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QUANTITATIVE ANALYSIS OF CHHOTA RANGIT RIVER BASIN IN DARJEELING HILL AREA, INDIA, USING REMOTE SENSING AND GIS TECHNIQUE

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ABSTRACT

Quantitative analysis of the river basin means the measurement and the mathematical analysis of the configuration of the various aspects of the river basin like its linear aspects, areal aspects and relief aspects. The quantification of the river basin is one of the prime factors for implementing, any kind of watershed management policies. But the quantitative analysis of the river basin is one of the most tedious and time consuming task, however, the introduction of remote sensing and GIS has made this task simpler and extremely easy in the present time. Thus in the present study, quantitative analysis of Chhota Rangit river basin has been conducted, based on secondary data like topographical maps 74 A/4 and 78 A/ 8and 78 B/1 issued by Survey of India with the scale 1:50000 using Arc GIS 10.3 software and the ASTER DEM with the 30 meters resolution (2011). The morphometric parameters of the basin were analyzed and the computed result revealed that the Chhota Rangit is the 5th order river basin having 347 first order streams, 71 second order, 16 third order and 3 fourth order steams, with the basin area of 140.98 km^2. The streams have been formed in pinnate drainage pattern. The total length of the Chhota Rangit river basin is 362.98 km. The result of the form factor of the basin is 0.29 which means that the drainage basin is elongated. The overall analysis of the various morphometric parameters of the Chhota Rangit River would assist the planner and the developer to understand the surface and subsurface structure of the basin and facilitate them in stimulating proper steps for sustainable utilization of the water resource as well as development of the river basin.

KEY WORDS: *Morphometry, drainage basin, sustainable utilization, geomorphic analysis, Arc GIS.*

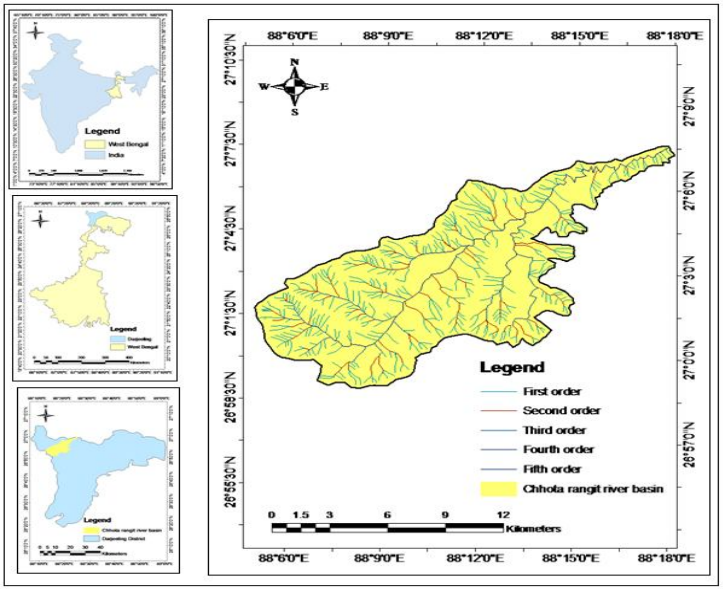
1. INTRODUCTION

Morphometry is defined as 'measurement of the shape, or geometry, of any natural form-be it plant, animal or relief features' (Strahler 1969). It is the most efficient and essential means in geomorphic analysis of an area. Morphometry incorporates quantative study of the area, altitude, volume, and slope, profiles of the land and drainage basin characteristics of the concerned area (S.Singh 1972). Fluvial morphometry on the other hand includes the consideration of linear, areal and relief aspects of a fluvially originated drainage basin. The linear aspects deal with the hierarchical orders of streams, numbers and lengths of stream segments and various relationships among them and related morphometric laws. The areal aspect includes the analysis of basin

perimeter, basin shape, basin area and related laws. The relief aspects incorporate the study of absolute and relative reliefs, relief ratios, slope, dissection index etc. (S.Singh 2009). At present, the efficiency and development in the field of Geographical Information System has helped the researchers to analyze the various aspects of drainage basin more precisely and easily. The present study is an attempt to analyze the different aspects of Chota Rangit river basin for finding out the characteristics of the concerned river, which may on the other hand help the planners and developers to understand the hydrological characteristics of the river basin for sustainable utilization of the water resource as well as imitating and implementing any kind of developmental policies for the river basin.

2. STUDY AREA

The Chhota Rangit or The Little Rangit originates from the area below Tanglu in Singalila range on the Nepal border and flows in the north easterly direction, draining the maximum areas of Darjeeling Pul Bazar Block and falls into Great Rangit at Singla Bazar as its major right bank tributary. The river has shelving bank and has a stony and sandy bed. The river along with its tributaries forms a pinnate drainage pattern. The principal tributaries of the Chota Rangit are the Kahel khola, Hospital jhora, Relling khola and Serjan on its left bank and Neora Jhora on its right. The Geographical location of the river is 26˚ 57’ 0” N to 27˚ 20 0” N and 88˚ 6’ 0” E to 88˚ 18’0” E.



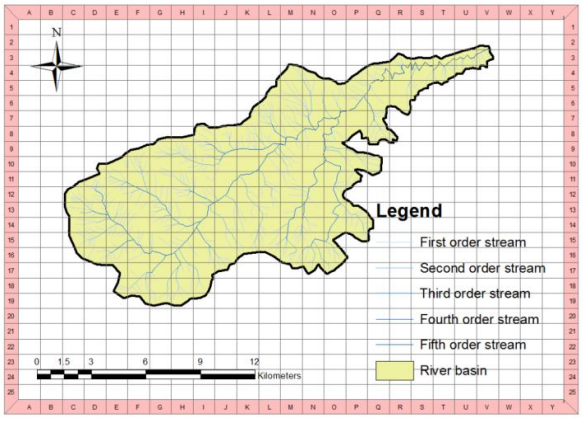
Map 1: Location of the Study Area

3. METHODOLOGY

The present study is based on the secondary data. Delineation of the Chota Rangit river basin and drainage map preparation is done based on the topographical maps no. 78 A/4 and 78 A/ 8, 78B/1 issued by SOI with the scale 1:50000 and ASTER DEM image with 30 meter resolution, using Arc GIS 10.3 software. Various aspects of river basin like Linear, Areal and Relief with different parameters like- stream order, stream length, mean stream length, bifurcation ratio, drainage density, stream frequency elongation ratio etc have been computed and analyzed based on the methods mentioned in table 1, using Arc GIS10.3.

Table 1: Methods of Analysing the Morphometric Parameters of Drainage Basin

Aspects	Parameters	Formula	References
Linear	Stream Order	Hierarchical Rank	Strahler, 1964
	Stream Length (Lμ)	Length of the Stream	Horton, 1945
	Mean Stream Length (Lsm)	Lsm = (Lμ/Nμ) Nμ = Number of stream	Strahler, 1964
	Length Ratio (Rl)	Rl= Lμ/ Lμ- 1 Lμ = The total stream length of order μ; Lμ- 1 = Length in next lower order	Horton, 1945
	Bifurcation Ratio (Rb)	$Rb = \frac{N\mu}{N\mu+1}$ Nμ = Number of stream; Nμ+1 = Number of stream in next higher order	Schumm, 1956
Areal	Form Factor (F)	$F = \frac{A}{L^2}$ A= Basin area; L= Basin length	Horton, 1932
	Law of basin area	$A\mu = A_{1R}Ra(\mu-1)$	Strahler, 1969
	Drainage Density (Dd)	$Dd = \frac{\sum L}{A}$ L = Length of the rivers; A= Area	Horton, 1932
	Stream Frequency (Df)	$Df = \frac{\sum N}{A}$ N = Number of river segments , A= Area.	Horton, 1945
	Drainage Texture (Dt)	Dt = Nμ/P Nμ = Total number of stream in all segments; P = Basin perimeter	Horton, 1945
Relief	Relative relief	Rr = (Rma–Rmi) Rma= Maximum Relief, Rmi= Minimum relief	Smith (1935)
	Dissection index	$DI = \frac{Rr}{Hx}\times 100$ Hx =Maximum relief; Rx = Relative relief	Dov Nir/Miller(1945)
	Ruggedness Index	Rn= Bh X Dd, Bh= Basin Relief, Dd= Drainage density.	Schumn, 1956



Map 2: Grid Map of Chhota Rangit River basin

4. RESULT AND DISCUSSION

4.1 Linear Aspects

Linear aspects of the river basins are related to the channel patterns of the drainage network where the topological characteristics of the stream segments in terms of open links of the network system are analyzed (Singh 1998).The linear aspects deals in particular with the hierarchical orders of streams, numbers and lengths of stream segments and various relationships among them and related morphometric laws. The analyses of Linear aspects like stream order, stream number, Stream Length (Lμ), Mean Stream Length (Lsm), Length Ratio (Rl) and Bifurcation Ratio (Rb) has been conducted for Chhota Rangit river basin and arrived at the following result.

Table 2: Results of the Morphometric Analysis of Linear Aspects

Stream Order	Stream Number	Bifurcation Ratio (Rb)	Mean bifurcation ratio (Rbw)	Stream Length (Lμ)(km)	Cumulative stream length (Km)	Length Ratio (Rl)	Mean Stream Length (Lsm)
1st	347	-	3.53	232.03	232.03	-	0.67
2nd	71	4.89		63.67	295.7	2.64	0.89
3rd	16	4.43		28.56	324.26	1.23	1.78
4th	3	5.33		20.1	344.36	0.42	6.7
5th	1	3		18.62	362.98	0.08	18.62

4.1.1 Stream Order

Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopold, Wolman, Miller, 1969). Stream ordering is an initial and essential requirement of morphometric analysis of a drainage basin. There are various methods of stream ordering as proposed by Gravelius (1914), Horton (1932, 1945), Strahler (1952), Shreve (1966), Scheidegger (1965) etc. Strahler's Scheme which is considerably modified version of Horton's Scheme has been applied in the present study. According to Strahler the smallest, unbranched fingertip streams are the first order streams. When two first order streams meets, the lower segment of the meeting point is identified as second order stream. When two second order stream meets the third order stream is created, i.e whenever the streams of same order meets they create a stream of higher order. In the present study it is found that the Chhota Rangit River is the 5th order stream. There are altogether 438 streams among which 347 are 1st order stream, 71 are 2nd order stream, 16 3rd order stream, 3 4th order stream and 1 5th order stream. The Chota Ranjit River along with its successive streams has formed a pinnate drainage pattern which is highly influenced by hilly topography of the study area. The study shows that the number of streams has decreased with the successive increase of the stream order.

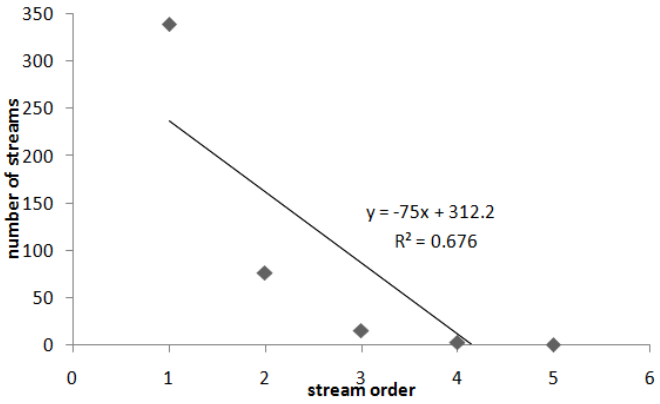


Figure 1: Stream Number Vs Stream Order

4.1.2 Bifurcation Ratio

Bifurcation ratio (Rb) is defined as the ratio of the number of streams of a given order to the number of stream of the next higher order (Schumm, 1956). According to Horton (1945) bifurcation ratio is an index of relief and dissections. Applying Schumm's method bifurcation ratio for Chhota Rangit River is computed and it is observed that the values of bifurcation ratio are not uniform throughout the drainage basin. The values of bifurcation ratio for the study area varies from 3-5.33 which indicates the influence of hilly and highly dissected geologic structure to the drainage basin. The mean bifurcation ratio (Rbw) for the whole river basin is 3.53 which indicates maximum number of stream integration and also shows that more than three segments of smaller streams merged to form the larger segment.

4.1.3 Stream Length (Lμ)

The study of the length of the river is an important aspect for understanding the basic hydrological characteristics of the river. The stream length of the study area is measured using Horton's Law of stream length (1945), and the length of the various stream orders are computed using Arc GIS 10.3. From the computed value it is observed that the length of the first order stream is 232.03 km, second order stream is 63.67 km, third order stream is 28.56, fourth order stream is 20.1 and fifth order stream is 18.62 km. The length of the stream order is maximum for first order stream and has decreased as the stream order increased. The change in the length may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes (Singh 1997).

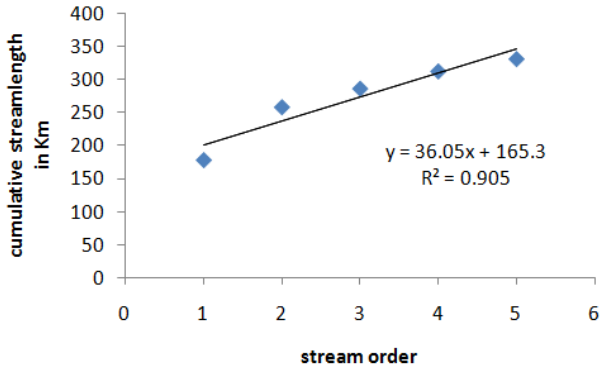


Figure 1: Stream Length Vs Stream Order

4.1.4 Mean Stream Length (Lsm)

According to Strahler 1964, the mean stream length is a characteristic property related to the drainage network and its associated surfaces. It is calculated by dividing the total stream length of order by the number of stream segment in the same order. The mean stream length of Chhota Rangit and its drainage network is 0.67 for first order, 0.89 for second order, 1.78 for third order, 6.7 for fourth order and 18.62 for fifth order. It is observed that the mean stream length of the study area increases with the increase of stream order.

4.1.5 Length Ratio (Rl)

Length ratio is the ratio of the mean length of the stream of a given order to the mean length of the streams of the next lower order. The length ratio of the study area varies from one order to the next order. The variations in length ratio, attributed to variation in slope of topography indicate youth stage of geomorphic development in the streams of the study area (Singh and Singh, 1997, Vittala et al., 2004).

4.2 Areal Aspects

Different areal aspects like Basin Area, Basin Perimeter, Form Factor (F), Circulatory Ratio (C), Drainage Density (Dd) and Drainage Texture (Dt) of the study area has been analyzed and arrived at the following results.

Table 3: Results of Morphometric Analysis of Areal Aspects

Areal Parameters	Results
Basin Area (km^2)	140.98
Basin Perimeter (km)	78.32
Form Factor (F)	0.29
Drainage Density (Dd) (km^2)	2.57
Stream Frequency (Df) ($km^{2)}$	3.11
Drainage Texture (Dt)	5.59
Drainage Intensity (DI)	7.99

4.2.1 Basin Area

The total area drained by a stream and its entire networks of subsequent segments is termed as the basin area. Basin area measures the average drainage area of streams in each order; it increases exponentially with increasing order. The total basin area of Chhota Rangit River which is the fifth order stream along with its entire stream segment is 140.98 km^2. The basin perimeter of the study area is 78.32 km.

4.2.2 Form Factor (F)

Form factor is defined as the ratio of basin area to square of the basin length (Horton 1932). The form factor of a basin is determined by geological structure, topographical characteristics, compactness and hardness of soil, vegetation characters, slope characters etc. The value of form factor varies from 0-1, if the value of the form factor is near 1, it means the circular basin and if it is 0 it means elongated basin. The higher the value of form factor the more circular the shape of the basin and vice versa (Singh 2007). So since the form factor of the study area is 0.29 it can be concluded that the basin is highly elongated in shape.

4.2.3 Drainage Density (Dd)

Drainage Density is the ratio of total length of all segments in a given basin and total area of that basin (Horton 1932). It is a measure of how well or how poorly a watershed is drained by stream channels. According to George and Welling, 1973, drainage density is sensitive parameter which in many ways provides the link between the forms attributes of the basin and the processes operating along stream

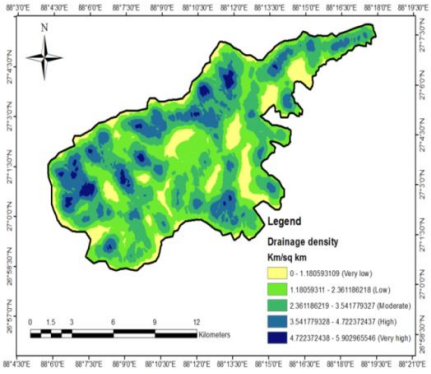
course. Drainage basin with high drainage density indicates that a large proportion of the precipitation runs off. On the other hand, a low drainage density indicates the most of rainfall infiltrates the ground and few channels are required to carry the runoff (Roger, 1971). The drainage density for the study area is done using Horton's formula and the computed result is 2.57 per km^2 indicating high drainage density and a high degree of surface runoff due to the steepness of the topography.

4.2.4 Stream Frequency (Df)

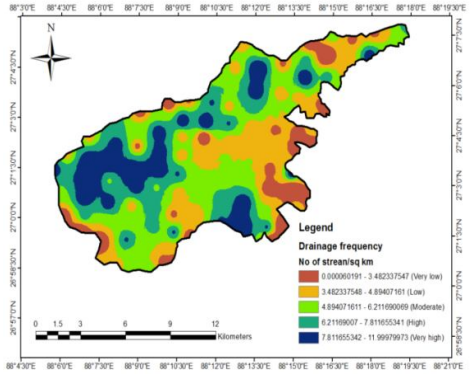
Stream frequency is defined as total number of streams of all orders per unit area (Horton 1945). The stream frequency of the Chhota Rangit drainage basin is 3.11 per km^2 which indicates a high stream frequency of the study area. The computed value of stream frequency for drainage basin shows a positive correlation with drainage density, indicating the increase in stream number with respect to increase in drainage density.

4.2.5 Drainage Texture (Dt)

According to Horton, 1945drainage texture is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). It is basically analysed to find out the relative spacing of streams per unit area. The drainage texture of the study area is computed using Horton's method and the result is 5.59/sq km which show the fine drainage texture of the study area.



Map 3: Drainage Density Map



Map 4: Drainage Frequency Map

4.3 Relief Aspects

Relief parameters like Relative Relief (Rr), Dissection Index (DI), Ruggedness Index (Rn), Average Slope etc has been analyzed for Chota Rangit River basin and the computed result is as follows.

4.3.1 Relative Relief (Rr)

Relative relief or amplitude of relief is defined as differences between maximum height and minimum height. It is an important morphometric parameter for analyzing the overall morphological characteristics of terrain. M.A. Melton (1957) proposed to calculate relative relief by dividing the difference between highest and lowest points in the basin (H) and basin Perimeter (P), thus relative relief is H/P. Relative relief for the study area is calculated using Smith's, (1935) method. The relative relief of the study area ranges between 50-1400 meters which on the other hand means a very high relative relief for the study area.

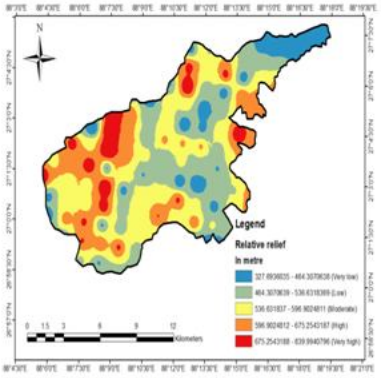
4.3.2 Dissection Index (DI)

Dissection Index can be defined as the ratio of maximum relative relief to maximum or absolute relief. It is an important indicator of the nature and magnitude of the terrain. The Dissection Index of the

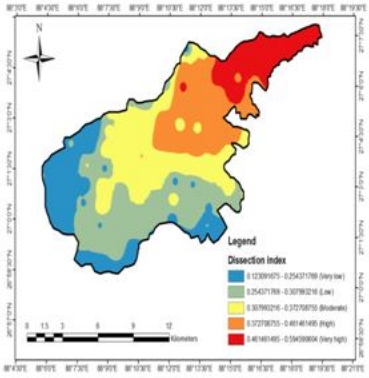
study area is calculated using Dov Nir/ Miller (1945) method. The calculated dissection index of the Chhota Rangit drainage basin ranges from 0.12- 0.59 which indicates a very high dissection of the study area.

4.3.3 Ruggedness Number (Rn)

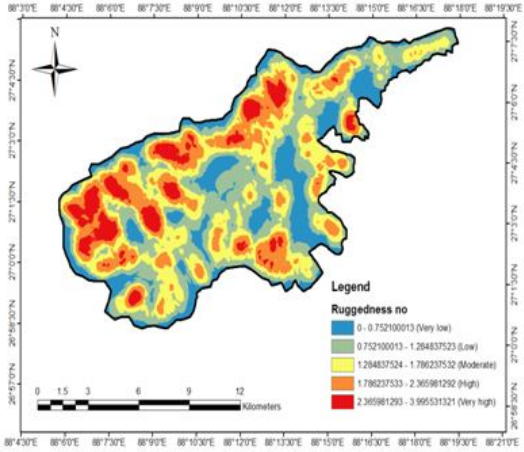
Ruggedness Number is the product of maximum relief and drainage density (Strahler 1968), where both the parameters are in same unit. It indicates the intensity of erosion and other geomorphic processes over surface. Extremely high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Strahler, 1956). The ruggedness number of the Chhota Rangit river basin is classified into five groups such as very low (0-0.752), low (0.752-1.285), moderate (1.285-1.787), high (1.787-2.366) and very high (2.366-3.99). Mostly the upper catchment of the river basin is influenced by the high very ruggedness number, and the lower catchment is influenced by moderate and low ruggedness number.



Map 5: Relative Relief Chhota



Map 6: Average Slope Chhota



Map 7: Ruggedness Number

5. CONCLUSION

The quantative analysis of the morphometric parameters like Linear, Areal, and Relief aspects for Chota Rangit River has been conducted using Arc GIS 10.3 software. The study shows that the Chota Rangit River is a Fifth order stream, and has formed a pinnate drainage pattern. The number of stream has decreased with the increased stream order for the study area. The total basin area is 140.98 km^2. The result of the analysis of different areal aspects of the study area shows a high drainage frequency, high drainage

density and a fine drainage texture for the study area which indicates a high degree of surface runoff. The analysis of the relief aspects shows that the Chhota Rangit Drainge basin has a very high relief features and a steep slopes. The hilly terrain of the study area on the other hand exhibits a high level of vertical erosion which is a typical character of a stream which is at its youthful stage.

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