Morphometric Analysis of Areal Aspects of Western Doon of Dehra, Uttrakhand (India)

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Abstract
The morphometric study of areal aspects of a geomorphic unit is very significant. This type of study through light on various drainage basin characteristics - like dissection of the area, intensity of erosion, sedimentation, length of overland flow, runoff etc. Characteristics of rocks can also be assessed by examination of the areal aspects 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 carried out. Database of areal analysis of doon is the Topographical Sheets published by Government of India. Study of drainage density reveals that scarp faces of the study area are under intense erosion. Low to moderate drainage density and drainage drainage frequency indicates that a large portion of study area is plain and also suggests late mature stage of landform development in the region. It has been investigated that the crest area of Tons watershed has medium drainage frequency which indicates that crest areas of Tons are comparatively flat topped. Upper reaches of Surna watershed, Sitla watershed and Siwaliks have high drainage density and drainage drainage frequency so flooding is most likely to occur in the upper area of these channels during the heavy rain. All the three shape indicators conclude that all the 5th and 6th order drainage basins are elongated in shape. The elongated shapes can help in minimizing the flood losses, when heavy rainfall occurs in peaks. The elongation values also suggest that the landforms are in a mature stage of development. Differences in these values among different similar order basins suggest the control of slope, geology and structure in the development of streams.

Keywords: Circulatory, Dehra, Density, Doon, Drainage, Elongation, Frequency

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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.

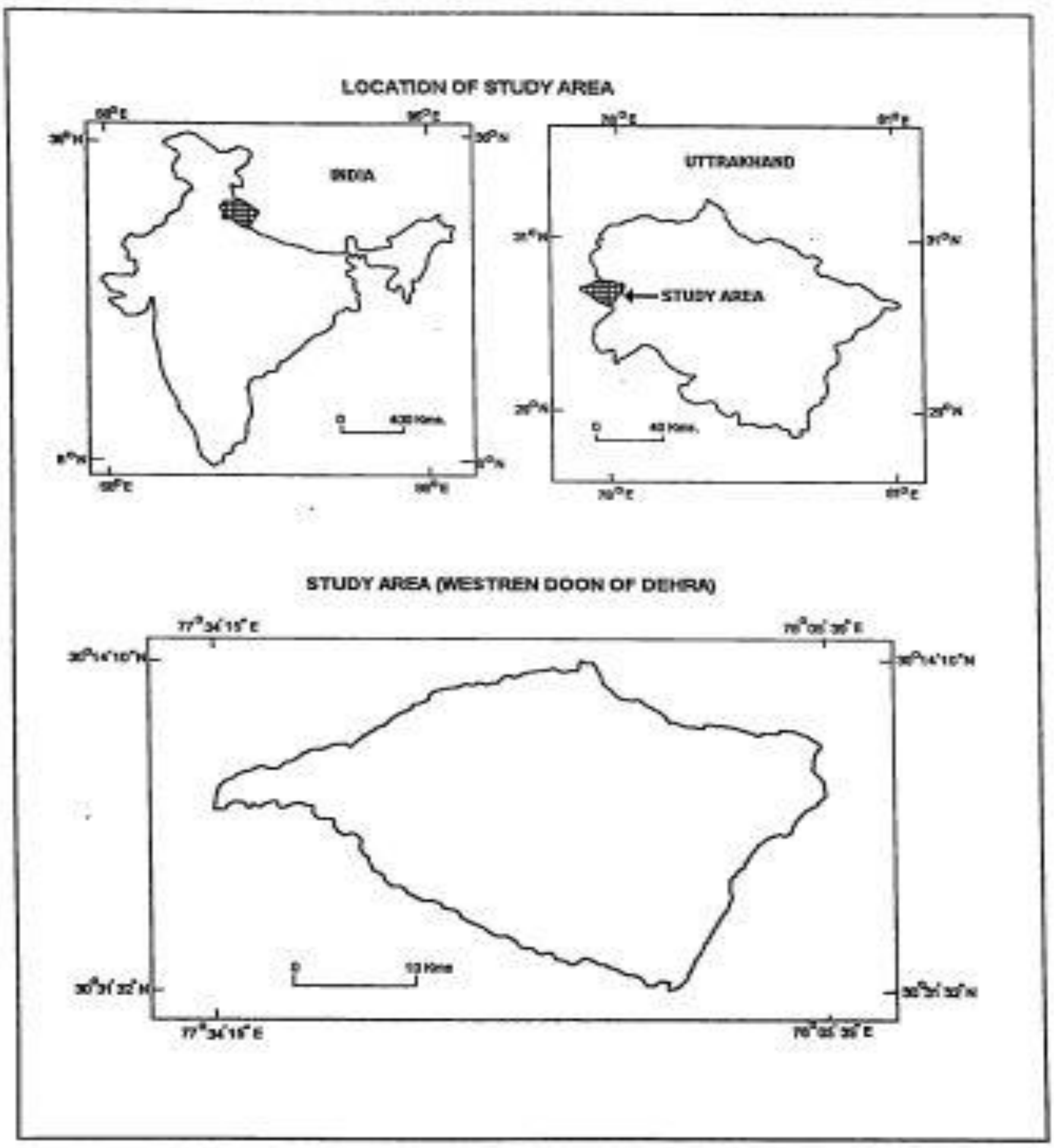

Fig.1

The morphometric study of areal aspects of any geomorphic unit is very significant. This type of study through light on various drainage basin characteristics - like dissection of the area, intensity of erosion, sedimentation, length of overland flow, runoff etc. Characteristics of rocks can also be assessed by examination of the areal aspects 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 study 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

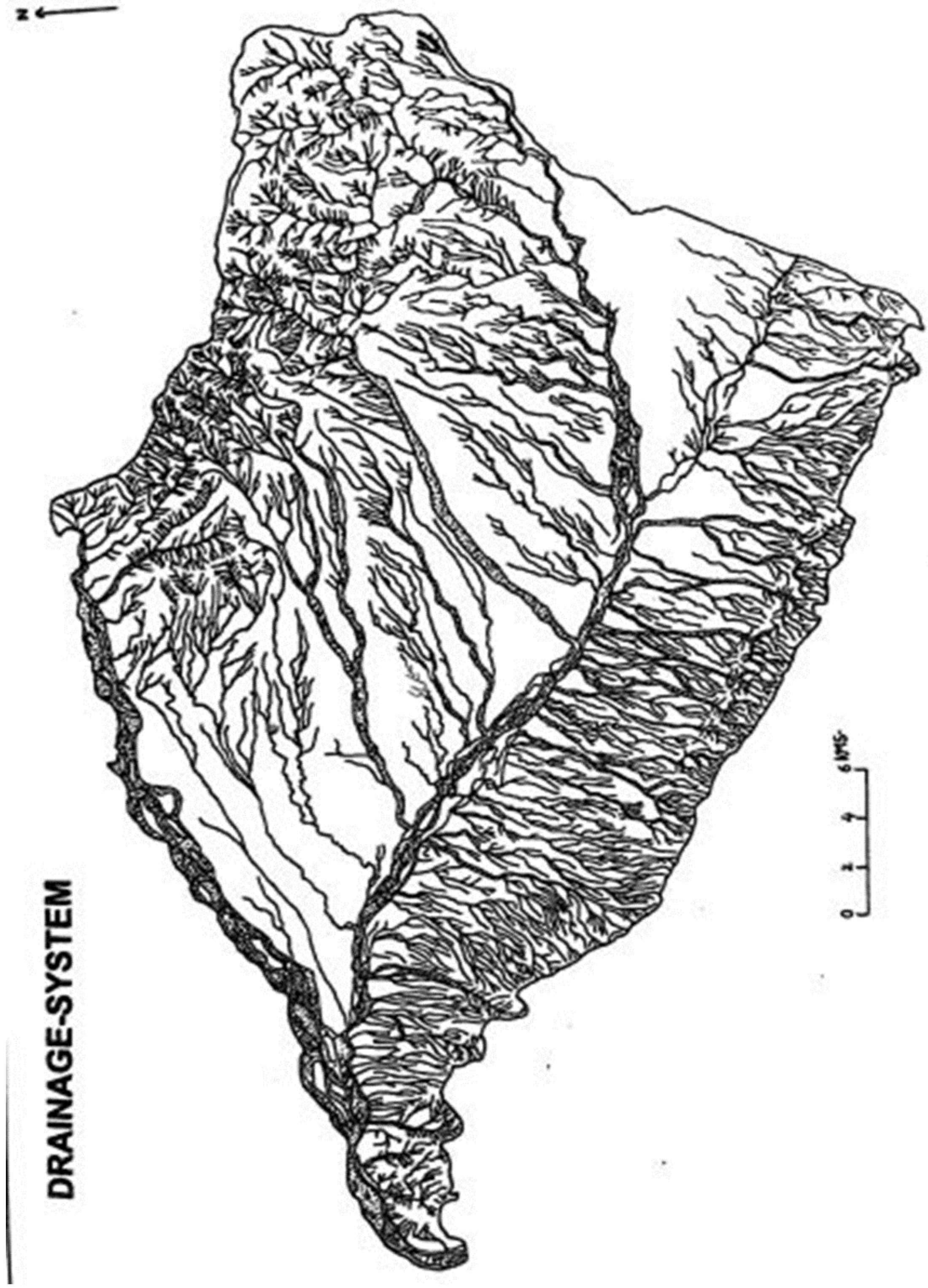

Fig.2

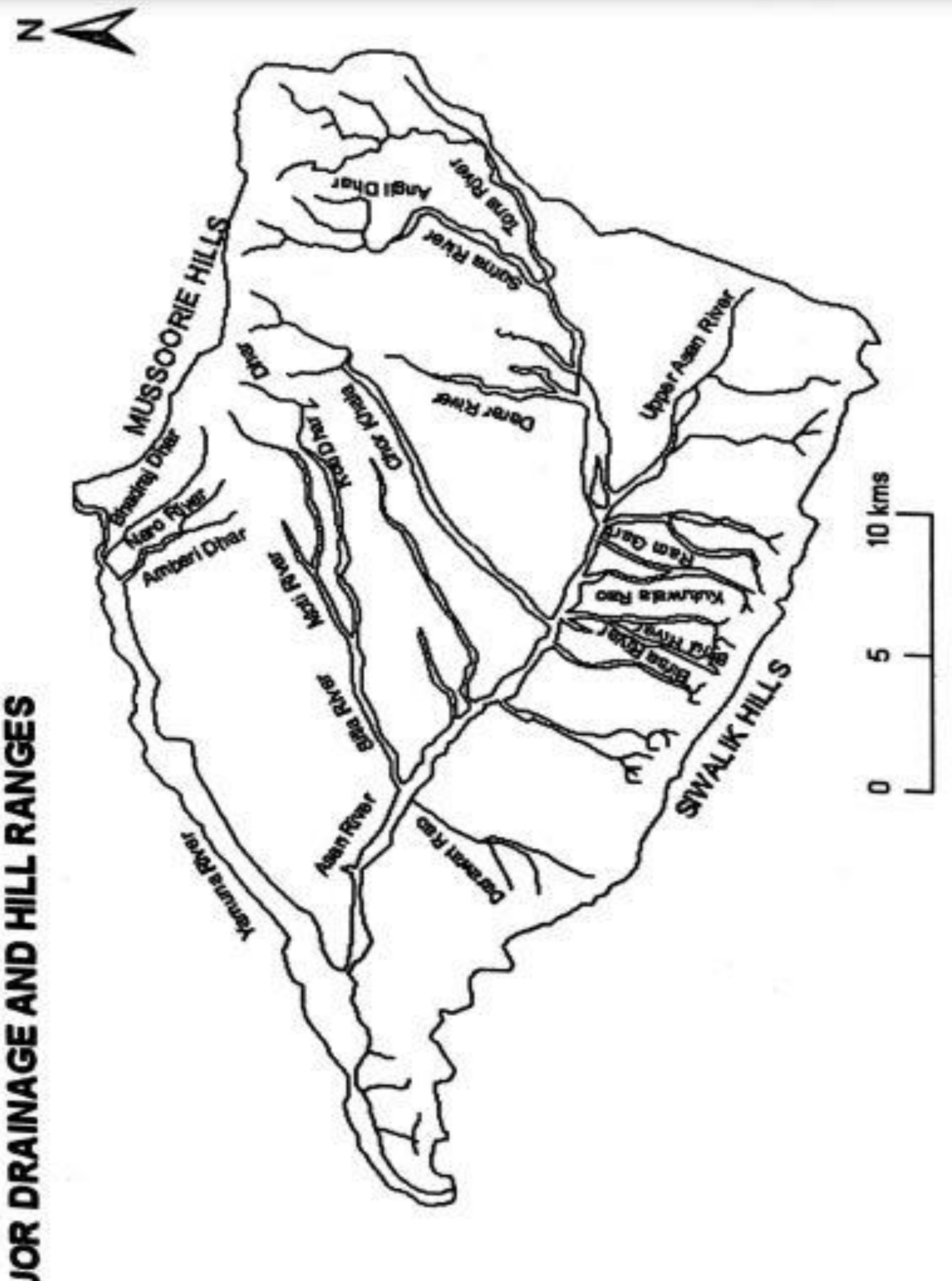
MAJOR DRAINAGE AND HILL RANGES
N
MUSSOORIE HILLS
SIWALIK HILLS
Angi Dhar
Tons River
Sutna River
Upper Asan River
Danar River
Dhar
Chor Khala
Bhadraj Dhar
Naro River
Amberi Dhar
Ram Garh
Kulurwala Rao
Asan River
Yamuna River
Darawat Rao
Bata River
0
5
10 kms

Fig. 3

(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 areal aspects of doon of Dehra has been carried out. Under this analysis drainage density, drainage frequency, basin shape and size has been examined.

2. 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. The grid method suggested by Horton has been applied to compute the drainage density and drainage frequency. The grid of one square kilometer has been taken for this purpose. To study basin shape, indicators, like- form factor, circulatory ratio, elongation ratio have been taken into account. The following formulas have been applied to calculate the indicators of form factor.

Indicators of form factor	**Formulas**	**Proposed by**
Form Factor	$R_f = A/(L_b)2$; Here A stands for area of basin & L_b is air distance along the longest dimension of basin	Horton (1932)
Circulatory Ratio	$R_C = \frac{4\pi A}{p^2}$ Here A is the area and p is of perimeter, 4 is constant value	Miller (1953)
Elongation Ratio	$R_e = \frac{2A/\pi}{L}$ Here, A is area of basin, L is maximum length of basin.	Schumn (1956)

3. Results and Discussion

The areal morphometry of doon has been studied under four heads. These are drainage density, drainage frequency, shape and size.

3.1) Drainage Density (D_d):

It is the ‘total length of all the channels in the unit area, irrespective of their orders’ (Horton 1945). Since, it is very difficult, tedious and time consuming to measure the length of channels in the unit area so a lot of scholars evolve their own method for calculation of drainage density. C.W. Carlston and WB langbein (1960) suggested 'the probabilistic line intersection method'. T. Wilgat (1966), used 'mean distance from the nearest water course' to calculate drainage density. J.J. Donahue (1972) used 'number of points on regular grids that touch a stream as an index of stream length', while calculating drainage density. Savinder Singh (1976) used drainage texture for estimation of drainage density. Gardiner (1979), estimated 'drainage density from topographical variables' of the unit. To examine drainage density of doon, the total length of all orders of streams grid wise has been measured. This grid consists of one square kilometer area. The area under study has been classified into five categories of drainage density viz extremely low (0-1), low (1–2), moderate (2-4), high (4-6) and very high (>6)

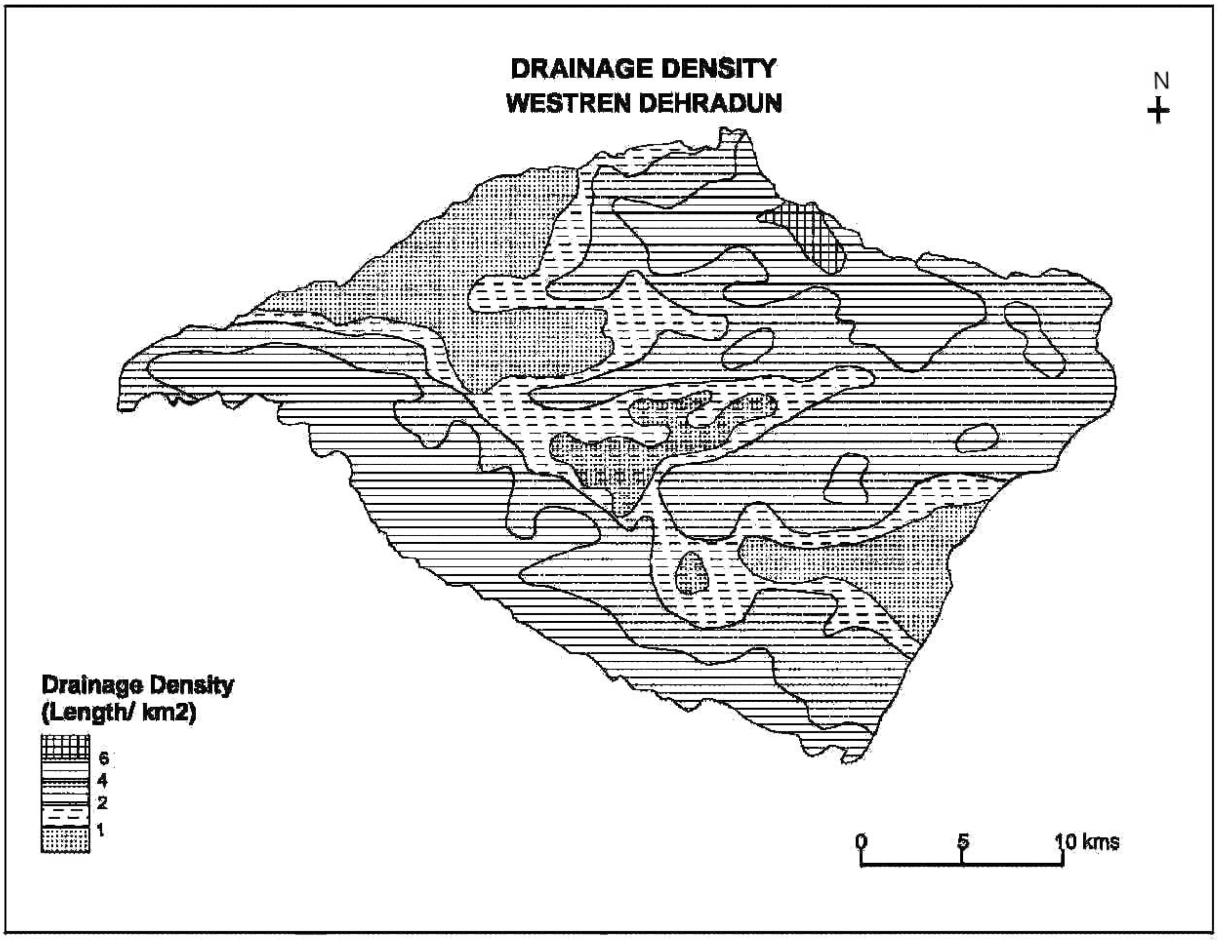

Fig.4

More than 34% of doon is under the classes of extremely low and low drainage density (Table-1). The geographical coverage of the low D_d is found inbetween the foothills of Siwaliks and the foot hills of Mussoorie (Fig 4). North-eastern portion of this geomorphic unit (bordering Yamuna river) exhibits extremely low drainage density.

Moderate drainage density; which occupies more than 38% of the study area (Table-1) extends over the upper part of waning slopes and debris slopes of Siwaliks and Mussoorie hills. Upper part of Tons watershed has also moderate drainage density (Fig-4).

More than 10% of area of doon falls inthe classes of high and very high drainage densities. These categories indicate the zone of high erosion. This zone of high drainage density is limited to the scrap faces of the region. Central crest area of Mussoorie hills has also high Dd.

Table 1: Areal Distribution of Drainage Density

(Area in square kilometer & drainage density in per square kilometer)

Drainage Density (Classes)	Area in class	Area in Percentage	Cumulative Area	Cumulative % Area
0 – 1	150.53	18.05	150.53	18.05
1 – 2	139.75	16.75	290.28	34.8
2 – 3	187.2	22.43	477.48	57.23
3 – 4	134.36	16.1	611.84	73.33
4 – 5	138.34	16.59	750.18	89.92
5– 6	78.15	9.37	828.33	99.29
> 6	5.95	0.71	834.28	100

Total	834.28	100		
Mean: 2.81 kms; Coefficient of Variation = 76.86 Standard Deviation = 2.16; Variance = 4.67				

3.2) Drainage Frequency (D_f):

The unit of square kilometer has been taken to compute the drainage frequency in the present investigation. Accordingly, area has been divided into grids of one square kilometer for the computation of stream frequency. The data obtained has been classified into 5 classes of drainage frequency. These are very poor (0–2), poor (2–4), moderate (4–8), high (8-12) and very high (>12).

Poor drainage frequency covers about 47% areas, out of which about 24% area has extremely poor drainage frequency (Table-2). This shows that a large part of this geomorphic unit is under plain which discourages the formation of streams. The area of low drainage frequency occupies the whole doon between Siwaliks and Mussoorie. The area between Surna and Sitla Rao exhibits very poor drainage frequency.

Moderate drainage frequency (4-8) is extended over 35% area of doon. This class is distributed on the debris slopes of both the uplands (Siwaliks and Mussoorie). The lower part of Tons basin exhibits medium drainage frequency; although the density is poor in lower parts of other similar order basins. Low to moderate drainage frequency indicates that most of the area under this geographic unit has entered into the late mature stage of its landform development. Variation in drainage frequency distribution is found between and within the watersheds (Table -4)

High drainage frequency, which covers about 20% of the region, extends on the scarp faces and crests, except the crest area of Tons basin which has medium drainage frequency. This indicates that the crest area of Tons is comparatively flat topped. Higher drainage frequencies in the central part of Mussoorie hills indicate the sharp crest.

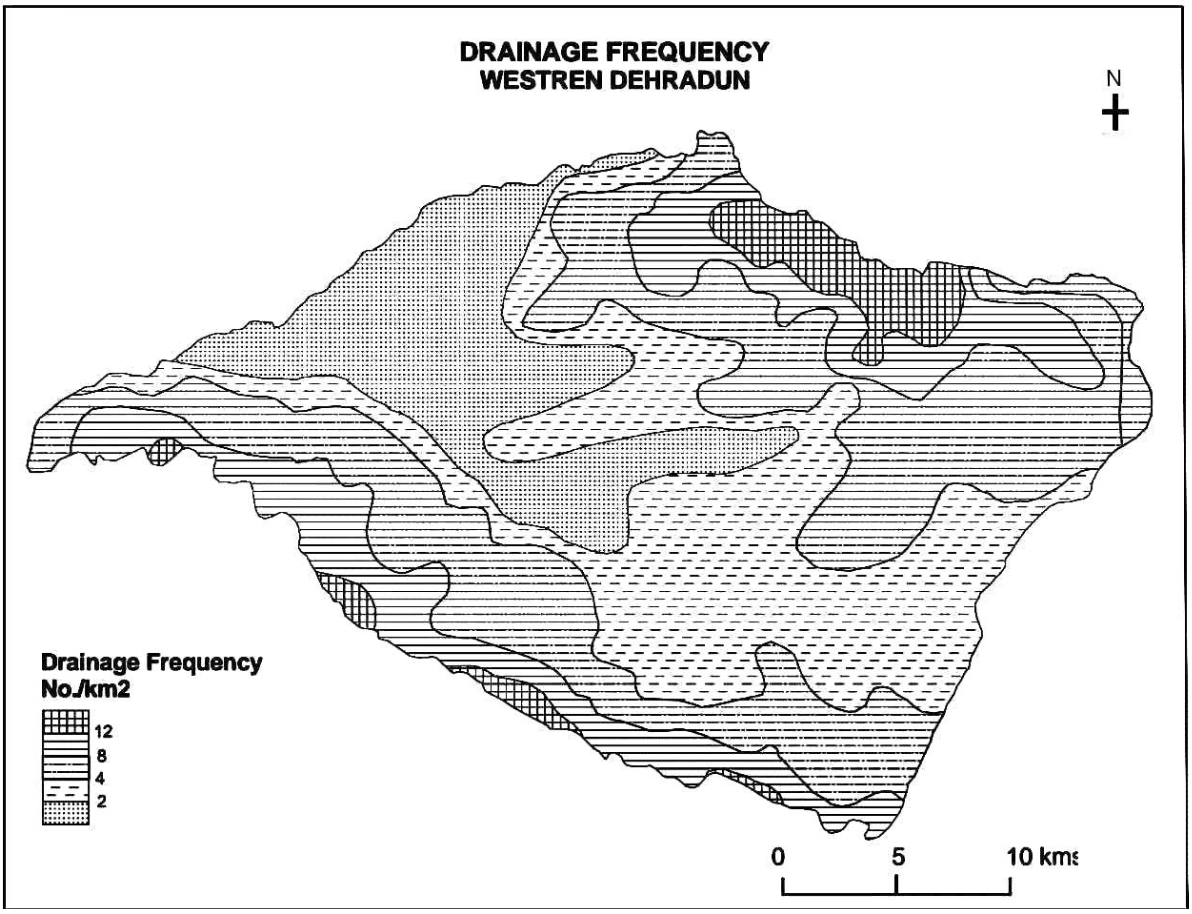

Fig.5

Table 2: Areal Distribution of Drainage Frequency

(Area in square kilometers and frequency per km^2)

Streams Frequency	Area under Class	% Area	Cumulative Area	Cumulative % Area
0 – 2	202.2	24.24	202.2	24.24
2 – 4	186.16	22.31	388.36	46.55
4 – 6	188.2	22.57	576.56	69.12
6 – 8	91.05	10.91	667.61	80.03
8 – 10	62.74	7.52	730.35	87.55
10 – 12	50.25	6.02	780.6	93.57
> 12	53.68	6.43	834.28	100
Total	834.28	100		
Mean: 5.24 Km; Coefficient of Variation = 74.43 Standard Deviation = 3.90; Variance = 15.21				

Table (2) reveals that the value of standard deviation (3.90) stands below the value of mean drainage frequency (5.24) and the coefficient of variation in the distribution is 74.73%. These statistical figures indicate moderately high variation in the distribution of drainage frequency. Thus, it can be concluded that the area is moderately heterogeneous in term of the distribution of drainage frequency. The frequency distribution (Table-2) reveals moderately positive skewed distribution of drainage frequency.

The diagrams - Frequency polygon and histogram (Fig-6) also reveals positive skewness. These diagrams express that high concentrations of frequencies are in the low classes of both the drainage derivatives (D_d & D_f). The cumulative percentage frequency curves (Fig. 6) denote very steep slope upto extremely low classes. After this, the curve becomes almost parallel to the horizontal axis, showing the fact that the magnitude of the derivative of drainage is increasing very rapidly but the rate of increase of frequency of drainage derivatives is extremely slow. All these facts lead to the conclusion that the relation between frequencies of dissection and magnitude of drainage derivative is negative. The high positive skewed distribution of frequencies again speaks of dominance of low dissection of the study area.

It may be pointed out that the choropleths depicting drainage density and stream frequency are almost identical with little differences, because, both the variables are related to streams in one or another way. If we divide the two variables (D_d &D_f) into only three broad categories (low, moderate, high) and examine the distribution of area of these two variables in aforesaid three categories, it gives about 5 to 12% variation in the distribution of area.

Table 3: Comparative Picture of Spatial Coverage of D_d and D_f

Broad Categories → Drainage ↓	Area in Percent		
	Low	**Moderate**	**High**
Drainage Density (Km/Sq. Km)	34.8 (0–2)	38.53 (2–4)	26.67 (>4)
Drainage Frequency (No. /Sq. Km)	46.55 (0–4)	33.48 (4–8)	18.97 (>8)

Both the derivatives of drainage (D_d & D_f) express the nearness of stream or spacing between channels. This spacing determines the momentum of runoff after a spell of heavy rain. In general, the higher the D_d and D_f the faster will be the runoff and vice versa. Surna and Sitla basin on slopes of Mussoorie and higher reaches of Siwaliks have high drainage density and frequency. Therefore flooding is more likely to occure in the watershed during heavy rains. These sites can also be used as water harvesting and water conservation sites.

Relationship between Drainage Density and Drainage Frequency: - Table (4) indicates that maximum occurrences of area lies in extremely low (0-1) drainage density within of extremely low (0-2) drainage frequency. Second maxima in moderately low category of drainage density is in the category of low (2-4) drainage frequency. There are very low occurrences or no occurrences of high drainage density within the limit of extremely low (0-2) and low (2-4) drainage frequency. There is almost absence of extremely low and low drainage density in the group of moderate to high drainage frequency. Thus it can be concluded that in general low D_d is associated with low D_f and high D_d with high D_f. Accordingly, both the variables are positively correlated and statistically, the correlation between the two variables is +0.666. Infact, these two variables are associated with streams in one or another way and are controlled by common environmental factors. A few and small patches of high drainage density in the group of low drainage frequency in the study area may be related to control of relief on the drainage derivatives.

PHYSICAL PARAMETERS AND AREA

DRAINAGE FEQYENCY

DRAINAGE DENSITY

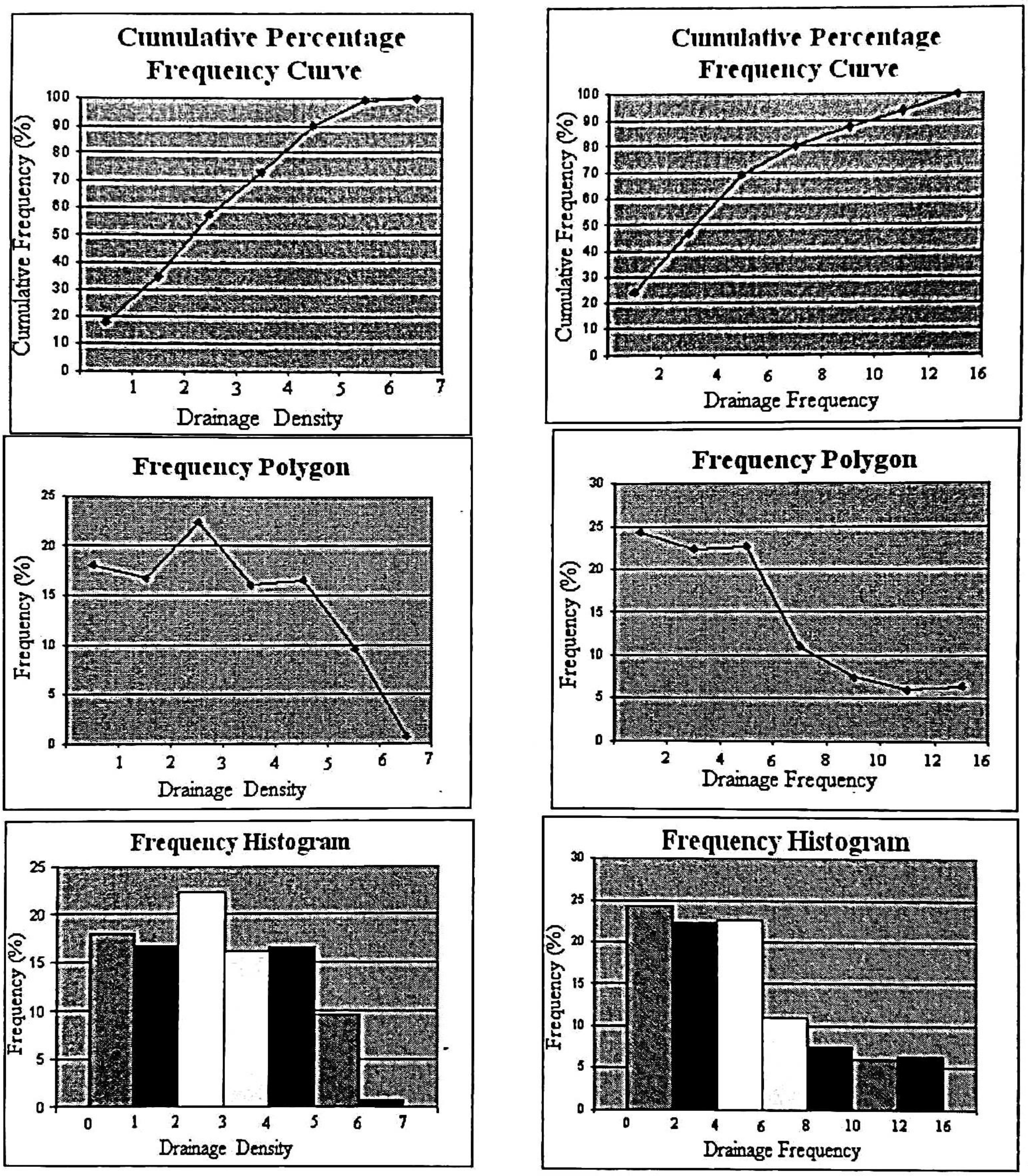

Fig.6

Table (5): Area Co-matrix of Drainage Frequency and Drainage Density (Two Way Classification)

Dd → Df ↓	Area in Km^2								
	0-1	1-2	2-3	3-4	4-5	5-6	>6	Total	% of Total
0-2	125.70	70.43	6.07	-	-	-	-	202.20	24.24
2-4	19.83	58.37	90.00	9.63	4.33	4.00	-	186.16	23.31
4-6	5.00	9.23	67.78	65.04	31.00	10.15	-	188.20	22.51
6-8	-	1.22	10.25	33.00	36.86	9.72	-	91.05	10.91
8-10	-	0.50	4.17	11.89	29.54	16.64	-	62.74	7.52
10-12	-		5.16	8.07	23.87	12.63	0.52	56.25	6.02
12-15	-		3.12	6.52	11.32	19.01	0.90	40.87	4.90
15-18	-		0.65	0.21	1.42	6.00	1.00	9.28	1.11
>18	-	-	-	-	-	-	3.53	3.53	0.42
Total	150.53	139.75	187.20	134.36	138.34	78.15	5.95	834.28	100
Percentage	18.05	16.75	22.43	16.10	16.59	9.37	0.71	100	

3.3) Basin shape

The study of basin shape and size has hydrological implications. These parameters affect the rate of discharge of water by the channels and the volume of runoff received at the principal channel in the watershed or basin. The shape of the basin governs the time taken by runoff to reach the main channel and outlets as well. Some methods, like-form factor, basin circulatory ratio and elongation ratio have been used to express the drainage basin shape.

3.3.1) Form Factor (R_f):

Form factor may be stated as the ratio of "basin area to square of basin length" (Horton, 1932). The mathematical expression of this dimensionless ratio is as under:

$$R_f = A/ (L_b)^2$$

The values of this ratio vary from 0.0 to 1.0. Values towards 1.0 indicate circular shape of basin, whereas values near to 0 represent highly elongated shape of basin. More circular will be the basin, higher will be the peak flow but for a shorter duration. so, floods are likely to occur if the form factor is near to 1.0. In the case of elongated basin (form factor near to zero) peak flow will be flatter but for longer duration. So, flood flow can easily be managed in an elongated basin as compared to circular basin.

The form factor of the 5th order watersheds in doon vary from 0.085 to 0.47 (table 5). The range of values suggests that all the fifth order basin are elongated. The Surna basin tops in respect of elongation followed by Sitla. The Upper-Asan basin is comparatively less elongated. This value is 0.441 for the river Asan. This value also indicates the elongation of the basin.

Table -5: Areal Parameters of of Doon of Dehra

Sr No	Drainage Parameters	Tons	Nun	Darar	Surna	Sitla	Upper Asan	Bin	Asan
1	Basin Area (A) Sq Km	50.41	39.60	21.93	35.89	51.29	96.13	10.02	741.11
2	Max. Basin Length: L_b (Km.)	18.00	14.20	13.70	22.00	21.00	11.20	8.30	53.00
3	Form Factor (R_f)	0.24	0.262	0.157	0.85	0.116	0.470	0.199	0.441
4	Basin Perimeter (B_p)	31.50	32.00	24.00	45.0	48.0	49.50	18.50	125.00
5	Circulatory Ratio (R_c)	0.639	0.486	0.479	0.223	0.280	0.493	0.368	0.596
6	Elongation Ratio (R_e)	0.312	0.326	0.253	0.186	0.217	0.436	0.284	0.423
7	Drainage Density (D_d)	2.85	3.39	3.67	3.32	2.46	2.05	5.68	2.60
8	Drainage Frequency (D_f)	4.28	5.70	4.74	5.32	4.00	2.60	10.60	3.10

3.3.2) Basin circulatory Ratio (R_c):

It is "the ratio of area of river basin to the area of a circle having the same perimeter as the basin" (Miller, 1953). Generally, R_c is found 0.6 and 0.7 for homogenous rocks and 0.4 to 0.5 for quartzite terrain. The Miller (1953) mathematical expression for the computation of basin circulatory ratio is as under:

$$R_c = \frac{4\pi A}{p^2}$$

This value is found one in a circular shaped basin and '0' in a highly elongated basin. The circulatory values (table 5) obtained from seven, 5th order basins indicate that Surna and Sitla Rao are more elongated. There is no watershed in the region which has a compact shape. The basins of Upper Asan, Bin, Tons, Darar, Nun are less elongated as compared to Surna and Sitla drainage basin. The Asan River has a circulatory value of 0.596 which again indicates the elongated shape of the Asan basin and all the fifth order watersheds indicate the advanced stage of development of this geomorphic unit.

3.3.3) Elongation Ratio (R_e):

Suchmm (1956) defined elongation ratio as "the ratio between the diameter of a circle with the same area as the basin and the maximum length of basin". He suggested the following equation for calculation of this ratio:

$$R_e = \frac{2A / \pi}{L}$$

Like the R_f and R_c here also the value is found near to one in a circular shaped basin and zero in highly elongated basin. The "values from 0.6 to 0.8 are generally associated with strong relief and steep ground slopes" (Strahler, 1964). The elongation ratio can help in predicting floods in streams. Table (5) indicates that the elongation ratio varies between 0.186 and 0.436 in fifth order watershed. These values indicate the elongation of all the fifth order watershed. The watershed of Surna and Sitla which have elongation values 0.186 and 0.217 are comparatively more elongated. The Asan basin has an elongation value of 0.423. This value also reveals the elongated shape of the Asan drainage basin.

All the three shape indicators described in preceding text, conclude that all the fifth and sixth order drainage basins are elongated in shape. The basins of Surna and Sitla are highly elongated. These elongated shapes can help in minimizing the flood losses, when heavy rainfall occurs in peaks; because water takes time to reach in Doon. These elongation values also suggest the mature stage of landforms. Differences in these values between different similar order basins also suggest the control of slope, geology and structure in the successive evolution of this geomorphic unit.

3.4) Basin Area:

The area under the Asan basin is 741.11 sq. Kms. The area of fifth order tributaries of Asan varies from 35.89 to 96.13 sq. km (table 5). Bin (tributary of Yamuna) has an area of 10.02 sq. Kms. In all the watersheds of fifth order, Upper-Asan occupies a maximum area of 96.13 sq. Km. and Bin basin is found to cover the least among all the watersheds.

Study of basin size is important from the hydrological point of view. Basin or watershed area affect the lag time of water at highest order stream in the watershed or basin. Smaller the watershed in size shorter will be the lag time. Shorter lag time leads to higher peak discharge. Consequently leads to flooding in streams. However, size should be correlated with the shape of watershed to arrive at the final result regarding the prediction of floods in the area. The analysis of watershed size and shape reveals that all the watersheds are elongated to highly elongated in shape, so there is not very much expectation of floods.

4. CONCLUSION

More than 10% area of doon falls in the classes of high and very high drainage densities. These categories indicate the zone of high erosion. This zone of high drainage density is limited to the scrap face of the region. Central crest area of Mussoorie hills has also high D_d. Poor drainage frequency covers about 47% area, out of which about 24% area has extremely very poor drainage densities This shows that a large part of this geomorphic unit is under plain which discourages the formation of streams. High drainage frequency, which covers about 20% of the region, extends on the scarp faces and crests, except the crest area of Tons basin which has medium drainage frequency. This indicates that the crest area of Tons is comparatively flat topped .Higher drainage frequency in the central part of Mussoorie hills indicate the sharp crest. Low to moderate drainage frequency indicates that most of the area under this geographic unit has entered into the late mature stage of its landform development.

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