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Soil Loss assessment of Lohawati River Basin, Central Himalaya

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Abstract

Estimation of soil loss helps to understand the erosion and sedimentation process existing in the area to assess the land degradation status. It is also a significant to suggest the conservation design and structures to go for the optimal land utilisation. The depleted forest cover, high slope and heavy rainfall accelerate soil erosion causing adverse impact on agriculture. Therefore, the present study comprises the soil loss estimation for a watershed (222.40 km^2) situated in the Central Himalaya. Study area lies between 29^{o}15’25’’ to 29^{o}26’00’’ North Latitude and 80^{o}01’55’’ to 80^{o}18’18’’ East Longitude. The height above Mean Sea Level of the study area is extending from 363 meters to 2209 meters. To carry out this work Revised Universal Soil Loss Equation (RUSLE) developed by the United States Department of Agriculture (USDA) as mentioned in Agricultural Handbook 537 is used. The total estimated soil loss is sliced into seven categories ranging from 0-10 to above 400 Tones ha^{-1} yr^{-1}. 41.22% area of the study is covered by below 10 Tones ha^{-1} yr^{-1} of soil loss. The category of 10 to 100 Tones ha^{-1} yr^{-1} includes 37.46% of the study area and remaining above 100 Tones ha^{-1} yr^{-1} includes 21.32% of the study area. Study shows the less rainfall, low slope length & steepness, sandy loam soil and good forest cover is responsible for lower amount of soil loss.

Keywords: Erosion, GIS, Remote sensing, RUSLE

Introduction

Soil, a natural resource, plays an important role to provide suitable human habitat for agriculture and forest. Soil formation is the product of many factors viz. parent material, relief, Organism, climate and time. According to Chorley (2019) Water detaches and transports hillside material through the effect of raindrop impact and flows over the surface and within the soil. Overland flow transports soil particles detached by rain splash and may erode distinct channels, some of which may become a permanent part of the drainage channel network, whereas others are obliterated between storms by mass-wasting processes. Lateral and vertical cutting by pre-existing streams may erode and steepen the lower parts of slope profile.

Toy and Renard (1998) pointed out that the sediment yield from the surface is the sum of the soil losses minus deposition in micro-topographic depressions, at the toe of the hillslope, along field boundaries, or in the terraces and channels sculpted into the hillslope, The entire Himalayan region is afflicted with a serious problem of soil loss (Jain et al., 2001; Rawat and Joshi, 2013). It has been reported that during the last 40 years 33% of the arable land of the world is lost by erosion and it continues to be lost at the rate of 10 million ha yr^{-1} (Gupta et al., 2010; Pimental et al., 1995; Rawat and Joshi, 2013).

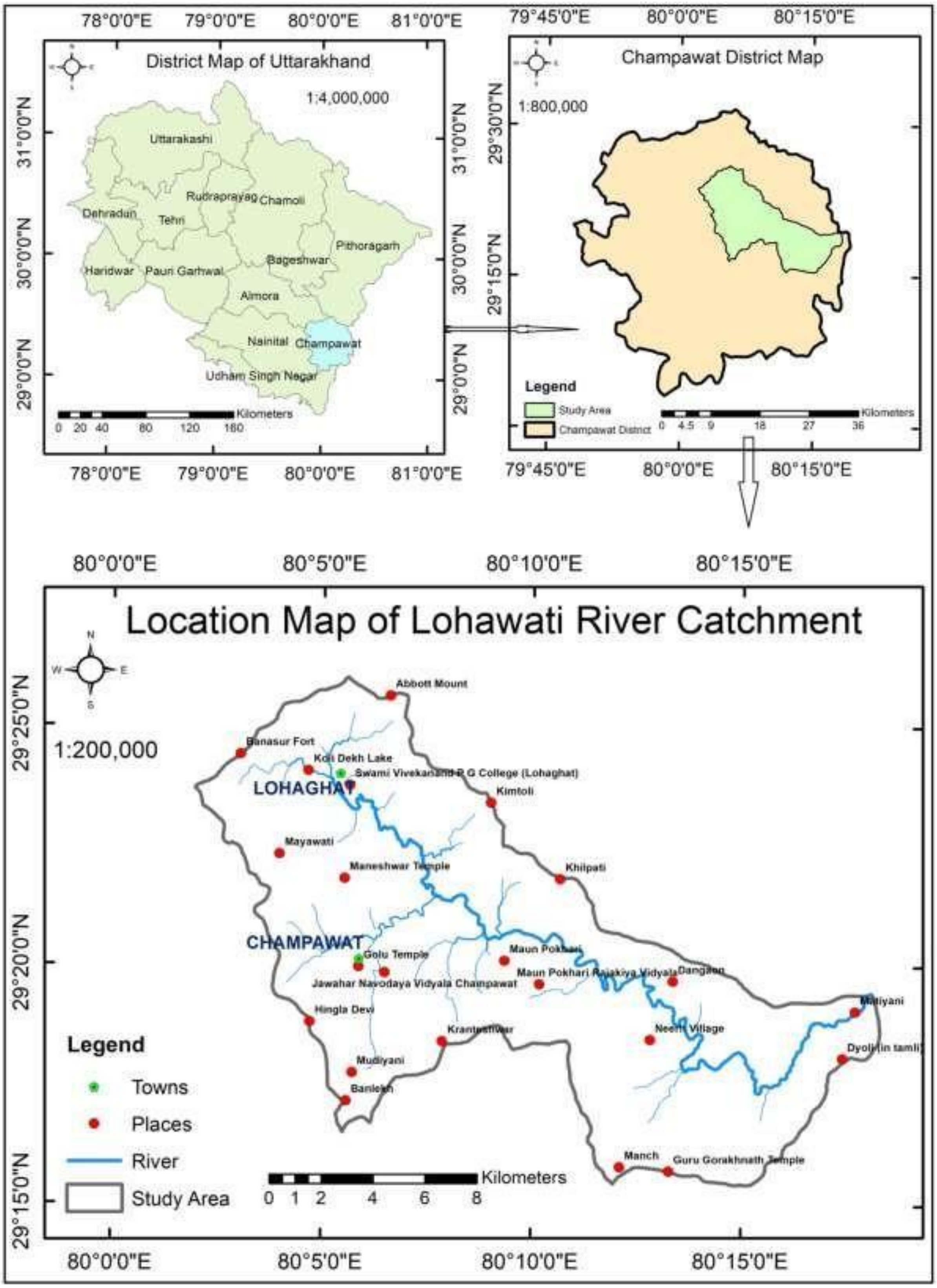
The soil loss model, namely the universal soil loss equation (USLE), was developed by W. H. Wischmeier and D. D. Smith in 1978. It is a widely used standard mathematical model to predict long-term average annual soil loss on arable land (Thakuriah, 2023). Revised Universal Soil Loss Equation (RUSLE) developed by the United States Department of Agriculture (USDA) as mentioned in Agricultural Handbook 537 is used. The RUSLE (Revised Universal Soil Loss Equation) is an updated version of the USLE (Universal Soil Loss Equation). The Revised Universal Soil Loss Equation (RUSLE) is an erosion model predicting longtime average annual soil loss resulting from raindrop splash and runoff from specific field slopes in specified cropping and management systems and rangeland (Renard et al., 1997). In my study area of Lohawati river catchment RUSLE (Revised Universal Soil Loss equation) is utilised to estimate the Potential soil loss.

Removal of the uppermost layer, productive surface soils, is the one of the problem to have an optimal land management in the Hilly regions. During the rainfall along the slope specially defrosted land is more vulnerable to soil loss. In the study area the practice of contour/ terraced agriculture up to some extent is able to control this problem.

In hilly terrain along the slope particularly in the deforested areas rainfall is responsible for the soil erosion and sedimentation. Soil erosion which is a complex dynamic process and leads detachment and transportation of soil from surface to subsurface and towards the lower reaches. The most dominant process involved in carrying the detached soil is the fluvial processes.

Study area

The study area lies in the Lesser Himalaya in Champawat district of Uttarakhand state. The area is situated in between 29°15’25’’ to 29°26’00’’ North latitude and 80°01’55’’ to 80°18’18’’ East longitude. The total study area is about 222.40 km^2. The altitude of area ranges from 363 meters to 2209 meters. The Lohawati is a tributary of Kali River. Kali River forms the boundary between India and Nepal (Fig. 1).



According to the Luirei Khayingshing et. Al. (2022) the geology of the study area is a part of the Crystalline zone of the Almora Group (Heim and Gansser, 1939; Valdiya, 1980), which is an overthrust succession of a variety of schists, micaceous quartzites and gneisses with concordantly emplaced plutonic bodies of granodiorites and granites (Agarwal, 1994; Agarwal et al., 2016; Joshi et al., 2017; Joshi et al., 2019; Kumar et al., 2020). Valdiya (1980) divided the Almora Group of rocks into three structural units: 1) the lower part is made up of garnetiferous mica-schists, micaceous quartzites and augen gneisses with felspathic schists; 2) batholithic and sill-like bodies of synkinematic granodiorite suite intruded by later lecucocratic granite and 3) the upper part consisting of schistose phyllite, carbonaceous or graphitic schists, alternating rhythmically with fine-grained micaceous, often garnetiferous metagreywackes. The second unit corresponds to the Champawat Granodiorite, which is a great batholithic body constituted predominantly of granodiorite that grades into tonalite and adamellite (Valdiya, 1962; 1980). The main body is massive non-foliated, coarse-grained equigranular to locally porphyritic in the central part and becoming progressively foliated or gneissose towards the margins. The Chamapawat Granodiorite is conspicuously rich in quartz and biotite and is intruded by younger granite.

The climate largely depends upon the altitude as altitude of Lohawati river catchment varies from 2209 meters to 363 meters. January is the coldest month with the mean maximum temperature of about 14°C and mean minimum temperature of about 3°C at Champawat town. At higher altitudes, temperatures may be lowered by 2 - 3°C. June is the warmest month with mean maximum temperature of about 27°C and mean minimum temperature of about 16°C at Champawat town. At higher altitudes temperatures may be lowered by about 2 to 3°C. With onset of the monsoon, day temperature falls slightly in July and is about 25°C till August. The temperatures fall rapidly after withdrawal of monsoon and weather becomes gradually cool and pleasant during post monsoon season. Both day and night temperatures rapidly fall till January when winter is fully established. The temperatures may be high by 6 - 8°C in low elevated areas with reference to Champawat town. (Climate of Uttarakhand, 2014). Based on IMD gridded data for 10 consecutive years from 2014 to 2023, the Rainfall varies from 1241 mm to 1417 mm in the Lohawati River Catchment.

Materials and Methods

The formula, known as revised universal soil loss equation which is applied in the work is as below:

A = RKLSCP

Where. "A" refers the estimate of average annual soil loss (t ha^{-1} yr^{-1}). "R" is the rainfall erosivity factor. "K" is the soil erodibility factor. "LS" is the topographic factor "C" is the cover and management factor. P is the support practice factor. The rainfall erosivity (R) factor is calculated using formula which is adapted by Arnoldus (1980) (Maurya and Tanwar, 2021)

Rainfall Erosivity Factor (R factor)

The rainfall erosivity (R) factor is calculated using formula which is adapted by Arnoldus (1980) (Maurya and Tanwar, 2021). The rainfall data is taken from online portal of IMD Pune in gridded format for four points which surrounds study area i.e. Point A (29.25°N, 80.25°E), Point B (29.25°N,80.00°E), Point C (29.50°N, 80.25°E), Point D (29.50°N,80.00°E). The rainfall data for 10 consecutive years from 2014 to 2023 is taken and then average monthly and yearly rainfall data is generated for all four points. The Rainfall Erosivity factor for these four points are calculated in Microsoft Excel and then by IDW interpolation method rainfall erosivity for whole study area is calculated.

Soil Erodibility Factor (K factor)

Soil erodibility refers the process of soil detachment by splash during rainfall or by surface flow or both (Renard et al.,1997). For the calculation of soil erodibility factor, an algebraic approximation of the nomograph given by Wischmeier and smith (1978) is used.

For calculating soil erodibility, a total of twenty-two soil samples are collected by making a pit of 30 centimeters depth, throughout the study area. The soil samples are analysed in Uttarakhand Tea Development Board Laboratory at Bhowali for organic matter, sand, silt, and clay percentage. The very fine sand content in percent is calculated using sieve method at the department of geography, D.S.B Campus, Nainital using Sieve of Mesh size 105 micron and 53 micron. Through IDW interpolation raster maps for very fine sand, Organic matter, sand, silt, and clay are generated. Then by combining the sand, silt and clay raster a separate raster for soil texture is generated in SAGA GIS.

Slope length and steepness factor or Topographic factor (LS factor)

Various approaches and algorithms for quantifying the LS factor have been developed. In this study Moore and Wilson (1992) (Zhang et al., 2013) and Badavath et al., 2024 are considered the calculated the Slope length and steepness factor.

Support Practice Factor or Conservation Practice Factor (P factor)

It refers to the effects of land conservation practices in minimizing the quantity and rate of rainfall - runoff induced soil erosion (Wischmeier and smith, 1978).

Conservation practice factor signifies the ratio of soil erosion from a land treated with a specific conservation measure to its equivalent soil loss from up and down slope tillage (Markose and jayappa, 2016). P value can be determined by the type of conservation measure implemented (Belayneh et al., 2019). In this study area terraced and contour agricultural is a common practice. The satellite data is utilized for the delineation of agricultural land. A DEM with spatial resolution of 10 meters is used to create slope in percent.

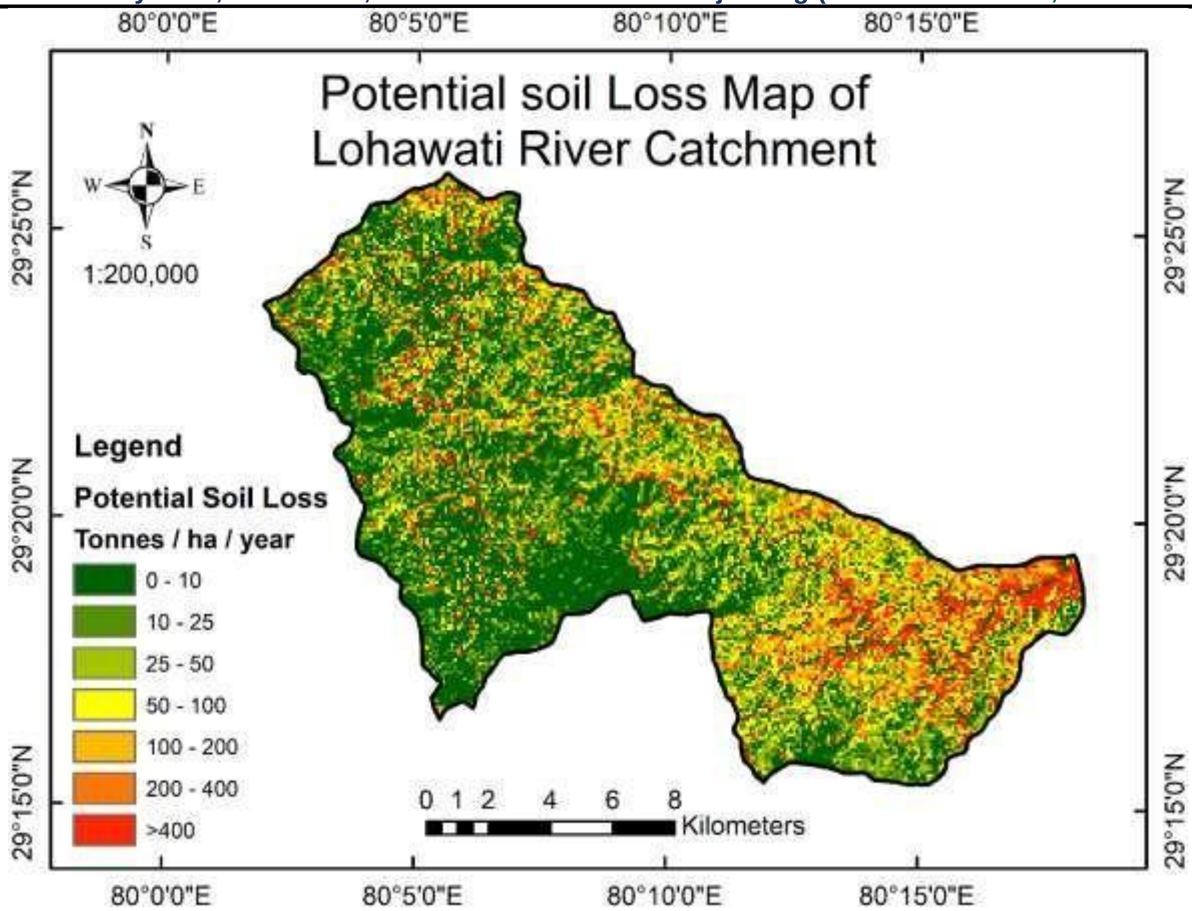


Figure 6.9: Final Soil Loss map of Lohawati River Catchment

Soil Loss from Lohawati River Catchment

After calculating all the factors for RUSLE soil loss equation, multiplication of all the layers is performed. The result we get was on a resolution of 10m × 10m, so we resample the data for 100m × 100m resolution i.e. for hectare. The resampled result is the result for soil loss. The soil loss is calculated in Tones per hectare per year (tones ha^{-1} yr^{-1}). The soil loss is divided into seven classes. Very low, low, moderately low, moderate, very high, and extremely high.

Potential Soil Loss (Tonnes ha^{-1} yr^{-1})	Area(km^2)	Area in %	Cumulative Area in %	Remark
0-10	91.67	41.22	41.22	Very Low
10-25	29.75	13.38	54.60	Low
25-50	29.14	13.10	67.70	Moderately Low
50-100	24.42	10.98	78.68	Moderate
100-200	19.51	8.77	87.45	High
200-400	10.84	4.87	92.32	Very High
>400	17.07	7.68	100	Extremely High

The total estimated soil loss is sliced into seven categories ranging from 0-10 to above 400 Tones ha^{-1} yr^{-1}. 41.22% area of the study is covered by below 10 Tones ha^{-1} yr^{-1} of soil loss. The category of 10 to 100 Tones ha^{-1} yr^{-1} includes 37.46% of the study area and remaining above 100 Tones ha^{-1} yr^{-1} includes 21.32% of the study area. Study shows the less rainfall, low slope length & steepness, sandy loam soil and good forest cover is responsible for lower amount of soil loss. Very steep slope is found responsible for the high amount of soil loss along the valley side slope.

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