SOIL LOSS USING USLE MODEL: A CASE STUDY OF KOTAGIRI TALUK, NILGIRIS DISTRICT.

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Abstract
The study was in order to assess soil erosion at watershed scale Universal Soil Loss Equation (USLE) erosion model has been used for the study in Kotagiri Region, Nilgiris district. Erosion calculation requires huge amount of information and data, usually coming from different sources and available in different formats and scales. Therefore GIS technique has been used, which helped considerably in organizing the spatial data representing the effects of each factor affecting soil erosion. The factors that most influence soil erosion are linked to topography, vegetation type, soil properties and land use/cover. Average annual soil losses were calculated by multiplying five factors. A set of factors as identified in the USLE were studied and reviewed. These include rainfall erosivity factor (R-factor), soil erodibility factor (K-factor), slope and slope length factor (LS-factor), and vegetative cover factor (C-factor) and conservation practice factor (P-factor). Each factor which consists of a set of logically related geographic features and attributes is used as data input for analysis. The factor layers were collected from existing information and extracted from Landsat imagery.

Keywords: USLE model, Nilgiris, Watershed and Topography.

INTRODUCTION
Soil erosion by water is one of the most important land degradation problems and a critical environmental hazard of modern times in erosion region. Accelerated erosion due to human-induced environmental alterations at a global scale is causing extravagant increase of geomorphic process activity and sediment fluxes in many parts of the world. The Revised Universal Soil Loss Equation (USLE) is a set of mathematical equations that estimate average annual soil loss resulting from inter rill and rill erosion. Strength of USLE is that it was developed by a group of nationally recognized scientists and soil conservationists who had considerable experience with erosion processes. USLE retains the structure of its predecessor, the Universal Soil Loss Equation (USLE).

- Soil erosion is linked to topography, vegetation type, soil properties and land use/cover.
- Each factor which consists of a set of logically related geographic features and attributes is used as data input for analysis
- The revised universal soil loss equation (USLE) is a set of mathematical equations this estimates average annual soil loss resulting from interrill and rill erosion. (Sujata Biswas 2012)
- Strength of USLE is that it is developed by a group of nationally recognized scientists and soil conservation who have considerable experience with erosion process USLE retains the strength of its predecessor the universal soil loss equation (USLE) (Jha Raghunath 2002)

Objectives
- To delineate and assess the erosion areas using USLE model
- To categorize the erosion class in different land use types
- To analyze the annual rainfall for the study area

Dataset
- Landsat ETM+, Geo Eye Imagery
- Elevation data SRTM
- Rainfall Data

Software
- Arc GIS
- ERDAS IMAGINE

STUDY AREA
Kotagiri is a Taluk in the Nilgiris District in the Indian state of Tamil Nadu. Kotagiri is situated at an elevation of around 1793m above sea level and is one of the three popular hill stations located in the Nilgiris. This picturesque hill station is bounded by verdant green tea estates and offers a number of trekking options.

This old hill station has been developed around innumerable knolls and valleys. The Dodabetta Range is 22 km away. Catherine Falls, Elk Falls and Rangaswami Pillar are the major attractions near Kotagiri and you can trek to these places. Kodanad View Point offers a spectacular view of the gentle sloping hills and blue hills. There is another jungle trekking trail that leads you to a small stream of water.
The three popular trekking trails are Kotagiri - Kodanad; Kotagiri - St. Catherine Falls and Kotagiri - Longwood Shola. The Kotagiri - Kodanad trail leads you through splendid views of lush-green tea estates and the magnificent Moyar River. One has to cross through meadows to reach Kodanad.

Location of Study Area

**RESEARCH METHODOLOGY**

Administrative Map has been completed. Annual Rainfall (R factor) has been calculated using ERDAS IMAGINE to find the vegetation cover (C factor) and land use map. Soil K factor is calculated based on the vegetation cover type and band soil index texture. Slope length, slope steepness is calculated from DEM model using SRTM Data. Support practice factor indicates the rate of soil loss according to the various cultivated land (P-factor).

**ANALYSIS AND INTERPRETATION**

**Soil Erosion Model**

The USLE was developed to estimate long-term average annual soil erosion and originally applied for plane area at plot scale. Studies in mountainous areas at the watershed level have been also conducted, and the sound results verified its capability of modeling the complex landscapes (Jha Raghunath 2002)

It is expressed as follows

\[ A = R \times K \times L \times S \times C \times P \]

\*where A is annual soil erosion (t/ha/a); R is the rainfall erosivity factor (MJ·mm/ha/h); K is the soil erodibility factor (t·h/MJ/mm); L is the slope length factor; S is the slope steepness factor; C is the crop and management factor; and P is the conservation supporting practices factor.

**Rainfall Erosivity Factor**

R is the long term annual average of the product of event rainfall kinetic energy and the maximum rainfall intensity in 30 minutes in mm per hour (Jha Raghunath 2002, Sujata Biswas 2012)

The rainfall distribution is not homogeneous all over the study area, for this reason an interpolation of annual precipitation data was applied to have a more representative rainfall distribution. Once the interpolation is performed a map representing annual rainfall in the region is obtained. This map was the input source for the R factor calculation using the Morgan (1994).

\[ R = 0.276 + P \times I_{30} \]

\* P = Mean annual rainfall in mm.
\* I_{30} is the 30 min average rainfall

Average rainfall data for kotagiri 1996-2011

**Kotagiri Rainfall Data in Average**

Rainfall Erosivity Factor
Soil erodibility factor (K)

K is the soil Erodability index referred as mean annual soil loss per unit of R for a standard condition of bare soil. Soil Erodability is related to the integrated effect of rainfall, runoff, and infiltration. From different available literature the following K value for was established.

Soil erodibility (K) represents the susceptibility of soil or surface material to erosion, transportability of the sediment, and the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. The standard condition is the unit plot, 72.6ft long with a 9 percent gradient, maintained in continuous fallow, tilled up and down the hillslope. K values reflect the rate of soil loss per rainfall-runoff erosivity (R) index. Soil erodibility factors (K) are best obtained from direct measurements on natural runoff plots. Rainfall simulation studies are less accurate, and predictive relationships are the least accurate (Hellden 1987). Therefore, considerable attention has been paid to estimating soil erodibility from soil attributes such as particle size distribution, organic matter content and density of eroded soil (Sujata biswas et al., 1971). Soil classification of the study area is divided into 7 types of soil with varying soil characteristics. In this study, Soil erodibility (K) of the study area can be defined using the relationship between soil texture class and organic matter content proposed by Morgan et al. (1988). The organic matter content is assumed to be 0.5% because there is no organic matter content survey data in the study area. Table 1 presents the soil erodibility factor (K) based on the soil texture class by Morgan. (1988).

Table 4.3 soil erodability

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Clayey</th>
<th>Clayey Skeletal</th>
<th>Coarse Loamy</th>
<th>Fine</th>
<th>Fine Loamy</th>
<th>Loamy</th>
<th>Loamy Skeletal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Erodibility</td>
<td>0.02</td>
<td>0.4</td>
<td>0.4</td>
<td>0.13</td>
<td>0.13</td>
<td>0.24</td>
<td>0.24</td>
</tr>
</tbody>
</table>

### Slope Length And Steepness (LS) Factor

Slope length factor (L) and slope degree (S) factors are typically combined together and defined as the topographic factor which is a function of both the slope and length of the land. The longer the slope length the greater the amount of cumulative runoff. Also the steeper the slope of the land the higher the velocities of the runoff which contribute to erosion. The soil erosion weightages for Slope factor (LS) were derived from the algorithm used by the Hellden (1987) as shown below. Based on the algorithm, the derived factor weightages were assigned to the corresponding slope length and steepness, the raster GIS database was generated.

\[
LS = \sqrt{L/22 (0.065 + 0.045S + 0.0065 S^2)}
\]

*Where*

\[L = \text{Slope Length}\]
S = Slope Steepness in percentage
The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978)

\[ LS = \left( \frac{X}{22.1} \right)m \ (0.065 + 0.045 \ S + 0.0065 \ S^2) \]

- Where \( X \) = slope length (m) and \( S \) = slope gradient (%)
- The values of \( X \) and \( S \) were derived from DEM. To calculate the \( X \) value, Flow Accumulation was derived from the DEM after conducting FILL and Flow Direction.

\[ X = (\text{Flow accumulation} \times \text{Cell value}) \]

By substituting \( X \) value, LS equation will be:

\[ LS = \left( \text{Flow accumulation} \times \text{Cell value} /22.1 \right)m \ (0.065 + 0.045 \ s + 0.0065 \ s^2) \]

The topographic (LS) factor grid for USLE was created according to the USLE model since the equations used in the calculation of the USLE’s, LS factor, takes rill erosion into account. The topographic factor consists of two sub-factors: a slope gradient factor and a slope length factor; both of which are determined from the Digital Elevation Model (DEM). According to the SEAGIS User Guide two methods exist for deriving the slope length factor from the DEM. It can be either calculated as the horizontal length of each cell or it can be measured from each high point in eight flow directions. The boundaries of slopes are determined according to a user specified cut-off value. The cut off value in this study was specified at 75% to give an accurate representation of the possible deposition occurring after initial downslope erosion in the watershed. The input requirement for the creation of the topographic grid is a filled DEM. Filling a DEM can be described as identifying any sinks or cells that have a lower elevation value than the surrounding cells and giving them a higher elevation value (Jennings, 2001). When the sinks are filled the area is given an average value, which is calculated using the value of the neighboring cells (Morgan, R.P.C. 1980). Using the equations shown below, the slope gradient and slope length factors were calculated from the DEM and combined to result in the topographical factor grid.

\[ LS = \sqrt{L/22} \ (0.065 + 0.045S + 0.0065 \ S^2) \]

Where

\[ L = \text{Slope Length} \]
\[ S = \text{Slope Steepness in percentage} \]

<table>
<thead>
<tr>
<th>Slope</th>
<th>0-1%</th>
<th>1-3%</th>
<th>15-30%</th>
<th>3-5%</th>
<th>30-60%</th>
<th>5-8%</th>
<th>8-15%</th>
<th>&gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weightage (Morgan R.P.C. 1980)</td>
<td>1</td>
<td>3</td>
<td>30</td>
<td>5</td>
<td>45</td>
<td>8</td>
<td>15</td>
<td>60</td>
</tr>
</tbody>
</table>

**Slope Length And Steepness (LS) Factor**

**Flow Chart Of LS Factor**

**COVER MANAGEMENT C – FACTOR**

The vegetation cover has a big impact in the erosion. The land cover intercepts the rainfall, increase the infiltration and reduce the rainfall energy. The land cover is the parameter more influenced by the hand man impact increase the erosion. The crop management factor was calculated mainly from literature review, since there was not local data available regarding this factor. C factor ranges from 1 to approximately 0, where higher values indicate no cover effect and soil loss comparable to that from a tilled bare fallow, while lower C means a very strong cover effect resulting in no erosion. The vegetation cover has a big impact in the erosion. The land cover intercepts the rainfall, increase the infiltration and reduce the rainfall energy. The land cover is the parameter more influenced by the hand man and your impact increase the erosion. The C factor depends of the land cover and a Landsat ETM, Sept 2008 with resolution 30 m was used in C factor calculation. The image was processed with a no supervised classification to prepare the land
Use/cover map of the study area. In this study, best results were obtained from K means classifier with 16 iterations.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Agriculture</th>
<th>Barren Rocky/Stony Waste</th>
<th>Canal</th>
<th>Crop Land in Forest</th>
<th>Dense/Closed</th>
<th>Floodplain</th>
<th>Industrial</th>
<th>Land with scrub</th>
<th>Open Deciduous (Moist/Dry)</th>
<th>Plantations</th>
<th>Rabi(Crop Land)</th>
<th>Residential</th>
<th>River</th>
<th>Scrub Forest</th>
<th>Tanks</th>
<th>Villages (Urban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value (morgan 1994)</td>
<td>0.2</td>
<td>1</td>
<td>0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>0.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Land use analysis C factor

**COVERAGE MANAGEMENT FACTOR (C-FACTOR)**

Support practice factor indicates the rate of soil loss according to the various cultivated lands on the earth. There are contour, cropping and terrace as its methods and it is important factor that can control the erosion. Table 2 shows the value of support practice factor according to the cultivating methods and slope (Morgan, R.P.C., 1980). P values range from 0 to 1, whereby the value 0 represents a very good manmade erosion resistance facility and the value 1 no manmade resistance erosion facility. In the study area there were some agricultural support practices, such as contour farmland and terraced farmland. However, most of the farmlands in the study area were small and consisted of self-managed lands. Since the spatial resolution of the Cartosat-1 imagery was 2.5 m, it was possible to distinguish the separate practices in the watershed from the available data. The distribution of the land use types is presented namely Barren Rocky/Stony Waste, Canal, Crop Land in Forest, Dense/Closed, Forest Plantations, Industrial Land with scrub, Open Deciduous (Moist/Dry), Plantations, Rabi(Crop land), Residential, River, Scrub Forest, Tanks, Villages (Rural)

Land use/land cover analysis

Land use/land cover classification of the Landsat imagery dated Sep 2008 data was done by Supervised classification by ERDAS IMAGINE Software. The land use/land cover map was classified in sixteen classes including Barren Rocky/Stony Waste, Canal, Crop Land in Forest, Dense/Closed, Forest Plantations, Industrial Land with scrub, Open Deciduous (Moist/Dry), Plantations, Rabi(Crop land), Residential, River, Scrub Forest, Tanks, Villages (Rural)

<table>
<thead>
<tr>
<th>Name</th>
<th>Agriculture</th>
<th>Barren Rocky/Stony Waste</th>
<th>Canal</th>
<th>Crop Land in Forest</th>
<th>Dense/Closed</th>
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<th>Land with scrub</th>
<th>Open Deciduous (Moist/Dry)</th>
<th>Plantations</th>
<th>Rabi(Crop land)</th>
<th>Residential</th>
<th>River</th>
<th>Scrub Forest</th>
<th>Tanks</th>
<th>Villages (Urban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Factor</td>
<td>0.8</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.003</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Open Deciduous (Moist/Dry)</th>
<th>Plantations</th>
<th>Rabi(Crop land)</th>
<th>Residential</th>
<th>River</th>
<th>Scrub Forest</th>
<th>Tanks</th>
<th>Villages (Urban)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Factor</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
<td>0.003</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Land use/land cover P-factor
Determination of soil erosion potential and verification using the location of landuse

The factors needed in the USLE model are obtained as follows: the factor R is extracted from the iso-erodent map, LS is derived from the DEM, K is derived from the soil database and C and P are derived from the land use database. The factors were converted to a grid for calculation of the soil erosion potential. In the study area, the total number of cells in the Raster, with point spacing was overlain with each geographic feature for the study area. The soil erosion potential was determined by multiplying the respective USLE factors interactively in Arc/Info GRID.

, resulting in the erosion hazard map and its distribution percentage shown in and For verification of the soil erosion map, was compared to the actual location of landuse .The landuse locations were overlain with the soil erosion map and the comparison is shown in . the percentage of land use was classified into the percentage of soil loss values. The illustrates how well the soil erosion map performs with respect to the landuse locations. The verification result shows satisfactory agreement between the erosion map and the existing landuse data.
Soil Erosion Risk

FINDINGS, SUGGESTION AND CONCLUSION

This research demonstrates the integration of USLE with GIS to model the potential for soil erosion. Moreover, the GIS and mathematical application and verification USLE equation for soil erosion using the location of land use are presented. An approach was applied that enabled the collection of representative data quickly and simply USLE can be applied to determine soil loss quantitatively and to predict the erosion hazard over a large area.

Soil erosion risk calculation

This table shows that the average potential erosion in the agriculture area and forest plantation are cone under the low and moderate erosion classes. Statistically it was evaluated from the overlay analysis was obtained the first erosion risk was in the scrub land 23.258sq km. and 2nd class of the erosion risk in the agriculture and crop land. Comparing with the overall area the agriculture area was moderately involved the erosion process.

References

1) Ashaq Hussein et al., (Recent Research in Science and Technology 2011,) integration of GIS and universal soil loss equation (USLE) for soil loss estimation in a Himalayan watershed, Research in Science and Technology 2011,3(3):51-57