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SOIL EROSSION ASSESSMENT IN NEYYAR WILDLIFE SANCTUARY USING GEOINFORMATICS

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ABSTRACT

Soil erosion is the process of detachment, transportation and deposition of soil particles from land surface. Agencies or the energy sources involved in the process of soil erosion are mainly water, wind, sea waves, human beings and animals. Soil erosion is a growing problem in Western Ghats of Kerala and particularly in the Neyyar wild life sanctuary in southern western Ghats, with rich biodiversity. Soil erosion not only decreases biodiversity of the area, but also reduces the water availability. In the current study, an effort to predict potential annual soil loss has been conducted. For the prediction, the Revised Universal Soil Loss Equation (RUSLE) has been adopted with Geographical Information System framework. The RUSLE factors were calculated for the entire sanctuary. The R-factor was calculated from monthly and annual precipitation data. The K-factor was estimated using Soil survey of India data. The LS-factor was calculated from a 20-m digital elevation model. The C-factor was calculated using Remote Sensing techniques. The P-factor was assigned based on field observations and forest management strategies. Soil erosion is one of the most widespread forms of land degradation resulting from such changes in land use. The soil erosion process affects 11.4% of the national territory and has significant consequences for the forest ecosystem. The present paper assess quantitatively the soil erosion potential of Neyyar wildlife sanctuary using geo informatics.

INTRODUCTION

Soil erosion is a wide spread problem in both developing and developed countries. The problem has far reaching economic, political, social and environmental implication due to both on site and off site damages (Thampapillai and Anderson, 1994; Grepperud, 1995; Pandey *et al*., 2007). In an overview of global erosion and sedimentation, Pimental *et al.,* (1995) stated that more than 50% of the world's forestland and about 80% of agricultural land suffer from significant erosion. In India, about 53% of the total land area is prone to erosion and has been estimated that in India about 5,334 metric tons of soil is being detached annually due to various reasons (Narayana and Babu, 1983). Unprecedented increases in soil loss and its economic and environmental impacts have made erosion one of the most serious global problems of the day (Bewket and Teferi, 2009; Wang *et al.*, 2009; Zhang *et al*., 2009).

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The present study uses the RUSLE (Revised Universal Soil Loss Equation), a predictive empirical model, to predict annual soil loss in the high land of Western Ghats. The dominant model applied worldwide to soil loss prediction is USLE/RUSLE. Wischmeier and Smith (1965, 1978) by collecting soil erosion data of 8,000 communities of 36 regions in 21 states in USA, analyzed and assessed various dominating factors of soil erosion, and introduced the universal soil loss equation (USLE) to assess soil erosion by water. Basically, USLE predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system, and management practices (soil erosion factors). By including additional data and incorporating recent research results, the USLE methodology is improved and a revised version of this model (RUSLE) further enhanced its capability to predict water erosion by integrating new information made available through research of the past 40 years (Renard *et al*., 1997; Yoder and Lown, 1995).

The factors that influence the rate of soil erosion include rainfall, runoff, slope, land cover and the presence or absence of conservation strategies. (Solanki and Singh, 1996). Climatic characteristics of the region such as having a long dry period followed by heavy erosive rainfall along with prolonged human intervention have made the region very susceptible to soil erosion (Kouli *et al*., 2009). Soil erosion is influenced by the spatial heterogeneity in topography, vegetation, soil properties and land use, among other factors (Le Rouxa *et al*., 2007; Jain and Das, 2010). The factors, which influence the rate of soil erosion, are rainfall, runoff, soil properties, slope, biological factors and the presence or absence of conservation measures (Morgan, 1998).

The present study envisages the application of USLE method along with remote sensing and GIS techniques in the assessment and quantification of the soil loss in the Neyyar wildlife sanctuary. The present study reveals that Universal Soil Loss Equation along with Geographic Information System and remote sensing is very powerful for quantifying the soil erosion and it is useful for prepare sustainable soil erosion management strategies.

MATERIALS AND METHODS

The study area extends over 100 sq. km with an elevation between 100-1785 above from MSL and is a part of Agasthyamala biosphere reserve. The area lies between latitudes 8° 54' 8''– 8 ° 57' 8'' N and longitudes 77° 3' 20" – 77 ° 6' 03" E. The forest acts as predominant land use in the study area.

The equation has a general format with the product of five factors (Eq.1):

$$A = R \times K \times LS \times C \times P \quad (1)$$

where A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t $h^{-1}y^{-1}$); R is the rainfall-runoff erosivity factor [MJ mm/(ha h $year^{-1}$)]; K is the soil erodibility factor [t ha h/(ha MJ mm)]; L is the slope length factor; S is the slope steepness factor; C is the cover and management factor (In this study, using IRS-1D LISS III data were used to identify the present land use status of the Shendurney wild life sanctuary); and P is the conservation support-practices factor. The LS, C, and P values are dimensionless. The following sections describe the computation of the R-, K- and LS-factors from precipitation data, soil survey data and digital elevation model (DEM), respectively.

Within the RUSLE rainfall erosivity factor K is estimated using the EI30 measurement (Renard et al., 1997). Since rainfall intensity of the study area could not be estimated in the absence of a recording type rain gauge, monthly values were used in annual R factor calculations using the following relationship proposed by Wischmeier and Smith (1978) and modified by Arnoldus (1980) (Eq.2).

$$R = \sum_{i=1}^{12} 1.735 \text{ X } 10^{\left(1.5\, log_{10}\left(\frac{Pi2}{P}\right) - 0.08188\right)} \quad (2)$$

where R is the rainfall erosivity factor (MJ mm ha^{-1} h^{-1} $year^{-1}$), *P*i is the monthly rainfall (mm), and *P* is the annual rainfall (mm).

The K factor map was prepared from the soil texture map collected from the National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Govt. of India. Soils in the study area were grouped into three major textural classes and the corresponding K values were identified from the table proposed by Stone and Hilborn (2000). Since the least resistant particles are silts and fine sands soils with high silt content are highly erodible. The estimated K values for the textural groups vary from 0.13 (loam); 0.2 (gravelly loam); and 0.3 (clay) respectively.

The combined LS factor was computed for the watershed by means of ArcInfo ArcGIS Spatial analyst extension using the Digital Elevation Model off the study area following the equation (Eq.3), proposed by Moore and Burch (1986).

$$LS = (\text{Flow accumulation X Cell size}/ 22{:}13)^{0.4} \text{ X } (\text{sin slope}/ 0.0896)^{1.3} \quad (3)$$

Where flow accumulation denotes the accumulated upslope contributing area for a given cell, LS = combined slope length and slope steepness factor, cell size = size of grid cell (for this study 20 m) and sin slope = slope degree value in sin. Due to the spatial and temporal variations in land use/ land cover pattern, satellite remote sensing data sets were used for the assessment of C factor (Karydas *et al*., 2008). The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigour and health along with vegetation data, is used along with the following formula (Eq.4) to generate the C factor value image for the study area (Zhou et al., 2008). (Eq.4)

$$C = \exp\left[-\alpha \cdot \frac{NDVI}{(\beta - NDVI)}\right] \quad (4)$$

where α and β are unit less parameters that determine the shape of the curve relating to NDVI and the C factor. Van der Knijff et al., (2000) found that this scaling approach gave better results than assuming a linear relationship and the values of 2 and 1 were selected for the parameters α and β respectively. The values of C factor can vary from 0 for very well protected soils to 1.5 for finely tilled, ridged surfaces that produce much runoff, leaving it susceptible to rill erosion.

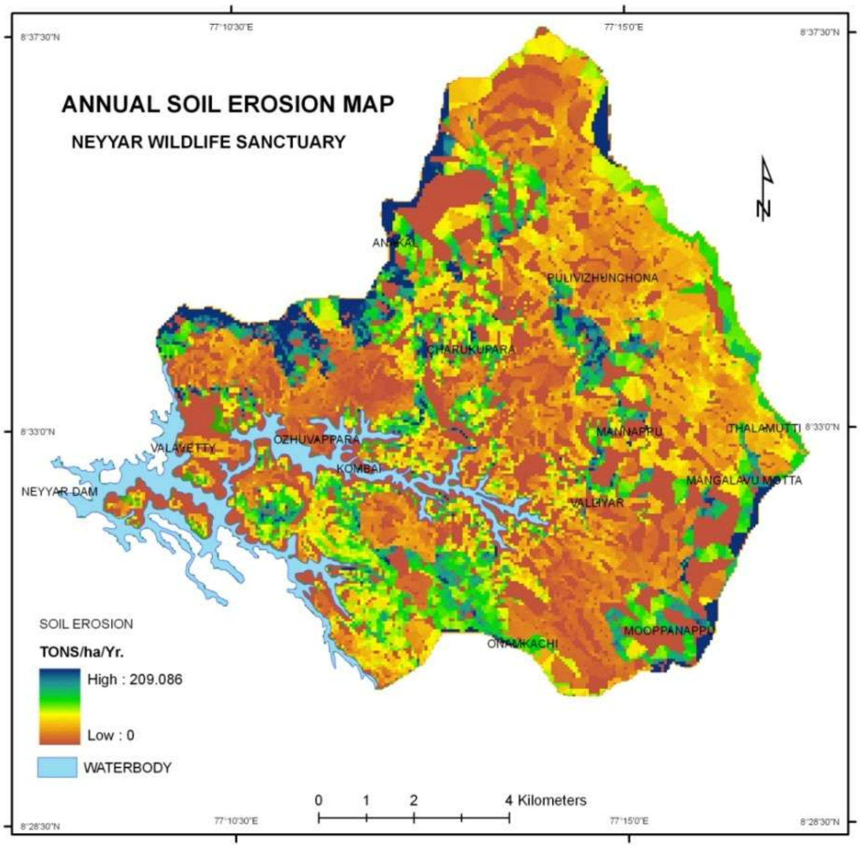
The P factor is strictly a soil management factor and is closely related to the forest cover and slope factor. The values are assigned based on field observations and data generated from the Satellite images. In the present study, RUSLE model is implemented to calculate the spatial soil erosion pattern in the area using ArcInfo GIS and ERDAS Imagine 9.3. Derivation of the factors that required to run the RUSLE model requires more caution in computation and the recent advancements in the field of GIS and remote sensing technology have enabled more accurate estimation of some of the RUSLE prediction factors like LS, C and P. In the present analysis, SOI toposheets, IRS-P6 LISS-III image, monthly rainfall, field level data and soil texture data were used to generate the parameters that are needed for running the RUSLE model.

With the aid of Spatial analyst extension in Arc GIS 9.3, each thematic layer for the RUSLE model was overlaid on the respective map layers. The output map showed the distribution of soil erosion for the entire sanctuary.

RESULTS AND DISCUSSION

The soil erosion map resulting from the spatial overlay of USLE factors in the Neyyar Wildlife Sanctuary is shown in the Figure. Table presents corresponding quantitative soil loss, in addition to the spatial information. Result of this study gives an erosion range of 0- 209.08 in Neyyar wildlife sanctuary. We mainly found inclinations of 10 to 30° to be affected by gullies, rills and mass movements.

a lowered groundwater table leads to increased groundwater velocity and, therefore, it eats away and erodes the soil cover (Li and Wang ,1990) The recurrence of wildfires causes physical changes in soils which enhance their susceptibility to erosion (Batjes, 2008).The occurrence of forest fire will increase the soil erosion proness. There is also ample evidence for higher soil erosion at several sites during the periods of highest human populations and intensive land uses (Beach *et al*., 2002) Amounts of sandy, highly water repellent material eroded from hillslopes have remained high under particularly high rainfall intensities, that means high intensity rainfall accelerate the soil erosion of an area (Shakesby *et al*., 2002). The major forest disturbance in an area accelerate the rate of soil erosion in an area (De-Bano *et al*., 2005).



Quantitative soil loss Neyyar wildlife sanctuary			
Erosion class	Rate of soil erosion(tons/ha/Yrs	Area (km^2)	Percentage
Low	0 - 10	63.5	49.60 %
Moderate	10 - 30	34.1	26.64%
High	30 - 60	17.7	13.82%
Severe	60 – 209.086	12.7	9.94%

Morgan (1994) also described that areas with lower inclination are less affected by gully erosion and mass movement. Areas with inclinations of more than 30° are less affected in the study area due to the fact that these sites still are covered with forest vegetation. Soil erosion decreases with increasing vegetation cover (Wischmeier and Smith, 1978; Morgan, 1994). Deforestation in this area brought about changes in the water balance and consequently a lowering of the water table.

Fuchs (2007) proved that there is a significant correlation between sedimentation rates and settlement history, and that soil erosion was triggered by human activity and then amplified by enhanced precipitation. In general, preventing erosion is more effective than controlling it. Also, the potential for increasing erosion rates by land-management activities is greater than that for reducing erosion by using erosion-control techniques.

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