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Morphometric and geometric analysis of kunur basin– A geomorphic analysis of well-known riverine landscape of Rarh Bengal, Barddhaman district West Bengal

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Abstract
Morphometry is the evident expression of integrated structure, process and morphological shape. Its pattern expresses the underlying structure, rock resistance, exogenetic processes, morphological process-form its spatial distribution, hydrological actions and processes etc. *The significant morphometric analysis can be used to correlate and associate the hydrologic characteristics with physiographic characteristics of drainage basins such as size, slope, shape, and drainage density, the slope of drainage area, size and length of the tributaries. The Kunur River, a 5th order tributary of Ajay River is a well-known name in the riverine landscape of Rarh Bengal (Figure 1). It originates from a spring near Bansgara in the Faridpur police station area of Burdwan district. The Primary aim of the present work is to find out and analysis on delineation, orientation, qualitative and quantitative appreciation and highlighting of geomorphic status of the studied basin*. To determine the aspects of Topography, slope and morphological disparity Topometry, morphometry and geometric observation and analysis have significant role in relation to distinguish the basin hydro-geomorphologic status. Various Linear, Aerial and Relief parameters are consider for the present study. *To determine the valley side and hill side slope drawing of profile along and across the area are the significant measures for depicting the basin geomorphologic scenario.* The overall results revealed that analysis of drainage system displayed significant information on geomorphic and hydrologic conditions. The analysis of the stream channels and rock composition demonstrate that some preferential orientations exist which are likely to be litho-structurally controlled. Drainage basin morphometry in terms of the linear aspects of 5th order sub-basin of Kunur show general conformity with available understanding on drainage development and landform evolution.

Keywords: morphometry, topometry; morphological disparity; dimensionless parameters; surface processes; neo-tectonics; dissection index

Introduction

The study of drainage basin provides incredible information and explanation about the geological and evolutionary history of the concerned area. In hydrology, the morphometry of drainage basin and river networks provide clues on water discharge, maximum and minimum specific runoff and their spatial variation. *Morphometry* can be defined as *"Measurement of the shape, or geometry, of any natural form – be it plant, animal or relief features" (A.N. Strahler, 1969)* [44]. In geomorphology *'morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms' (J.I. Clarke, 1966)* [7].

Morphometry is the evident expression of integrated structure, process and morphological shape. Its pattern expresses the underlying structure, rock resistance, exogenetic processes, morphological process-form its spatial distribution, hydrological actions and processes etc. *Fluvial morphometry* incorporates a long range of quantitatively definable aspects like *linear or one dimensional aspect*, *areal or two dimensional aspects and relief or three dimensional aspects* of Fluvio-defined landforms. Each parameter has credit to express the topographical and hydrological features. The morphometric analysis of the drainage basin reflects climate, geomorphology, structure and Topography and geo-tectonic features. The geomorphic investigation helps to explain the evolution of surface drainage *(Horton, 1945; Leopold and Maddock, 1953; Abrahams, 1984)* [16, 17, 19]. Morphometric analysis of watershed also reveals a quantitative description of the drainage basin *(strahler, 1964)* [44]. *The significant morphometric analysis can be used to correlate and associate the hydrologic characteristics with physiographic characteristics of drainage basins such as size, slope, shape, and drainage density, the slope of drainage area, size and length of the tributaries*. Hydrologists and geomorphologists were identified that certain relation is significant between runoff and geographic and geomorphic characteristics of the drainage systems. *(Abedkareem 2016),* the drainage basin analysis can also be used in any such investigation of ground water potential, and management. *Following Methods have been adopted for calculating morphometric parameters here--*

Linear Parameters
Stream order (U) -- Hierarchical order/ Rank—
Strahler, 1964----------------- (i)
Stream length (Lu) -- Length of the stream (Order wise)—
Horton, 1945--Length of the stream /sq. km. in a given order--(ii)
Mean stream length (Lsm)---Lsm = Lu/Nu where, Lu=Stream length of order 'U' Nu=Total number of stream segments of order 'U'---
Horton, 1945---(iii)
Stream length ratio (Rl) -- Rl=Lu/Lu-1; where Lu=Total stream length of order 'U', Lu-1=Stream length of next lower order; -- Horton, 1945---(iv)
Bifurcation ratio (Rb) -- Rb = Nu/ Nu+1; where, Nu=Total number of stream segment of order'u'; Nu+1=Number of segment of next higher order ---Schumn, 1956--(v)

Relief parameters
Basin relief (B_h) -- Vertical distance between the lowest and highest points of watershed.—
Schumn, 1956----(vi)
Relief ratio (R_r) -- $R_r = B_h / Lb$; Where, B_h=Basin relief; Lb=Basin length –
Schumn, 1956----------------------(vii)
Ruggedness number (Rn)--Rn = $B_h \times Dd$-Where, B_h =Basin relief; Dd=Drainage density
Schumn, 1956--- (viii)

Arial parameters
Drainage density (Dd)---Dd=L/A where, L=Total length of streams; A=Area of watershed—
Horton, 1945---(ix)
Stream frequency (Fs)--Fs = N/A where, N=Total number of streams; A=Area of watershed –
Horton, 1945 (x)
Texture ratio (T) --T= Ni / P where, Ni=Total number of first order streams; P=Perimeter of watershed--Horton,1945--(xi)
Form factor (Rf) --Rf= A/(Lb) 2; where, A=Area of watershed, Lb=Basin length; ---
Horton, 1932---------(xii)
Circulatory ratio (Rc)--Rc= 4πA/P2; where, A=Area of watershed, π=3.14, P=Perimeter of watershed—
Miller,1953--(Xii)
Elongation ratio (Re) -- Re =2√(A/π)/Lb; where, A=Area of watershed, π=3.14, Lb=Basin length ---
Schumn,1956---(xiv)
Length of overland flow (Lof) -- Lof = 1/2Dd; where, Dd =Drainage density—
Horton, 1945--------------(xv)

The basin geomorphic characteristics have long been believed to be important indices of surface processes. These parameters have been used in various studies of geomorphology and surface-water hydrology, such as flood characteristics, sediment yield, and evolution of basin morphology. More recently, terrain characterization became an important part in modelling surface processes *(Nogami, 1995).* The detailed analysis of morphometric and morphological character indicate the role of the neo-tectonics in shaping the drainage basin.

This modern approach of quantitative analysis of drainage basin was given inputs by *Horton (1945)* [19] the first pioneer in this field. Horton's law of Length of overland flow and stream lengths suggested that a geometric relationship exists between the numbers of stream segments in successive stream orders. *The law of basin areas indicates* that the mean basin area of successive ordered streams formed a linear relationship in the graphical presentation. Horton's laws were subsequently modified and developed by several geomorphologist, *most notably by Strahler (1952, 1957, 1958, and 1964)* [42, 39, 40], *Schumm (1956)* [29], *Morisawa (1957, 1958)* [22, 23], *Scheidegger (1965)* [27], *Shreve (1967), Gregory (1968)* [13], *Gregory and Walling (1985)* [1]. Subsequently a number of books by Bloom (2002), Keller and Pinter (1996) have further propagate the Morphometric analysis of different scales. Stream profile analysis and stream gradient index by Hack (1973) is another milestone in morphometric analysis. Many workers have used the principles developed by these pioneers to quantitatively study the drainage basin as a tool for landscape analysis *(Sharma, 1987, Raj et. al., 1999, Awasthi and Prakash, 2001, Phukon, 2001, Sinha Roy 2002). Major common morphometric parameters and their correlation and association are described here in the following table;*

Study area

The basin area can be delimited by 23°25'50.4"N. latitude to 23°39'21"N latitude and 87°16'26.4"E longitude to 87°54'12.6"E covering an area of about 753.90 sq. km. with 112 km. total length of the main channel and shape of the basin is elongated in nature. This basin lies to the south of the Ajay River and to the north of the Khari River. The upper portion of the study area has few numbers of protected and reserved forests.

The Kunur River, a 5th order tributary of Ajay River is a well-known name in the riverine landscape of Rarh Bengal (Figure 1). It originates from a spring near Bansgara in the Faridpur police station area of Burdwan district. It has been flowing through Durgapur-Foridpur, Kanksa, Ausgram- I and II police stations and finally terminates into the Ajay River near Kogram village of the Mongalkote block.

Fig 1: Locational Identity of Kunur River- A Tributary system of Ajoy River.

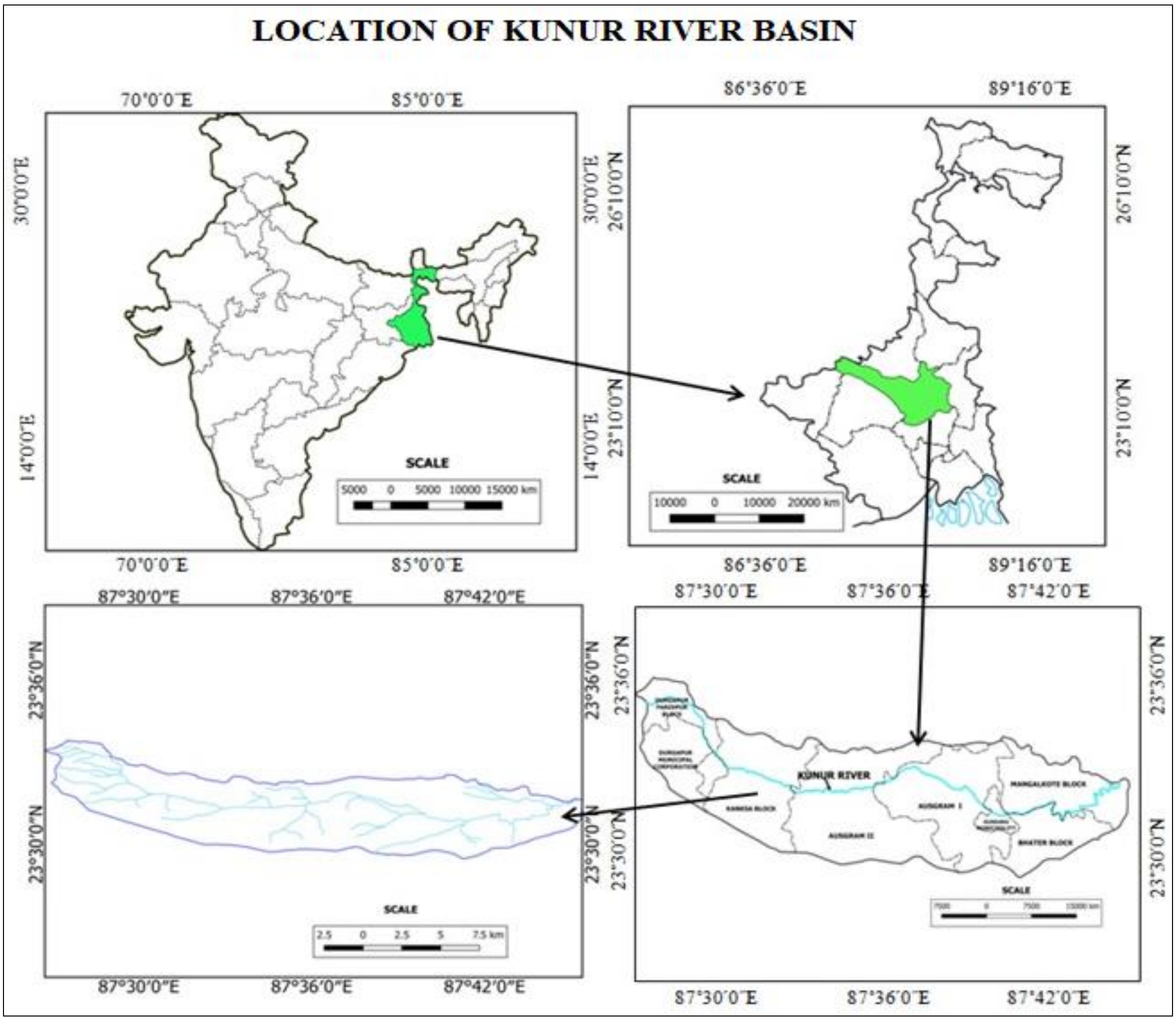


Fig 2: Location of Kunur River Basin

Objectives of The Study

The morphometric evolution of the Earth's surface forms is considered to be the backbone of physiographic Investigation and an important branch of geomorphology. The major emphasis has been given on the morphometric, geometric and topometric analysis of drainage basin of Kunur River. *The Primary aim of the present work is to find out and analysis on delineation, orientation, qualitative and quantitative appreciation and highlighting of geomorphic status of the studied basin*. The subsequent investigations are as follows:

1. *To delineate Kunur river Basin from Ajoy River system.*
2. *Quantitative analyse of the major morphometric attributes to determine the geomorphic status.*
3. *To demarcate the geomorphic units of parameters at different levels.*

4. *To define the correlation and association between the different morphometric attributes.*
Finally to draw the inference of geomorphic status of the concerned basin.

Database and Methodology

1. A number of database from varied sources—especially qualitative, Quantitative and Digital format have been employed for this painstaking research. A number of maps (SOI, GSI, All India Soil and Land Use Survey, CGWB etc have been collected for getting various information about the basin concerned. *The present study is based on survey of India (SOI) topographic maps with no. 73M/7, 73 M/10, 73 M/11, 73 M/14 and 73 M/15.* All the morphometric, Topometric and palnimetric configuration and other attributes were analyzed quantitatively and morphometric compartments were delineated.
2. Apart from that, *observation, collection, field investigation, Tabulation, calculation and presentation stages have been performed as standard methodological steps*. Base map has been prepared based on those collection.
3. Remote sensing images have been collected and map to image referencing has been performed for preparing the maps and collection of subsequent data. For overall data collection SOI Topographical maps and Images are used
4. Maps are prepared in the modern GIS environment and statistical and morphometric analysis have been done with the help of Excel statistical application and data representation techniques.
5. The present study is based on survey of India (SOI) topographic maps with no. 73M/7, 73 M/10, 73 M/11, 73 M/14 and 73 M/15.
6. Different morphometric parameters such as *linear aspects of the drainage network*: *stream order (N_u), bifurcation ratio (R_b), stream length (L_u)* and *areal aspects of the drainage basin*: *drainage density (D), stream frequency (F_s), texture ratio (T), elongation ratio (R_e), circularity ratio (R_c), form factor ratio (R_f)* of the basin and *various relief aspects of the present drainage basin* were computed.

Results and Discussion

Observation – Physical Environment

The Kunur River is a right-bank tributary of the Ajay River, in the Barddhaman district, representing a significant riverine landscape in the Lower Ajay River Basin. It originates from the western undulating flat of the Barddhaman District at more than 100 m. of altitude, flowing from west to east. It is nearly flowing a length of about 114.1 km. The outlet of this watershed is close to the village Kogram, about 38-km. from the Barddhaman town on Bardwan-Katwa road. The catchment extends over an area of about 922.40 sq. km., having an elongated and asymmetrical shape. The studied area is surrounded by the hills of Vindhayans formation in the west and Gondowana formation, and on the north by the Rajmahal hills *(Chaudhari, 1995).* The geological formation of the area consists of lower Gondwana system and Quaternary to Pleistocene sediment with depth of 200 to 300 m *(Pal, 1991).* This basin area has been covered with different geological units, like Panskura formation, Sijua formation during the Quaternary Period (Figure-03).

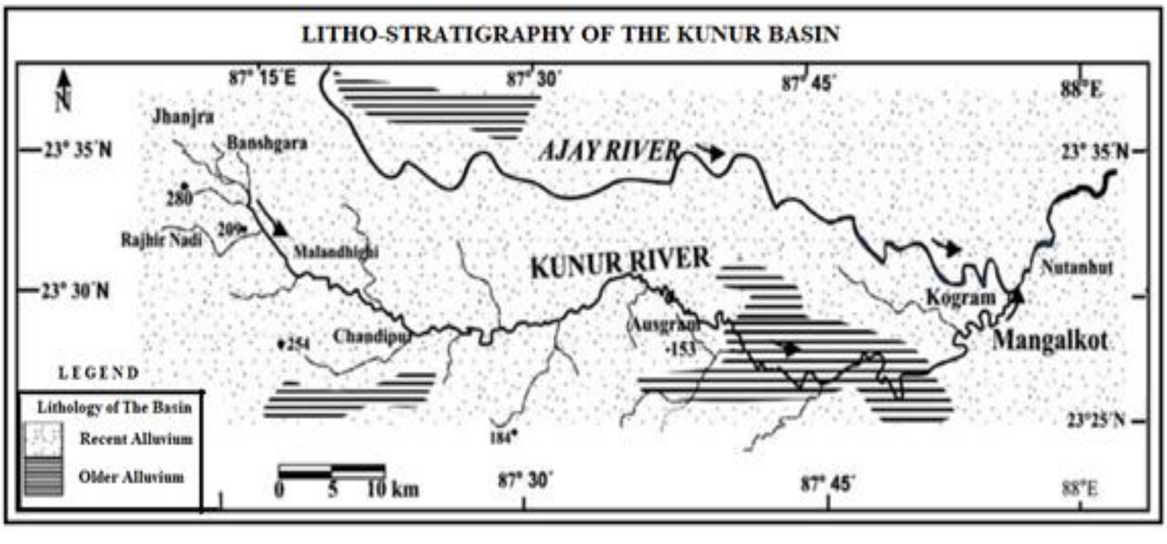


Fig 3: Litho-Stratigraphy of The Basin

The Kunur river basin has been *characterised by three major geohydrological provinces and specifically identified (Niyogi, 1985) as hydro-geomorphic zones. First one* is the upper catchment of the Kunur Basin, which is covered by hard rock, mainly Archaean formation with highly degraded metamorphic rocks of which granite gneiss commonly referred as 'Bengal Gneiss', *next is middle portion of the kunur basin* which consists with semi-consolidated formation of the Gondwana Sedimentary and hard lateritic patches, and *lastly, the lower riverine plain area*, which is mainly un-consolidated with new alluvial of the Ajay and Kunur floodplains.

Majority of the river course falls within the canal command area of Damodar river Basin covering 277 villages and three urban areas, located partly or fully within the basin. The morphometric and Topometric analysis play decisive role in understanding the geo-hydrological behaviour of present basin. *Topographically, the upper part of this basin* is an extended undulating part of the plateau fringe area of the Chotonagpur plateau, where maximum elevation of the surface is about 124m. from mean sea level. The upper part is moderately undulating, dissected and erosion prone. The lower part of this basin starts just from the eastern flank of the lateritic hard crust (below 40 m. contour), which is almost flat surface with sinuous and acute meandering course.

Geographically this basin is under the control of humid tropical climate, Tropic of Cancer (23°30'E) passes over the basin from West to East. The average annual rainfall is 1400 mm of which the maximum occurs within the second week of the month of June to September. During the summer season rainfall exceeds 100 mm and it is even over 1500 mm during the rainy season. The marked seasonal variation of temperature is observed.

The reddish alluvial soil is primarily observed which also includes lateritic in nature. Clay with sand, kankar and alluvium are major soil types within the basin. The basin is characterised by wet and humid tropical vegetation, but most of the vegetation cover is replaced by agricultural and other anthropogenic uses.

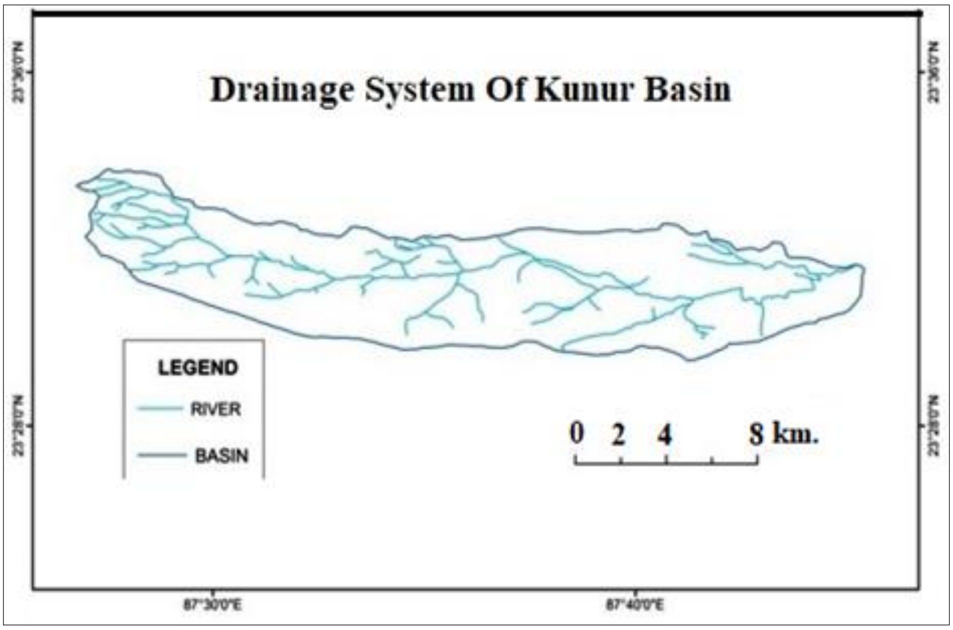
Topometry and Morphometry – Observation and Analysis

To determine the aspects of Topography, slope and morphological disparity Topometry, morphometry and geometric observation and analysis have significant role in relation to distinguish the basin hydro-geomorphologic status. There are several parametric measures in relation to that. Those are Linear, Aerial and Relief parameters and a number of indices have also significant contribution to determine the hydro-geomorphic status of a drainage basin. Results have been extracted from those parameters and subsequent inferences have been taken into consideration. Since long the linkage among different drainage parameters are well established (Horton, 1945; Strahler, 1957; Pakhmode, Kulkarni, & Deolankar, 2003; Magesh and Chandrasekhar 2012; Markose *et al*. 2014; Pophare & Balpande, 2014) [16, 17, 19, 39]. In tectonically active regions, the drainage network reveals the relation between surface processes and the structural deformations (Burbank & Anderson, 2001; Delcaillau, Carozza, & Laville, 2006) [2, 8]. Though, limited studies have focused on the relationship among channel orientation and tectonics (Beneduce, Festa, Francioso, Schiattarella, & Tropeano, 2004; Hodgkinson, Mc Loughlin, & Cox, 2006; Lupia Palmieri *et al*., 1998). A systematic approach toward the development of drainage basin in the area demands a detailed understanding to delineate morphometric parameters and structural control in the drainage basin (Rai, Mohan, Mishra, Ahmad, & Mishra, 2014; Ribolini & Spagnolo, 2008).

Linear Parameters of Basin Analysis

The linear aspects consist of stream number, stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio (Table 3). Stream number is the total number of streams present in a basin. This analysis is very useful for deriving the relationship between stream discharge and area of basin. It is the ratio of total length of stream to its total drainage area. It is important factor for indication of landscape dissection and peak runoff potential of basin. A linear aspect of a drainage network reveals behavior of a river and its tributaries from head to mouth along with lithological and structural controls of the drainage basin. The linear aspects consist of stream number, stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio *(Table 3).* Stream number is the total number of streams present in a basin. The variations in stream order and the sub-basin are largely due to physiographic and structural conditions of the region. The stream length is the maximum area of the basin in a particular order. The different stream orders are derived from the extracted stream network. Using this extracted stream network, estimated the hydrological characteristics of the drainage extent and the bedrock. The stream length ratios vary at the basin and sub-basin levels.

The entire area drained by a stream or system of streams such that all streams flow originating in the area is discharged through a single outlet is termed as the Drainage Area. Drainage area measures the average drainage area of streams in each order; it increases exponentially with increasing order. The area is well dissected by Kunur river itself and its large number of small tributaries as it is mainly composed of old and new alluvium.. *The drainage system of Kunur Basin is given* in (Figure no.—04 & 05). Streamlines are often guided by geologic structure and morphogenetic process. They act as an index of the various stages in landscape evolution. Study of drainage attributes is therefore the most important aspect in the analysis of landforms. The quantitative analysis of the drainage basin is called as a drainage analysis. It includes drainage pattern, stream ordering, stream number, drainage frequency, drainage density, bifurcation ratio, elongation ratio circularity ratio etc. These are not only representing the shape of the drainage basin but did take the dimension and the volume of drainage basin also. These attributes have been analysed in details to show the morphological characteristics of basin.



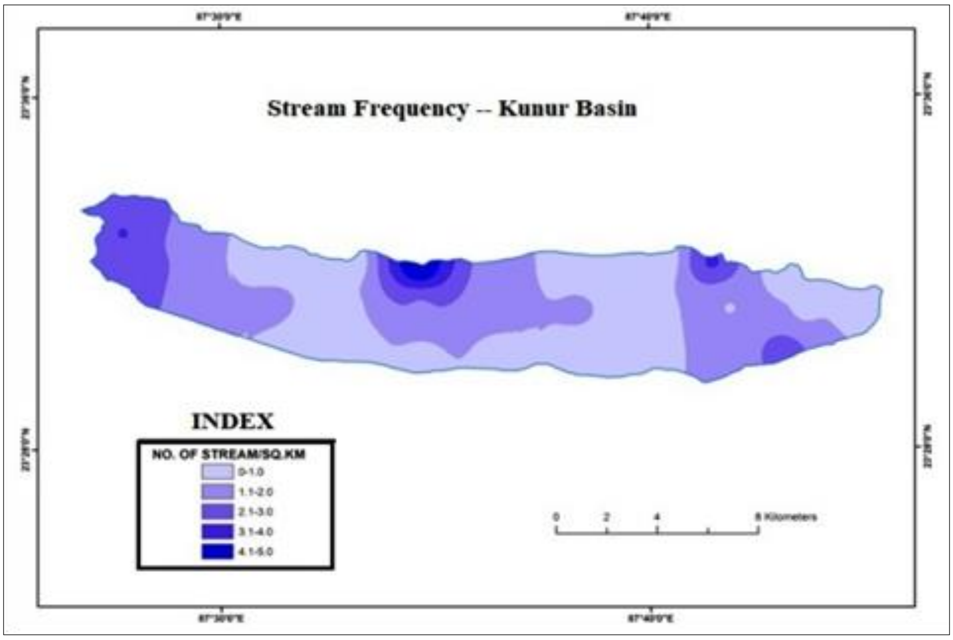


Fig 4 & 5: Drainage Network and Stream Frequency—Kunur Basin

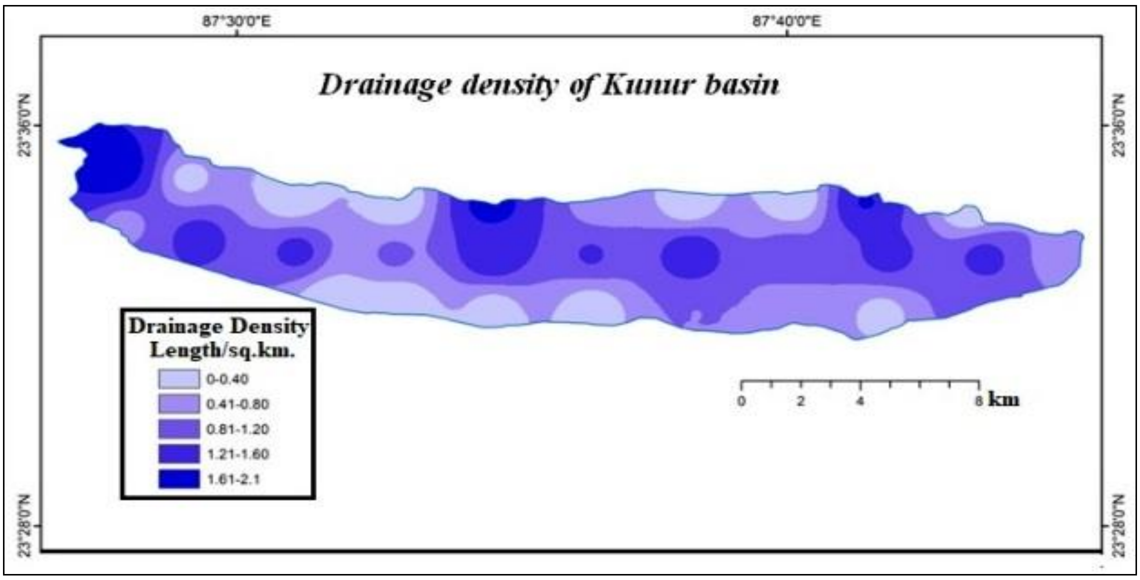


Fig 6: Drainage Density of Kunur Basin

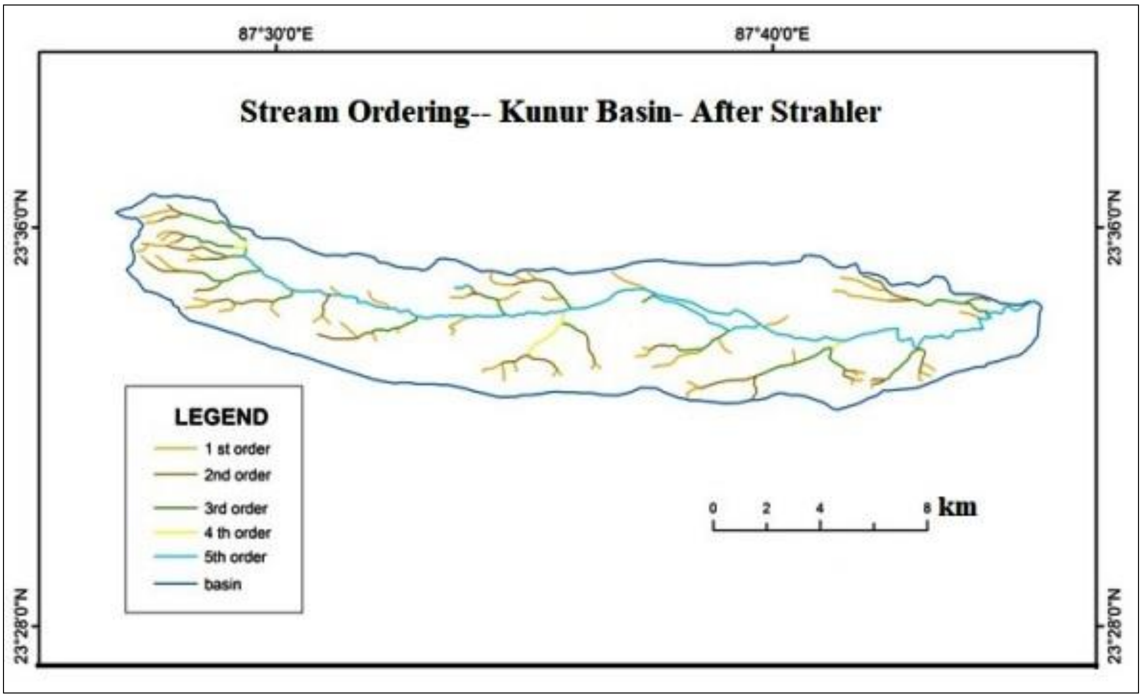


Fig 7: Stream Ordering (After Strahler)—Kunur Basin

Table 1: Stream Frequency and area Covered S_f—Number of Stream

Stream Frequency (S_f)	% of area
0-1	69
1-2	21
2-3	5
3-4	3
4-5	2

Table 2: Drainage Density and Area Covered D_d – Length of the stream / sq. km.

Drainage Density (D_d)	% area
0-0.40	12
0.41-0.80	15
0.81-1.20	40
1.21-1.60	19
1.61-2.1	14

Table 3: Stream Order and Bifurcation Ratio

Stream order(s)	Stream Segment(s)	Bifurcation Ratio
1	48	2.53
2	19	1.46
3	13	6.5
4	2	2
5	1	
Mean	83	3.12

In the present study, based on the Horton's system of overland flow (xv) and subsequent ordering system, I have here followed the modified system of Hortonian stream ordering especially modified by Strahler's system of stream order, (i, v) which is a slightly modified system of Horton. This has been followed because of its simplicity, where the smallest, unbranched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channel segments of 2 order, two 2nd order streams join to form a segment of 3rd order and so on. When two channel of different order join, then the higher order is formed and maintained. The trunk stream is the stream segment of highest order. According to Strahler method Kunur River is a 5th order stream

(Fig.-06). Stream order can highlight on some specific geomorphic points of the basin in relation to flood probability and water availability of the basin.

Number of stream segments can also be a significant parameter to determine the hydro-geomorphic status of the basin. The total number of stream segments present in each order ***is the stream number (Nu).*** Nu is number of streams of order u. By adding different stream we can able to found to total stream number of the whole basin. According to Horton, the numbers of the steam segments of each order form and Inverse geometric sequence with order number.

A number of streams of various order are found in Kunur basin. The number of streams of different Orders and the total number of streams in the basin are counted independently for Kunur basin. The total stream segments in the study area are 83. It is observed that there is a decrease in the stream frequency as the stream order increases. 1st order streams constitute 58% while the 2nd order stream has 23% of the total number of streams. 3rd and 4th order stream constitutes 15% and 2% of the total number of steam respectively while 5th order stream constitute only 1 % of the total number of streams. Thus the law of lower the order higher the number of stream is implied throughout the catchment.

Table 4: Stream Numbers in Relation to Stream Order

Stream Order	***Stream (Number) Segment***	***% of Total Stream Segments***
1	48	58 %
2	19	23 %
3	13	16 %
4	2	2 %
5	1	1 %
Total	83	100

Stream length reveals surface runoff characteristics of the river basin to conduct the hydrological interpretation of the Kunur basin. The total length of the individual stream segments of the each order is the stream length of that particular order. Stream length measured the average or mean length of a stream in each orders and it is calculated by dividing the total length of all streams in a particular order by the number of streams in that order. The stream length in each order increases exponentially with increasing stream order. Streams with relatively short length are representative of areas with the steep slopes and final texture whereas the longer length of streams is generally indicated of low gradient *(ii, iii, iv)*

The stream segment length decreased with the increase in the stream order with the exception of 5th order stream which has higher length than 2nd, 3rd, and 4th order stream length. From table no. 5 it is cleared that 1st order stream constitute 28 %, 2nd order stream constitute 22 %, 3rd order stream constitute 19 %, 4th order constitute 03 % and 5th order constitute 28% of total length.

Table 5: Observed Order wise Length of The Kunur Basin

Stream Order	***Stream length (Km.)***	***Percentage of total length***
1	37.14	28 %
2	28.87	22 %
3	25.26	19 %
4	3.32	03 %
5	36.64	28 %
Total	131.23	100

Observation and Analysis of Relief Parameters

Basin elevation and altitude are significant parameter(s) to determine the determine the Relief status of the drainage basin. Absolute, Relative relief, Total relief i.e., the elevation difference between two points, spot relief, aspects of slope etc., deserve special mention, which can reveal the erosional status of the basin. The difference in altitude, between the highest and lowest point in any given area may be defined as relief. The relief aspects of drainage basin are related to the study of three dimensional features of the basins involving area, volume and altitude of vertical dimension of landforms where in different morphometric methods are used to analyze the terrain characteristics and subsequent evolution which are finally the result of basin processes. A relief aspect of a river basin describes the elevation of surface from surrounding common surface. It is always measured in terms of difference in elevation of highest and lowest elevation in an aerial unit. Thus the analysis includes the analysis of relative relief, dissection index and longitudinal profile.

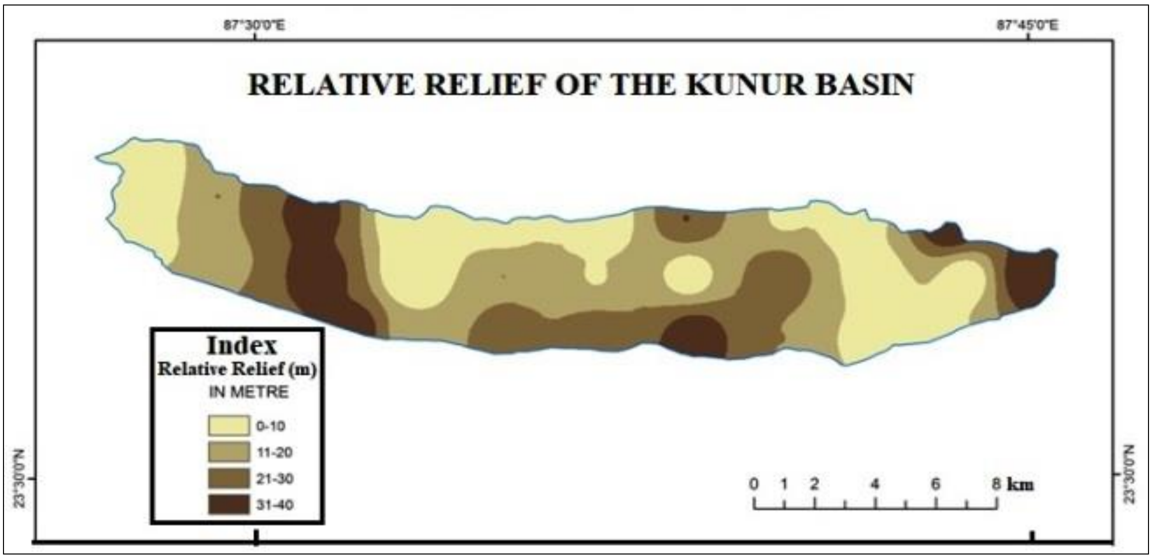


Fig 8: Relative Relief of The Kunur Basin

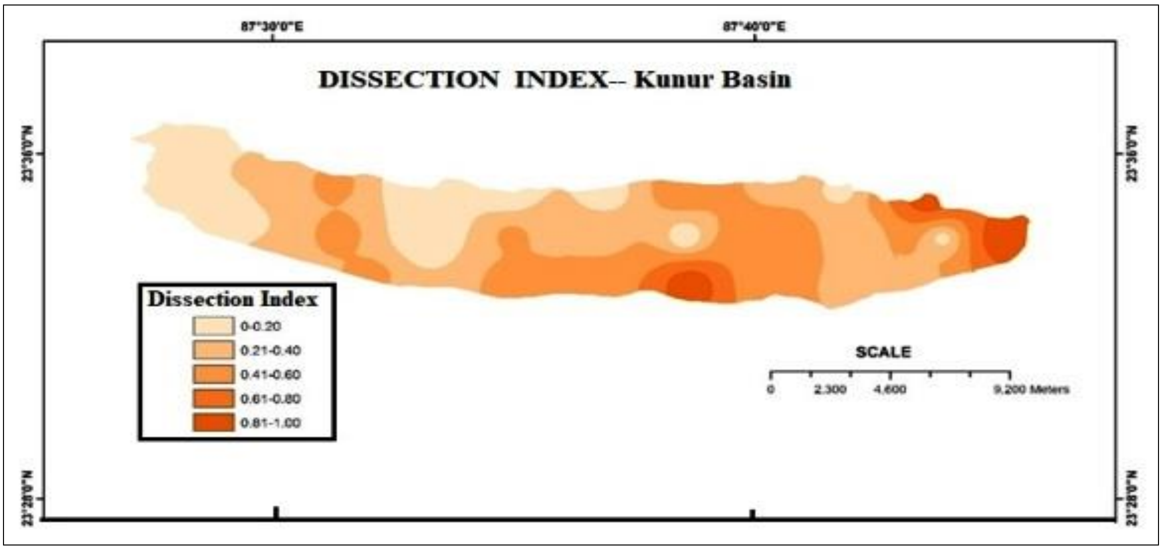


Fig 9: The Degree of Dissection (Index) –Kunur Basin

Relative relief is the difference between the maximum and minimum relief in a specified unit area. Alternatively, the term relative relief denotes the actual variation of height in a unit with respect to local base level (Fig. - 07). Relative relief is one of the significant techniques which is effectively capable of presenting the relief characteristics without considering sea level. Initially, a scientific and the systematic study of relative relief was done by Smith (1935). The Kunur River basin has the maximum value of relative relief as 40 meter and minimum value of 2 meter and it is divided into four categories i.e. 0-10, 11-20, 21-30, 31-40. Fig. 2 shows spatial pattern of relative relief of Kunur basin.

The degree of dissection is represented by an index which is ratio between absolute relief and relative altitude (Fig.-08). The Dissection index by and large follows the same spatial pattern and that of relative relief to absolute relief, the index gives the degree of dissection and also indirectly indicates the proportion of non-eroded component. *The areas with low value of the index are generally found in the regions of high altitude where the erosion agents have yet to do considerable work*. This index is also useful in the study of the development of slopes within the region and it depends mainly on the response of Lithology to the intensive frequency and magnitude of forces operating in given area and value of dissection index varies from 0 to 1. The following formula suggested by Dovnir (1957, Singh & Dubey, 1994) is considered while analyzing Kunur basins, dissection index

Dissection Index = Relative Relief / Absolute Relief

Ruggedness Number describes the complexity of the topography as well as the roughness of the terrain. The surface Ruggedness indicates the degree of dissection of a region where drainage has also been taken as an important parameter. Chorley (1972) has derived the principles of Ruggedness Number (Dimensionless Number):

Ruggedness Number = [(RR x DD) / 1000]

This index is being widely used by the earth scientist in connection with the morphological studies of terrain and it leads to better understanding of the surface configuration evolved under Complex geomorphic processes. Actually it is more than development of slope or dissection index as it incorporates in number of determinant factors related to the development of landforms. This index reflects the combined effect of evolutionary rhythmic processes in the development of relief (Mukhopadhyay 1984). The Ruggedness index (Number) of Kunur basin is calculated and it is seen that most area of the basin has very low value of the same i.e. 0-0.05. The entire basin is divided into five categories in terms of ruggedness disparity. It is to be ascertained that high value of ruggedness number within the basin is very rare.
The term in its broadest sense means an element of earth's solid surface, including both terrestrial and submarine surfaces (Strahler, 1956). Terrain morphology is characterized by slope condition which is governed by a number of factors including climate, geological and tectonic condition. There is also a close relationship between slope condition and morphometric attribute of terrain, i.e. absolute relief, relative relief, dissection index, drainage density and drainage frequency. Slopes are ubiquitous elements of the landscapes (king C.A.1962). Slopes are the fundamental types of landscape feature. Slope may be defined as the tangent of the angle of inclination of a plane defined by a land surface. It is the result of a complex and continuous interaction between internal and external forces acting upon the earth's surface. The technique of Wentworth (1930) being easier and involving lesser measurement and calculation and more rapid procedure.

Average slope (AS), = $\tan^{-1} N \times i / K$, Where, N=Av. number of contour crossing / km.
i = Contour interval, K=constant (3361 for mile grid and 636.6 for kilometer grid)

Slope analysis of Kunur basin is calculated and is given in figure 9. Average slope of Kunur basin vary in very little i.e. 8.35 to 8.45. Lower the value of average slope, higher is the probability of flood. Here it is found that most of the areas have lower average slope which means that most of the areas have high probability of flood.

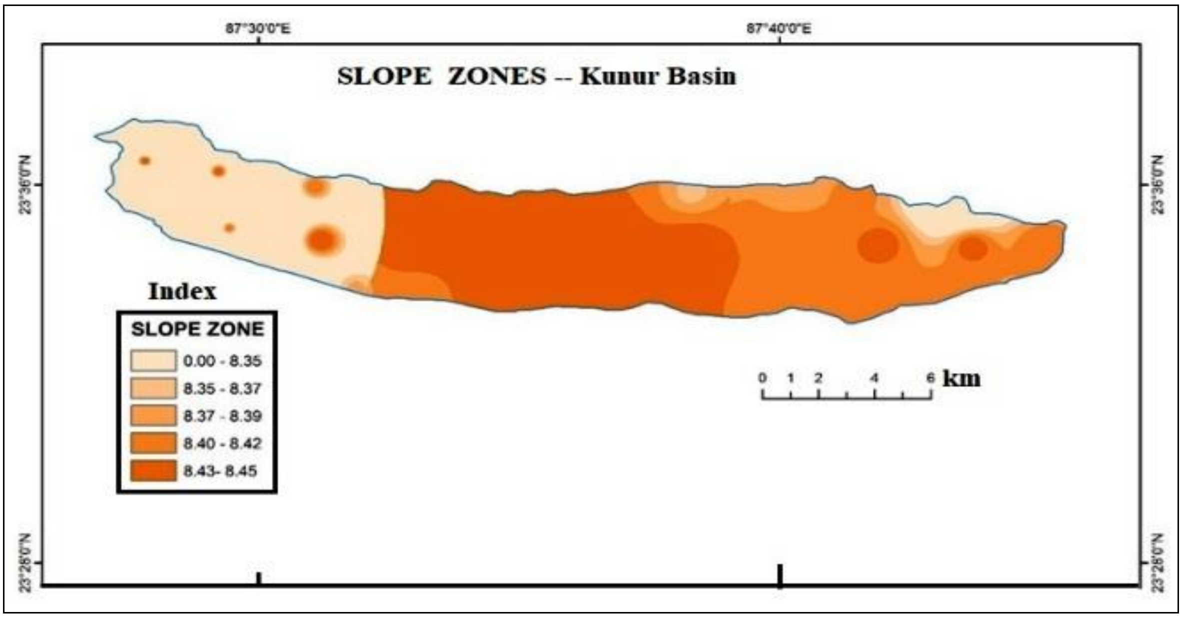


Fig 10: Slope Zones of Kunur Basin

To determine the valley side and hill side slope drawing of profile along and across the area are the significant measures for depicting the basin geomorphologic scenario. Bank profile (along the bank) and Terrace profile can also represent the significant deviation from the particular unit of land parcel. The bank to bank profile across the width of a river is known as cross profile. In other words, a cross profile is a diagrammatic representation of depicting the transverse profile of a valley in order to demonstrate the valley side slope gradient, the terrace sequence etc. It gives an idea about the width of the valley and its varying depth. The valley deepening, Widening and lengthening processes are closely associated and correlated along with the profile demonstration processes on the land.

Table 6: Extraction of Morphometric Parameters – Kunur Basin

Relative Relief (m)	Dissection Index	Stream Frequency (Numbers of stream/sq. km.)	Drainage Density (Length/sq.km.)	Average Slope (in Dec. Degree)	Ruggedness Number
2	0.02	1.96	2.09	8.43	0.004
19	0.19	1.07	0.25	8.43	0.009

6	0.09	4.35	1.69	8.41	0.01
6	0.09	0.77	0.44	8.41	0.26
5	0.13	2.06	1.38	8.4	0.007
11	0.11	1.92	0.51	8.38	0.006
17	0.18	0.78	1.08	8.41	0.02
35	0.35	0.85	1.05	8.45	0.04
1	0.02	0.49	0.71	8.43	0.001
19	0.32	1.08	1.3	8.43	0.025
12	0.23	0.69	0.95	8.45	0.011
6	0.10	0.69	1.26	8.43	0.008
26	0.44	0.49	0.81	8.41	0.021
7	0.18	0.6	1.07	8.43	0.008
5	0.15	0.56	1.04	8.43	0.005
40	1	0.42	0.55	8.41	0.022
25	0.38	0.37	0.385	8.41	0.004
24	0.41	0.39	0.1	8.43	0.001
39	1	0.33	1.93	8.41	0.025
19	0.32	0.32	1.41	8.4	0.009
8	0.21	0.93	0.58	8.41	0.002
10	0.25	1.56	0.43	8.4	0.007

Correlation and Association among The Parameters

Correlation and association among the parameters especially among the Linear and Relief parameters have high proficiency value in relation to determine the geomorphic status of the kunur basin. The law of stream number and length in terms of order are justified here by correlation analysis. The relationship between stream order and stream segment is derived by regression analysis method. Here the value of multiple R is equal to 0.918 which suggests that the line has good fit with data. With the help of ANOVA again the value of the significance of F has been extracted and the value is 0.02 which is below 0.05and hence there is a strong correlation between stream order and stream segment. Stream order and stream segment has negative correlation. From this plot we can conclude that higher the order of river, lower is the value of stream segment.

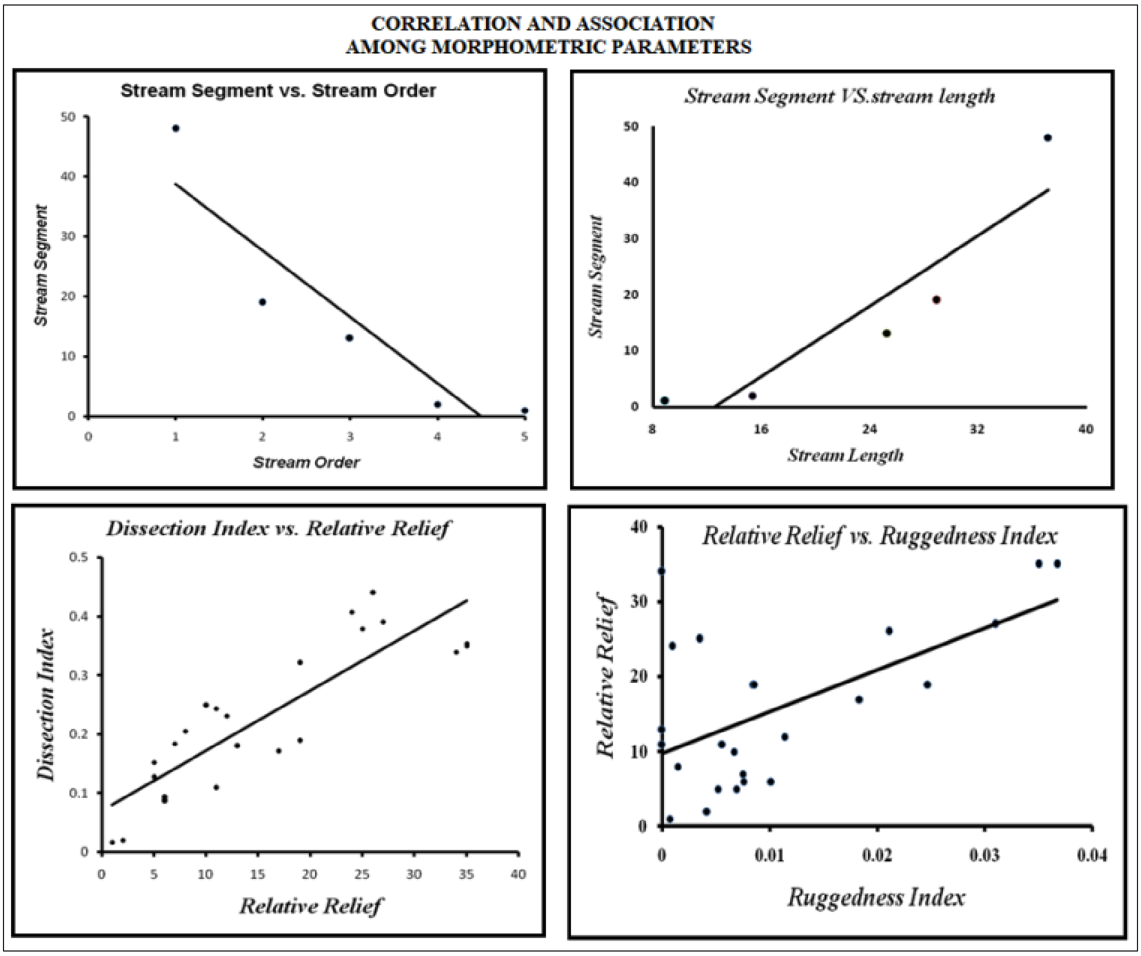


Fig 11: Correlation and Association among Morphometric Parameters-[RR (in m), Stream Length (in m.)]

Relationship between stream length and stream segment is determined by regression method. It is seen that value of multiple R is equal to 0.909 which means the linear fitting is very good fitting. Again the value of Significance F is equal to 0.03 which is below 0.05. This means there is a significant correlation between stream length and stream segment. Positive correlation is present between stream length and stream segment. From this plot it can be concluded that stream segment increases with stream length.

Regression method is used to estimate the relationship between dissection index and relative relief. The result shows that the value of multiple R is equal to 0.86 which is greater than 0.5 which suggest that this plot is good fit. The value of significance -F for this plot is 3.91×10^{-8} which is very low with respect to 0.05 and hence it means this plot has lower error and strong correlation between dissection index and relative relief and this correlation is positive correlation. From this plot we can conclude that dissection index increases with relative relief.

The relation between ruggedness index and relative relief is determined with the help regression method. Here multiple R value is equal to 0.59 which is greater than 0.50 which suggest that the linear plot has good fit. The value of significance F is equal to 0.002 which is below 0.05 which suggests there is a strong positive correlation between ruggedness index and relative relief.

Regression method is used to estimate the relationship between stream frequency and drainage density. The result shows that the value of multiple R is equal to 0.60 which is greater than 0.5 which suggest that this plot is good fit. The value of significance -F for this plot is 0.001 which is very low with respect to 0.05 and hence it means this plot has lower error and strong correlation between drainage density and stream frequency and this correlation is positive correlation. From this plot we can conclude that stream frequency increases with drainage density.

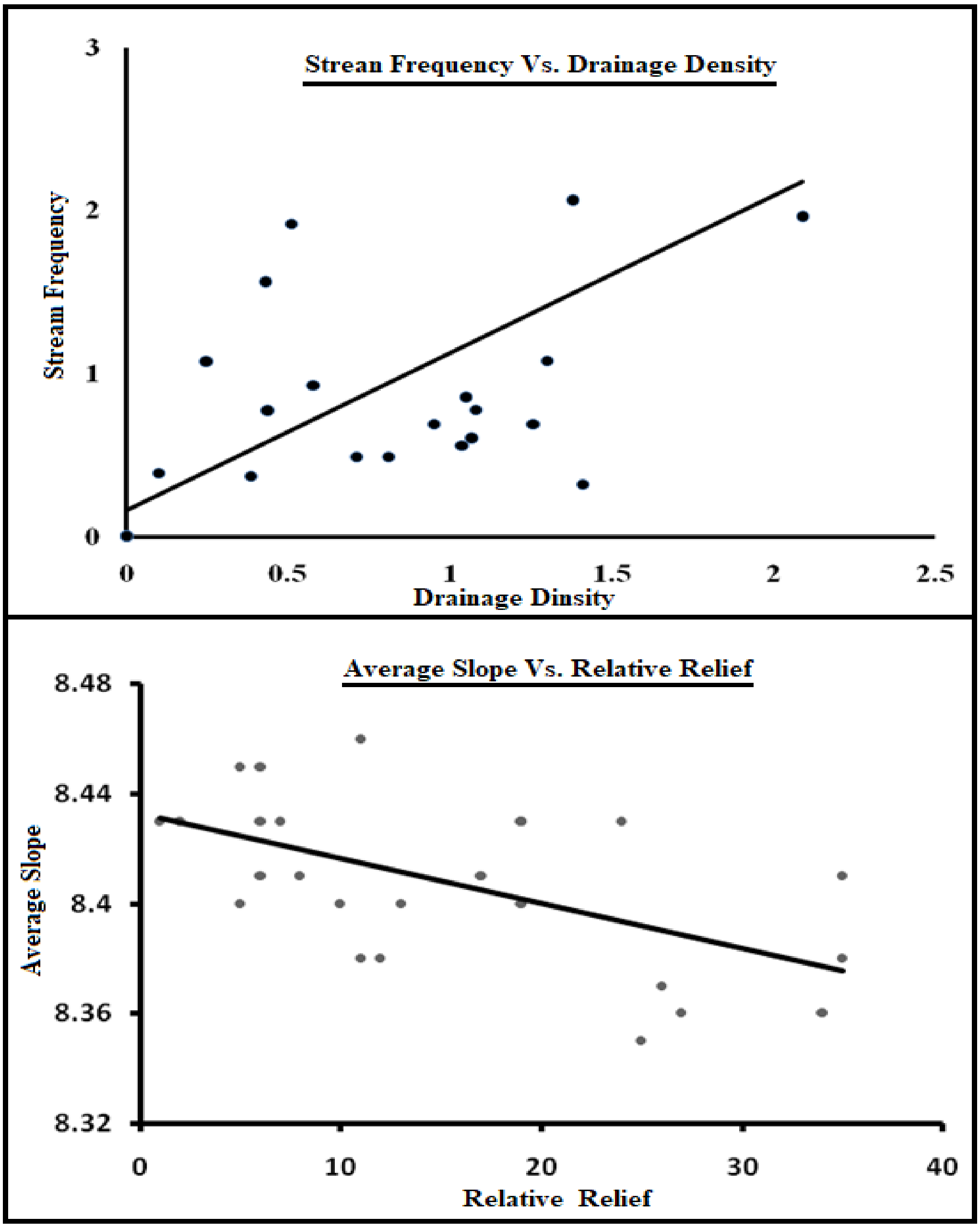


Fig 12: Correlation and Association –Aspects of Relief and Drainage

Conclusion

The morphometric analysis carried out in a selected drainage system in Rarh plain of Barddhaman district indicated that the basin representing low relief terrain, moderate ruggedness, high elongated in shape and fine texture that revealed litho-Stratigraphic control within the basin. The morphometric parameters evaluated using GIS help to understand various terrain parameters such as nature of the bedrock, infiltration capacity, and runoff. The computed values refer to moderate to low runoff (with high seasonal variation) and high infiltration capacity. The overall results revealed that analysis of drainage system displayed significant information on geomorphic and hydrologic conditions.

The analysis of the stream channels and rock composition demonstrate that some preferential orientations exist which are likely to be litho-structurally controlled.

The linear arrangement of stream number and stream order reveals the flow direction strictly controlled by external forces. The Kunur basin, as a result of neo- tectonic activity and erosion on the development of the channel orientation is (i) most channels are directly or indirectly related to the litho-structural factors, (ii) the pattern of the drainage network is dendritic to sub-dendritic and partially sub-parallel to parallel pattern are observed. All these evidence point toward the Litho-tectono-structural uplift-induced drainage system for the Kunur system

Drainage basin morphometry in terms of the linear aspects of 5^{th} order sub-basin of Kunur show general conformity with available understanding on drainage development and landform evolution. There are however, drainage anomalies reflected in the quantitative basin parameters that can be correlated with geotectonic elements. Such anomalies are mostly recorded from the areas with pronounced structural control on drainage.

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