ANALYSIS OF RELIEF THROUGH QUANTITATIVE INDICATORS: A CASE STUDY OF WESTERN DOON OF DEHRA, UTTRAKHAND (INDIA)

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The quantitative study of relief of a geomorphic unit is very significant. Such a study of geomorphic unit highlights the relief Characteristics - like, maximum basin, slope aspects, relief ratio, ruggedness number, length of overland flow, constant of channel maintenance etc. These relief parameters also highlight some characteristics of rocks and sequential evolution of landscape as well. The study area, the Western Doon of Dehra is an important small geomorphic unit from the perspective of cultural and natural landscape. Infact, Dehradun which is the capital city of Uttarakhand is a part of this area. So, the conservation of cultural and natural landscape also becomes important for this unit. Keeping in view the importance of this unit for mankind, present study has been carried out. Database of relief analysis of doon is the Topographical Sheets published by Government of India. The available landmass in doon of Dehra varies between 300m to 1830 m, The relief ratio varies from 0.27 to 0.181 in fifth order watersheds; whereas, It is 0.033 in the Asan basin which is 6th order channel in the study area. Study reveals the negative correlation between area and relief ratio of watersheds. The Rn value in all the fifth order watersheds of the study area varies from 0.006 to 0.85. The high value of Rn in the Bin watershed indicates young topography. The higher ruggedness number on the scrap faces and crest of Mussoorie also indicates the tilt or upliftment of the area in recent past. The length of overland flow varies from 88 meters to 288 in different fifth and sixth order watersheds. The highest length of overland flow in Upper Asan watershed indicates the possibility of the sheet erosion in the watershed. Mean gradient of ground in different basins varies between 0.012 and 0.70. High value of mean gradient of Bin watershed suggests that this watershed is susceptible to erosion. The investigation reveals an inverse relationship between slope of streams and stream orders. The deviation of some points from the best fitted line suggests the role of other physical factors in the formation of gradients.

Keywords: Constant, Dehra, Doon, Form, Gradient, Ground, Maintenance, Mean, Ruggedness,

1) INTRODUCTION

The study area falls in Himalayan region. It lies between lesser Himalayas and Siwaliks. It is one of the famous doons situated between these two ranges. The crests of lesser Himalayas and Siwaliks respectively in north and south, Song water divide in the east and Yamuna in north-west and west make the boundaries of Western Doon of Dehra. This doon covers an area of 834.28 square kilometers. The latitudinal extension of the area is from 30° 14' 10" to 30° 31' 32" north. Its longitudinal extension is from 77° 34' 15" to 78° 05' 39" east. Politically, this area falls in Dehradun district of Uttarakhand. Asan is the major stream in this geomorphic unit. It is a sixth order stream. Six fifth order tributaries - Upper Asan, Nun, Darer, Sitla Rao, Tons, Surna join the major stream (Asan). Bin is also a fifth order stream in the area, but it directly joins Yamuna. It is not a tributary of Asan.

The morphometric study of relief aspects of any geomorphic unit is very significant. Such type of study highlight the various drainage basin characteristics like - maximum basin relief, relief ratio ruggedness number, length of overland flow, constant of channel maintenance and various slope aspects of the area. Some characteristics of rocks can also be assessed by examination of the relief Indicators of drainage basin. The study area, the Western Doon of Dehra is an important small geomorphic unit from the perspective of cultural and natural landscape. Infact, Dehradun which is the capital city of Uttarakhand is a part of this area. So, the conservation of cultural and natural landscape also becomes important for this unit. Keeping in view the importance of this unit for mankind, present study has been executed.

The morphometric analysis of drainage basin or watershed was pioneered by Horton (1932, 1945) which has further been extended by different scholars all over the world during the last seven decades. Among the early scholars, Miller (1953), Schumn (1956), Coats (1958), Melton (1958), Sumit (1958), Morisawa (1959), Maxwell (1960), Chorley (1962), Strahler (1950, 1956, 1958, 1964, 1971) Schneider (1965), Miller (1981), Strahler (1950, 1952, 1956, 1958, 1964, 1971) and their associates published a number of research papers establishing the base of drainage analysis. Following these ideas the morphometric study of relief aspects of doon of Dehra has been carried out. Under this analysis maximum basin relief, relief ratio ruggedness number, length of overland flow, constant of channel maintenance, mean ground slope, mean stream gradient, valley side slope has been examined.

1) DATABASE AND METHODOLOGY

Topographical sheets published by the government of India are the database of study. The topographical sheets bearing sheet numbers - 53F/10, 53F/11, 53F/15, 53F/14, 53J/3 covers the Western Doon of Dehra. The scale of these sheets is 1:50000. Rotameter has been used to measure the distances. The following formulas have been applied to calculate the indicators of relief (Table-1).

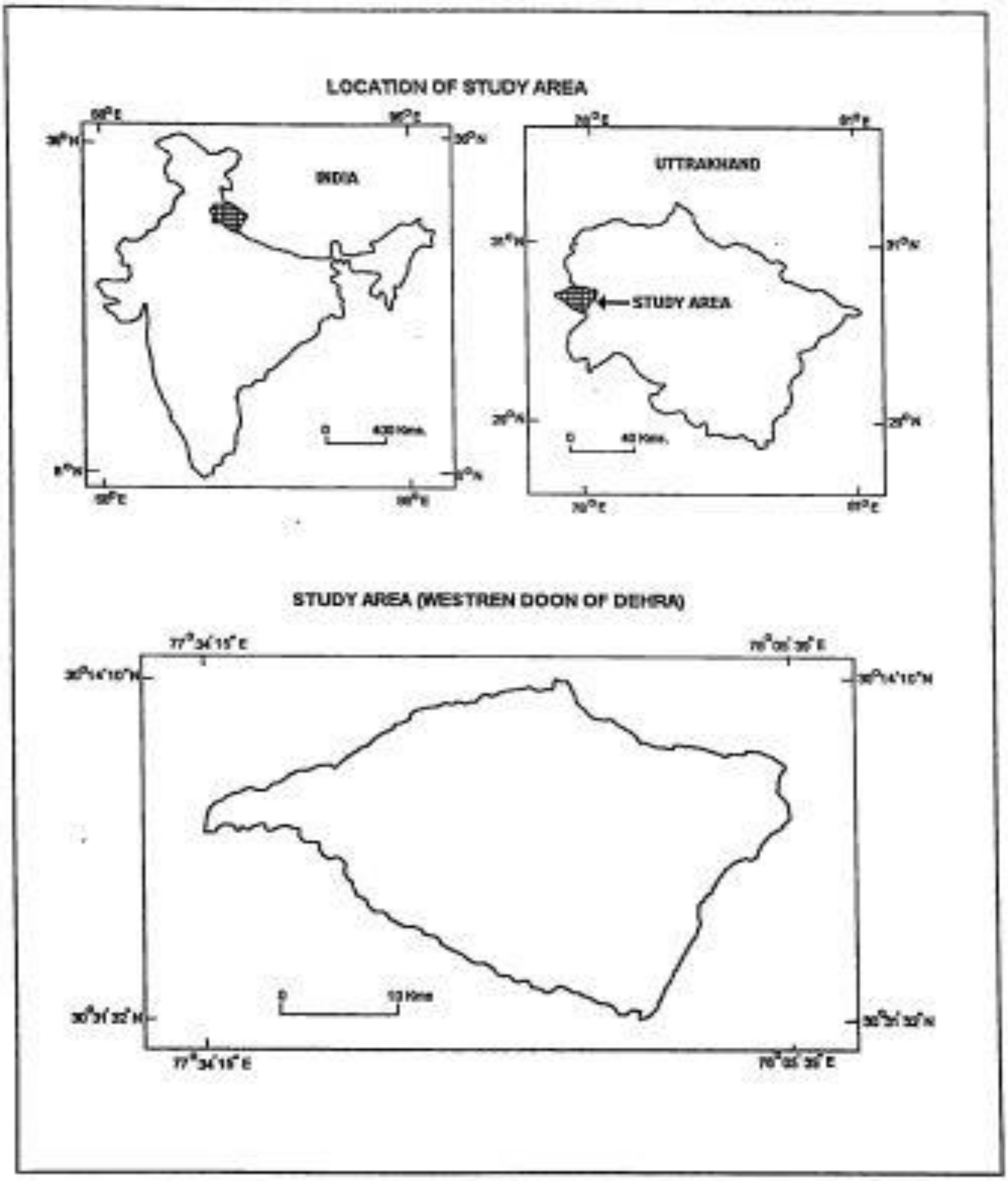

Fig. 1: Location of study area

Table (1): Methods of calculation of parameters of relief morehometry

Sr. No.	Relief parameter	Method	Reference
1	Maximum Basin Relief (Br)	Br = H-h Here, H & h respectively represent highest and lowest point in the unit	Strahler (1952)
2	Relief Ratio (Rh)	Rh = H/Lb Here H stands for relative relief and Lb is length of basin along longest dimension of basin.	Suchmm (1956)
3	Length of Overland Flow (Lg)	Lg = 1/2Dd Here, Dd is drainage density	Horton (1945)
4	Constant of Channel Maintenance	Ccm = 1/Dd Here, Dd is drainage density	Schumm (1956)
5	Ruggedness Number (Rn)	RN = R × Dd, where R = H-h & Dd is drainage density	Suchmm (1956)
6	Mean Ground Slope (θs)	θs = ∑Lc × C.I. /Ba; Here ∑Lc is total length of contours in the basin, C.I. is contour interval & Ba is area of basin,	Chorley (1979)
7	Mean Stream Gradient (Sg)	*Sg = V.I/H.E Here, V.I. is Vertical Interval & H.E. is Horizontal Equivalent	-
8	Stream Order wise Gradient	Sg = ∑GUn/€NUn Here, ∑GUn is the sum of gradient of all streams in specific order and ∑NUn is total number of streams in that specific order	-

*The result obtained from the equation has also been used to compute the tangent of the angle for valley side slopes.

Analysis of Slope, Relief and Related Parameters:

Under this head maximum basin relief, relief ratio, ruggedness number, valley side slopes, channel slope, general ground slope, length of overland flow etc. have been taken for expressing relief and slope characteristics of drainage basin.

Maximum Basin Relief:

It may be defined as 'the elevation difference between highest and lowest point in the given area' (Strahler, 1952). It is the simplest method for expressing relief and slope characteristics of the geographic unit. Maximum basin relief also indicates the height of landmass to be eroded. Intensity of erosion can also be worked out by establishing the relationship between maximum relief and other variables like length of basin, nature of rocks and vegetation. Table (2) indicates that available landmass for erosion in Upper Asan is about 300 m.; while it is 1830 m in Asan basin, the 6th order drainage basin. Table (2) also indicates that the available landmass for erosion varies between 920 and 1830 m except the basin of Upper - Asan.

Relief Ratio:

It is defined as the "ratio between the total relief of a basin and the longest dimension of the basin, parallel to the principal drainage line" (Schumm, 1956). It is the ratio between height and length of drainage basin. Thus, it shows the overall gradient of the drainage basin. This gradient is equal to the tangent of angle framed by the plane of height and the plane of length, intersecting at the mouth of highest order stream in the drainage basin. This ratio indicates the overall steepness of the drainage basin. So, it may also be taken as an indicator of the intensity of the process of erosion on the slopes of the drainage basin. The formula suggested by Suchmm (1956) has been adopted for the calculation of relief ratio, which is given below

$Rh = H/Lb$

Where H is the total relief (elevation difference of lowest and highest point of basin) and Lb is the basin length.

The Rh value varies from 0.027 to 0.181, the minimum for upper Asan basin and maximum for Bin watershed (Table-2). Bin is a tributary of Yamuna River. The maximum value of Rh in fifth order watersheds of Asan is 0.110. The highest value is confined to Nun watershed. The Rh value for the 6th order Asan basin is 0.33.

Joji V.S. (2001) maintained that low Rh value is generally confined to resistant bedrock with gentle slope. This value usually increases with decrease in watershed area. Bin basin occupies the least area among fifth order watersheds but highest value of relief ratio. The study of total area of basins and relief ratio reveals that there is negative correlation between basin-area and relief ratio of the basin.

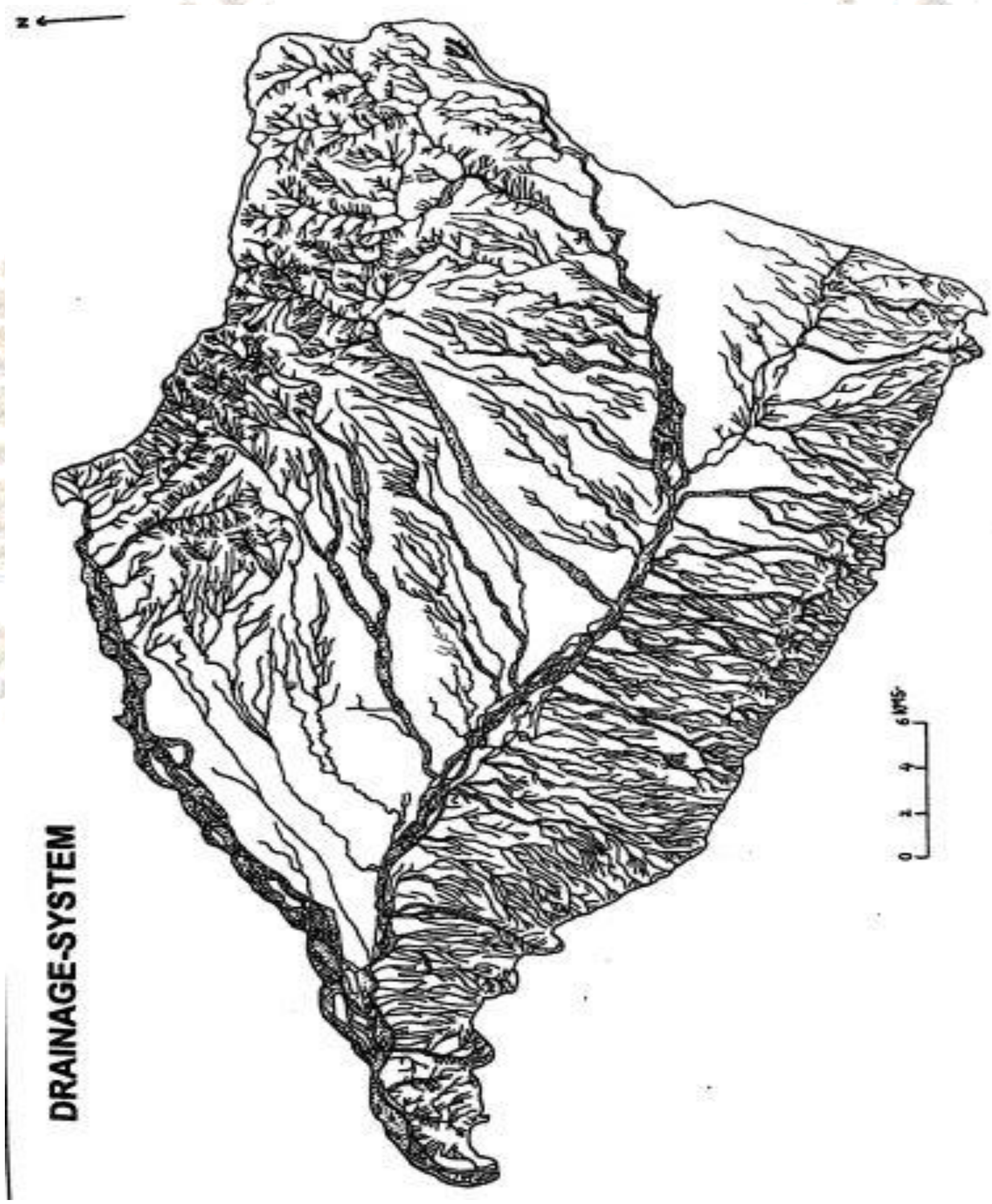

Fig.2: Drainage System

Ruggedness Number (Rn):

It is the combination of slope characteristics and drainage parameters of the basin. This may be defined as a product of relative relief (H) and drainage density (Dd). To calculate the ruggedness number in the basin both the parameters are taken in the same unit of measurement. The ruggedness will be high when both relative relief and drainage density (Dd) are high. The equation of ruggedness (Strahler, 1964) is:

$$Rn = H \times Dd$$

The Rn value in all the fifth order watersheds of study area varies from 0.006 to 0.85 (table 2). It is lowest in Upper Asan and highest in Bin watershed. This high value indicates young topography in Bin watershed. This basin extends in western part of Mussoorie range. This value in western part (Bin - watersheds) of Mussoorie range indicates the tilt or upliftment in the region. Fig.3 reveals that almost all the scrap and crest of Mussoories and extremely north-eastern reaches of Siwaliks experience high ruggedness, while it is extremely low in the alluvial plain and waning slopes of uplands.

Length of Overland Flow:

Horton (1945) first proposed the concept of stream flow generation by overland flow. If the water supply by rainfall exceeds the rate of infiltration capacity in the soil; excess water leads to accumulates on the surface, fills all surface depression and the excess water flows over the land surface as the overland flow. Generally it is taken to be "approximately equal to half the reciprocal of drainage density" (1/2 Dd) (Horton 1945). In fact it is the distance that water has to flow on the earth surface before it drains into the stream.

The length of overland flow is lowest in Bin watershed. This value is 0.088 Km. (88 meters) for the Bin drainage basin (Table-2). In the fifth orders watersheds of Asan drainage system this value varies between 136 m and 244 m and for the Asan watershed as a whole the overland flow value is 192 meters. The length of overland flow is minimum in Bin watershed due to more dissection and more undulation of surface. It is maximum (244 m) in Upper-Asan. The reason being, the relief with this watershed is comparatively less undulating.

This flow is responsible for sheet erosion of the soil. The length of overland flow is maximum in Upper Asan watershed, so the landscape under this watershed is more susceptible to erosion hence, plantation may be required in the watershed to check the soil erosion. This indicator may also be used as detailed studies of runoff processes in the watershed or in the management of hydrological aspects of drainage basin.

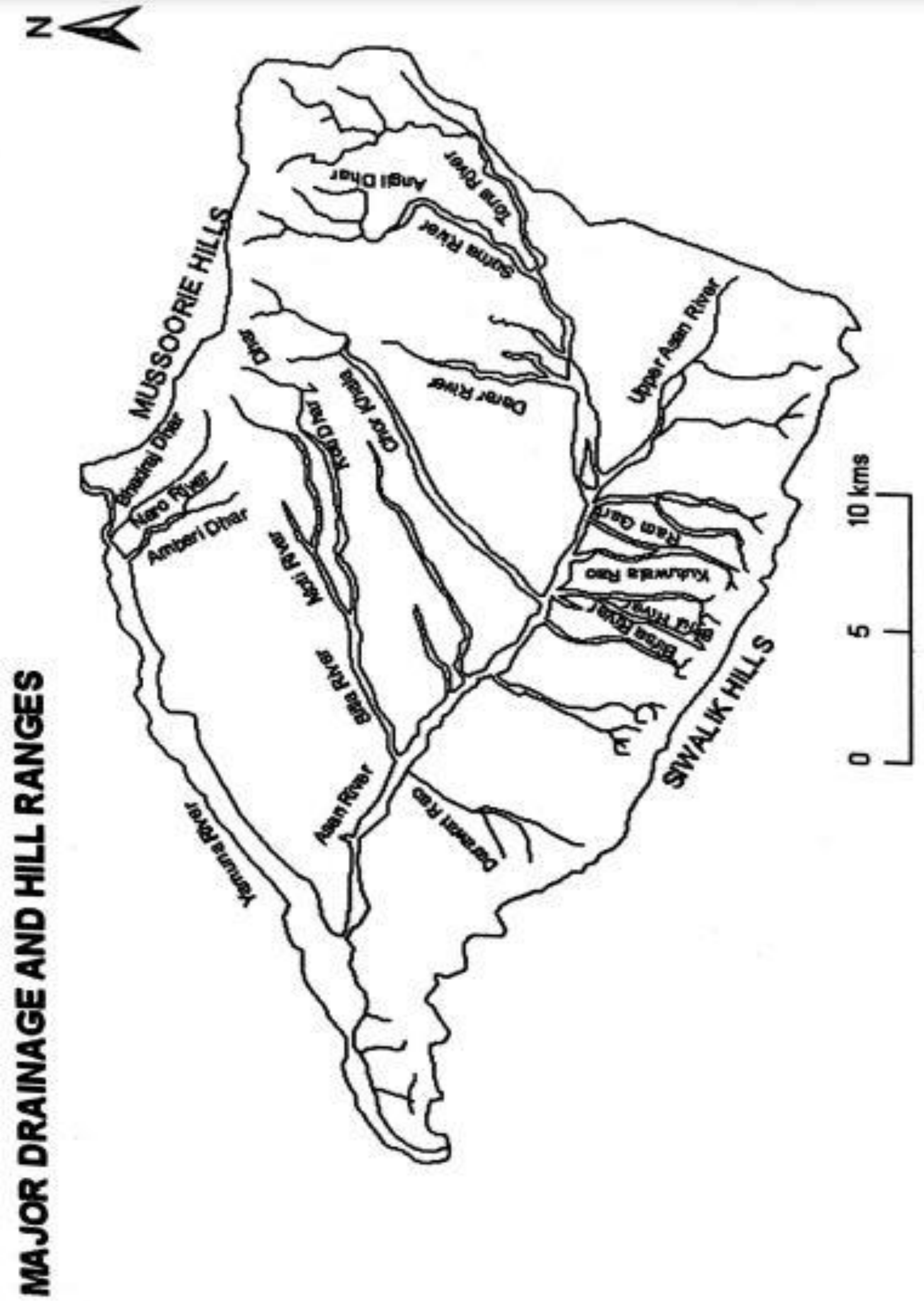

Fig.3: Major Drainage and Hill Ranges

Table: (2) Relief Indicators of Drainage Basins

S.No.	Parameters	Tons	Nun	Darar	Surna	Sitla	Upper Asan	Bin	Asan
1	Total Basin Area (A) Sq. Km.	50.41	39.6	21.93	35.89	51.29	96.13	10.02	741.11
2	Max. basin length (L) Km	18	14.2	13.7	22	21	11.2	8.3	53
4	Basin Perimeter (Bp) Km	31.5	32	24	45	48	49.5	18.5	125
9	Length of Overland Flow Km	0.175	0.147	0.136	0.151	0.203	0.244	0.088	0.192
10	Max. Basin Relif (H) m.	1591	1561	920	1600	1789	300	1500	1830
11	Relief Ratio (Rh)	0.088	0.11	0.065	0.08	0.085	0.027	0.181	0.033
12	Ruggedness Number (Rn)	0.09	0.134	0.154	0.148	0.086	0.006	0.85	0.006
13	Gradient of Ground Surface (Sg)	0.180	0.268	0.308	0.296	0.172	0.012	0.70	0.012
14	Constant of Channel Maintenance Km2	0.351	0.295	0.272	0.301	0.407	0.488	0.176	0.384
15	Slope of Channel (θc)	4.8	5.2	2.6	3.6	4.8	0.28	8.9	0.35
16	Mean Valley Slide Slope (θg)	13.59	16.81	9.46	15.62	11.7	1.6	20.3	1.2
17	Maximum Valley Slide Slope (°)	21.3	28.65	11.35	29.25	28.0	1.9	26.45	1.9

Constant of Channel Maintenance:

'Constant of channel maintenance is the area required to feed to sustain a stream' Schumm (1956). It may also be defined as the average distance between the channels in a basin or watershed. Infact constant of channel maintenance is the number of square kilometers that are needed to maintain one square km of channel. It is inverse to drainage density. Generally, if the rock character is favorable to the development of drainage density, a small area is required to maintain one kilometer of channel. Along with the drainage density this constant value may also be used for comparing the surface erodibility in different watersheds.

While investigating the area constant of channel maintenance was found highest in Upper Asan watershed and lowest in Bin watershed. The reasons for such differences are slope and dissection of the area. The Upper Asan watershed is gentle sloped, so the value of constant of channel maintenance is maximum among the watersheds. The watershed of Bin is highly dissected so the value of constant of channel maintenance is lowest among the watersheds.

Mean Slope of Ground Surface: Mean slope of overall basin has been computed after Chorley (1969) but slightly modified as

$\theta s = \sum Lc \times C.I. / Ba$; here

$\sum Lc$ is total length of contours in the basin, C.I. is contour interval & Ba is area of basin,

Table -2 indicates that the mean gradient of ground in different watersheds varies between 0.012 and 0.70. Bin watershed has the highest Sg. The value of Sg indicates various characteristics of the drainage basin such as, erosive power of the process, drainage density, drainage frequency, nature of terrain and landuse in the basin. Some scholars have studied that drainage density, drainage frequency and erosion is directly proportional to mean ground slope in a fluvial environment.

Mean Stream Gradient:

It is the average drop in elevation from origin point to mouth of a channel. Order wise mean stream gradient has been calculated for the study area. To calculate the mean stream gradient, the drop in elevation of all the streams of an order has been added together. The calculations so obtained have been divided by the total number of streams in that particular order. The results derived from calculation indicate an inverse relationship between stream order and mean gradient of the channels (Table-3). Channel gradient is progressively decreasing with the increase in the order of channels. Schumm (1956) stated:

"There is a fairly definite relationship between slope of streams and stream orders, which can be expressed by an inverse geometric series"

A glance at the figure-4 reveals that some points are deviating from the best fitted line. The deviation of points from this line suggests role of other physical factor in the formation of gradient.

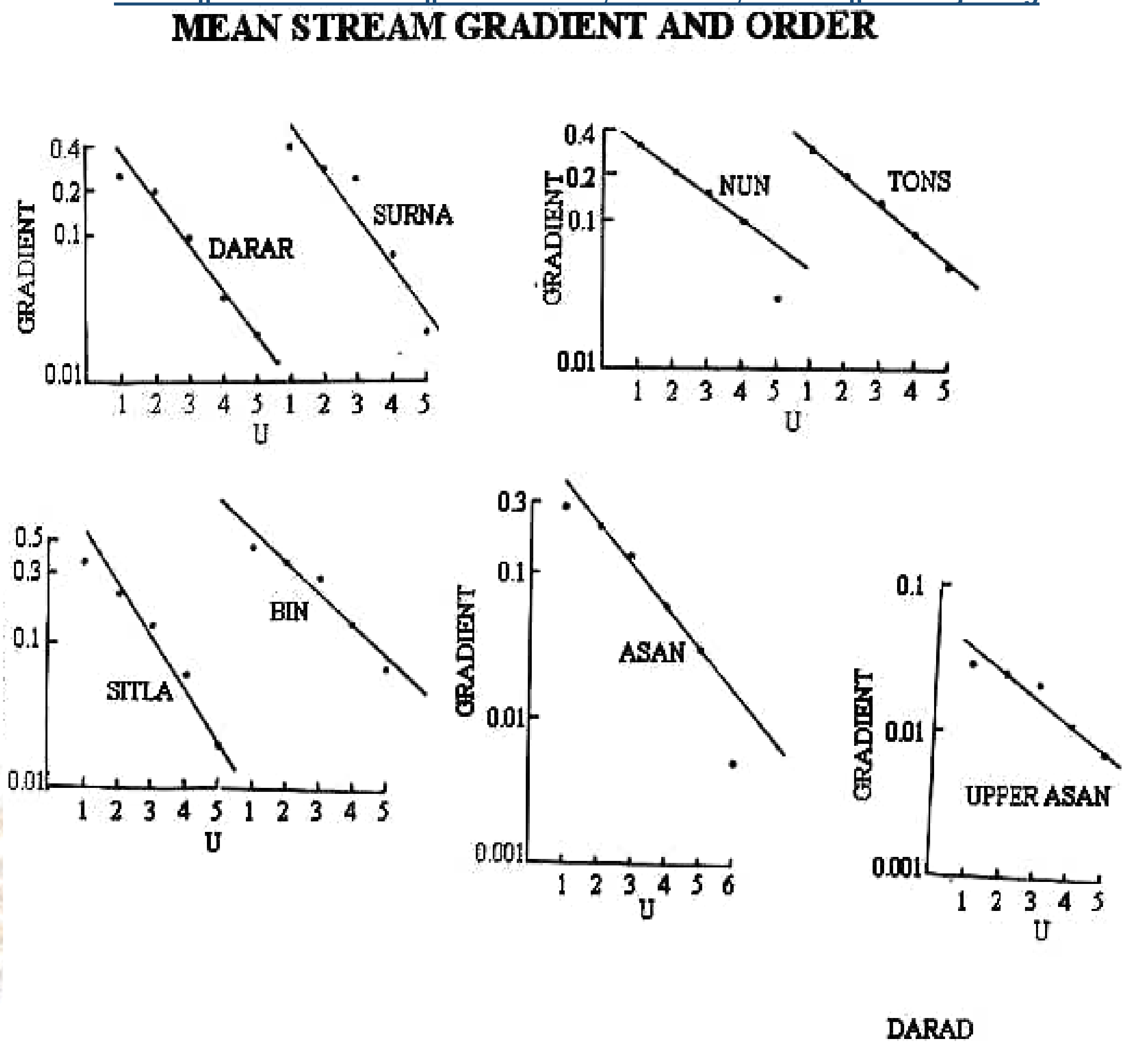

Fig.4: Stream Gradient and Order

Table (3): Order-wise Mean Gradient of Streams

Drainage	Order-Wise Mean Gradient of Stream					
Basin	1st	2nd	3rd	4th	5th	6th
Tons	0.298	0.206	0.14	0.088	0.049	–
Nun	0.314	0.208	0.161	0.108	0.031	–
Darar	0.264	0.196	0.098	0.037	0.021	–
Surna	0.396	0.278	0.244	0.071	0.022	–
Sitla Rao	0.346	0.218	0.14	0.056	0.024	–
Upper Asan	0.049	0.026	0.022	0.012	0.002	–
Bin	0.456	0.383	0.286	0.156	0.066	–
Asan	0.283	0.213	0.137	0.062	0.025	0.005

Valley Side Slope:

Valley side slope is expressed as the mean angle of complete valley side profile or sampled over the whole basin. Mean valley side slope is an indicator of development of basin. Higher the valley side slope, younger will be the topography in a normally developed basin; however these values may not be an important indicator in the areas having high structural control. The valley side slopes in the watersheds vary between 1.9° and 29.25°. It is lowest in Upper Asan and highest in Surna basin (29.25°) followed by Nun watershed (28.65°). There are interesting features to note with regard to channel slope (θc) and valley side slope (θg). It can be concluded from the table-2 that higher the channel slope still higher is the valley side slope. There is almost a triple range of increase within the channel slope (θc) and valley side slope (θg).

2) CONCLUSION

The available landmass in doon of Dehra varies between 920 m to 1830 m, except watershed of Upper Asan, where it is 300 meters. The relief ratio varies from 0.27 to 0.181 in fifth order watersheds. It is 0.033 in Asan basin which is sixth order channel in the study area. There has been found negative correlation between area and relief ratio of watersheds. The Rn value in all the fifth order watersheds of study area varies from 0.006 to 0.85. It is lowest in Upper Asan and highest in Bin. High value of Rn in the Bin watershed indicates young topography. This higher value also indicates the tilt or upliftment of the area. The scrap faces and crest of Mussoorie and extremely north-eastern higher reaches of Siwaliks experience high ruggedness, while it is extremely low in the alluvial plain and waning slopes of uplands. The length of overland flow varies from 88 meters to 244 m in fifth order watersheds and for the Asan watershed as a whole the overland flow value is 192 meters. The length of overland flow is maximum (288 m) in Upper Asan watershed, so the landscape under this watershed is more susceptible to erosion; hence, plantation may be required in the watershed to check the soil erosion.

Mean gradient of ground in different watersheds varies between 0.012 and 0.70. Bin watershed has the highest Sg which indicates that the erosive power of the process will be highest in this watershed. The investigation reveals inverse relationship between slope of streams and stream orders. This relationship can be expressed by an inverse geometric series. Investigation also reveals that some points are deviating from the best fitted line. The deviation of points from this line suggests role of other physical factor in the formation of gradient. Maximum valley side slope in the basin varies between 1.9° and 29.25°. It is lowest in Upper Asan and highest in Surna basin (29.25°).

In nutshell it can be concluded that negative correlation exists between area and relief ratio of watersheds. The high value of Rn in the watershed of Bin, on the scrap faces and crest of Mussoorie indicates the tilt or upliftment of the area in the recent past. The highest length of overland flow in the Upper Asan watershed indicates the possibility of sheet erosion in the watershed. High mean gradient of Bin watershed suggests that this watershed is susceptible to erosion. The deviation of some points from the best fitted line of stream slopes and orders suggests the role of other physical factors in the formation of gradients.

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