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Catchment Characteristics in Relation to Soil Erosion Hazard in Sub-mountain Punjab, India

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ABSTRACT

Information on slope, areal characteristics, runoff and sediment density was collected from three catchments in sub-mountain Punjab and analyzed so as to develop relationships between slope and shape indices of the catchments and the severity of soil erosion taking place from these. Based on the shape indices *viz*. lemniscate ratio, compactness coefficient and form factor, catchment III was adjudged as the most prone to erosion hazard. The peak runoff and sediment density were also highest in catchment III followed by catchment II and I. The average slope of catchment III was also highest and nearly 3% area was under slope steepness of 120-150% compared to 1.7 and 0% in catchment II and I, respectively. The average fall in gully slope was not in line with average slope of the catchments. Soil loss was more a function of peak runoff than runoff amount in all the three study catchments.

Key Words: Soil erosion; Catchment characteristics; Sub-mountain Punjab

INTRODUCTION

Soil erosion by water is a serious hazard in sub-mountainous tract of Punjab. Due to indiscriminate human interference, undulating topography, climatic hazard and high erodibility of soils, a spectacular picture of accelerated erosion is provided by dissection of the whole terrain by innumerable seasonal streams. Severity of erosion, however, varies among various catchments even with the similar soil and vegetation characteristics (Kukal & Sur, 1989). The catchment characteristics VI area, shape and slope have an important bearing on soil erosion taking place from the catchments (Bocco, 1990; Morgan, 1996; Meyer & Martinez-Casasnovas, 1999). However, no such relationships between catchment characteristics and soil erosion exist in the area. This study attempts to relate shape indices and slope characteristics with runoff and sediment density taking place from three selected catchments in sub-mountain Punjab.

MATERIALS AND METHODS

The information about shape and slope parameters was collected in three catchments with almost similar vegetative status, in village Saleran of district Hoshiarpur in sub-mountain Punjab. It is situated 31^o 36' N latitude and 75^o 58' E longitude and is 360.5 m above the mean sea level. The soils of the area remain dry for 4 to 5 months in a year and qualify for an ustic soil moisture regime (Sehgal, 1970). The major soil groups recognized in the area are Ustipsamments and Ustorthents. The texture of the soils varies from loamy sand to sandy loam with pH ranging from 6.8 to 8.2 and these are low in organic carbon content.

The area has sub-humid type of climate. Owing to the type of terrain and difficulty involved in exploitation of underground water, rainfall in the area constitutes the major water resource. The annual rainfall in the area varies from 800-1100 mm. Rainfall during the summer monsoon months (July to September) is of major concern as it constitutes major portion (80%) of the annual rainfall that causes soil erosion in the area. The mean monthly rainfall is maximum in July and minimum in April followed by October and November. The high coefficients of variation of monthly rain indicate that the rains are very much uncertain in the area. The mean annual temperature in the area was 24.1^{o}C with mean summer and winter temperatures of 32.8^{o}C and 14.5^{o}C, respectively.

The shape of the study catchments was expressed on the basis of lemniscate ratio, form factor and compactness coefficient. Lemniscate ratio was calculated as the ratio of square of maximum length (L) of the catchment and four times its area (A), whereas form factor was determined as the ratio of average width to the maximum length of the catchment and compactness coefficient as the ratio of catchment perimeter (p) to the area (A) of the catchment as $P/2\ (\pi\ A)^{0.5}$. The average slope of the catchments was determined by contour length method as $\sum$ CL x CI/A, where CL is contour length (m) and CI is contour interval (m) and n is the number of contours. Average fall in gully slope was determined as the ratio of the difference of elevation at the highest and lowest points of the main gully to the distance between the two points.

Runoff was measured with the help of stage level recorders fitted in each catchment. For measuring sediment density, four 1.5 L samples of runoff were collected in plastic cans after each rainfall event. These were thoroughly mixed and a sample of 200 mL was transferred to a 500 mL beaker and decanted off after adding sodium fluoride as flocculating agent. The wet soil after decantation was dried in an oven at 105^{o}C for 24 h and weight of dry soil in 200 mL sample was expressed as t ha^{-1} for the total runoff during a rain event.

RESULTS AND DISCUSSION

Shape of the catchments. The shape of the catchments defined on the basis of various indices *viz*. lemniscate ratio, form factor and compactness coefficient (Table I) shows that the lemniscate ratio was lowest (0.88) for catchment III, followed by catchment I (0.98) and II (1.13). Similar trend was observed in case of compactness coefficient, which was lowest (1.27) in catchment III followed by that in catchment I (1.34) and highest (1.49) in catchment II. Form factor which is the ratio of the average width and maximum length of the catchment, varied as highest in catchment III (0.26) followed by catchment I (0.23) and II (0.21).

Table I. Shape indices of the study catchments

Catchment	Size (ha)	Lemniscate ratio	Form factor	Compactness coefficient
I	11.9	0.98	0.23	1.34
II	20.6	1.13	0.21	1.49
III	8.8	0.88	0.26	1.27

The lower values of lemniscate ratio indicates more compactness of the catchments and hence more hazard of soil erosion. It is because of lesser time of concentration for runoff in compact catchments compared to oblong ones (Morgan, 1996). Lower values of compactness coefficient and higher values of form factor are associated with more erosion hazard because of more compactness of the catchments. Based on these three indices, catchment III could be adjudged as most prone to soil erosion hazard followed by catchments I and II. Interestingly, catchment III was also of minimum size (8.8 ha) followed by catchment I (11.9 ha) and catchment II (20.6 ha).

Slope characteristics of the catchments. Average slope of catchment III was highest (39.5%) followed by that of catchment I (38.0%) and II (35.9%) (Table II). The average fall in gully slope was not in line with average slope of the catchments nor was it related to the size of the catchments. It was highest in catchment I (13.4 cm m^{-1}) followed by 12.6 cm m^{-1} in catchment III and 8.3 cm m^{-1} in catchment II. Based on slope steepness, catchment III is more prone to erosion followed by catchments I and II. Slopes of higher steepness (120-150%) were present in Catchment II and III (Table II). Bocco (1990) concluded that gully erosion was positively correlated with slope steepness. Meyer and Martinez-Casasnovas (1999) found that slope and spatial variability of slope degree are the quantitatively measured factors that show highest relationship with the existence of gully erosion.

Table II. Slope characteristics of the study catchments

Catch-ment	Average slope (%)	AFGS (cm/m)	Area under slope categories(%)			
			0-40	40-80	80-120	120-150
I	38.0	13.4	59.4	27.8	20.1	--
II	35.9	8.3	69.6	20.1	8.6	1.7
III	39.5	12.6	62.2	23.6	11.5	2.7

AFGS= Average fall in gully slope

Runoff and sediment density Runoff amount varied from 35.7 to 90.6 mm in the three catchments (Table III). It was 17.4, 16.7 and 6.9% of the seasonal rainfall in catchments II, III and I respectively. Peak runoff was maximum in catchment III (197.9 L s^{-1} ha^{-1}) followed by catchment II (182.9 L s^{-1} ha^{-1}) and I (103.0 L s^{-1} ha^{-1}). Sediment yield from the catchments also followed the trend of peak runoff. It was maximum (12.9 t ha^{-1}) in catchment III followed by 5.4 t ha^{-1} in catchment II and 2.2 t ha^{-1} in catchment I. The results show that soil loss was more a function of peak runoff than the runoff amount. Interestingly, catchment III was smallest in size compared to other catchments. Burkard and Kostachuk (1997) reported that the factor most commonly related to gully growth rate is the catchment area. Highest values of peak runoff and sediment yield in catchment III, also support the statement based on shape indices and slope characteristics that catchments with more compact shape and slope steepness are having higher risk of soil erosion hazard in the area.

Table III. Runoff amount, peak runoff and sediment yield from the catchments (seasonal rainfall =520.4 mm)

Catchment	Runoff amount (mm)	Peak runoff (L/s/ ha)	Sediment yield (t/ha)
I	35.7 (6.9)	103.0	2.2
II	90.6 (17.4)	182.9	5.4
III	87.1 (16.7)	187.9	12.9

Figures in parenthesis indicate per cent runoff

The above results indicate that shape indices of the catchments provide a reliable tool for assessing the risk of soil erosion by water in different catchments. This can provide a base for allocating priority while treating the catchments.

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