Analysis of Drainage Morphometry for Water Resource Management of KumariRiver Basin in Purulia District of West Bengal using Remote Sensing and GIS

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ABSTRACT

Identification and analysis of Drainage Morphometry of River Basin has immense significance in Water Resource Management. The effectiveness of any Water Resource Planning, Conservation and Management is highly associated with drainage morphometric analysis of a Watershed. This analysis facilitates planner, researcher to conduct the study on a watershed and implement a proper plan. The present study accomplishes the essential drainage morphometric analysis for Water Resource Management in Kumari-Hanumata and Kumari-Chaka Watersheds of Kumari River Basin of Purulia district, West Bengal. The study will help in analyzing of drainage parameters such as linear, areal and relief aspect in Kumari-Hanumata , Kumari- chaka watersheds of Kumari River Basin using Remote Sensing and GIS, two advance effective tools and the study also reveals the enormous importance of drainage morphometric analysis in Water Resource Planning and Management. The study has been investigated using the Linear parameters of Drainage Morphometric analysis, which includes Stream number (Nu), Stream length (Lu) Mean stream length (Lsm), Stream length ratio (R_L), Bifurcation ratio (R_b), etc., Areal parameters comprise Watershed Perimeter (P), Watershed Area (A), Drainage density (D_d), Stream frequency (F_s), Elongation ratio(R_e), Circulatory ratio (R_c) etc and Relief aspect such as Relative relief, Ruggedness index etc. The result of the present GIS based Drainage Morphometric analysis has revealed that the Kumari-Hanumata and Kumari-Chaka are 6th order River Basin where the Stream number has been decreasing with increasing Stream order. The Mean bifurcation ratio of the Kumari-Chaka and Kumari Hanumata watersheds are 3.7 and 3.6 which indicates that the watershed is largely controlled by the structure and there is strong structural control on the drainage pattern. The Drainage density of these watersheds has been computed at 1.28, 1.51 km/sq km. The shape of the watersheds are elongated as studied the value of Circularity Ratio and Elongation Ratio. The analysis demonstrates the characteristics and relationship of drainage Morphometry with Watershed geometry of the Kumari- Hanumata and kumari-chaka watersheds that helps in decision and planning related with Water Resource Management for Sustainable development.

Keywords: Geographical Information System (GIS), Geomorphology, Morphometric Analysis, Remote Sensing, Watershed Resource Management,

I.INTRODUCTION

Analysis of morphometry of a drainage basin has an important role in understanding the geo-hydrological behavior of drainage basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of land forms. The analysis of drainage basin is highly important in any hydrological investigation like, identify groundwater potential zone, groundwater management, watershed prioritization, drainage basin evaluation etc. Various important hydrologic phenomena are related with physio-graphic characteristics of drainage basin systems. Many of the basins are difficult to access. Therefore , Remote Sensing has the ability of obtaining the study and view of larger area and analyze drainage morphometry easily. Many researchers have attempted studying on morphometric analysis using advanced tool Remote Sensing and GIS like in Kanhar River Basin (Rai et al. 2017), Rajasthan (Kumar , 2013), Shakkar River Catchment (Gajbhiya, 2015), Karnataka (Ramu et al. 2013) etc River Basin.

In this study, Drainage morphomery analysis of Kumari- Hanumata and Kumari-Chaka Watersheds in Purulia District, West Bengal have been done using Remote Sensing and GIS for Water Resource Management.

II.STUDY AREA AND RELEVANT DATA

2.1 Description of the Study Area

The work has been conducted on Kumari-Hanumata and Kumari-Chaka watersheds of Kumari River Basin of Purulia District. The latitudinal extension of the study area is 22°51'46.108"N to 23°14'9.324"Nand longitudinal extension is 86°9'44.368"Eto 86°43'15.815"E . Location map of the study area has been shown in Fig.1.

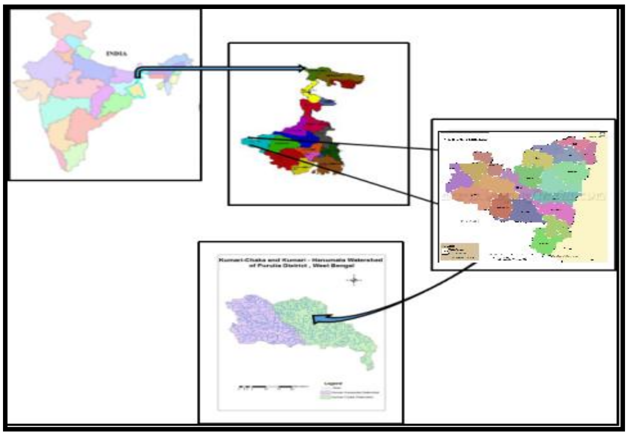

Fig.1: Location map of Study area

2.2 Relevant Data

In this study, Remote Sensing and Ancillary data have been used to prepare necessary maps which are associated with this study. The specifications of these data have been revealed in **(Table.1, 2 and 3).** In this study, Survey of India Toposheet Maps No. 73E, 73I and 73 J (Scale 1: 2,50,000) data have been used. IRS-P6, LISS-III Imageries of National Remote Sensing Centre (NRSC), Indian Space Research Organization, Government and SRTM DEM data (90-meter Resolution) have been collected. The work has been carried out by the help of GIS software, shown in **(Table.4).**

Table.1 Specifications of Satellite data

Satellite	Sensor	Spatial Resolution	Radiometric Resolution	Swath
IRS-P6	LISS-III	23.5 m	7 bits	141 Km

Table. 2 Specifications of Shuttle Radar Topographic Mission (SRTM-DEM)

Data	Resolution
SRTM DEM data	90 m

Table.3 Specification of Ancillary Data

Data	Source
Topo sheet Maps of Purulia District (Map No. 73 E, 73 I, 73 J) (Scale: 1: 2,50,000)	Survey of India (SOI)
District Planning Map (Scale: 1: 2,50,000)	Survey of India (SOI)

Table.4 Software used in the study

Software	Purpose
ERDAS Imagine 9.2	Satellite Image Processing
ArcGIS 10	Rest of the Geographical Information System work
MS-Office (MS-Word, MS-Excel, MS-Access)	Documentation and Calculation

III. METHODOLOGY

Assessment of morphometric parameters of a drainage basin is necessary to understand the form and structure of a basin, therefore the present study mainly concentrates on morphometric characteristics of Kumari-Hanumata and Kumari-Chaka watersheds of Kumari River Basin using Remote Sensing and GIS. In this study, watershed boundaries of Purulia district, West Bengal has been delineated using Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) by assigning Pour Points/Outlet Points based on determination of flow direction by D8 (Deterministic Eight Neighbors) algorithm using Geographical Information System (GIS) tool after detail study of topographical map of 73E, 73I and 73 J with 1: 2,50000 scale to obtain correct result. Stream order wise drainage map of the watersheds has been prepared using toposheets and IRS-P6, LISS III satellite imagery.

The drainage morphometric analysis of Kumari-Hanumata and Kumari-Chaka watersheds of Purulia district, West Bengal has been done aspect wise, such as linear aspect, areal aspect and relief aspect. Many Essential linear morphometric parameters of drainage network such as such as Stream order, Bifurcation ratio, Stream length of the basin, etc. have been computed.Similarly, areal aspects of the drainage network such as Drainage density, Stream frequency, Elongation ration, Circulatory ratio, Form factor, etc. And some relief aspect parameters have been computed using ArcGIS 10 software and Excel file. The morphometric parameters for the delineated watershed area were calculated in GIS environment based on the formula suggested byStream order -Strahler (1964),Stream Number-Horton (1945), Stream Length-Horton (1945),Mean Stream length-Strahler (1964), Stream Length Ratio-Horton (1945), Bifurcation Ratio- Schumm (1956)Basin Area- Schumm (1956), Perimeter - Schumm(1956), Basin Length- Schumm(1956), Drainage Density- Horton (1945), Stream Frequency- Horton (1945), Elongation Ratio - Miller (1953), Form Factor - (Horton 1932), Circulatory Ratio - Miller (1953), Relative Relief- Schumm (1956),Ruggedness Index-Schumm,1956.

IV.RESULT AND DISCUSSION

4.1 Linear Aspect of River Basin

In the present paper, discussed linear aspect of drainage parameters are Stream order, Stream Number, Stream Length, Mean Stream length, Stream Length Ratio, Bifurcation Ratio,

4.1.1 Stream Order and Stream Number:

Stream Ordering is an initial and first step of quantitative analysis of watershed.The concept of Stream ordering was first advocated by Horton (1945), but it has modified by Strahler (1952). In the present study the stream ordering of Kumari-Hanumata and Kumari-Chaka watersheds of Kumari River Basin of Purulia district werecarried out based on the proposed hierarchicalRank method of Strahler (1964). In this study, it was observed that the maximum Stream frequency shown in first order stream. The Stream order of the both watersheds vary from 1st order to 6th order.

Stream number is the count of stream channel in its order. The stream number is directly proportional to the size of the watershed. Horton (1945) states that the number of stream segments of each order form an inverse geometric relation with order number. It was observed that Stream numbers were decreased with increased stream orders in both watersheds of KumariRiver Basin. Total number of streams in Kumari- Hanumata is 657 and Kumari-Chaka watersheds is 676.

4.1.2 Stream Length:

In this study, the stream length of different order streams have been calculated with the help of ArcGIS 10 software based on proposed theory of Horton (1945). The stream lengths of Kumari-Chaka watershed of Purulia districtwas decreased with increased stream orderwhich indicate that geometrical similarity is preserved generally in watersheds of increasing order. But The stream length of 5th order stream of Kumari-hanumata watershed higher than the 4th order stream this discrepancy is attributable to variation in relief and lithology. The total length of the streams of Kumari-Chaka and Kumari-Hanumata Watersheds are 789.1818 km, 741.2920 km.

4.1.3 Mean Stream Length

Mean stream length revealing the characteristic size of components of a drainage network and its contributing surfaces (Strahler, 1964). Basically, Mean stream length of a given order is higher than the lower order and less that its next higher order. In this study, the mean stream length of both watersheds followed the trend properly that indicated that the watershed controlled by lithology and structure.

4.1.4 Stream Length Ratio

The stream length ratio express the relationship with surface flow and discharge and erosion stage of the basin. Stream Length Ratio is the ratio of the mean stream length of any order to the mean stream length of next lower order. Horton (1945) states that the length ratio tends to be constant throughout the successive orders of a basin. The Value of Stream Length Ratio of the watershedsdid not follow a trend It reveals that hard terrain is controlled by structure and variation in slope and topography.

4.1.5 Bifurcation ratio

The bifurcation ratio is the ratio of the number of the stream segments of given order to the number of streams in the next higher order. Horton (1945) considered the bifurcation ratio is an index of relief and dissertation.It was stated by the (Strahler 1964) the that the Rb is not same from one order to next order these dependent upon the geological and lithological development of the drainage basin. In this study, it was observed that Bifurcation Ratio is not same from one order to its next order for both watersheds of Kumari River Basin, it reveals that these irregularities depend on the geological and lithological development of the watershed.

Table 5: Linear Aspect of Kumari-Chaka and Kumari-Hanumata Watersheds

Watersheds	Stream Number (Nu)						Total Order Number (N)	Stream Length (Lu) (in Km)						Stream Length (in Km)	Mean Stream Length (Lsm)					
							$N=\sum N_u$	$\sum L_u$							$Lsm = L_u/N_u$					
	First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order		First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order		First Order	Second Order	Third Order	Fourth Order	Fifth Order	Sixth Order
Kumari - Chaka	493	145	30	5	2	1	676	370.0604	199.6145	105.0891	46.4727	39.5554	28.3898	789.1818	0.7506	1.3767	3.5030	9.2945	19.7777	28.3898
Kumari - Hanumata	479	139	30	6	2	1	657	329.9370	186.0678	98.5271	47.6631	52.3033	26.793734	741.2920	0.6888	1.3386	3.2842	7.9438	26.1517	26.7937

Watersheds	Stream Length Ratio					Total Stream Length Ratio	Bifurcation Ratio (Rb)					Mean bifurcation ratio (Rbm)
	$R_L = L_U/L_u - 1$											
	II/I	III/II	IV/III	V/IV	VI/V		I/II	II/III	III/IV	IV/V	V/VI	
Kumari - Chaka	0.5394	0.5265	0.4422	0.8512	0.7177	3.0770	3.4000	4.8333	6.0000	2.5000	2.0000	3.7467
Kumari - Hanumata	0.5639	0.5295	0.4838	1.0974	0.5123	3.1869	3.4460	4.6333	5.0000	3.0000	2.0000	3.6159

4.2 Areal Aspect:

In the presentstudy, the areal aspects of drainage basin such as basin area, perimeter, drainage density, stream frequency, elongation ratio, form factor, circulatory ratio etc were calculated to obtain brief knowledge of the characteristics of areal aspect of River Basin.

4.2.1 Area and perimeter:

Basin area is an important parameter of areal aspect in the quantitative geo-morphology analysis.The basin area and Perimeters of thetwo Watershedsof Purulia district were computed using ArcGIS-10 software. The basin area of Kumari-Chaka and Kumari- Hanumata watersheds are 611.8112sq km, 489.3956 sq km. And Perimeters of Kumari-chaka and Kumari- Hanumata watersheds are 204.3789 Km and 153.6440 Km.

4.2.2 Drainage Density:

Drainage density is defined as the total length of streams of all orders per drainage area. It is measured by dividing the total length of the streams of all orders by area of the basin. The high drainage density indicates highly dissected drainage basin with a relatively rapid hydrological response to rainfall events. The Drainage density of Kumari-Chaka and Kumari- Hanumata watersheds of Kumari River Basinare 1.2899 and 1.5147km/ km^2 respectively ,which indicated the coarser drainage pattern.

4.2.3 Stream Frequency

Stream frequency is the total number of stream segments of all orders per unit area (Horton, 1932). It is the ratio of the total number of stream segments by area of the basin. The range of stream frequency ofKumari-chaka, Kumari- hanumata watersheds of Kumari River Basinare1.1049 and 1.3425. The stream frequency and drainage density is positively correlated.

4.2.4 Elongation Ratio

The elongation ratio is the ratio of the diameter of a circle of the same area as the drainage basin to the maximum length of the basin (Schumm, 1956). The value of elongation ratio generally varies from .6 to 1.0. The range of the elongation ratio of ofKumari-chaka, Kumari- hanumata watersheds of Kumari River Basinare 0.3026, 0.4679. the lower value of watersheds indicated the strong relief.

4.2.5 Form Factor

Form factor as the ratio of the area of the basin to the square of the basin length (Schumm, 1956). Zero value indicates highly elongated shape and one indicates circular shape of the basin. The basin became circular when the value of form factor is greater than .78. The smaller value of form factor indicates the basin is elongated. The value of the form factorof ofKumari-chaka, Kumari- hanumata watersheds of Kumari River Basinare 0.2875, 0.6876 respectively.

4.2.6 Circulatory ratio

The dimensionless ratio of area of basin (Au) to the area of the circle having the same perimeter of the same basin (Miller, 1935). It is used as a quantitative measure of shape of the basin. The value near one means more circular shape of the basin. Runoff is stays more time in circular basin than elongated basin. The value of the form factorof ofKumari-chaka, Kumari- hanumata watersheds of Kumari River Basinare 0.1840, 0.2604. The value of the circulatory ratio of watershedsof Purulia indicates the shape of the watersheds is elongated.

Table 6. Areal Aspect of Kumari-Chaka and Kumari-Hanumata Watersheds

Watersheds	Perimeter (P) (Km)	Basin Area (A) (Sq. Km)	Stream Frequency (Fs)	Drainage Density (Dd)	Form Factor (Rf)	Circularity ratio (Rc)	Elongation ratio (Re)
Kumari - Chaka	204.3789	611.8112	1.1049	1.2899	0.2875	0.1840	0.3026
Kumari - Hanumata	153.6440	489.3956	1.3425	1.5147	0.6876	0.2604	0.4679

4.3 Relief Aspect

4.3.1 Relief Ratio

Relief Ratio is the horizontal distance between the highest and lowest points of the valley floor of a basin to the horizontal difference between the same two points. It is the direct relationship between the relief and channel gradient. The lower value of the relief ratio indicates low permeable and high slope basin. It has been observed that areas with high relief and steep slope are characterized by high value of relief ratios.

4.3.2 Relative Relief

Relative Relief is the elevation difference of the highest and lowest point of the basin. To show spatial variation from one place to another calculation of relative relief (Rao,2011) is paramount. The value of the relative relief of Kumari-Hanumata and Kumari-Chaka watersheds are 473, 194 respectively.

4.3.3 Ruggedness Index

Ruggedness number is generated from relative relief and drainage density. The topographic ruggedness index too indicates the extent of instability of land surface (Strahler, 1956). An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Strahler, 1956). The value of the ruggedness index of Kumari-Hanumata and Kumari-Chaka watersheds are .8391 and .0593 which indicate the study area is extremely rugged with high relief and high stream density.

Table 7. Relief Aspect of Kumari-Chaka and Kumari-Hanumata Watersheds

Watersheds	Maximum Hight(H)	Minimum Hight (h)	Relative Relief (Rhp)	Ruggedness number (Rn)
Kumari - Chaka	325	131	194	0.0593
Kumari - Hanumata	656	183	473	0.8391

V.DISCUSSION

Dendritic Drainage pattern are found in both Kumari-chaka and Kumari-hanumata watersheds of Kumari River Basin. Calculation of bifurcation ratio is good indicator of structural development of drainage pattern. Higher value of bifurcation ratio of the study area indicates the structural disturbances to the drainage basin. The bifurcation ratio of the study area between 2 to 5 which indicates that the drainage network of the study area is well developed. The values of the drainage density of the area indicates that impermeable rocks are underlying. Circularity ratio and elongation ratio were indicated that the study area is elongated in shape. A circular basin is more efficient in discharge of runoff than of an elongated basin (Singh and Singh 1997).

Low value of relief ratio of the study area indicates resistant basement rocks.The high value of ruggedness value of the watersheds indicates high prone to soil erosion.

Kumari-chaka and Kumari-hanumata watersheds has low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope (Kuldeep pareta and Upasana pareta, 2011) and low ruggedness value of the watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

Mean Biffurcation Ratio, Drainage Density, Stream Frequensy (Fs), Form Factor (Rf), Circulatory Ratio (Rc), Elongation Ratio(Rc), are also termed as erosion risk assessment parameters and have been used for prioritizing watersheds. Some morphometric parameters like, drainage density, stream frequency, bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility, higher the value, more is erodibility.

VI.CONCLUSION

Morphometric analysis of River Basin is one of the most important aspect and study for watershed management. The present study demonstrates the utility of Remote Sensing and GIS techniques in morphometric analysis and the significance of morphometric analysis in geomorphological study and understand the form and structure of a basin. Results of morphometric analysis of the basin showed that the drainage network of the study area is well developed and dendritic, elongated basin , impermeable rocks are underlying etc. Therefore, The study can be very much necessary and helpful for Kumari-chaka and kumari-hanumata watersheds management in and protecting the natural environment and water resource planning..

VII.ACKNOWLEDGMENT

The authors would like to extend the heartiest thanks to the University Grant Commission (UGC), Government of India, for funding the research work; also extending the heartiest thanks to Department of Civil Engineering, Jadavpur University, for providing the golden opportunity to work on this problem. The authors are also thankful to Survey of India, National Remote Sensing Center (NRSC), Government of India, National Aeronautics & Space Administration (NASA), United States Federal Government, for providing the data to carry out the Research Work. The authors would like to extent the thanks to 'UGC-BSR Research Fellowship in Science for Meritorious Students', 2012-2013 for funding.

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