Surface Runoff, Soil Loss and Land Use Studies in Two Micro-Catchments of the Western Himalaya, India

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Abstract

Runoff and sediment loss were monitored in two micro-catchments of the Garhwal Himalayas, India, during 1994 and 1995. These catchments differ from each other with respect to land use considerably. While the Srikot Gad catchment has 50 per cent of its area under forest cover and only 12 per cent is wasteland, the Dugar Gad has only about 9 per cent of its area forested, 53 per cent being wasteland. Data indicate that while the former catchment was characterised by low runoff (18.1% of the annual rainfall) and low sediment loss (4.69 t ha^{-1} yr^{-1}), the latter catchment had a high runoff (41.3%) and high sediment loss (9.13 t ha^{-1} yr^{-1}).

This preliminary study emphasises that land use governs the hydrometeorological parameters of a catchment to a large extent. Therefore, land use which allows greater water retention in the fragile catchments of Himalayan mountains should be encouraged for soil and water conservation in this region.

Introduction

Land-use practices have a decisive role in soil and water conservation, particularly in the mountains (Ives and Messerli 1989, Dunne et. al. 1991). Several studies focussing on soil erosion and water yield have emphasised the role of an effective vegetation cover which dissipates much of the raindrop energy and promotes high rates of infiltration (Sorriso-Valvo et al. 1995, Oyarzun and Pena 1995).

In the Himalayan mountains, as a consequence of loss of forest cover coupled with the influence of the monsoon pattern of rainfall, the fragile catchments have become prone to low water retention and high soil loss associated with runoff (Valdiya 1985, Rawat and Rawat 1994, Joshi and Negi 1995). These key factors of ecosystem stability have seriously impaired the life support system in this region (G.B. Pant Institute of Himalayan Development and Environment 1992). Therefore, understanding the hydrometeorology of the Himalayan mountains needs to be developed before any mitigating plans can be formulated.

This study was undertaken in two representative micro-catchments having distinctly different land-use profiles in the Ganga basin of the Garhwal Himalayas (Fig. 1). The main objective was to quantify runoff and suspended sediment loss in order to recommend an ideal land use practice that allows maximum soil and water conservation within the catchment and provides ways to improve the quality of life of the inhabitants.

Materials and Methods

The study area (Fig. 1), Srikot Gad and Dugar Gad catchments, are located (between 30°5' to 30°11'N and 78°46' to 78°48'E) in Pauri district of the Garhwal Himalayas, India. In 1990 these catchments were targetted for soil and water conservation measures by the World Bank-assisted *Jalagam Prabandh Pariyojana*. Under that, project silt and runoff observation posts (SOP) consisting of a stage level recorder with flume arrangement (Plate 1) were installed, and these were transferred to us with the termination of the project in 1993. We subsequently carried out runoff and soil loss studies in these catchments, considering land use as the main determinant governing hydrological behaviour.

Land-use data and population attributes of the catchments are based on revenue records of the U.P. government, toposheet mapping of our own, household inventories, and our repeated field checks and ground-truth verifications in 1993 through 1994. Runoff volume was measured using standard techniques at the SOP of each catchment, and samples were brought to the laboratory and filtered for sediment.

Results and Discussion

The human and livestock populations of the Dugar Gad catchment (958 and 1,926 respectively) were much higher than those of the Srikot Gad catchment (501 and 1,046). In terms of human and livestock densities per hectare of land, the former catchment had twice the burden.

Land-use attributes of both catchments (Figs. 2 and 3) indicate that although their cultivated land was almost similar in relative area, the Dugar Gad catchment was characterised by a high proportion of wasteland and an extremely low proportion of forested land. The annual rainfall (average over 1994 and 1995), while measuring 2,365mm in Srikot Gad and 1,697mm in Dugar Gad, when converted into the amount of water falling on each unit of land, leads to large differences (Table 1). Runoff efficiency (i.e., the proportion of rainfall which flows out of the catchment via runoff) was found inversely proportional to rainfall. A runoff efficiency of up to 20 per cent has been found in mountain catchments of northern Thailand, making them among the most 'arid' on earth (Alford 1992). Considering this fact, the Dugar Gad catchment, too, can be put under the most arid category, while in the Srikot Gad catchment, water retention is two times greater. It can be concluded from this preliminary study that each micro-catchment has its own behaviour with regard to retention of water, and this is influenced by land use, rock types, gradient of the stream, use of the water, and other, meteorological factors.

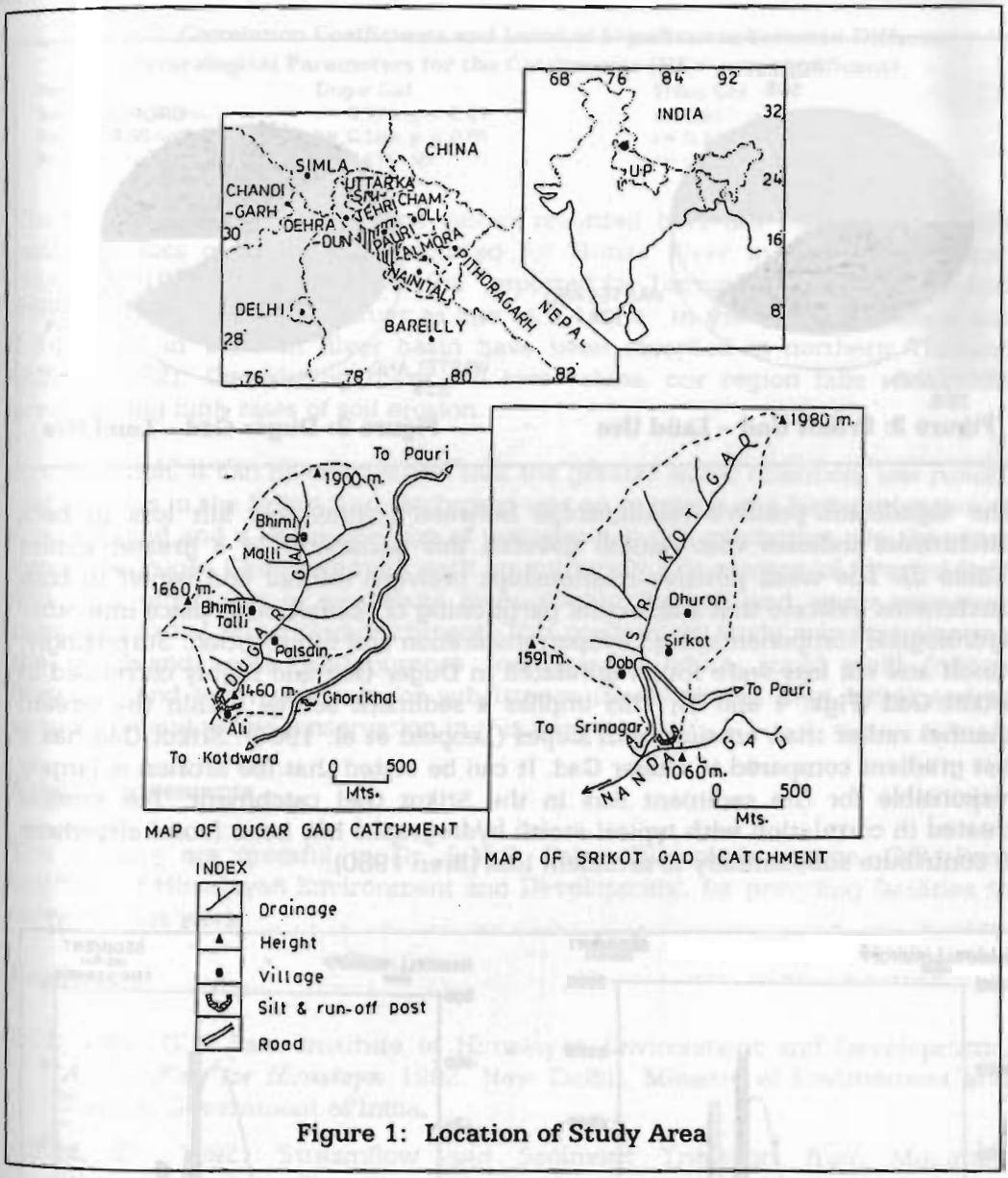

Figure 1: Location of Study Area

Table 1. Hydrometeorological Data of the Catchments

Parameters	Dugar Gad (306ha)	Srikot Gad (286ha)
Annual rainfall (mm)	1,697.72	2,365.00
Rainfall (m^3/ha)	16,977.00	23,650.00
Runoff (m^3/ha)	7,000.60	4,274.00
Runoff efficiency	41.50	18.10
Base flow (m^3/ha)	2,251.90	1371.80
Additional runoff (m^3/ha)	4,748.30	2,902.20
Runoff coefficient	16.22	7.36
Infiltration coefficient	75.53	67.62
Sediment output (kg/ha/yr)	9,130.50	4,690.20

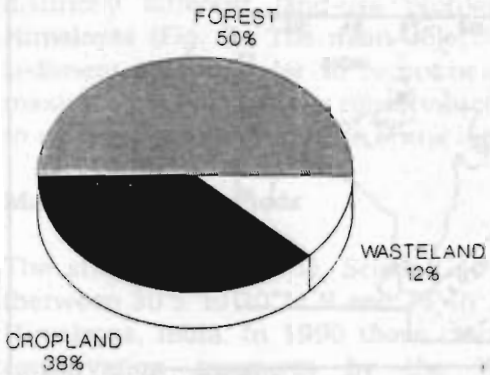

Figure 2: Srikot Gad – Land Use

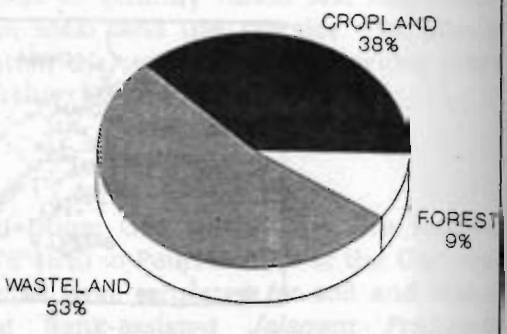

Figure 3: Dugar Gad – Land Use

The significant positive relationships between rainfall and silt loss in both catchments indicate that rainfall governs this parameter to a greater extent (Table 2). The weak positive relationships between rainfall and runoff in both catchments indicate that substantial partitioning of rainfall takes place into other hydrological components, e.g., evapotranspiration and interception. Surprisingly, runoff and silt loss were found unrelated in Dugar Gad and highly correlated in Srikot Gad (Figs. 4 and 5). This implies a sediment source within the stream channel rather than erosion from slopes (Leopold et al. 1964). Srikot Gad has a fast gradient compared to Dugar Gad. It can be stated that toe erosion is largely responsible for the sediment loss in the Srikot Gad catchment. Toe erosion created in correlation with typical storm hydrographs has been found elsewhere to contribute substantially to sediment loss (Bren 1980).

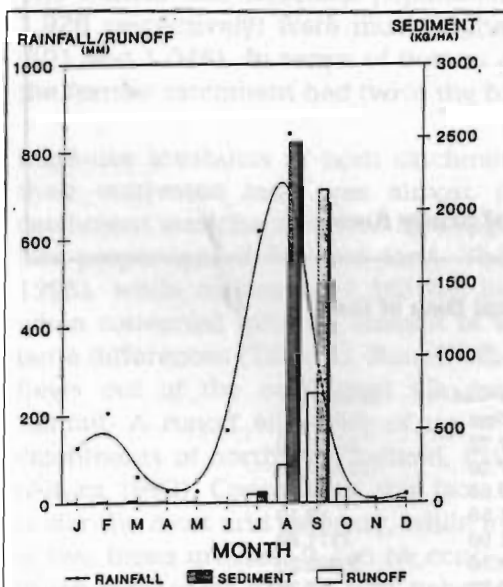

Figure 4: Srikot Gad

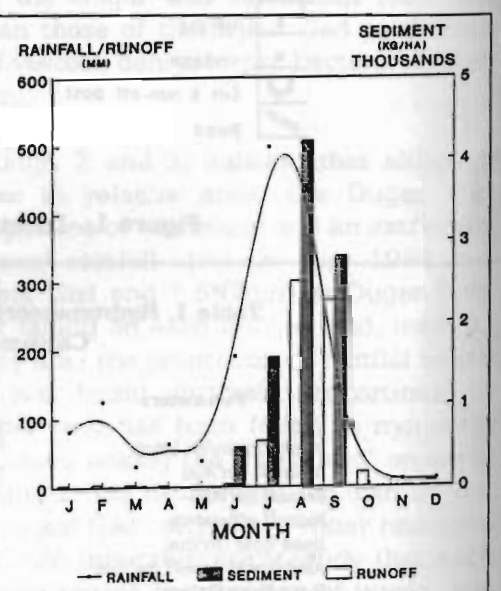

Figure 5: Dugar Gad

Table 2. Correlation Coefficients and Level of Significance between Different Hydrological Parameters for the Catchments (NS= non-significant)

Parameters	Dugar Gad	Srikot Gad
Rainfall vs soil loss	r= 0.774; $p < 0.01$	r= 0.667; $p < 0.05$
Rainfall vs runoff	r= 0.599; $p < 0.05$	r= 0.344; NS
Runoff vs soil loss	r= 0.275; NS	r= 0.827; $p < 0.01$

The suspended sediment output values recorded here are comparable to the sediment loss of 13.2 t ha^{-1} reported for Hunza River in northern Pakistan (Ferguson 1982) and that of 5.5 t ha^{-1} reported for Tamur River in eastern Nepal (Carson 1985). However, values as low as 0.4 t ha^{-1} in the Ping River basin and 2.56 t ha^{-1} in the Nan River basin have been recorded in northern Thailand (Alford 1992). Considering these soil loss values, our region falls within the areas having high rates of soil erosion.

In conclusion, it can be emphasised that the greater water retention, low runoff, and soil loss in the Srikot Gad catchment was an outcome of a high proportion of forested land and a low proportion of wasteland in this catchment. On the other hand, the Dugar Gad catchment with an extremely low amount of forested land and high proportion of wasteland loses double the soil and water resources compared to the Srikot Gad catchment. This preliminary study warrants planting the wastelands with multipurpose tree species which could yield fodder, firewood, and other products for subsistence (Nautiyal and Negi 1994) and to ensure soil and water conservation in this region.

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Plate 1. Silt and Runoff Observation Post (SOP) in the Dugar Gad Catchment.