INTERNATIONAL
SOIL AND WATER
CONSERVATION RESEARCH

Temporal variations in runoff and soil loss in relation to soil conservation practices in catchments in Shiwaliks of lower Himalayas

S. S. Kukal[1] and S. S. Bawa[2]

Abstract

The soil conservation strategies adopted in the catchments of Shiwaliks, the most fragile region in the Himalayan ecosystem, failed to serve their purpose after a few years of their execution. A study was carried out in four differentially-treated catchments to monitor the variation in runoff and soil loss. The treatments imposed during 1988 included fencing, planting native vegetation and engineering structures in catchment Ⅰ; planting native vegetation and fencing in catchment Ⅱ; fencing alone in catchment Ⅲ in addition to an untreated catchment Ⅳ. The soil loss during the initial years (1989 – 1995) of imposition of the treatments was lowest (25.2 t ha^{-1}) in catchment Ⅰ, treated to the maximum extent and highest (43.3 t ha^{-1}) in untreated catchment Ⅳ. During the later period (1996 – 2006) the trends reversed, i. e., catchment Ⅳ recorded the lowest (14.1 t ha^{-1}) soil loss whereas catchment Ⅰ recorded the highest (23.4 t ha^{-1}) soil loss despite the fact that there was no change in the status of soil conservation or the characteristics of the catchments. The runoff was 71% higher in untreated catchment than in treated catchments initially and this difference decreased to 27% during the later period.

Key Words: Catchment, Gully erosion, Sediment loss, Soil conservation

1 Introduction

The increased exploitation of land resources in the catchment areas of the Shwialiks belt (2.14 million ha, 30°10′–33°37′ N, 73°37′–77°39′ E, 415 AMSL), the most fragile region of the Himalayan ecosystem (Sidhu et al., 2000), has resulted in increased sediment yields in the runoff thereby reducing the capacity of reservoirs at the downstream end. The drying of vegetation during the months of April – June (due to extremely high temperatures and low relative humidity) and frequent forest fires creates a stage for soil erosion to take place at potentially high rates during the months of July – September when 80% of the annual rainfall occurs (Sur and Ghuman, 1994).

Gully erosion is the most serious form of soil erosion with catchments having a dense network of gullies in the Shiwaliks region of the lower Himalayas. The severity of gully erosion measured in terms of gully intensity (number of first-order gullies per unit area) varies from 254 – 768 km^{-2} and gully length (total length of gullies per unit area) from 8.7 – 16.3 km km^{-2} (Kukal and Singh, 2004). Recent studies (De Vente et al., 2005; Huon et al., 2005) indicate that gullies are often the main source of sediments from the catchments. Gullies are often blamed for enhanced drainage and accelerated aridification processes (Daba, 2003). In tropical NW Australia, about 80% of the sediments in the reservoirs come from gully erosion (Krause et al., 2003). Gullied catchments in NSW were observed to be at least one order of magnitude higher in sediment load than the catchments without gullies (Armstrong and Mackenzie, 2002). The impact of sediment trapping and grade stabilization works on sediment yield mainly depend on the activity of the gully being treated and the mobility of bed sediments. At the catchment

[1] Professor of Soil Conservation and Director, School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana, India. Corresponding author: E-mail: sskukal@rediffmail.com
[2] Senior Soil Physicist, Zonal Research Station for Kandi Area (PAU), Nawanshahar, India

scale, it is often the combination of widespread conservation measures in the gullies (plugging structures) as well as in the inter-gully zone that leads to a decrease in soil erosion rates (Nyssen et al., 2004 a, 2004 b). The frequent siltation of plugging structures (Kukal and Singh, 2004) or their collapse is due to the runoff volume and velocity (Nyssen et al., 2004a). The rainfall aggressiveness – ratio of highest monthly rainfall squared to the total annual rainfall, varies from 55.9 – 502.4 with an average annual value of 207.8±121.7 (Singh, 2000) in the region and is shown to be related to gully intensity and the sediment yield in the streams and rivers (Fournier, 1960). Studies in the region (Matharu et al., 2002) have shown that about 77% variation in annual sediment yield could be explained by rainfall aggressiveness.

Recently, the Shiwaliks region has started receiving attention for the management of runoff and soil loss on micro-watershed basis through various anti-erosion measures. However, it had been a common observation that the soil conservation measures, particularly the gully plugging structures, installed in the highest-order gullies, were successful in controlling the runoff and sediment losses from the catchments during the initial years, but after 3 – 4 years of their installation the soil erosion rates in treated catchments exceed from those in untreated ones (Kukal et al., 2002). The gully plugging structures installed in the catchment get silted up within no time leading to enhanced runoff and sediment losses from the catchment areas. This has baffled the soil conservation planners in the region. A study was thus initiated in 1989 to monitor the runoff and soil loss in relation to soil conservation practices at catchment scale.

2 Materials and methods

2.1 *Study site*

The study was conducted in the northwest part of Punjab in India, located in the Shiwaliks belt of lower Himalayas. The climate of the region is semi-arid sub-tropical with warm summers and cold winters. The mean annual summer and winter temperatures in the region vary from 15 – 22℃ and 5 – 6℃. The mean summer soil temperature varies from 29 – 32℃ and mean winter soil temperature varies from 8.4 – 15℃. The area receives an annual average rainfall of 950±291 mm of which about 80% is received during a short period of three months (July – September) with a high degree of coefficient of variation (Sur and Ghuman, 1994). Shallow soil depth and stoniness in the region generates rapid runoff due to low storage, low water holding capacity and low nutrient status. Stoniness covering 25% of the area is the main problem in severely eroded areas (Sidhu et al., 2000). Soils in the region are generally light textured, well drained and highly erodible (Kukal et al., 1991).

2.2 *Treatments*

Four catchments, varying in size from 3 – 16 ha and treated with a combination of different anti-erosion measures viz. afforestation, fencing and gully control structures were monitored for runoff and soil loss (Table 1). The catchment Ⅰ was fenced, planted with native vegetation with gully control structures installed in the highest-order gullies; catchment Ⅱ was fenced and planted with native vegetation; and catchment Ⅲ was fenced only. The catchment Ⅳ was kept untreated and was designated as control (C). The fencing was carried out with barbed galvanized iron wire fixed thrice all around the catchment using cemented (reinforced concrete cement) fixtures with the aim of preventing wild animals from grazing and deforestation by humans. The native vegetation mainly comprised of *Acacia catechu* trees and *Eulaliopsis binata* grass. The engineering structures for plugging the gullies were gabions and lose rock dams (made from the locally-available stones) installed as check dams in series at upper, middle and lower segments of the main (highest-order) gullies (Fig. 1 and Fig. 2).

Table 1 General catchment characteristics

Catchment	Area (ha)	Average relief	Lemniscate ratio
Ⅰ	11.8	0.19	0.66
Ⅱ	20.6	0.11	1.00
Ⅲ	8.75	0.19	0.60
Ⅳ	42.6	0.33	0.79

Note: Catchment Ⅰ – planted vegetation, fencing and engineering structures; catchment Ⅱ – planted vegetation and fencing; catchment Ⅲ – fencing alone and catchment Ⅳ – untreated.

2.3 *Observations*

Detailed ground surveys were carried out in all the catchments to mark the gullies up to the first-order. For