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CAUSES AND IMPACTS OF SPATIAL VARIABILITY IN EROSION AND SEDIMENT YIELD OF SUKETI CATCHMENT, HIMACHAL PRADESH

Doctoral Dissertation Abstract (2019)

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Soil erosion due to water is one of the major factors responsible for degradation of land resources. It has far reaching impacts on land, crop production, hydrological systems, water quality and environment. Civilizations that have neglected their lands had either to migrate en masse or gradually disappeared, resulting in total extinction. There is a reason to believe that parts of the Sahara, the Central Asian deserts, parts of Palestine, Mesopotamia and the Gobi have been once fertile lands and therefore, have been heavily populated. The forces that led these lands to be converted into deserts must have originated from the problem of soil erosion, which have not been recognized at right time in the right perspective and manner.

Mountain areas around the world are largely susceptible to high rates of erosion. A very high rate of soil erosion to the tune of 30-40 t ha^{-1} yr^{-1} occurs in the mountains of Asia, Africa and South America. Nearly, 54 per cent geographical area in Himachal Pradesh is degraded due to water erosion. The soils of the state fall under very high category of soil erosion with erosion rate of more than 2,000 t km^{-2} yr^{-1}. Erosion from the Greater Himalayas, as represented by Kinnaur Basin of Sutlej River covering 5,157 km^2 is $11,340\times10^3$ t, deliver a higher sedimentation rate of 219.8×10^3 t 100 km^2. The cold desert represented by Spiti basin of 5,875 km^2 delivers $7,840\times10^3$ t sediments annually to Spiti River having a sedimentation rate of 133.4×10^3 t 100 km^2. Erosion from the middle Himalayan region spreading over Shimla, Solan and Sirmaur districts covering about 2,800 km^2 area is $2,488.2\times10^3$ t, producing sedimentation at the rate of 95.7×10^3 t km^2. Bater micro-watershed in Sirsa catchment with an area of less than one km^2 has recorded average sediment loss of 3,600 t km^{-2} yr^{-1}. The degradation of primary resource base of soil at such an alarming rate in the state may jeopardize the food and fodder security besides posing a major threat to the existence of fragile mountain ecosystem over a period of time. In the light of these facts, the present study has been attempted to investigate the causes and impacts of spatial variability in erosion and sediment yield of Suketi catchment in Himachal Pradesh.

Objectives

Major objectives of the study are:

- to assess the soil erosion susceptibility of Suketi and its sub-catchments in lower Himachal Himalaya.
- to examine the spatial and temporal pattern of rainfall erosivity, density and seasonality in the catchment.

- to investigate the temporal variations in rainfall, stream flow and sediment fluxes (concentration, load, yield and denudation).
- to estimate the variations in quantity of nutrients (micro and macro) in stream water at the outlet of Suketi catchment.

Study Area

The Suketi catchment, located in lower Himachal Himalaya is primarily an agricultural catchment of about 422 km^2 and extends between latitudes 31º 27′ 08″and 31º 45′ 00″ north and longitudes 76º 48′ 20″ and 77º 03′ 09″ east. The catchment area falls entirely in the mountain zone which has a peculiar physiographic character, because it encompasses a central inter-montane valley and surrounding mountainous terrain. The major rock types in eastern sector of the catchment are composed of granite, gneisses, quartzites and phyllites, whereas the western part is occupied by sandstone, phyllite, schists, dolomites, limestones and quartzites. The alluvium in the form of unconsolidated sediments is restricted in central parts and comprises of boulders, cobbles, pebbles, gravels, sand, silt and clay. The climate of the catchment is sub-tropical highland type. The mean monthly temperature ranges from a minimum of 10.5ºC during January to the maximum of 27.5ºC during June. The average annual rainfall is about 1500 mm, highest being in the month of July and lowest in November.

Database and Methodology

The objectives of present study were accomplished by secondary sources of data which include (1) Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM), with 30 m spatial resolution to generate the topographical (slope) and hydrological parameters (drainage network), (2) Survey of India (SOI) topographical sheets no's. 53A/14, 53A/15, 53E/2 and 53E/3, (3) High resolution digital globe image data from Google Earth through the software Map Graber 1.0.7 on a resolution of 7 m, (4) National Bureau of Soil Survey and Land Use Planning (NBSSLUP) soil map on 1: 500000 scale, (5) Geological map of the catchment (modified after Srikantia and Bhargava, 1998), (6) Indian Remote Sensing (IRS) Resource Satellite-2, Linear Imaging Self Scanner (LISS III) data with 23.5 m spatial resolution acquired on October 10, 2014 for preparation of land use map, (7) India Meteorological Department (IMD) and Bhakra Beas Management Board (BBMB) rainfall data for the period 1971-2015 gauged at Mandi, Sundarnagar and Baggi stations and (8) BBMB monitored stream flow, suspended sediment concentration and nutrient out flow data for different periods. Additional information of the catchment was collected through field surveys, reports and research papers. Based on this data, soil erosion susceptibility, rainfall erosivity, density, seasonality and concentration, sediment fluxes and nutrient outflow for the Suketi catchment have been carried out. To demonstrate the spatial and temporal pattern of these parameters, various maps were prepared by applying geostatistical techniques. Apart from this, tabular, graphical, statistical and modeling approaches were followed for analysis.

Major Observations

Soil erosion susceptibility based on the combined effects of catchment characteristics (areal, linear, shape), geological stages and formations, slope, soil texture, rainfall distribution and land use types revealed that more than 90 per cent area of the catchment falls in moderate to high erosion and runoff susceptible zones, which are potential areas for preferential soil and water conservation works. These results of this study can be useful for different stakeholders such as farmers, water resource managers and policy makers for better management practices and decision making.

Annual rainfall erosivity in the catchment varied from 146.82 MJ mm ha^{-1} h^{-1} yr^{-1} in 1983 to 2007.76 MJ mm ha^{-1} h^{-1} yr^{-1} in 1992, with a mean value of 775.90 MJ mm ha^{-1} h^{-1} yr^{-1}. Similarly, the erosivity density ranged between 1.01 MJ ha^{-1} h^{-1} to 2.85 MJ ha^{-1} h^{-1} with an average value of 1.92 MJ ha^{-1} h^{-1}. Both rainfall erosivity and erosivity density exhibited a long-term decreasing trend over the entire study period. The decreasing trend in annual rainfall erosivity time series was found to be statistically significant ($p=0.05$), whereas it was found statistically non-significant in annual series of erosivity density. Both annual rainfall erosivity and erosivity density were found to be highest in northern parts, whereas the lowest are concentrated in central and south western parts of the catchment. A scatter plot of annual rainfall erosivity and erosivity density against rainfall showed a moderate linear relationship, thereby revealing that the role of climate change cannot be denied in aggravating the soil erosion in Suketi catchment in general and western Himalayan region catchments in particular. The highest values of both rainfall erosivity and erosivity density were observed in the month of July followed by August and June particularly in northern parts of the catchment. These results indicate that July month followed by August and June were the most susceptible months for soil erosion with lower reaches being the most vulnerable one. A noticeable seasonality was observed over the catchment because pattern of rainfall is largely unimodal.

The mean monthly suspended sediment concentrations for July, August and September were observed to be 3298.6, 3764.1 and 1912.4 mg/l, respectively with a mean daily value of 3003.4±2265.3 mg/l (CV= 75 per cent). Similar observations were recorded for suspended sediment load and about 50 per cent of the load was transported in the month of August. The catchment yielded 4413 t sediments km^{-2} yr^{-1}, which is higher than that of the mean annual erosion rates recorded in India. Various hysteretic loops obtained for the catchment revealed channel erosion and transfer of eroded, deposited and loose particles as the major source of sediments. The denudation rate for the catchment was found to be 1.67 mm yr^{-1} which again found to be among the highest erosion rates recorded in India. The average percentages of coarse, medium and fine size particles were found to the tune of 10.77, 18.84 and 70.38 per cent, respectively, suggesting towards low flow volumes which may not have enough energy to transport the coarse and medium size particles. The particle size distribution indicated that more than 75 per cent suspended sediment load in the catchment is principally composed of fine size particles. Higher percentage transfer of fine size particles from the catchment is attributed to various anthropogenic activities, such as crop canopy, tillage timing, mining, road construction, waterway condition, and reservoir operation (desilting) and maintenance activities.

Nutrient export from land to water is a major environmental problem, which has accelerated over the last 50 years as a result of landscape development for agricultural and urban pursuits. Year-wise mean seasonal concentrations of selected micro nutrients varied from 0.03 (2008) to 0.41 (2010) for zinc, 0.13 (2008) to 6.64 (2007) for iron and 0.02 (2008) to 1.30 (2006) mg/l for copper. Amongst the selected micro nutrients, iron had the maximum and zinc had the minimum amount of outflow from the catchment. The overall mean seasonal micro nutrient losses from the catchment were observed to the tune of 1.01 kg

ha^{-1} for zinc, 22.80 kg ha^{-1} for iron and 3.08 kg ha^{-1} for copper. Amongst the macro nutrients highest seasonal concentrations were observed for sulphate (11.81 mg/l) followed by phosphate (0.97 mg/l) and nitrate (0.40 mg/l). The maximum outflow of both micro and macro nutrients occur in the month of July in Suketi catchment duly substantiated by the hypothesis that higher the amount of discharge, greater will be the outflow of nutrients.

The total dissolved solids load in the catchment varied from 20.05×10^3 tonnes (2007) to 55.78×10^3 tonnes (2005) with a mean value of $33.39\times10^3\pm13.24$ tonnes. It showed a variability of about 40 per cent. The results of Pearson's coefficient correlation analysis indicate that nutrient outflow from the catchment is dependent on amount of the stream discharge as an increase in stream discharge leads to an increase in most nutrients outflow from the catchment. However, the degree of correlation between discharge and nutrient concentrations was, in general, low or non-significant in the catchment. This may be as a consequence of different hydrological processes operating and subsequently controlling each pollutant dynamic in the catchment.

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