IF : 4.547 | IC Value 80.26

VOLUME-6, ISSUE-7, JULY-2017 • ISSN No 2277 - 8160

Original Research Paper

Geology

Morphometric Analysis and Correlation between Morphometric Parameters with Mean Basin Altitude and Slope: A case study of Alaknanda Basin, Uttarakhand, India

Kamini Purohit Department of Geology, H.N.B. Garhwal Central University, Srinagar Garhwal

M.K. Parmar Department of Rural Technology, H.N.B. Garhwal Central University, Srinagar Garhwal

ABSTRACT The development of Morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network, comparing the characteristic of several drainage networks and examining the effect of variables such as lithology, rock structure, rainfall etc. The correlation of the data is carried out in three ways, viz. correlation between morphometric parameters with mean basin altitude and slope.

KEYWORDS : Morphometric Analysis, mean basin altitude, slope.

Introduction

The basin morphometric characteristics of the various basins have been studied by many scientists using conventional (Horton, 1945; Smith, 1950; Strahler, 1957) and remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal,1998; Biswas et al., 1999; Narendra and Nageswara Rao, 2006). Drainage basins, catchments and sub catchments are the primary units for organizational purposes to safeguard natural resources. Morphometric study of drainage basin includes quantitative analysis of the characteristic features formed by a river. The quantitative study of landforms was carried out in order to understand the evolution of drainage system, which reflects the denudation history of the area. A drainage basin is the area which contributes water to a particular channel or a set of channels. It is the source area of precipitation eventually provided to the stream channels through various paths. As such, it forms a unit for the consideration of the process determining the formation of specific landscapes (Leopold et. al;., 1964)

The hydrological characteristic of the drainage basin was understood by the analysis of drainage parameters of its contributing factors. The lithology, tectonic set-up and the terrain characteristics including slope and altitude governs the overall hydrological behavior of the area. A detailed analysis of the various morphometric parameters of the drainage system provides a vivid insight into the qualitative and quantitative aspects.

The description of these morphometric variables with their symbols and units are presented in table 1

Table 1 Morphometric variables with their symbol and unit

No.	Morphometric variable	Symbol	Unit
Drainage network			
01	Number of streams of order u (1,2,3)	Nu (1,2,3)	Enumerative
02	Total no. of streams within basin order u	(∑N)u = N1+N2…Nu	Enumerative
03	Bifurcation ratio	Rb = Nu/Nu+1	
04	Total length of streams of order u (1,2,3)	Lu (1,2,3,4)	Km
05	Total stream length	(∑L) = L1+L2……Lu	Km
06	Mean length of stream of order u	Lu = Lu/Nu	Km
07	Stream length ratio	Rl = Lu/Lu-1	Enumerative
08	Sinuosity index	Si	Enumerative
Basin Geometry			
09	Area of the basin	Au	Km2
10	Length of the basin	Lb	Km
11	Width of the basin	Wb	Km
12	Basin shape		
	a. Form factor	F = Wb/Lb	Enumerative
	b. Shape index	Sw = Lb/Au	Enumerative
13	Basin elongation	Be = d/Lb	Enumerative
Measures Involving Heights			
14	Height of basin mouth	Z	Km
15	Height of highest point of the basin	Z	Km
16	Total basin relief	H = z – Z	Km
17	Relief ratio	Rh = H/Lb	Enumerative
18	Mean basin altitude	H = Z + z/2	Km
Measures of intensity of dissection			
19	Drainage density	Du = (EL)u/Au	/km
20	Constant of channel maintenance	1/Du	Km
21	Stream frequency	Fu = Nu/Au	No/Km2
22	Drainage texture	Tu = Fu x Du	No/Km
23	Crenulation number	Cn	Enumerative
24	Texture ratio	Tr = Cn/Au	No/km
25	Ruggedness number	Rn = H x Du	Enumerative

(After Doornkamp & King, 1971 and Chorley, 1969)

Location of the area

The study area comes under the Survey of India toposheet Nos. 53N/6, 53N/7, 53N/10 and 53N/11. The toposheets have been enlarged up to the scale of 1:25,000 for the study. The area lies within in the Chamoli District of Uttarakhand state. The geographical position of the area is 79°15' to 79°40' E longitudes and 30°20' to 30°25' N latitudes. The area is drained by Alaknanda and its tributaries named as Gorsal gad, Balasuti gad, Bhimtala gad, Chinka gad, Pipalkoti gad, Garur Ganga, Belakuchi gad, Ganesh ganga, Kalp Ganga, Karamnasa, Dunli gad and Vishnu gad and Dhauliganga. Alaknanda river basin is considered to be tectonically active where damaging earthquakes and landslides have occurred.

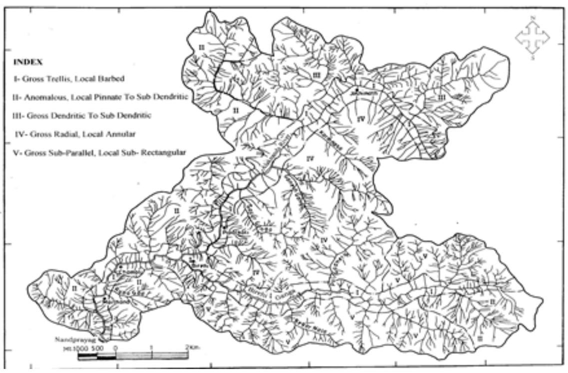

Fig 1: Drainage map of Alaknanda Basin

Third order basin morphometry

For morphometric analysis of the area, third order basins were selected for the analysis and interpretation, as they are widely distributed. In the area, one hundred fifty four 3rd order basins were marked and their morpho-statistical parameters were calculated and analyzed. The data thus obtained was superimposed on geological and structural maps of the study area for the interpretation purposes.

The morphometric data was divided into two groups viz. measured and calculated parameters, their maximum and minimum values along with mean is presented in Tables 1.2 and 1.3. The data indicate that the mean value of number and length of stream present in a 3rd order basin is 12 and 6.3 km respectively. The mean value of number as well as length of 1st order to 3rd order streams are decreasing. The mean value of length and width of the basin depicts that most of the basins are elongated in shape. The average values of lowest and maximum elevations are 2170 and 3410 m respectively. A high order of crenulation number (15.5) indicate that majority of the basins are structurally controlled.

The calculated morphometric data show a higher value of basin area, drainage density, drainage texture, constant of channel maintenance etc. which reflects that majority of the basins have mature drainage network. The bifurcation ratio and stream length also reveals that the basins are constituted by a rugged and highly dissected topography. It is also supported by texture ratio and ruggedness number of the 3rd order basins of the area. The measured and calculated morphometric parameters obtained from the analysis are presented in Tables 1.4 and 1.5.

Table 2 Range and mean of the measured morphometric parameters

Variable	Basins of Garhwal Group			Basins of Central Crystallines			Mean for entire study area
	Min.	Max.	Mean	Min.	Max.	Mean	
N1	4	34	9.12	4	28	8	8.38
N2	2	9	2.60	2	7	2.44	2.5
N3	1	1	1	1	1	1	1
∑N	7	44	12.75	5	36	11.44	11.9
L1	0.35	27.5	4.87	0.42	12.60	3.81	4.16
L2	0.075	3.15	1.19	0.15	4.05	1.12	1.14
L3	0.05	2.45	0.98	0.10	9	1.00	0.99
∑L	0.95	29.5	7.04	0.87	17.35	5.93	6.3
Au	0.40	13	3.28	0.10	13.25	2.87	3
Lb	1.45	7.75	2.85	1.15	7.45	2.73	2.76
Wb	0.75	6	1.69	0.50	9	1.60	1.64
z	0.92	2.64	1.58	0.92	3.80	2.47	2.17
Z	1.60	3.76	2.83	1.72	5.52	3.70	3.41
Cn	7	48	16	3	45	15	15.5
Sa	15	43	24.84	4	52	24.97	24.91

Table 3 Range and mean of the calculated morphometric parameters

Variable	Basins of Garhwal Group			Basins of Central Crystallines			Mean for entire study area
	Min.	Max.	Mean	Min.	Max.	Mean	
Rb	2	5.08	30.3	2	6	2.86	2.93
Rl	1.24	40.75	4.72	0.55	35.75	3.74	4.06
F	0.24	0.98	0.60	0.20	3.46	0.61	0.61
H	0.36	1.84	1.26	0.12	2.32	1.22	1.24
h	1.26	3.14	2.20	1.34	4.60	3.08	2.79
Rh	0.19	0.94	0.47	0.06	1.33	0.49	0.48
Fu	1.65	17.50	5.08	0.68	19.46	5.39	5.70
Du	0.40	8.76	2.54	0.14	8.44	2.59	2.57
1/Du	0.11	2.51	0.51	0.02	7.26	0.61	0.56
Tu	1.34	87.50	14.61	0.48	150.12	17.37	16.00
Tr	2.08	17.50	6.18	1	20	6.45	6.32
Rn	0.35	14.37	3.15	0.09	14.96	3.23	3.20

Correlation of data

The correlation of the data is carried out in three ways, viz. correlation between morphometric parameters with mean basin altitude and slope.

1. Correlation of altitude and morphometry

An attempt has been made to find out the relationship between the altitude and the various morphometric parameters. Scattered diagrams were prepared and their trends were plotted. Comparing to the valley sides slopes, the summit surface and ridges of the study area receives a higher precipitation. It was observed that climatic factors like precipitation, temperature etc. have significant control over the morphometric parameters.

(i) Mean basin altitude and number of 1st order streams

Fig. 5.1 was drawn between the mean basin altitude and number of 1st order streams, which shows a very poor negative relationship for the basins located in the rocks of Central Crystallines, indicating that the development of drainage is not normal and may be controlled by some structural features.

It also indicates that the number of 1st order streams decreases very feebly with an increase in altitude. In case of the basins located in Garhwal Group the relationship is feebly positive, indicate normal development of the drainage as the number of 1st order streams are increasing with an increase in altitude.

(ii) Mean basin altitude and basin area

The plot for mean basin altitude and basin area was drawn as Fig. 5.2 The basins located in the Garhwal Group reflect that at higher altitude the larger basins are located. However the relation between these two parameters is very poor. The basins located in Central Crystalline do not possess any significant relationship.

(iii) Mean basin altitude and basin shape

The relationship between the mean basin altitude and basin shape is very pronounced (Fig. 5.3). The trend lines show a positive relationship for the basins of Garhwal Group and a negative relationship for Central Crystallines. The data reflect that at higher altitude more elongated basins are located in the rocks of Garhwal Group while less elongated basins are situated in the Central Crystallines.

(iv) Mean basin altitude and stream frequency

In the basins located in the rocks of Central Crystallines, the relationship between mean basin altitude and stream frequency indicates that stream frequency is increases at higher altitude while the basins located in the Garhwal Group reflects a negative relationship (Fig. 5.4). It also reflects that at lower altitude the stream frequency do not show a clear relationship with altitude due to high rate of mass-wasting on the valley side slopes.

(v) Mean basin altitude and drainage density

For the basins located in Garhwal Group, the trend line between mean basin altitude and drainage density indicates lower drainage density at higher altitudes (Fig. 5.5). The relation between these two parameters is not significant for the basins located in the Central Crystallines.

(vi) Mean basin altitude and ruggedness number

The plot between mean basin altitude and ruggedness number show that basins located in Central Crystallines are more rugged with higher altitude (Fig. 5.6). Similar trend is also shown by the basins of Garhwal Group, however, the relationship is very poor.

2. Correlation of slope angle and morphometry

The slope inclination has a definite influence on various morphometric parameters. In order to identify the influence of slope on the drainage development in the study area, various scattered diagrams were drawn between the slope and morphometric variables. For this purpose mean basin altitude, constant of channel maintenance, basin shape and texture and bifurcation ratios etc. were selected. Their detailed description is presented in the following paragraphs.

(i) Slope angle and mean basin altitude

Fig. 5.7 is the plot drawn between slope angle and mean basin altitude. The trend line of the basins located in Central Crystallines shows a positive relationship which indicates that steeper slope angles are generally associated with higher altitudes. In case of Garhwal Group the trend is feebly negative. It was observed that basins at lower altitudes do not show clear relationship may be because of recurring mass-wasting on valley side slopes (Prassad and Mathur, 1976).

(ii) Slope angle and constant of channel maintenance

Fig. 5.8 depicts a very strong negative relationship which shows that lower values of constant of channel maintenance are associated with steeper slopes. The relationship between these two parameters is more pronounced for the basins located in the rocks of Central Crystallines.

(iii) Slope angle and basin shape

The correlation between the slope angle and basin shape depicts that narrow basins are located over the steeper slopes for the basins associated with the rocks of Garhwal Group (Fig. 5.9). In the Central Crystallines, wider basins are associated with the steeper slope.

(iv) Slope angle and texture ratio

Fig. 5.10 is a plot between slope angle and texture ratio, which reflects a positive relationship for the 3rd order basins of the study area. The basins of Garhwal Group as well as Central Crystalline reveal that steeper slopes have greater value of texture ratio.

(v) Slope angle and bifurcation ratio

The diagram (Fig. 5.11) was drawn between the slope angle and bifurcation ratio. The trend line for Garhwal Group and Central Crystalline indicates a negative relationship, which reflects that steeper slopes are less bifurcated. Furthermore, the basins of Garhwal Group shows more pronounced negative relationship.

Conclusion

1. Effects of altitude over morphometry

The analysis of various morphometric variables shows that they have a clear relationship with altitude of the area. Basins located in Garhwal Group reveals that at higher altitudes the numbers of streams are more, the basins are wider, more elongated and rugged, with lower values of drainage density and stream frequency. While the basins of Central Crystalline show that higher values of drainage density and stream frequency are associated with higher altitudes. The lower altitudinal basins of the study area do not show clear relationship, as mass wasting process is dominant over the valley side slopes.

2. Effects of slope over morphometry

In order to understand the effects of slope over morphometry, the data reveals that there is a significant relationship between these two aspects. The data for the basins of Central Crystalline shows that areas with steeper slopes have wider basins and higher mean basin altitude. Both the sectors (basins located in Garhwal Group as well as Central Crystallines) indicate that higher values of texture ratio and smaller values of bifurcation ratio and constant of channel of maintenance are associated with steeper slopes. It indicates that basins located over the steep slopes are highly dissected and are formed by texturally coarser material. The data also reflect that slope steepness is one of the major controlling factors in the development of drainage.

The valley side slopes do not shows clear relationship with morphometric parameters, as they come under the zone of high intensity of erosion (Brusden and Kesel, 1973). The pairwise relationships of morphometric parameters reflect that wider basins are associated with smaller relief ratio and having longer streams. More bifurcated and rugged basins indicate higher values of stream lengths ratio and basin relief.

3. Effects of lithology over morphometry

The rocks of the Garhwal Group are highly deformed and are relatively more permeable than the rocks of Central Crystallines, therefore, they have lower drainage density, stream frequency, ruggedness number, less elongation ratio and coarser texture with moderate slope angle and relief. They also have higher bifurcation ratio and stream length ratio. The basins located in the rocks of Central Crystalline possess moderately dissected and elongated basins with relatively less permeable rocks. Therefore, they are characterized by wider basins, finer texture, high relief, steeper slopes, greater ruggedness number etc.

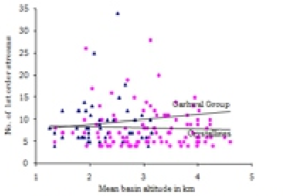

Fig. 5.1 Correlation between Mean basin altitude and Number of 1st order streams

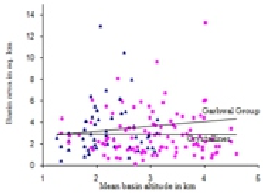

Fig. 5.2 Correlation of Mean basin altitude and Basin area

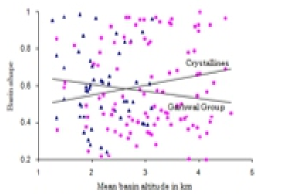

Fig. 5.3 Correlation of Mean basin altitude and Basin shape

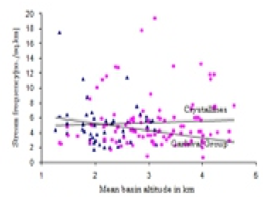

Fig. 5.4 Correlation of Mean basin altitude and Stream frequency

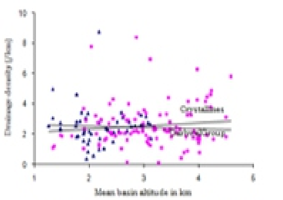

Fig. 5.5 Correlation of Mean basin altitude and Drainage density

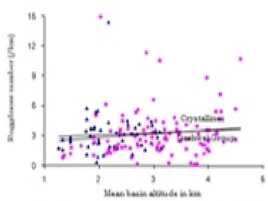

Fig. 5.6 Correlation of Mean basin altitude and Ruggedness number

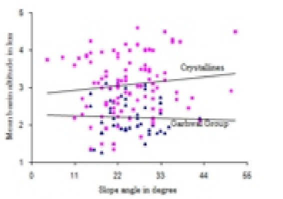

Fig.5.7 Correlation of slope angle and Mean basin altitude

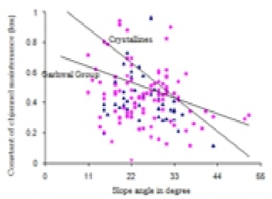

Fig.5.8 Correlation of slope angle and Constant of channel maintenance

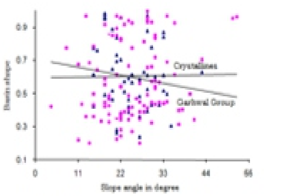

Fig.5.9 Correlation of slope angle and Basin shape

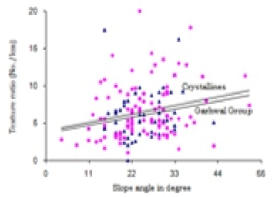

Fig. 5.10 Correlation of slope angle and Texture ratio

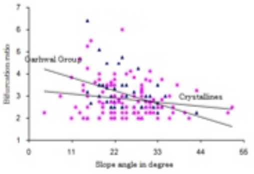

Fig. 5.11 Correlation of slope angle and Bifurcation ratio

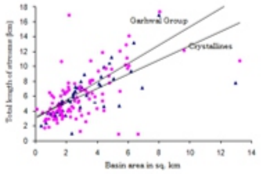

Fig. 5.12 Correlation of Basin area and Total length of streams

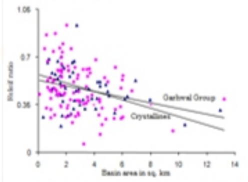

Fig.5.13 Correlation of Basin area and Relief ratio

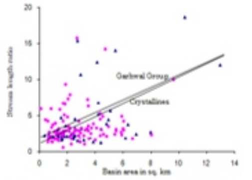

Fig. 5.14 Correlation of Basin area and Stream length ratio

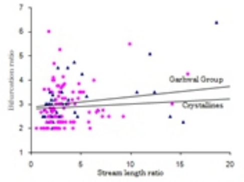

Fig. 5.15 Correlation of Stream length ratio and Bifurcation ratio

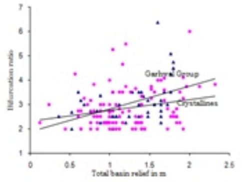

Fig. 5.16 Correlation of Total basin relief and Bifurcation ratio

Reference

1] Agarwal, C. S. "Study of drainage pattern through aerial data in Naugarh area of Varanasi district, UP." Journal of the Indian Society of Remote Sensing 26, no. 4 (1998): 169-175.

2] Biswas, Sujata, S. Sudhakar, and V. R. Desai. "Prioritisation of subwatersheds based on morphometric analysis of drainage basin: A remote sensing and GIS approach." Journal of the Indian society of remote sensing 27, no. 3 (1999): 155-166.

3] Chorley, R.J., 1969. The drainage basin as the fundamental geomorphic unit. In: Introduction to Physical Hydrology, Chorley, R.J. (ed.), Methuen and Co. Ltd., London, 30-52.

4] Doornkamp, J.C. and King, C.A.M., 1971. Numerical analysis in geomorphology. Edward Arnolds, 181 p.

5] Leopold, L.B., Wolman, M.G. and Miller, J.P., 1964. Fluvial processes in geomorphology. San Francisco and London.

6] Horton, H.E. (1945), Erosional development of streams and their drainage basins.Bulletin, Geological Society of America, 56 pp. 275-370.

7] Krishnamurthy and Srinivas, 1995; Krishnamurthy, J. and Srinivas, G. (1995) Role of Geological and Geomorphological Factors in Ground Water Exploration: A Study Using IRS LISS Data. International Journal of Remote Sensing, 16, 2595-2618.

8] Narendra, K., and K. Nageswara Rao. "Morphometry of the Meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resourcesat data." Journal of the Indian Society of Remote Sensing 34, no. 2 (2006): 101-110.

9] Nooka Ratnam, K., Srivastava, Y.K., Venkateswara Rao, V., Amminedu, E. and Murthy, K.S.R(2005). Check dam Positioning by Prioritization of Microwatersheds using SYI model and MorphometricAnalysis - Remote sensing and GIS Perspective. J. Indian Soc. Rem. Sens., 33(1): 25-38.

10] Smith, Kenneth Grant. "Standards for grading texture of erosional topography." American Journal of Science 248, no. 9 (1950): 655-668.

11] Srtvastava, V. K., and D. Mitra. "Study of drainage pattern of Raniganj Coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS II imagery." Journal of the Indian Society of Remote Sensing 23, no. 4 (1995): 225-235.

12] Strahler, A.N., 1958. Quantitative analysis of watershed geometry. Trans. Amer. Geophys. Union, 38, 913-92.