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Soil Erosion Mapping of Khursi Micro-Watershed

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ABSTRACT

Land degradation in the form of soil erosion is a worldwide phenomenon leading to nutrient loss and is a major constraint to farming activities and sustainable agricultural development. In this study, Geographical Information System (GIS) has been integrated with universal soil loss equation (USLE) for the assessment of soil loss at micro-watershed level in the Nilser sub-catchment, Ningle catchment of Jhelum basin in J&K State. Topographically the area falls under steep slopes to moderately steep slopesand undulating terrain compromising 8% area under Agriculture land-1 (kharif crop) and 27% area under Agriculture land-2 (double crop). An area of 18% was noticed under orchards and 5% area under Agriculture plantation. Forest-evergreen-open and forest scrub was 30% and 1% respectively. 4%, 5% and 2% area was under settlement, wasteland with scrubs and wastelands without scrubs. The annual soil loss value was estimated from the USLE was represented pictorially using ARICGI-10.2 software.Thecontour map of the study area was digitized usingthe GIS system andtoposheet (1:50,000). The IRS-ID LISS III satellite imagery was classified and used for preparing the landuse/landcover which estimates cover management factor (C) and the landuse factor (P). The digital elevation model (DEM) was used to delineate catchment boundary and to calculate slope and LS factor. Soil erodibility (K) values were computed for all mapping units of the study area. The rainfall erosivity factor (R) was directly computed from rainfall intensities. Values of all the above mentioned USLE factors, with associated attributed data, were multiplied using Raster calculator of ARCGIS 10.2 software to obtain a composite map of factors RKLSCP and to produce a resultant layer of soil erosion rate under different erosion classesin t ha^{-1}yr^{-1}. The study demonstrated that USLE model with GIS serves robust and vital tool in identifying spatial distribution of soil erosion risk area in the micro-watershed for soil conservation planning.

Key words: *GIS, USLE, DEM, Soil loss, Watershed*

INTRODUCTION

Soil erosion, and its associated impacts, is one of the most important global environmental problems by which productive surface soils are detached, transported and accumulated in a distant place resulting in exposure of subsurface soil and sedimentation of runoff in water reservoirs.

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As per the Ministry of Agriculture, Govt. of India report (1985), about 113.3 Mha land is subjected to water erosion. The entire Himalayan region is afflicted with a serious problem of soil erosion an drivers, flowing through this region, transport a heavy load of sediment. The Himalayan and Tibetan regions cover about 5% of the Earth's land surface, but supply about 25% of the dissolved load to the world oceans[5]. Soil erosion has long been a serious problem in Kashmir valley especially in highlands like other Himalayan regions. The high degree of potential erosivityin Kashmir valley has led to the net nutrient depletion and severe soil health loss. Universal Soil Loss Equation (USLE) is the most popular empirically based model used globally for erosion prediction and control[2,8]. The equation is one of the best-known and most comprehensive models in terms of data, for predicting soil erosion. Several studies were made to evaluate various factors in USLE for agriculture lands. Rainfall characteristics, soil properties and ground surface conditions are represented by empirical constants in these methods. Joshi *et al.*[3] analyzed the effect of different land use practices on soil characteristics and the effect of major land use practices on erosion losses. Sharma *et al*.[6] studied rainfall-runoff-soil relationships under different landuses in midhill region of Himachal Pradesh. Dijk*et al.*[1] reviewed the relationship between rainfall intensity versus drop size distribution or kinetic energy and its variation in time and space. Sharma and Sharma[7] reported that the information obtained through remote sensing and GIS technique helps in better understanding of geographical location, distribution of quality land in watershed's and prioritization of critical areas for soil and water conservation treatments. A few studies have been carried out using Geographical Information System (GIS) integrated with universal soil loss equation (USLE) for the assessment of potential soil loss in different cell size[2,9,10]. Therefore, an attempt was made to map the soil erosion at micro-watershed level in the Nilser sub-catchment, Ningle catchment of Jhelum basin in J&K State using GIS technique. The GIS technique was also utilized for the determination of physical parameters of 29 grid locations related to soil erosion. Surface erosion was then computed within individual cells using the USLE.

MATERIALS AND METHODS

Universal Soil Loss Equation (USLE)

A= R*K*LS*C*P

Where, A is the Computed annual soil loss rate (tons ha^{-1} $year^{-1}$), R is the Rainfall erosivity factor, K is the soil erodibility factor, LS= Slope length and Slope gradient (topographic) factor, C is the Cover types factor and P is the Land management and conservation practice factors. The USLE developed by Wischmeier and Smith[8] is an erosion model for prediction of long-term average annual soil loss from specified area in specified cover and management conditions. The equation predicts losses from sheet and rill erosion only. It computes soil loss for a site in tons per hectare per year (t $ha^{-1}yr^{-1}$). The information of 29 grid locations in the study area were collected from the soil resource data of the state for computation of K, LS, C and P factors. Value of R factor were calculated for each grid point form the rainfall erosivity map of the study area generated by GIS technique from annual and seasonal rainfall data. The latitude, longitude and annual soil loss values for all grid points were marked on the map of study area and soil erosion map was generated using GIS (ARC INFO Ver. 10.2) technique. Annual soil loss was divided into seven erosion classes on the basis of range agreed upon at the national level to keep uniformity in the interpretation of data and, thus, final soil erosion map was generated and area under each class was determined. ERDAS IMAGINE was mainly used for image processing purpose.

Study Area

The selected Nallah Khurshi micro-watershed belongs to Wagoora Block of Baramulla district and has an area of3179.00 ha (Fig-1). The micro-watershed is located between 34^{o}9'4.9"N and 34^{o}14'3.9"N latitude and

74°22'27.1"E and 74°27'31.6"E longitude. The average elevation of micro-watershed is 1700 m above mean sea level (MSL). The micro-watershed is situated in North-Southern aspect of the Himalayan range. The configuration confirms in general to uniform steep slopes. The steepness of slope ceases towards the lower reaches. Scattered vegetation constitutes of natural local grasses and naturally grown hedges/shrubs with predominance of *Cynodon dactylon*, *Dactylis glomerata*, *Trifolium pretense*. The commonly observed tree species in the study area are Accacia species, willow (*Salix alba*), popular (*Populus alba*), kiker *(Rubinia pseudo-acacia*), chinar (*Plantanus orientalis*) walnut, plum, pear, apricot, mulberries. These tree species, observed throughout the micro-watershed, are mostly scattered in the cultivated landscape. There are about 34 ha of community land grazing and pasture lands scattered in all villages of study area. Due to open grazing practices in the selected villages, land remains poorly grassed. The precipitation results in the loss of top soil due to erosion and generally these lands are deteriorated and degraded. Being predominantly rainfed, maize and wheat (fodder) are cultivated in the major area of arable lands of the study area. Few parts of micro-watershed are covered by apple orchards (mostly newly established). Cultivation of maize, M.P Cherry grass etc. in orchards is the common practice in the area. Other horticultural crops Pear, Apricot, Plum are also grown. The soil gets saturated even during low intensity rains and water moves through fissures rapidly.

Generation of Thematic layers

The contour map of the study area was digitized using the GIS system and survey of India topo-sheet at a scale of 1:50,000. The Aster digital elevation model (DEM) was used to delineate catchment boundary and to calculate slope and LS factor (Fig2A).The LS factor is the product of slope length and slope steepness factor. Contour lines of 20 m interval from SOI top sheets were digitized and interpolated to generate digital elevation model (DEM) of micro-watershed with grid cell size of 30 m in ARCGIS-10.2. Land cover map was generated using IRS ID LISS III data of path /Row 99/65 and 100/66 for the year 2012. Nine land cover categories, namely Agriculture land-1 (*kharif* crop), Agriculture land-2 (double crop), agriculture plantation, forest-evergreen-open, forest scrub, orchards, settlement, wasteland with scrubs and wastelands without scrubs were derived using supervised classification scheme and are shown in fig 2B. The soil erodibility factor (Fig 2C) was calculated using field and laboratory estimated data of texture, organic matter content, structure and permeability of surface soil samples following monographs given by Wishmeier and Smith (1978). The soils in the micro-watershed were characterized and soil erodibility of surface soils (Fig. 2C) were computed for each mapping units based on salient characteristics. Soil map units were grouped into five major physiographic soil unitsand erodibility factor of these five physiographic units ranged from 0.30-0.35, 0.35-0.40, 0.40-0.45, 0.45-0.50 and 0.50-0.60.

RESULT AND DISCUSSION

USLE parameters were derived using field and laboratory estimated data and integrated in GIS environment to compute average soil loss and to find soil erosion risk area in the micro-watershed. To predict average annual soil loss caused by sheet and rill erosion from the study, the parameters used in the USLE equation depends on soil characteristics, topography and landuse of the area. Based on this analysis the values of annual soil loss in the state have been categorized into six different erosion risk classes (Table 1). Spatial distribution of soil loss in the study area into different erosion classes is generated using GIS techniques in the form of soil erosion map (Fig. 2D). The area calculated from the map under different erosion classes is given in Table 1.About 86.9% (2762.18 ha) of TGA of micro-watershed produces annual soil <5 t ha^{-1} yr^{-1}. Slight erosion (5-10 t ha^{-1} yr^{-1}) occurs in 300.99 ha, constituting 9.47% area of micro-watershed. Moderate erosion (10-15 t ha^{-1} yr^{-1})

is experienced in 2.39% area. About 1.24% TGA of micro-watershed is suffering from severe form of erosion (>15 t ha^{-1} yr^{-1}). Annual soil loss is 15-20, 20-40, > 40 t ha^{-1} yr^{-1} occurs in 0.60, 0.48 and 0.16% of TGA of the micro-watershed, respectively. As shown in fig 2Dand table 1 these areas are scattered in patches in almost all the upper and middle zones. Katiawalay, Larey, Masjid Angan and Vulraman villages have small areas under moderately high and high erosion classes. Very high erosion is also experienced in the entire upper zone. The generated spatial representation of the soil loss map is very much useful for further analysis. From the thematic map, it was found that topographic and the vegetation cover factors are the most important factors affecting soil loss in mountainous watershed. Open forests having very poor vegetation cover increases surface runoff in micro-watershed and were predicted to have higher soil erosion rate than land with scrub and without scrub (fallow land). This could be risk erosion areas in the micro-watershed were found to be associated with moderate steep to steep sloping areas having scrub and open forest cover. This area has to be given special priority for the implementation of erosion control measures. Higher and moderately soil erosion rate areas are dispersed throughout the micro-watershed and are attributed to higher topographic and soil erodibility factors. Based on the results of the study, the agronomical measures including contouring, strip cropping, agro-forestry and tillage practices are recommended to control soil erosion in the areas subjected to very low to moderate erosion. Fencing of pastures should be done in order to avoid overgrazing. This would make grazing lands more productive by their judicious utilization through proper management. Engineering measures like terracing and bunding are suggested to be practiced in high and very high soil erosion risk areas of micro-watershed particularly in the upper zone.

Table 1: Soil loss assessment

Erosion risk classes	t ha-1 yr-1	Area (ha)	% of TGA
Very low	0-5	2762.2	86.9
Low	5-10	300.9	9.5
Moderate	10-15	75.9	2.4
Moderately high	15-20	19.0	0.6
High	20-40	15.2	0.5
Very high	>40	5.1	0.2

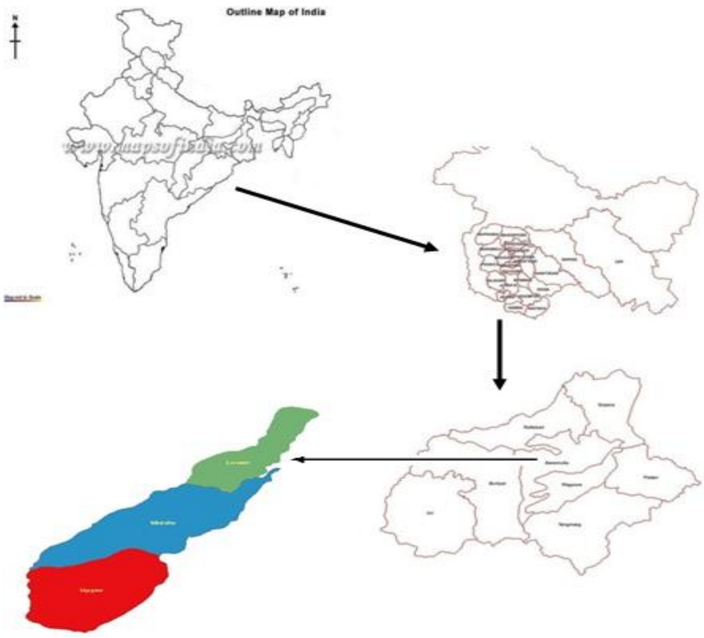

Fig. 1: Location map of Khursi micro-watershed, district Baramulla, J& K

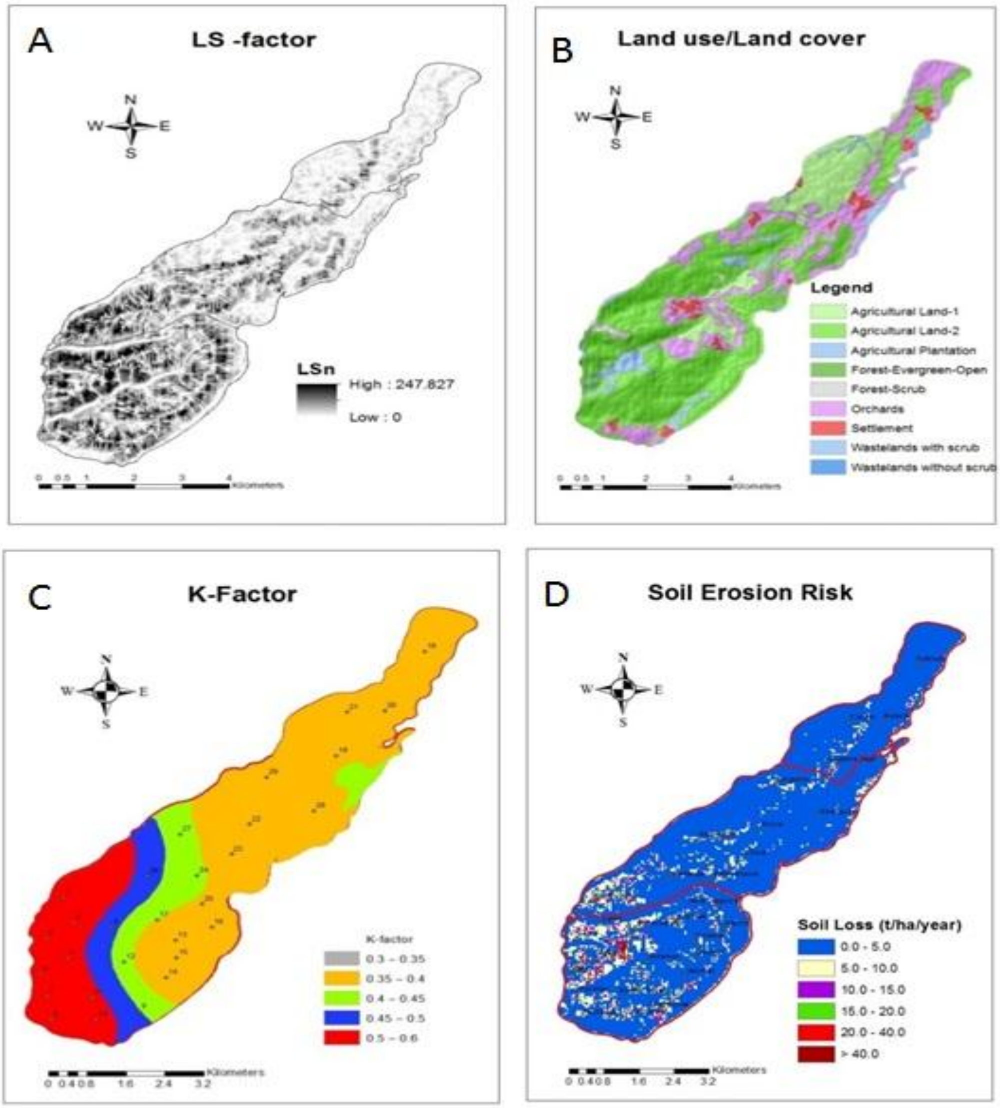

Fig. 2: GIS maps showing A) DEM of study area, B) landuse of study area C) soil erodibility factor and D) Soil erosion risk map of Khursi micro-watershed, district Baramulla, J&K

CONCLUSIONS

This paper is aimed at assessing the soil erosion hazard area in the micro-watershed using USLE and GIS technique. A grid approach has been used along with GIS for the determination of the soil loss from the micro-watershed. The estimated soil loss values are presented pictorially using Arc View 10.2 version of GIS software. The remote sensing data and GIS can be used to generate the input grids. GIS platform provides faster and better method for spatial modeling and gives output maps that can be understood better. Surface erosion in the individual cell was determined using the USLE model, which is cost and time effective. Information about soil erosion risk classes helps to adopt suitable conservation measures for protecting soil from further erosion.

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