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THE DISTRIBUTION AND DEVELOPMENT OF SLOPE IN A GREATER HIMALAYAN BASIN

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ABSTRACT : The present study is an attempt to analyse the distributional and development aspects of the average slope and its statistical measures of distribution to expose the stages of cycles of erosion and slope development. The functional analysis has been carried out to find out the inter-relationship between average slope and morphometric components and their degree of influence in the development of average slope in Dhauliganga basin lying in higher Himalayan part.

The slope, defined as an angular inclination of terrain between the hill tops and valley bottoms has great influence on man's activities. However, slope itself is a function of various exogenetic and endogenetic forces, to name few of them are absolute relief, relative relief, dissection index, drainage texture, stream frequency, climate, geology, tectonics operating in the area and vegetal cover etc. Obviously, the study of slope seems to be inevitable in understanding the nature of existing landforms and to diagnose the intensity of processes operating in the area. It is particularly so in Himalaya where endogenetic forces are still in operation.

The present paper is, thus, an attempt towards measuring the slope in Dhauli-ganga basin lying in Central Himalayan part. The area extends between 79° 30' E to 80° 15' E longitude and 30° 15' N to 30° 45' N latitude. Politically, it covers an area of Chambli district of Garhwal and Pithoragarh district of Kumaon region in extreme north of Uttar Pradesh (Fig. 1), encompasses an area of 1992 sq. kms. The region consists of two distinct lithological formations i.e. metamorphic rocks (schists and gneiss) of central crystalline and sedimentary rocks (mainly lime stone) of Tethys zone separated by Dhar-Martoli fault (Heim and Gansser).

METHODOLOGY

The computation of average slope from the topographic maps using contours have been attempted by several workers. Nevertheless the contribution made by Wentworth, Raisz and Henry, Smith, Calef and Newcomb, Strahler, Miller et al and Eyles are worth mentioning. The scheme developed by Wentworth has been used by the Indian geographers frequently, but in the

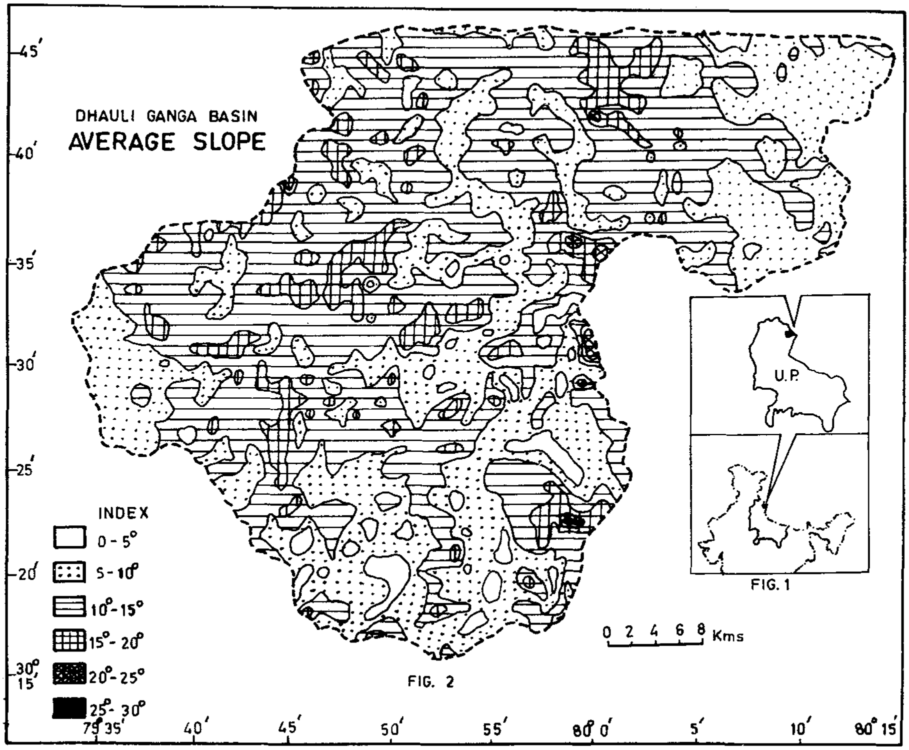

FIG. 2

present study a new technique suggested by Dhurandher with a slight modification in Wentworth's formula has been used. This scheme gives a more rational picture of the slope categories because in this technique all contours of different values in a grid have been taken into account on the basis of the following formula:

$$\tan 0 \qquad \frac{N \; X \; CI}{3361}$$

Where, N = Number of contours of different values in a grid of 1 sq. km.

CI = Contour Interval

3361 = Constant

The distribution of average slope have been assessed in the basin in terms of various statistical measures. The variations has been analysed by using coefficient of variance, skewness and kurtosis.

Besides, stepwise regression analysis has been attempted in order to find out functional relationship between average slope and some selected morphometric attributes. Tests of significance have also been worked out.

NATURE OF SLOPE DISTRIBUTION IN THE BASIN

The slope degree in the area ranges between a maximum of 27.5^{o} to a minimum of 0.7^{o} with a range of 26.08^{o}. The slope values of all grids in the entire basin have been classified into the following six categories, which have been exhibited in the table 1.

TABLE 1 : FREQUENCY DISTRIBUTION OF SLOPE VALUES

Sl.No.	Slope Categories	Frequency	Cumulative Frequency	%	Cumulative %	Remarks*
1.	0 – 5°	128	128	6.42	6.42	Gentle (Sg)
2,	5 – 10°	700	828	35.17	41.59	Moderate (Sm)
3.	10 – 15°	898	1726	45.06	86.65	Moderately
4.	15 – 20°	241	1967	12.09	98.74	Steep (Sms)
5.	20 – 25°	17	1984	0.85	99.59	
6.	25 – 30°	8	1992	0.40	100.00	Steep (Ss)
	Total	1992	–	100.00	–	–

* Classification based on R.L. Singh (1967).

The above table 1 and Map (Fig.2) clearly portray the distribution of different slope categories. It is apparent from the table 1 that about 58% of the total frequency is represented by moderately steep slope category. The mean value of the average slope in the study area stands at 10.85°, which indicates the early stage of cycle of erosion in the study area. The gentle and moderate slope categories share about 6.42% and 35.17% respectively of the total frequencies while the steep category having only 0.40% of the total frequencies is located only over the hill tops of high relative relief in small patches.

The mean, median and mode are the important statistical tools which are used frequently to know the concentration of slope values. Following table 2 reveals the different statistical measures of the slope values in the study basin.

Table 2 reveals that the mean, median and mode values of average slopes of the Dhauli-ganga basin standing at 10.85°, 10.94° and 11.16° respectively indicate concentration of maximum slope frequencies (58%) in the category of moderate steep slope. The present study recorded maximum concentration in the category of moderate steep slope ranging 10° – 25° Thus, the uneven distribution of slope frequencies of different slope categories placing the mode and median values (more than mean) to the right of mean value in the cumulative frequency graph (Fig. 3-b) indicate the initial stage of slope development in the study area.

Dispersion of variation dealing with the variability in the number of observations in general range also gives a precise measure of the variation. Statistical measures of dispersion include, range, interquartile range, semi-quartile range or quartile deviation, average deviation or mean devia-

TABLE 2 : DIFFERENT STATISTICAL MEASURES OF THE SLOPE VALUES

1.	Mean	10.85	8.	Q.D.	3.03
2.	Median	10.94	9.	Co. Q.D.	0.28
3.	Mode	11.16	10.	Variance	13.19
4.	Q1	7.65	11.	S.D.	3.63
5.	Q3	13.71	12.	Co Variation	33.46
6.	Range	26.80	13.	Skewness	–0.31
7.	I.Q. Range	6.06	14.	Kurtosis	1.868

tion and standard deviation etc. The first and third quartile (Q1, Q3) values standing at 7.65 and 13.71 again indicate towards the concentration of slope values in moderately steep slope category and thus prove the results drawn by mean, mode and median. The most frequently used measure of dispersion is standard deviation which gives an exact degree of variation from the normal distribution. For the present study, calculated standard deviation of the slope values of different categories standing at 3.63 indicate wide degree of variation. This fact is supported by the value of coefficient of variation which is 33.46% of the mean, hence support the wider degree of variation from the normal values of slope concentration. The values of quartile deviation (3.03) and coefficient of quartile deviation (28.30%) also follow the same pattern of distribution within the quartiles of slope values.

The above discussed different measures of central tendencies and dispersions indicate the central values and concentration of values around the central values and the degree of variation in dispersion from the central value respectively but these measures are silent on the question of symmetery or asymmetry of the distribution on either side of the mean value. Skewness is a statistical measure which clearly explains

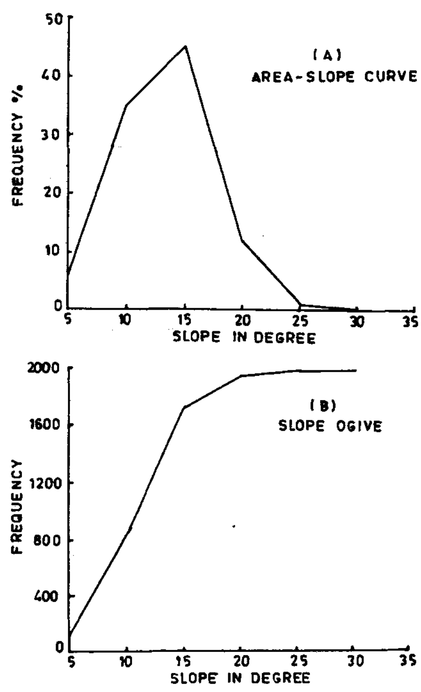

FIG.-3

the nature of distribution – whether symmetrical or asymmetrical. The coefficient of skewness is for a symmetrical distribution and it becomes a complete number in the case of asymmetrical distribution. When the curve is skewed to the right the mean value would be more than mode and median and it is called positive skewness but in the case of negative skewness as in the present study the value of mean would be less than the mode and median values. The percentage frequency polygon (Fig. 3-A) indicates a negative skewness for which coefficient of skewness stands at –0.31. This is an indication that majority of the slope frequencies lie in the moderately steep slope category which is a characteristic of early stage of slope development. In the same way Kurtoris indicates whether a distribution is more flat topped or more peaked than the normal distribution. The value of Kurtoris of slope values of the Dhauli-ganga basin standing at 1.868 indicates leptokurtic (peaked) distribution.

FUNCTIONAL RELATION BETWEEN MORPHOMETRIC ATTRIBUTES AND AVERAGE SLOPE

As it is already mentioned that slope is a resultant of combination of many factors, such factors which have their direct impact on slope development have been discussed below:

Dependent variables:

X_5 Average slope

Independent variables:

X_1 Drainage density

X_2 Drainage frequency

X_3 Relative relief

X_4 Absolute relief

X_6 Ruggedness number

X_7 Dissection index

CORRELATION MATRIX

A correlation matrix of the above mentioned variables has been prepared to pick up the best explanatory variables of slope development. It shows that average slope (X_5) is significantly and positively related with drainage density (X_1), drainage frequency (X_2), relative relief (X_3), ruggedness number (X_6) and dissection index (X_7) (Appendix I). The correlation matrix also shows the inter-correlation among the explanatory variables. Dissection index which is a dominant parameter of topography and affects the development of slope upto a large extent, as it is clear from the high correlation coefficient 0.772, which is significant at 0.001 level, has a positive and significant correlation with X_1, X_2, X_3, X_4, X_5 and X_6. Similar to this dissection index, ruggedness number also shows a significant and positive correlation with all other variables under present study. It is apparent from the correlation of coefficient of ruggedness number with X_1 (0.882), X_2 (0.773), X_3 (0.324), X_4 (0.337) and X_7 (0.482) that all are significant at 1 per cent probable level of significance. In the same fashion other variables also show their positive and significant relationship with maximum number of variables.

The above results which have been worked out from the correlation matrix reveal that the development of average slope is directly related with all above mentioned variables except absolute relief (X_4). It is also clear from the above discussion that variables selected for the present study are quite important and well defined.

APPENDIX I : CORRELATION MATRIX OF GEOMORPHIC VARIABLES OF DHAULI-GANGA BASIN

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	1.000						
X_2	.872	1.000					
X_3	0.060	.053	1.000				
X_4	.380	.288	.037	1.000			
X_5	.087	.079	.930	.047	1.000		
X_6	.882	.773	.324	.337	.347	1.000	
X_7	.227	.175	.776	.509	.772	.452	1.00

OTHER STATISTICAL MEASURES

1.	Mean of variables	1.610	3.116	635.154	4873.229	10.737	1.042	0.13363
2.	Standard deviation	1.610	3.391	251.196	967	3.970	1.168	.6188
3.	Coefficient of variation	1.000	1.088	0.396	0.198	0.369	1.1121	0.463

On the basis of the above results bivariate regression equations have been obtained to find out the exponential function and relationship of average slope with other aforesaid explanatory variables. Results of the bivariate regression analysis which have been summarised in the table (Appendix II) clearly indicate that all morphometric components i.e. drainage density, drainage frequency, relative relief, ruggedness number and dissection index have a positive and linear relationship with the average slope, which are significant at 0.001 level of significance.

On the basis of the above discussion following equation of the explanatory variables of average slope, has been obtained:

$$X_5 = f(X_1, X_2, X_3, X_6, X_7)$$

All these factors have a combined impact to determine the average slope. Stepwise regression analysis has been further used to obtain the best set of explanatory variables.

STEPWISE REGRESSION ANALYSIS

A stepwise linear regression analysis is attempted here to identify the contri-

APPENDIX II : FACTORS AFFECTING THE AVERAGE SLOPE – A BIVARIATE REGRESSION ANALYSIS RESULTS

Varia-bles	Intercepts	Regression Coefficients of X_1	X_2	X_3	X_4	X_6	X_7	R	R^2	$\overline{R}$	$\overline{R}^2$
X^1	10.392	0.214 (3.891)*						0.087	0.008	0.087	0.008
X_2	10.449		0.092 (3.529)*					0.079	0.006	0.079	0 006
X_3	1.429			0.015 (113.022)*				0.930	0.865	0.930	0.865
X_4	9.794				0.000 (2.107)			0.047	0.002	0 047	0.002
X_6	9.509					1.179 (16.508)		0.347	0.120	0.346	0.119
X_7	4.121						0.495 (54.147)*	0.772	0.596	0.771	0 594

* Significant at 0.01 level
** Insignificant

bution of various factors in slope development in Dhauli-ganga basin. It will be useful to find out the factors which explain maximum variations in slope development. Stepwise regression analysis helps to choose the best possible set of explanatory variables which explain maximum variations.

In the initial step, the explanatory variable which has the highest correlation with the dependent variable is considered the most important variable and is entered into the regression equation generating a bivariate relationship. Then, first order partial correlation between dependent variable and the remaining independent variables are computed. Among these remaining explanatory variables, the one which has the highest correlation with the dependent variable will then enter the regression equation. At this stage, two explanatory variables simultaneously operate in the regression equation. This procedure is continued in the above sequence till the entire set of explanatory variables have entered the regression equation.

The coefficient of determination (R^2) and the adjusted coefficient of determination ($\overline{R}^2$) are obtained at each step of the regression analysis. This exercise also provides standard error of estimated regression coefficients for each step.

By applying the above technique and tests of significance viz. 't' and 'f' following equation of the best explanatory variables of average slope has been obtained:

$$X_5 = 5.58 + 0.008\ X_3 + 0.345\ X_7 + 0.001\ X_4 + 0.144\ X_1 \quad \overline{R}^2 = 0.897$$

(26.235)* (24.55)* (22.662)* (7.477)*

The above equation reveals that in the first step, relative relief (X_5) entered as explanatory variable has the highest correlation with explained variable. It alone explains 86.5 per cent of variations in average slope and the coefficient of regression is quite significant (Table 3).

In the second step dissection index (X_7) entered as the second best explanatory variable has the second highest correlation with explained variable X_5. These two explanatory variables together explain 87 per cent of variations in average slope and again both the coefficients of regression are significant.

In the third step absolute relief (X_4) is entered as the third explanatory variable. Here it is worth-mentioning that absolute relief (X_4) does not show any relationship (significant at any level of significance) with average slope, individually, while in the presence of other geomorphic factors it plays an important role to determine the average slope. All these three variables simultaneously, explain 89.5 per cent of the variations in average slope. All regression coefficients are quite significant.

In the final step drainage density (X_1) entered as the other explanatory variable of significance and in presence of three already mentioned variables, regression equation explain 89.7 per cent of variations in average slope. All regression coefficients are quite significant.

After fourth step R bar value decreases and coefficients of regression are also insignificant. Thus, above equation of fourth step has been retained as the set of explanatory variables

CONCLUSION

On the whole, the study of the various aspects of the average slope in the basin conclude the following results:

TABLE 3 : FACTORS AFFECTING THE AVERAGE SLOPE–A STEPWISE REGRESSION ANALYSIS RESULTS

intercepts	Steps	Regression Coefficients of							
		X_3	X_7	X_4	X_1	R	R^2	$\bar{R}$	$\bar{R}^2$
1.429	I	0.015 (113.022)*				0.930	0.865	0.930	0.865
1.328	II	–0.013 (65.319)*	0.080 (9.781)*			0.933	0.870	0.933	0.870
4.789	III	0.008 (26.834)*	(0.337) (23.683)*	0.001 (21.140)*		0.946	0.895	0.946	0.895
5.580	IV	0.008 (26.235)*	0.345 (24.550)*	0.001 (22.662)*	0.144 (7.477)*	0.948	0.899	0.947	0.897

* Significant at 0.001 level.

The concentration of average slope frequencies around the mean value is an indicator of the early stage of cycle of erosion in the area. The negatively skewed distribution of slope frequencies, placing the mode and median values (more than mean) to the right of mean value in the cumulative frequency graph, indicate the initial stage of the slope development in the basin. The obtained results of the correlation matrix reveal the fact that the development and distribution of slope is significantly and positively related with the drainage density, drainage frequency, dissection index, relative relief. Absolute relief does not show any direct relationship with the average slope, but in presence of relative relief, dissection index and drainage density, it plays a significant role in slope development. The results of the stepwise regression analysis prove that relative relief emerged as the most dominant factor in the development of average slope, followed by dissection index, absolute relief and drainage density in sequence of their degree of influence.

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