

Prediction of Sediment Yield from the Bandi Catchment Using Morphometric Characteristics

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Abstract Morphometric characteristics of different drainage basins, their interrelationship and regression analysis for the prediction of sediment yield from the Bandi catchment have been highlighted in this paper. The regression analysis of sediment yield with different morphometric characteristics showed that the sediment yield from different drainage basins could be predicted by constant of channel maintenance, followed by relief ratio and drainage density.

Key words Sediment yield prediction, morphometric characteristics, watershed geomorphology

In the arid part of Rajasthan, particularly in the west of the Aravallis, the Luni river and its tributaries are posing a serious problem of soil erosion due to increasing degradation of their catchment areas and accelerated fluvial action. The Bandi river which is the tributary to the Luni river constitutes several small agricultural drainage basins of various shapes and sizes. These drainage basins, due to their degraded catchment areas, generate varying amounts of surface runoff and sediment yield, depending upon their biophysical resources and inherent morphological characteristics. As a result, the engineering structures, such as, *nadis*, reservoirs, anicuts and embankments constructed along the master streams, without assessing sediment yield and evaluating the morphometric characteristics of these drainage basins, result in the sedimentation, removal and/or breaching of such structures.

Realising the seriousness of the problem of soil erosion and its impact on the engineering structures and agricultural lands, the studies on the evaluation of morphometric characteristics of the drainage basins, their mutual interrelationship and also relation with hydrological variables have been done in the Luni-Jawai drainage system (Ghose *et al.* 1967, Singh & Ghose 1973, Singh *et al.* 1977, Singh & Sharma 1979). But the studies on the regression analysis of the morphometric characteristics to develop the regression equations and mathematical models for prediction of sediment yield was not attempted. Accordingly, the study on the regression analysis of various mor-

phometric variables was undertaken in the Bandi catchment.

The Environment

The Bandi catchment, covering an area of 2748 sq. km, is located between latitude 25°15' and 25°55' N and longitude 72°58' and 74°0' E. The climate of the catchment is arid with Thornthwaite aridity index varying from 70 to 87 per cent.

The average annual precipitation varies from 300 mm in the northwest to 600 mm in the southeast. About 90 per cent of the rainfall is received from June to September. Biophysical factors which influence the surface runoff and sediment yield are different types of landforms like hills, rocky/gravelly and buried pediments and alluvial plains, light to medium textured soils varying from loamy sand to sandy loam and loam and land use/land cover comprising of crop lands, fallow lands and pastures and trees, shrubs and grasses, respectively. Major lithological formations encountered in this catchment are schist, gneiss, quartzite, granite and older and younger alluvium.

Materials and Methods

Aerial photographs, Landsat MSS and TM and IRS LISS-I and LISS-II false colour composites and Survey of India topographical maps (1:250,000 and 1:50,000 scales), Mirror stereo-

scope, Zeiss stereopret, planimeter and rotameter were used as basic materials for this study. The catchment was divided into 71 small agricultural drainage basins of 3rd, 4th and 5th orders and stream ordering by using the method developed by Horton (1945) and modified by Strahler (1957) was done. The morphometric characteristics/variables of different order basins like number of streams, total stream length, drainage basin area, drainage density, constant of channel maintenance, bifurcation ratio, relief ratio, circularity ratio and elongation ratio were computed using the method suggested by Melton (1958) and their relationship by least square method were established. Regression analysis of the morphometric characteristics/variables was done to develop regression equations and mathematical models for the prediction of eventual sediment yield, as reported by Sharma *et al.* (1992) in the Bandi river basin.

Results and Discussion

Morphometric characteristics of drainage basins: The values of range, average and standard deviation of the morphometric characteristics like basin area, drainage density, bifurcation ratio and circularity ratio, etc., of different basin orders were computed and are presented in Table 1.

The range and average values of drainage basin area and total stream length increase with the increase in basin order. Whereas, the values of the drainage density, bifurcation ratio and circularity ratio decrease with the increase in basin order, indicating that the lower order basins

are more circular than that of higher order and will generate higher runoff and sediment yield. The problem of soil erosion is directly correlated with drainage density of the basin, higher the drainage density more will be the soil erosion.

Interrelationships between different morphometric characteristics: By developing the regression equations, the interrelationships between drainage basin area and total stream length, stream frequency and drainage density, circularity ratio and elongation ratio, number of streams and bifurcation ratio, relief ratio and drainage density, and relief ratio and constant of channel maintenance were established (Table 2).

The interrelationships between different morphometric variables indicate that the variables of different order basins were significantly correlated to each other at 1 per cent level of significance, except the correlation between circularity ratio and elongation ratio of the 3rd order basins. In case of 5th order basins, relief ratio was significantly correlated with drainage density ($r=0.842$) and constant of channel maintenance ($r=0.819$) at 5 per cent level of significance. It may be inferred from the significant correlations between different variables that constant of channel maintenance, drainage density, bifurcation ratio and relief ratio will be useful variables for evaluating and predicting the sediment yield from different order basins of the Bandi catchment.

Sediment yield prediction using morphometric variables: The correlation of sediment yield is the highest with constant of channel maintenance,

Table 1 Values of range, average and standard deviation (SD) of morphometric characteristics of the Bandi drainage basins

Basin order	Aspect	Drainage basin area (km ²)	Total stream length (km)	Drainage density (km km ⁻²)	Constant of channel maintenance (km ² km ⁻¹)	Bifurcation ratio	Circularity ratio
3	Range	1.72-42.80	7.00-73.75	1.09-4.53	0.22-0.92	2.25-6.39	0.28-0.81
	Average	9.50	20.25	2.88	0.35	4.27	0.48
	SD	9.33	12.72	0.90	0.16	1.06	0.11
4	Range	7.40-61.33	18.25-146.50	1.96-4.68	0.21-0.51	2.43-5.12	0.27-0.72
	Average	22.68	52.15	2.56	0.39	3.42	0.47
	SD	12.63	25.15	0.79	0.21	0.62	0.15
5	Range	36.37-209.17	97.50-383.50	1.53-2.83	0.35-0.65	2.89-4.25	0.18-0.60
	Average	109.21	216.22	2.18	0.46	3.61	0.34
	SD	61.43	97.15	0.48	0.24	0.40	0.15

Table 2 Regression analysis of different morphometric variables

Variable	Basin order	Regression equation	Correlation coefficient	Level of significance (%)
Drainage basin area and total stream length	3	L=1.508 A + 3.857	0.905	1
	4	L=2.199A + 7.054	0.925	1
	5	L=1.511A + 51.190	0.955	1
Stream frequency and drainage density	3	D=0.450F + 1.224	0.862	1
	4	D=0.361F + 7.053	0.904	1
	5	D=0.565F + 0.920	0.826	1
Circularity ratio and elongation ratio	3	Re=0.418Rc + 0.373	0.638	1
	4	Re=0.628Rc + 0.373	0.797	1
	5	Re=0.885Rc + 0.276	0.807	1
Total number of streams and bifurcation ratio	3	Rb=0.107N + 1.789	0.892	1
	4	Rb=0.019N + 2.518	0.905	1
	5	Rb=0.004N + 2.840	0.962	1
Relief ratio and drainage density	5	D=45.070Rh + 1.086	0.852	5
Relief ratio and constant of channel maintenance	5	C= -8.612Rh + 0.675	0.819	5

followed by relief ratio, circularity ratio and drainage density (Table 3). Whereas, the correlation of sediment yield with other morphometric variables is not significant.

Since the constant of channel maintenance and relief ratio are highly correlated with sediment yield, they were the best choice to use them as independent variables to develop regression equation for predicting sediment yield ($t km^{-2}$). These two independent variables were, therefore, plotted against sediment yield, using PLOT software to get multiple regression equation for sediment yield prediction in 5th order basins of the Bandi catchment (Fig. 1). The equation developed by second order polynomial is given by :

$$S_y = 9.1013 \times 10^2 C + 1.2091 \times 10^3 R_h - 5.6617 (C)^2 - 15.837 CR_h - 9.025 (R_h)^2 - 3.5718 \times 10^4$$

Where,

S_y = Sediment yield $t km^{-2} event^{-1}$

C = Constant of channel maintenance $\times 10^2$

R_h = Relief ratio $\times 10^3$

This equation, thus was found significant at 5 per cent with a high value of coefficient of

Table 3 Correlation between sediment yield and different morphometric variables

Morphometric variables	Coefficient of variables	Level of significance (%)	Rank
Total number of streams	-0.221	5	6
Number of first order streams	-0.286	5	5
Drainage density	0.819	1	3
Constant of channel maintenance	-0.884	1	1
Circularity ratio	-0.824	1	4
Relief ratio	0.948	1	2

correlation ($r = 0.881$). The standard error of estimate was $22.54 t km^{-2}$. This study thus indicates that the drainage basins with more rugged topography, circular shape and higher drainage density and integrated drainage network will generate

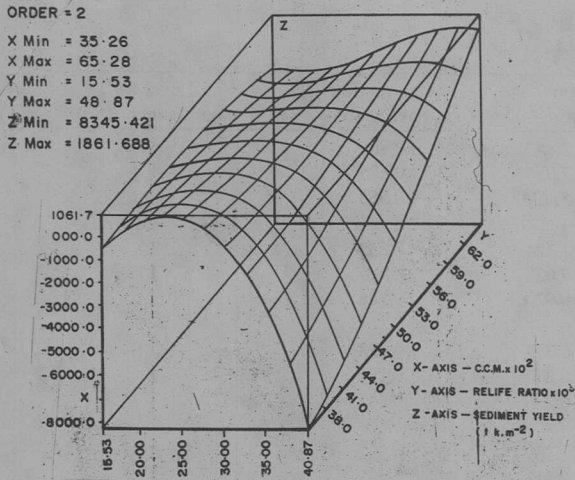


Fig 1 Plot of C.C.M., relief ratio & sediment yield

greater runoff and sediment yield. Kumar *et al.* (1990) have also reported that the regression equations were useful in modelling runoff and sediment yield from small watersheds.

It has been inferred from the analysis of different morphometric characteristics of the drainage basins, their interrelationships and regression correlation with sediment yield, that the constant of channel maintenance and relief ratio are the best choice to be used as independent variables, for the prediction of the sediment yield in the Bandi catchment.

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