23rd, 30th, 39th, 53rd, 61st has highest value, and respectively 6.00 to 2.00, 4.00 to 2.00, 6.00 to 2.00, 3.17 to 6.00, 2.60 to 5.00, 4.00 to 2.00, 4.50 to 2.00, 4.57 to 7.00, 4.40 to 10.00, 3.25 to 4.00, 3.00 to 4.00 (Table 2); these values indicate that those sub basins have highest potential for flash flood during heavy rainfall.

The weighted bifurcation ratio is an index of the more representative bifurcation ratio for apiece successive pair of orders which get from multiplying the bifurcation ratio for apiece successive pair of stream orders by the total number of streams involved in the ratio and then dividing the sum of these values by the sum of the total number of stream segments involved in apiece pair [8].Weighted bifurcation ratio of sub basin number 4th, 10th, 20th, 34th, 36th, 37th, 38th, 39th value was respectively 5.07, 5.07, 5.53, 4.43, 4.88, 4.14, 5.53, 5.54 (Table 2) these value result indicates mature stage of the sub basin [16].

3.2 Areal Aspect

3.2.1 Drainage Density (Dd)

Drainage density can be defined as the ratio between the total lengths of stream in a particular basin to the total area of that particular basin [9,14]. Drainage density depicts that closeness of the spacing of stream channel. In the upper catchment area were generally high drainage density, also third order sub basin was high drainage density. Among the 64th third order basin, basin number 1st, 3rd, 6th, 8th, 9th, 10th, 11th, 12th has the very high drainage density, that means north western part of the upper catchment area were very high drainage density and rest of the area moderate to low drainage density.

3.2.2 Drainage Frequency (Df) and Drainage Intensity (Di)

According to Horton (1945) drainage frequency is defined as the ratio of the total number of stream segment to the basin area. In the upper catchment area of the Kumari river basin has been laying on hard crystalline rock. In the study area drainage frequencies were very high. North western and western part of the upper catchment area of river basin has highest frequency. Among 64th third order sub basin 1st, 3rd, 5th, 6th, 8th, 9th, 10th, 11th, 12th, 13th, 28th, 29th, 31st, 32nd, 40th number of sub basin has very high drainage frequency and rest of third order basin high to moderate drainage frequency. These higher values of drainage frequency indicate that the sub basins were laying on hard crystalline rock where permeability is low, sloppy topography and higher relief. Owing to impermeable sub surface material the infiltration capacity was low and simultaneously surface runoff was high, drainage frequencies were high.

Drainage intensity denotes to the ratio between the drainage frequency and drainage density [11]. From the table 3, it was observed that drainage intensity value ranges from 0.69 to 2.61.

3.2.3 Drainage Texture (Dt)

Drainage texture is another paramount important drainage parameter as well as unique concept of geomorphology which indicates that the relative spacing of drainage lines [17,2, 14] also depend on a number of physical factors which are relief, rock type, soil type, climate, vegetation, infiltration capacity [17,15,14]. Drainage texture defines as the total number of all streams in given basins to that particular basin perimeter [9]. Drainage texture indicates the underlying rock system and infiltration capacity of basin for these reason drainage texture is a paramount important for morphometric analysis. From the table 3, it was observed that overall drainage texture was high which indicate low infiltration, high relief with very low permeability and among the 64th third order sub basin 3rd, 6th, 8th, 9th, 10th, 11th, 12th,13th, 28th, 36th, 37th, 39th, 40th number of third order basin has been higher value respectively 1.61, 1.74, 1.82, 2.14, 1.61, 2.79, 1.57, 1.69, 1.76, 1.5, 1.90, 1.50.

3.2.4 Infiltration Number (Dn)

Infiltration number can be defined as the outcome of drainage density and drainage frequency production [14]. And we have been known infiltration characteristics of a basin from the result of infiltration number. The higher rate of infiltration number indicates that higher runoff and low infiltration of that particular basin [15]. From the table 3, it was observed that the overall infiltration number was high and among the 64th third order sub-basin, 1st, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 27th, 28th, 29th, 30th, 31st, 32nd, 40th number of sub basin was very high and rest of the sub basin moderate to low. From the analysis of infiltration number, it indicates that the area has impermeable of soil and runoff were high.

3.2.5 Length of Overland Flow (Lof)

Horton's (1945) view on length of overland flow is to the length of the run of the rainwater on the ground surface before it is localized into particular channel. Length of overland flow depends on basin geology, and their climatic condition, vegetation cover and different physiographic features [15]. Sometimes it is just about equal to half the reciprocal of drainage density [18,15] and reciprocally to the average slope of the channel [19]. Length of overland flow is one of the most paramount important autonomous variables which affects both hydrologic and physiographic development of drainage basin [2]. Overall third order sub basin it was observed that the slope was steep to moderate and surface runoff was high. Amon the 64th third order sub basin, 2nd, 15th, 16th, 17th, 20th, 21st, 22nd, 25th, 34th, 36th, 37th, 38th, 39th, 45th, 47th,48th, 49th, 51st, 52nd, 53rd, 55th, 56th, 57th, 58th, 59th, 61st, 62nd, 63rd number basins have very high value respectively 0.47, 0.37, 0.39, 0.37, 0.41, 0.46, 0.40, 0.40, 0.41, 0.63, 0.46, 0.51, 1.04, 0.43, 0.41, 0.39, 0.38, 0.40, 0.54, 0.39, 0.41, 0.46, 0.50, 0.46, 0.54, 0.36, 0.51, 0.40. these values indicate that slopes were steep to moderate and surface runoff was high.

3.2.6 Form Factor (FF)

Form Factor (Ff) refers to the ratio of basin area to the square of basin length and it was proposed by Horton (1945). Form factor always points out the flow intensity of a basin of a defined area [14] and for the perfectly circular basin, the value of form factor is always not more than 0.754 [19]. It was observed that (from table 3) the basin no. 2nd, 5th, 7th, 9th, 13th, 15th, 17th, 19th, 20th, 23rd, 25th, 28th, 29th, 35th, 37th, 39th, 43rd, 51st, 53rd, 55th, 58th, 62nd, 63rd has high value of form factor respectively 0.69, 0.46, 0.57, 0.69, 0.43, 0.43, 0.50, 0.54, 0.45, 0.42, 0.40, 0.49, 0.40, 0.41, 0.65, 0.68, 0.49, 0.48, 0.51, 0.43, 0.67, 0.60, 0.75, 0.61 which was indicated moderately high peak discharge for short duration. Remaining sub basin has moderately less discharge with longer duration.

3.2.7 Elongation Ratio (Re)

The shape or form of the basin area is expressed by elongation ratio [19]. Elongation Ratio refers to the ratio between the perimeter of a circle with the same area as basin and maximum basin length [10]. Elongation ratio can be classified into some groups that is Circular (>0.9), Oval (0.9-0.8), less elongated (0.8-0.7), elongated (0.7-0.5), and more elongated (<0.5). From the table 3, it was observed that all third order sub basins were more elongated in shape. Among the 64th third order basin some sub basins were more elongated such as basin number 1st, 3rd, 21st, 22nd, 24th, 27th, 30th, 33rd, 36th, 50th and the value of such sub basins were respectively 0.28, 0.27, 0.28, 0.29, 0.29, 0.28, 0.29, 0.29, 0.29, 0.27, 0.27.

3.2.8 Circularity Ratio (Rc)

The circularity ratio refers to the ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin, which is spoken by Strahler (1964) [8]. Basically circularity ratio has been used for quantitative analysis and we have been obtained the concept of basin outline, dendritic stage of basin [2]. From the table 3, it was observed that among the 64th third order sub basin Rc value range from 30 to 81 which_indicated that the study area has low permeable hard rock materials.

3.3 Relief Aspect

3.3.1 Relative relief (H)

Relative relief is a paramount important morphometric variable which is used for the whole evaluation of morphological characteristics of terrain [15]. Relative relief refers to the difference in elevation between the highest and the lowest elevation of basin [10]. Relative relief controls the gradient of river basin [20], therefore influence on flood pattern and sediments transportation. From the table 4, it was observed that the maximum sub basin has high relative relief which value was 200m, 240m, 323m, 193m, 300m, 389m, 200m, 162m, 340m, 220m, 260m, 99m, 100m, 142m, 100m, 257m, 340m, 113m, 133m, 60m, 150m, 140m, 60m, 50m, 130m, 70m, 80m, 55m, 51m, 80m, 193m, 55m, 79m, 68m which sub basin no. respectively 1st, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 14th, 18th, 19th, 20th, 21st, 22nd, 26th, 27th, 28th, 29th, 34th, 35th, 37th, 387th, 39th, 40th, 42th, 43th, 48th, 49th, 51st, 52nd, 55th.

3.3.2 Relief Ratio (Rh)

The relief ratio refers to the ratio between the relative relief of the basin and the longest basin length which is alongside to the main river [10]. We can get the concept of overall steepness of a drainage basin for relief ratio [14]. From the table 4, it was observed that most of the sub basin have higher value of relief ratio. In the study area north and north western side of third order sub basin has maximum relief ratio respectively sub basins no. 1st, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 14th, 26th, 28th, 35th and value was respectively 54.05, 62.18, 72.26, 81.09, 123.46, 150.19, 125.00, 115.71, 83.33,81.78,83.87, 94.49, 76.23, 55.19, 44.03. High value of ratio means higher degree of slope and high runoff consequently high soil erosion.

3.3.3 Ruggedness Number (Rn)

Ruggedness number can be defined as the product of relative relief and drainage density and divided by 1000 (where contour interval in meter) [10]. Ruggedness number was used to measure the flash flood potential of a stream [21] and a measurement of surface unevenness [16]. Among the 64th third order basin ruggedness number ranges from 0.02 to 1.06 (Details in table 4) which expresses that surface was uneven.

3.3.4 Dissection Index (DI)

Dissection index is calculated as the ratio between relative relief and maximum altitude [12,13]. Dissection index expresses the erosional potentiality within a river basin [22]. Dissection index determine vertical erosion and expounded the stage of landscape development [23]. Among the 64th third order basin dissection index value ranges from 0.08 to 0.58 which express the third order sub basin was moderate to high dissected.

4. Conclusion

The quantitative analysis of a drainage basin is to be immense utility in geo-hydrological studies. Geospatial based approach facilitates analysis of different morphometric parameters and also explores relationship among the drainage basin morphometry and allied aspects. The result revealed that GIS software’s have the capability in morphometric analysis and through morphometric analysis it has the capability in geo-hydrological analysis. The upper catchment of Kumari river basin has 7th order stream. This whole basin has passed through the mature stage of fluvial cycle. The stream of 64th third order basin has very much affected by south west monsoonal rainfall. Among the 64th third order basin D_d values indicates that the nature of sub-surface strata has impermeable and hard rock material. Here drainage density ranges from 0.48 (only 36th number basin) to 3.72 and maximum sub-basin were high value. 64th third order sub basins D_t, D_n, D_i value revealed that high runoff and low infiltration capacity. R_b values of 64th third order sub basins indicate that highest potentialities for flash flooding during heavy rainfall. R_n values of 64th third order sub-basin expressed that surface was uneven in the study area. Relative relief and relief ratio values of 64th third order sub basin was quite high which means higher degree of slope and high runoff and consequently high soil erosion and sediments transportation. As per the higher degree of slope, infiltration opportunity during rainfall was less and consequently groundwater condition was poor. Hence from the study it has been proved that geospatial technology has competent tool in morphometric analysis and this type of study is useful for management and planning of drainage basin.

5. Acknowledgement

From the core of our heart, we are very much thankful to University Grants Commission (UGC) for providing us the required fund.

Table 2: Linear aspect of the 3rd order basin in upper catchment of Kumari River Basin

3rd Order Basin No.	Stream Order (Su)				Stream Length (Lu) in km				Bifurcation Ratio (Rb)		Weighted Bifurcation Ratio (Rbw)	Mean Stream Length (Lsm)			Stream Length Ratio (RL)	
	1st	2nd	3rd	Total	1st	2nd	3rd	Total				1st	2nd	3rd		
1	10	3	1	14	4.21	1.95	2.84	8.99	3.33	3.00	3.02	0.42	0.65	2.84	1.55	4.36
2	8	3	1	12	5.62	3.22	3.16	11.99	2.67	3.00	2.53	0.70	1.07	3.16	1.53	2.94
3	10	3	1	14	5.96	2.48	2.14	10.58	3.33	3.00	3.02	0.60	0.83	2.14	1.39	2.59
4	12	2	1	15	9.11	2.00	3.31	14.42	6.00	2.00	5.07	0.76	1.00	3.31	1.31	3.32
5	6	2	1	9	3.93	0.72	0.89	5.54	3.00	2.00	2.44	0.65	0.36	0.89	0.55	2.47
6	7	2	1	10	2.01	1.95	0.45	4.41	3.50	2.00	2.85	0.29	0.98	0.45	3.40	0.46
7	8	2	1	11	5.09	1.10	2.62	8.82	4.00	2.00	3.27	0.64	0.55	2.62	0.87	4.74
8	5	2	1	8	2.30	0.98	0.18	3.45	2.50	2.00	2.06	0.46	0.49	0.18	1.06	0.36
9	9	2	1	12	3.88	1.83	0.10	5.80	4.50	2.00	3.71	0.43	0.91	0.10	2.12	0.11
10	12	2	1	15	5.89	2.88	1.51	10.28	6.00	2.00	5.07	0.49	1.44	1.51	2.93	1.05
11	19	6	1	26	5.40	2.27	2.29	9.96	3.17	6.00	3.70	0.28	0.38	2.29	1.33	6.05
12	9	3	1	13	5.04	2.33	1.47	8.84	3.00	3.00	2.77	0.56	0.78	1.47	1.39	1.89
13	9	3	1	13	3.34	2.07	0.95	6.37	3.00	3.00	2.77	0.37	0.69	0.95	1.86	1.38
14	6	3	1	10	6.19	1.10	1.35	8.64	2.00	3.00	2.10	1.03	0.37	1.35	0.36	3.67
15	10	3	1	14	6.74	3.76	2.82	13.32	3.33	3.00	3.02	0.67	1.25	2.82	1.86	2.25
16	5	2	1	8	2.92	1.52	1.85	6.29	2.50	2.00	2.06	0.58	0.76	1.85	1.30	2.43
17	13	5	1	19	8.97	2.26	3.21	14.44	2.60	5.00	3.09	0.69	0.45	3.21	0.65	7.12
18	4	2	1	7	4.51	1.27	0.93	6.71	2.00	2.00	1.71	1.13	0.63	0.93	0.56	1.48
19	6	2	1	9	3.44	2.81	0.27	6.52	3.00	2.00	2.44	0.57	1.41	0.27	2.45	0.19
20	13	2	1	16	7.03	7.11	1.62	15.77	6.50	2.00	5.53	0.54	3.55	1.62	6.57	0.46
21	9	2	1	12	4.06	5.10	1.37	10.54	4.50	2.00	3.71	0.45	2.55	1.37	5.66	0.54
22	12	4	1	17	4.74	1.37	5.27	11.38	3.00	4.00	3.06	0.40	0.34	5.27	0.87	15.33
23	8	2	1	11	5.46	3.27	1.16	9.89	4.00	2.00	3.27	0.68	1.64	1.16	2.40	0.71
24	5	2	1	8	2.70	1.99	1.95	6.64	2.50	2.00	2.06	0.54	1.00	1.95	1.84	1.96
25	6	2	1	9	3.16	3.24	0.96	7.35	3.00	2.00	2.44	0.53	1.62	0.96	3.07	0.59
3rd Order Basin No	Stream Order (Su)				Stream Length (Lu) in km				Bifurcation Ratio (Rb)		Weighted Bifurcation Ratio (Rbw)	Mean Stream Length (Lsm)			Stream Length Ratio (RL)	
	1st	2nd	3rd	Total	1st	2nd	3rd	Total				1st	2nd	3rd		
26	9	3	1	13	4.32	3.34	4.07	11.73	3.00	3.00	2.77	0.48	1.11	4.07	2.32	3.66
27	8	2	1	11	3.66	3.90	0.40	7.96	4.00	2.00	3.27	0.46	1.95	0.40	4.26	0.21
28	8	3	1	12	3.34	2.67	0.82	6.83	2.67	3.00	2.53	0.42	0.89	0.82	2.13	0.93
29	8	3	1	12	3.57	3.23	0.82	7.62	2.67	3.00	2.53	0.45	1.08	0.82	2.41	0.77
30	9	2	1	12	4.15	4.39	1.13	9.66	4.50	2.00	3.71	0.46	2.19	1.13	4.76	0.51
31	6	2	1	9	2.64	0.54	1.84	5.03	3.00	2.00	2.44	0.44	0.27	1.84	0.62	6.79
32	8	3	1	12	3.00	1.23	1.77	6.01	2.67	3.00	2.53	0.38	0.41	1.77	1.10	4.30
33	6	3	1	10	2.80	2.19	2.42	7.41	2.00	3.00	2.10	0.47	0.73	2.42	1.57	3.31
34	19	4	1	24	5.19	3.18	7.29	15.67	4.75	4.00	4.43	0.27	0.80	7.29	2.91	9.16
35	12	3	1	16	5.91	3.73	1.89	11.54	4.00	3.00	3.56	0.49	1.24	1.89	2.53	1.52
36	32	7	1	40	4.01	1.59	10.09	15.69	4.57	7.00	4.88	0.13	0.23	10.09	1.81	44.44
37	23	6	1	30	7.07	2.23	5.06	14.35	3.83	6.00	4.14	0.31	0.37	5.06	1.21	13.62
38	13	2	1	16	5.76	4.95	1.24	11.95	6.50	2.00	5.53	0.44	2.47	1.24	5.59	0.50
39	44	10	1	55	6.71	4.64	10.87	22.22	4.40	10.00	5.34	0.15	0.46	10.87	3.05	23.42
40	9	2	1	12	3.44	2.21	1.02	6.66	4.50	2.00	3.71	0.38	1.10	1.02	2.89	0.92
41	5	2	1	8	3.32	1.66	1.91	6.89	2.50	2.00	2.06	0.66	0.83	1.91	1.25	2.31
42	11	4	1	16	5.30	1.42	3.66	10.38	2.75	4.00	2.89	0.48	0.35	3.66	0.74	10.33
43	12	3	1	16	5.32	6.36	2.29	13.96	4.00	3.00	3.56	0.44	2.12	2.29	4.78	1.08
44	7	2	1	10	4.29	0.98	1.64	6.91	3.50	2.00	2.85	0.61	0.49	1.64	0.80	3.33
45	7	2	1	10	3.35	5.47	0.32	9.14	3.50	2.00	2.85	0.48	2.73	0.32	5.71	0.12
46	6	2	1	9	2.42	3.48	0.39	6.30	3.00	2.00	2.44	0.40	1.74	0.39	4.31	0.23
47	9	4	1	14	6.95	2.04	4.03	13.02	2.25	4.00	2.59	0.77	0.51	4.03	0.66	7.91
48	6	2	1	9	3.61	2.86	2.05	8.53	3.00	2.00	2.44	0.60	1.43	2.05	2.37	1.44
49	4	2	1	7	2.27	0.77	1.18	4.23	2.00	2.00	1.71	0.57	0.39	1.18	0.68	3.07
50	7	2	1	10	3.60	3.39	0.73	7.72	3.50	2.00	2.85	0.51	1.69	0.73	3.29	0.43
51	17	5	1	23	6.67	4.67	3.89	15.23	3.40	5.00	3.60	0.39	0.93	3.89	2.38	4.17
52	19	5	1	25	5.24	2.05	8.04	15.33	3.80	5.00	3.89	0.28	0.41	8.04	1.48	19.63
3rd Order	Stream Order (Su)				Stream Length (Lu) in km				Bifurcation Ratio		Weighted Bifurcation	Mean Stream Length (Lsm)			Stream Length Ratio (RL)	

Basin No	1st	2nd	3rd	Total	1st	2nd	3rd	Total	(Rb)		Ratio (Rbw)	1st	2nd	3rd		
53	13	4	1	18	4.89	3.78	3.30	11.97	3.25	4.00	3.24	0.38	0.94	3.30	2.51	3.50
54	7	2	1	10	3.82	2.47	1.06	7.35	3.50	2.00	2.85	0.55	1.24	1.06	2.27	0.86
55	6	2	1	9	2.70	2.21	0.45	5.36	3.00	2.00	2.44	0.45	1.10	0.45	2.45	0.41
56	7	2	1	10	7.78	5.10	1.40	14.29	3.50	2.00	2.85	1.11	2.55	1.40	2.29	0.55
57	7	2	1	10	7.26	3.34	3.90	14.50	3.50	2.00	2.85	1.04	1.67	3.90	1.61	2.34
58	6	2	1	9	3.81	2.39	0.21	6.42	3.00	2.00	2.44	0.64	1.19	0.21	1.88	0.18
59	18	5	1	24	7.38	4.31	5.42	17.11	3.60	5.00	3.74	0.41	0.86	5.42	2.10	6.29
60	5	2	1	8	3.31	2.54	1.36	7.22	2.50	2.00	2.06	0.66	1.27	1.36	1.92	1.07
61	12	4	1	17	5.42	1.04	2.98	9.45	3.00	4.00	3.06	0.45	0.26	2.98	0.58	11.47
62	4	2	1	7	2.64	1.07	1.20	4.92	2.00	2.00	1.71	0.66	0.54	1.20	0.81	2.24
63	7	2	1	10	3.57	1.98	1.75	7.29	3.50	2.00	2.85	0.51	0.99	1.75	1.94	1.77
64	4	2	1	7	2.84	0.70	1.10	4.64	2.00	2.00	1.71	0.71	0.35	1.10	0.49	3.12

Table 3: Areal aspect of 3rd Order Basin in the upper catchment of Kumari River Basin

3rd Order Basin No.	**Area (A) In Sq. KM**	**Perimeter (P) In KM**	**Maximum Basin length (Lb) In KM**	**Drainage Density (Dd)**	**Drainage Frequency (Df)**	**Drainage Texture (Dt)**	**Infiltration Number (Dn)**	**Drainage Intensity (Di)**	**Length of Overland Flow (Lof)**	**Form Factor (Ff)**	**Elongation Ratio (Re)**	**Circularity Ratio (Rc)**	**Shape Index (Sw)**
1	3.43	9.86	3.7	2.62	4.08	1.42	10.71	1.56	0.19	0.25	0.28	0.44	3.99
2	11.37	13.93	4.06	1.05	1.06	0.86	1.11	1.00	0.47	0.69	0.47	0.74	1.45
3	3.32	8.70	3.86	3.19	4.22	1.61	13.46	1.32	0.16	0.22	0.27	0.55	4.49
4	6.27	13.42	4.47	2.30	2.39	1.12	5.50	1.04	0.22	0.31	0.32	0.44	3.19
5	2.58	6.73	2.38	2.15	3.49	1.34	7.49	1.62	0.23	0.46	0.38	0.71	2.20
6	1.62	5.75	2.43	2.73	6.19	1.74	16.90	2.27	0.18	0.27	0.30	0.61	3.66
7	3.84	10.76	2.59	2.29	2.86	1.02	6.56	1.25	0.22	0.57	0.43	0.42	1.74
8	1.12	4.40	1.6	3.07	7.12	1.82	21.88	2.32	0.16	0.44	0.37	0.73	2.28
9	1.56	5.60	1.5	3.72	7.69	2.14	28.63	2.07	0.13	0.69	0.47	0.62	1.44
10	3.30	9.29	4.08	3.12	4.55	1.61	14.18	1.46	0.16	0.20	0.25	0.48	5.05
11	3.98	9.31	2.69	2.50	6.53	2.79	16.34	2.61	0.20	0.55	0.42	0.58	1.82
12	2.92	8.30	3.1	3.03	4.45	1.57	13.49	1.47	0.17	0.30	0.31	0.53	3.29
13	3.11	7.57	2.68	2.04	4.17	1.72	8.54	2.04	0.24	0.43	0.37	0.68	2.31
14	5.58	10.78	3.81	1.55	1.79	0.93	2.78	1.16	0.32	0.38	0.35	0.60	2.60
15	9.77	13.05	4.75	1.36	1.43	1.07	1.96	1.05	0.37	0.43	0.37	0.72	2.31
16	4.85	10.23	4.05	1.30	1.65	0.78	2.14	1.27	0.39	0.30	0.31	0.58	3.38
17	10.66	13.17	4.62	1.35	1.78	1.44	2.41	1.32	0.37	0.50	0.40	0.77	2.00
18	3.80	8.69	3.28	1.77	1.84	0.81	3.25	1.04	0.28	0.35	0.34	0.63	2.83
19	4.17	8.72	2.78	1.56	2.16	1.03	3.38	1.38	0.32	0.54	0.41	0.69	1.85
20	12.92	14.76	5.36	1.22	1.24	1.08	1.51	1.01	0.41	0.45	0.38	0.74	2.22
21	9.68	14.84	6.31	1.09	1.24	0.81	1.35	1.14	0.46	0.24	0.28	0.55	4.11
22	9.14	14.34	5.93	1.25	1.86	1.19	2.32	1.49	0.40	0.26	0.29	0.56	3.85
23	6.49	11.61	3.95	1.52	1.69	0.95	2.58	1.11	0.33	0.42	0.36	0.61	2.40
24	4.46	10.11	4.15	1.49	1.79	0.79	2.67	1.20	0.34	0.26	0.29	0.55	3.86
3rd Order Basin No.	Area (A) In Sq. KM	Perimeter (P) In KM	Maximum Basin length (Lb) In KM	Drainage Density (Dd)	Drainage Frequency (Df)	Drainage Texture (Dt)	Infiltration Number (Dn)	Drainage Intensity (Di)	Length of Overland Flow (Lof)	Form Factor (Ff)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Shape Index (Sw)
25	5.81	10.45	3.81	1.27	1.55	0.86	1.96	1.22	0.40	0.40	0.36	0.67	2.50
26	6.90	16.94	4.46	1.70	1.88	0.77	3.20	1.11	0.29	0.35	0.33	0.30	2.88
27	4.12	10.69	4.07	1.93	2.67	1.03	5.16	1.38	0.26	0.25	0.28	0.45	4.02
28	2.87	7.12	2.41	2.38	4.19	1.69	9.98	1.76	0.21	0.49	0.40	0.71	2.03
29	3.73	8.97	3.07	2.04	3.22	1.34	6.58	1.57	0.24	0.40	0.35	0.58	2.53
30	6.29	11.54	4.86	1.54	1.91	1.04	2.93	1.24	0.33	0.27	0.29	0.59	3.76
31	2.38	6.40	2.41	2.11	3.78	1.41	7.97	1.79	0.24	0.41	0.36	0.73	2.44
32	2.69	6.83	2.49	2.23	4.46	1.76	9.95	2.00	0.22	0.43	0.37	0.72	2.30
33	4.97	11.25	4.28	1.49	2.01	0.89	3.00	1.35	0.34	0.27	0.29	0.49	3.69
34	12.87	17.54	5.74	1.22	1.87	1.37	2.27	1.53	0.41	0.39	0.35	0.53	2.56
35	6.56	11.00	3.18	1.76	2.44	1.46	4.30	1.39	0.28	0.65	0.45	0.68	1.54
36	19.83	22.79	9.45	0.79	2.02	1.76	1.60	2.55	0.63	0.22	0.27	0.48	4.50
37	13.09	19.29	4.4	1.10	2.29	1.56	2.51	2.09	0.46	0.68	0.46	0.44	1.48
38	12.10	17.64	6.19	0.99	1.32	0.91	1.31	1.34	0.51	0.32	0.32	0.49	3.17

39	46.11	29.01	9.72	0.48	1.19	1.90	0.57	2.48	1.04	0.49	0.39	0.69	2.05
40	3.49	8.02	2.99	1.91	3.44	1.50	6.58	1.80	0.26	0.39	0.35	0.68	2.56
41	4.40	10.29	3.63	1.56	1.82	0.78	2.84	1.16	0.32	0.33	0.33	0.52	2.99
42	7.11	13.49	4.92	1.46	2.25	1.19	3.28	1.54	0.34	0.29	0.31	0.49	3.40
43	9.04	14.12	4.35	1.54	1.77	1.13	2.73	1.15	0.32	0.48	0.39	0.57	2.09
44	4.56	9.31	3.61	1.52	2.19	1.07	3.33	1.45	0.33	0.35	0.33	0.66	2.86
45	7.94	12.78	4.81	1.15	1.26	0.78	1.45	1.09	0.43	0.34	0.33	0.61	2.91
46	4.22	8.41	3.37	1.49	2.13	1.07	3.18	1.43	0.34	0.37	0.34	0.75	2.69
47	10.64	14.19	5.84	1.22	1.32	0.99	1.61	1.08	0.41	0.31	0.32	0.66	3.20
48	6.59	11.40	4.84	1.29	1.37	0.79	1.77	1.06	0.39	0.28	0.30	0.64	3.56
49	3.22	7.65	3.12	1.31	2.17	0.92	2.85	1.66	0.38	0.33	0.32	0.69	3.02
50	4.08	9.97	4.21	1.89	2.45	1.00	4.65	1.29	0.26	0.23	0.27	0.52	4.35
3rd Order Basin No.	Area (A) In Sq. KM	Perimeter (P) In KM	Maximum Basin length (Lb) In KM	Drainage Density (Dd)	Drainage Frequency (Df)	Drainage Texture (Dt)	Infiltration Number (Dn)	Drainage Intensity (Di)	Length of Overland Flow (Lof)	Form Factor (Ff)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Shape Index (Sw)
51	12.16	16.04	4.88	1.25	1.89	1.43	2.37	1.51	0.40	0.51	0.40	0.59	1.96
52	16.70	19.61	7.58	0.92	1.50	1.28	1.37	1.63	0.54	0.29	0.30	0.55	3.44
53	9.35	12.82	4.65	1.28	1.93	1.40	2.47	1.50	0.39	0.43	0.37	0.71	2.31
54	4.88	9.21	3.69	1.51	2.05	1.09	3.09	1.36	0.33	0.36	0.34	0.72	2.79
55	4.41	8.82	2.57	1.21	2.04	1.02	2.48	1.68	0.41	0.67	0.46	0.71	1.50
56	13.17	14.32	5.39	1.08	0.76	0.70	0.82	0.70	0.46	0.45	0.38	0.81	2.21
57	14.42	17.84	6.44	1.01	0.69	0.56	0.70	0.69	0.50	0.35	0.33	0.57	2.88
58	5.93	9.44	3.14	1.08	1.52	0.95	1.64	1.40	0.46	0.60	0.44	0.84	1.66
59	18.39	19.83	7.46	0.93	1.30	1.21	1.21	1.40	0.54	0.33	0.32	0.59	3.03
60	4.33	8.95	3.4	1.67	1.85	0.89	3.07	1.11	0.30	0.37	0.35	0.68	2.67
61	6.85	10.75	4.2	1.38	2.48	1.58	3.42	1.80	0.36	0.39	0.35	0.74	2.58
62	5.01	8.93	2.59	0.98	1.40	0.78	1.37	1.42	0.51	0.75	0.49	0.79	1.34
63	5.82	9.65	3.1	1.25	1.72	1.04	2.15	1.37	0.40	0.61	0.44	0.78	1.65
64	3.13	8.44	3	1.48	2.24	0.83	3.32	1.51	0.34	0.35	0.33	0.55	2.88

Table 4: Relief Aspect of 3rd Order Basin in upper catchment of Kumari River basin

3rd Order Basin No.	Relative Relief (H)	Relief Ratio (Rh)	Ruggedness Number (Rn)	Dissection Index (DI)
1	200	54.05	0.52	0.43
2	40	9.85	0.04	0.14
3	240	62.18	0.77	0.48
4	323	72.26	0.74	0.55
5	193	81.09	0.41	0.45
6	300	123.46	0.82	0.52
7	389	150.19	0.89	0.58
8	200	125.00	0.61	0.31
9	162	115.71	0.60	0.27
10	340	83.33	1.06	0.55
11	220	81.78	0.55	0.41
12	260	83.87	0.79	0.48
13	20	7.46	0.04	0.07
14	360	94.49	0.56	0.56
15	26	5.47	0.04	0.10
16	20	4.94	0.03	0.08
17	36	7.79	0.05	0.12
18	99	30.18	0.17	0.28
19	100	35.97	0.16	0.28
20	142	26.49	0.17	0.37
21	100	15.85	0.11	0.33
22	257	43.34	0.32	0.49
23	46	11.65	0.07	0.15
24	50	12.05	0.07	0.17
25	25	6.56	0.03	0.10
26	340	76.23	0.58	0.56
27	113	27.76	0.22	0.30
28	133	55.19	0.32	0.35
29	60	19.54	0.12	0.19
30	30	6.17	0.05	0.10

31	30	12.45	0.06	0.11
32	40	16.06	0.09	0.13
33	30	7.01	0.04	0.10
34	150	26.13	0.18	0.37
35	140	44.03	0.25	0.34
36	20	2.12	0.02	0.08
3rd Order Basin No.	Relative Relief (H)	Relief Ratio (Rh)	Ruggedness Number (Rn)	Dissection Index (DI)
37	60	13.64	0.07	0.21
38	50	8.08	0.05	0.18
39	130	13.37	0.06	0.39
40	70	23.41	0.13	0.26
41	20	5.51	0.03	0.08
42	80	16.26	0.12	0.29
43	55	12.64	0.08	0.22
44	36	9.97	0.05	0.14
45	40	8.32	0.05	0.14
46	20	5.93	0.03	0.08
47	25	4.28	0.03	0.10
48	51	10.54	0.07	0.22
49	80	25.64	0.10	0.29
50	22	5.23	0.04	0.08
51	193	39.55	0.24	0.43
52	55	7.26	0.05	0.19
53	20	4.30	0.03	0.08
54	20	5.42	0.03	0.08
55	79	30.74	0.10	0.23
56	30	5.57	0.03	0.11
57	40	6.21	0.04	0.15
58	20	6.37	0.02	0.08
59	68	9.12	0.06	0.25
60	20	5.88	0.03	0.08
61	40	9.52	0.06	0.17
62	20	7.72	0.02	0.09
63	20	6.45	0.03	0.09
64	20	6.67	0.03	0.09

6. References

1. Altaf F, Meraj G, Romshoo SA. Morphometric Analysis to Infer Hydrological Behavior of Lidder Watershed, Western Himalaya, India. Geogr J. 2013, 1-14. doi:http://dx.doi.org/10.1155/2013/178021.
2. Ahmad Hajam R, Hamid A, Ahmad Dar N, Ullah Bhat S. Morphometric analysis of vishav drainage basin using geo-spatial technology (GST). Int Res J Geol Min. 2013; 3(3):2276-6618. http://www.interesjournals.org/.
3. Martins AK, Gadiga BL. Hydrological and Morphometric Analysis of Upper Yedzaram Catchment of Mubi in Adamawa State, Nigeria. Using Geographic Information System (GIS). World Environ. 2015; 5(2):63-69. doi:10.5923/j.env.20150502.03.
4. Sreedevi PD, Owais S, Khan HH, Ahmed S. Morphometric analysis of a watershed of south India using SRTM data and GIS Morphometric Analysis of a Watershed of South India Using SRTM Data and GIS. Journa Geol Soc India. 2009; 73(4):543-552. doi:10.1007/s12594-009-0038-4.
5. Aadil Hamid RAH, Hamid A, Bhat S. Application of Morphometric Analysis for Geo-Hydrological Studies Using Geo-Spatial Technology –A Case Study of Vishav Drainage Basin. Hydrol Curr Res. 2013; 4(3):1-13. doi:10.4172/2157-7587.1000157.
6. Mondal P. Morphometric Analysis of Birbhum District. Asian J Multidiscip Stud. 2013; 1(4):141-148.
7. Das D. Drainage and lineament analysis towards artificial recharge of groundwater. Adv Res Aquat Environ. 2011; 2:37-38. doi:10.1007/978-3-642-24076-8.
8. Strahler AN. Quantitative geomorphology of drainage basins and channel networks. In: Handbook of Applied Hydrology. 1964; 4(76):39-4.
9. Horton RE. Erosional development of streams and their drainage basins, hydrophyrical approach to quantitative morphology. Nihon Ringakkai Shi/Journal Japanese For Soc. 1955; 37(6):257-262. doi:10.1130/0016-7606(1945)56.
10. Schumm SA. The disparity between present rates of denudation and orogeny. USGS Prof Pap. 1963, 1-17. papers2://publication/uuid/EC192577-BD07-4939-A5C5-CD6F36DC6AD6.
11. Sujatha ER, Selvakumar R, Rajasimman UAB, Victor RG. Morphometric analysis of sub-watershed in parts of Western Ghats, South India using ASTER DEM. Geomatics, Nat Hazards Risk. 2015; 6(4):326-341. doi:10.1080/19475705.2013.845114.
12. Pande CB, Moharir K. GIS based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra India. Appl Water Sci. 2017; 7(2):861-871. doi: 10.1007/s13201-015-0298-7.
13. Nir D. The Ratio of Relative and Absolute Altitudes of Mt.

Carmel : A Contribution to the Problem of Relief Analysis and Relief Classification. Geogr Rev. 1957; 47(4):564-569.

14. Sujit, Gupta Das K. MORPHOMETRIC ANALYSIS OF THE POLYGENETIC DRAINAGE BASIN: A STUDY IN SALI RIVER, BANKURA DISTRICT, WEST BENGAL. Geo-Analyst. 2014; 4(1):11-23.
15. Gayen, Sumita Bhunia GS. Morphometric Analysis of Kangshabati-Darkeswar Interfluves Area in West Bengal, India using ASTER DEM and GIS Techniques. J Geol Geosci. 2013; 2(4):1-10. doi:10.4172/2329-6755.1000133.
16. Soni S. Assessment of morphometric characteristics of Chakrar watershed in Madhya Pradesh India using geospatial technique. Appl Water Sci. 2016; 7(5):2089-2102. doi:10.1007/s13201-016-0395-2.
17. Pal SC, Debnath GC. Morphometric analysis and associated land use study of a part of the Dwarkeswar watershed. 2013; 3(2):351-363.
18. Pareta K, Pareta U. Quantitative Geomorphological Analysis of a Watershed of Ravi River Basin, H.P. India. Int J Remote Sens GIS. 2012; 1(1):41-56. www.rpublishing.org.
19. Nayar V, Natarajan K. Quantitative Morphometric analysis of Kosasthalaiyar sub basin (Chennai basin) using remote sensing (SRTM) data and GIS techniques. Int J Geomatics Geosci. 2013; 4(1):89-102.
20. Mesa LM. Morphometric analysis of a subtropical Andean basin (Tucumán, Argentina). Environ Geol. 2006; 50(8):1235-1242. doi: 10.1007/s00254-006-0297-y.
21. Sujatha ER, Selvakumar R, Rajasimman B. Watershed prioritization of Palar sub-watershed based on the morphometric and land use analysis. J Mt Sci. 2014; 11(4):906-916. doi: 10.1007/s11629-012-2628-7.
22. Biswas A, Das Majumdar D, Banerjee S. Morphometry Governs the Dynamics of a Drainage Basin: Analysis and Implications. Geogr J. 2014, 1-14. doi:10.1155/2014/927176.
23. Pareta K, Pareta U. Quantitative Morphometric Analysis of a Watershed of Yamuna Basin, India using ASTER (DEM) Data and GIS. Int J Geomatics Geosci. 2011; 2(1):248-269.