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Quantitative Analysis of Watershed Geomorphology Using Remote Sensing Techniques

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Abstract : Dimensional and dimensionless geomorphic characteristics/variables of 13 watersheds of the Jojri catchment have been discussed in this paper, using remote sensing techniques and ground truth. Interrelationship between these geomorphic variables have also been established and these are, by and large, significantly correlated to each other. Based on these findings, priorities have been fixed under four categories for the development of watersheds into croplands, grasslands, woodlands and water harvesting at suitable sites.

Key words : Watershed, remote sensing, geomorphology, drainage basins.

The method of quantitative analysis of watersheds/drainage basins was developed by Horton (1945) and was further modified by Strahler (1964). Sufficient work on the quantitative analysis of the geomorphic characteristics of watersheds/drainage basins has been done in India and abroad (Ghose *et al*, 1967, 1969; Miller, 1954; Strahler, 1957). Relationship between and among different geomorphic and hydrological variables have also been established (Morisawa, 1959; Singh and Ghose, 1973; Singh *et al*., 1977; Singh and Sharma, 1979).

The results have proved useful in the integrated development planning of the watersheds under different morphoclimatic conditions. Therefore, a study on the quantitative analysis of the geomorphic characteristics/variables and their interrelationships, using remote sensing techniques and ground truth, was carried out in the Jojri catchment which is located in an arid environment. Salient findings of this study are discussed in this paper.

Jojri catchment covers an area of 1310 km^2 and is located between latitudes 26°23′N and 26°36′N and longitudes 72°40′ and 72°51′E. The Jojri river and its tributaries form a drainage system with several watersheds/drainage basins of various shapes and sizes (Fig. 1). The climate is arid, characterised by extreme temperatures, low and erratic rainfall, low humidity and high wind velocity. Hills, rocky/gravelly and buried pediments, flat older alluvial plains, sand dunes and interdune plains are the major geomorphic units. These units are acting as an environment for the distribution, growth and development of soils, water resources and vegetation.

Materials and Methods

Aerial photographs (1:25,000 scale), Survey of India (SOI) topographical maps, Zeiss stereopret, Old Delft scanning stereoscope, Zeiss sketchmaster, rotameter and electronic planimeter were used as basic materials for this study. The drainage map of the catchment was prepared from SOI maps and aerial photographs. Interpretation of aerial photographs under stereoscopes provided three dimensional view of the terrain features and also enabled to identify, delineate and map the boundaries of 13 watersheds/drainage basins accurately and quickly. The method of quantitative analysis of the geomorphic characteristics of watersheds/drainage basins was used for designating the order to each drainage channel and to determine the dimensions of the watersheds.

Dimensional and dimensionless geomorphic characteristics of different order watersheds/drainage basins were measured and tabulated by using rotameter and electronic planimeter. The boundaries and other geomorphic characteristics of the watersheds were check-

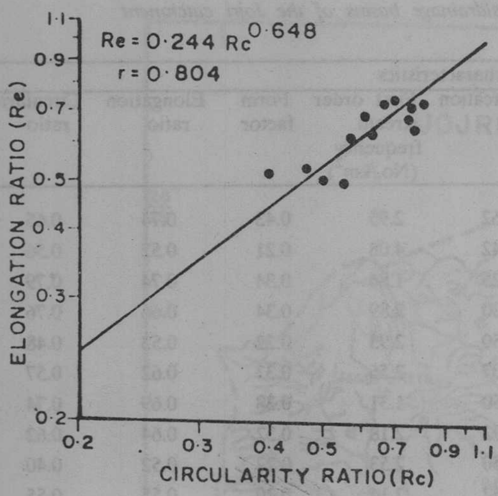

Fig. 2. Relation of elongation ratio to circularity ratio.

timating water and sediment yield of a drainage basin in a given environment. To express this relationship mathematically, the values of elongation ratios were plotted against circularity ratios on log-log paper (Fig. 2). The variables are significantly correlated (r = 0.804) to each other. The relationship between R_e and R_c is expressed by the equation:

$$R_e = 0.2446\ R_c^{\ 0.648} \quad \text{..... (1)}$$

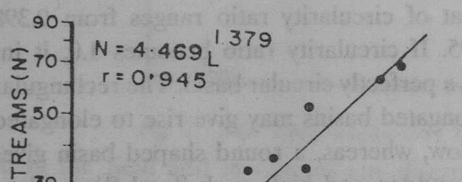

Fig. 3. Relation of total number of streams to total stream length.

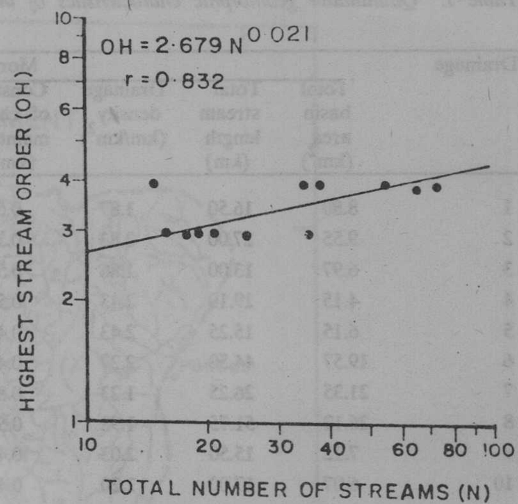

Fig. 4. Relation of highest stream order to total number of streams.

The standard error of estimate from the regression is 0.070.

Relation of total number of streams (N) to total stream length (L) : The total stream length includes the length of the total streams of all orders measured in each drainage basin. To correlate these two variables, the total number of streams which includes streams of all orders in a basin was plotted against the total stream length

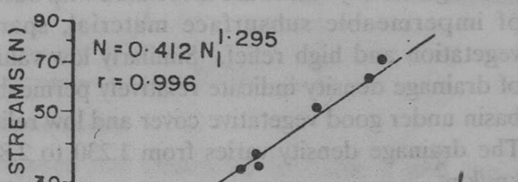

Fig. 5. Relation of total number of streams to number of first order streams.

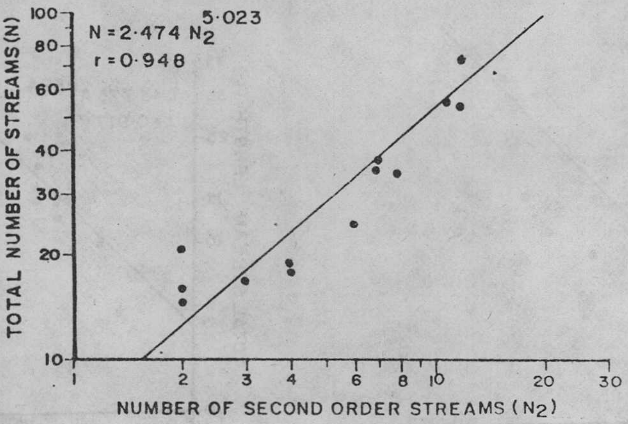

Fig. 6. Relation of total number of streams to number of second order streams.

on a log-log paper (Fig. 3). The regression line drawn through the points is significantly correlated by equation:

$$N = 4.469\ L^{1.379} \quad .....(2)$$

It shows that the two variables are interdependent. The standard error of estimate from regression is · 0.066.

Relation of highest stream order (OH) to total number of streams (N) : The trunk stream through which all discharge of water and sediment pass, is referred to as the stream segment of highest order. The data obtained in this study showed that the order of the trunk stream in a basin increases with increase in total number of streams. To test this hypothesis, the values of highest stream order were plotted against total stream numbers on log-log paper (Fig. 4). The regression line drawn through the points with a little scatter (r = 0.832) is expressed by the equation:

$$OH = 2.679N^{0.0213} \quad .....(3)$$

The values of the highest stream order corresponding to given total number of streams can be obtained with reasonable accuracy from this

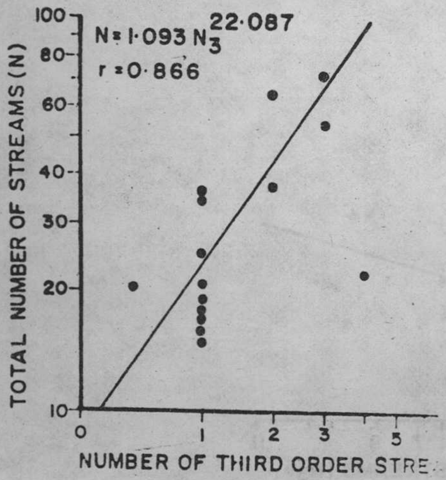

Fig. 7. Relation of total number of streams to number of third order streams.

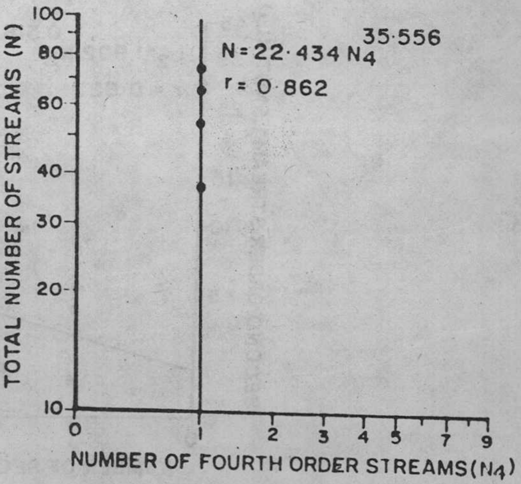

Fig. 8. Relation of total number of streams to number of fourth order streams.

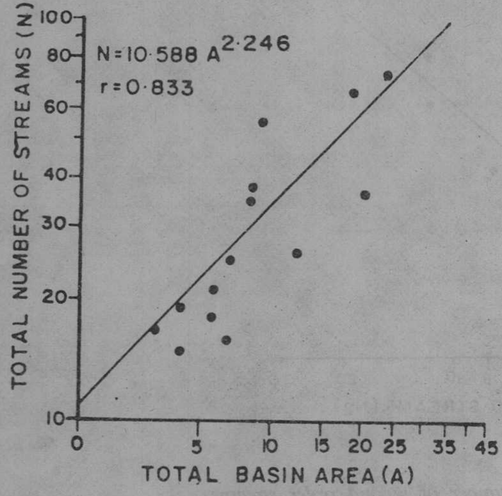

Fig. 9. Relation of total number of streams to total basin area.

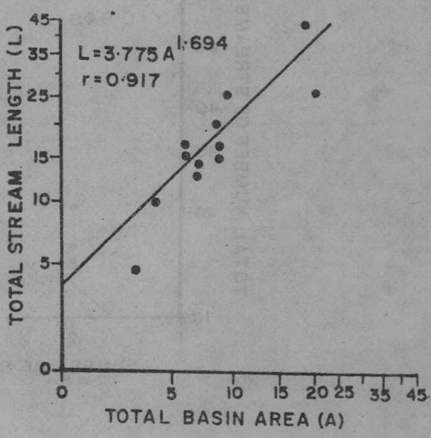

Fig. 10. Relation of highest stream length to total basin area.

equation, if the drainage basin lies within the range of geomorphic characteristics of the drainage basins used in this study. The standard error of estimate for the regression is 0.013.

Relation of different order streams (N_1, N_2, etc.) to total number of streams (N) : The total number of streams in a basin increases as the number of different order streams increases, depending on various morphological factors. To develop a relationship of different order streams to total number of streams these variables were plotted on logarithmic paper (Fig. 5 to 8). The regression lines drawn through these points are expressed by the following equations:

$$N = 0.412 \quad N_1^{1.295} \qquad .... (4)$$

$$N = 2.474 \quad N_2^{5.023} \qquad .... (5)$$

$$N = 1.093 \quad N_3^{22.087} \qquad .... (6)$$

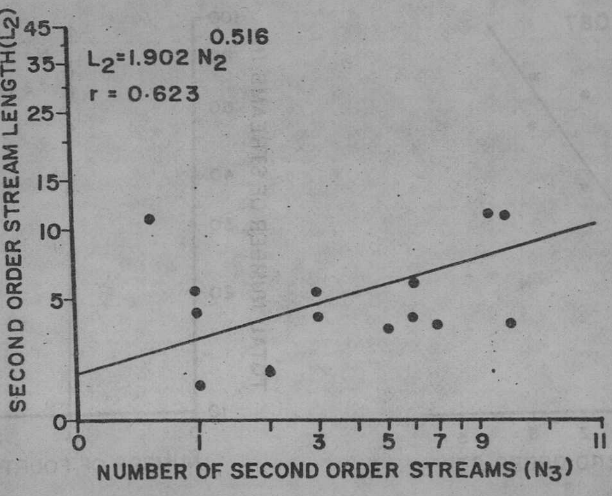

Fig. 11. Relation of second order stream length to number of second order streams.

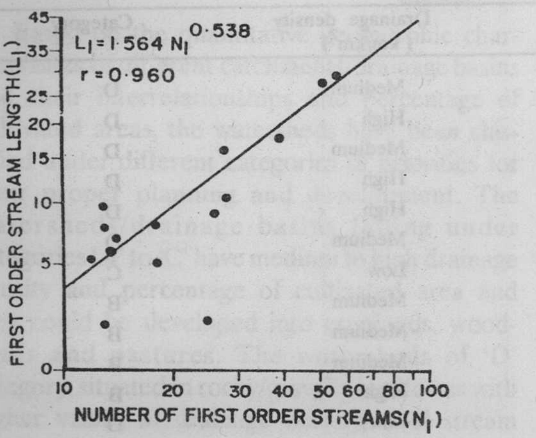

Fig. 12. Relation of total number of streams to total basin area.

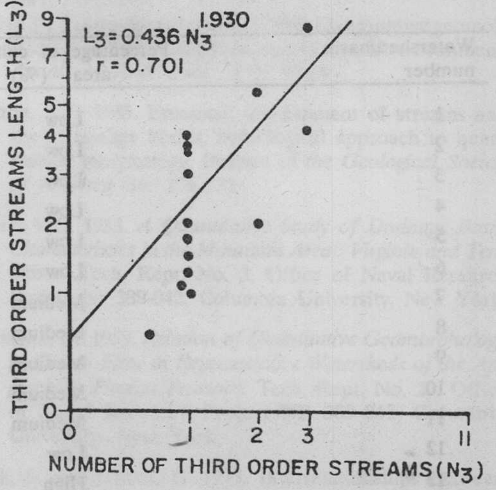

Fig. 13. Relation of highest stream length to total basin area.

$$N = 22.434\ N_4^{35.56} \quad \text{.... (7)}$$

Relation of total number of streams (N) to total basin area (A) : The study shows that the total number of streams increases with an increase in total basin area. When total number of streams was plotted against total area of each basin on a logarithmic paper (Fig. 9) the two variables were found to be interdependent. One variable may be used to predict the other and vice-versa. The regression line drawn through the points with a little scatter (r = 0.833) is expressed by the equation:

$$N = 10.588\ A^{2.246} \quad \text{.... (8)}$$

The standard error of estimate from the regression is 0.121.

Relation of total stream length (L) to total basin area (A) : The total stream length was plotted against the total basin area on a logarithmic paper (Fig. 10). These two variables are

Table 2. Percentage of cultivated area and drainage density of the watersheds/drainage basins

Watershed/basin number	Cultivated area (km^2)	Total area of watershed (km^2)	Percentage of cultivated area	Drainage density (km/km^2)
1	3.94	8.80	44.81	1.87
2	1.87	9.56	19.63	2.82
3	2.39	6.97	34.24	1.86
4	1.41	4.15	33.96	2.43
5	2.01	6.15	32.73	2.48
6	7.77	19.57	39.72	2.27
7	13.02	21.35	61.00	1.23
8	13.04	26.12	51.48	1.98
9	5.26	7.12	73.89	2.03
10	3.85	6.07	63.37	2.20
11	2.00	4.10	73.32	2.80
12	1.55	3.10	56.00	1.53
13	6.75	8.87	76.06	2.31