Assessment of Soil Erosion Susceptibility in Kothagiri Taluk Using Revised Universal Soil Loss Equation (RUSLE) and Geo-Spatial Technology

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Abstract- Soil erosion is a serious environmental problem in Kothagiri Taluk. Many studies have been carried out to map shifting cultivation and areas susceptible to soil erosion. Mostly, estimated soil loss is taken as the basis to classify the level of soil loss susceptibility of area. The Revised Universal Soil Loss Equation (RUSLE) function is a commonly used erosion model for this purpose in Kothagiri Taluk. This research integrates the RUSLE within a Geographic Information System (GIS) environment to investigate the spatial distribution of annual soil loss potential in the Kothagiri Taluk. Both magnitude and spatial distribution of potential soil erosion in the catchment is determined GIS data layers including, rainfall erosivity (R), soil erodability (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors were computed to determine their effects on average annual soil loss. The rainfall erosive factor was developed from local annual precipitation data using a modified Fournier index: The topographic factor was developed from a Digital Elevation Model (DEM); the K factor was determined from a combination of the soil map and the geological map; and the land cover factor was generated from IRS LISS III images. The resultant map of annual soil erosion shows a maximum soil loss of 27.11 t h-1 y-1 with a close relation to built-up land areas, crop land and forest plantation on the steep side-slopes (with high LS). The derived soil susceptibility map from RUSLE model is classified into five categories ranging from very low to very high risk (< 3 to > 20 t h-1 y-1) depending on the calculated soil erosion amount. The soil erosion in each cell was calculated using the revised universal soil loss equation (RUSLE) by carefully determining its various parameters and classifying the study area into different levels of soil erosion severity. The high soil erosion probability zone was observed in areas with high terrain alteration, high relief and slopes with the intensity and duration of heavy precipitation during the monsoons. The soil erosion susceptibility map is linked to elevation and slope maps to identify the area for conservation practice in order to reduce the soil loss.

Index Terms- Soil erosion; RUSLE; GIS; Kothagiri, Western Ghats, Nilgiris

I. INTRODUCTION

Soil erosion susceptibility mapping is one of most important requirement for its planning management and conservation. Soil loss processes are site specific and differ in kind, intensity and aerial coverage of the affected area. Soil degradation and erosion are insidious processes, not readily apparent to farmers until the effects are severe and irreversible (Cleaver and Schrieber 1995) and a threat to long term soil productivity (Narain 2008; Bhattacharyya et al. 2007). Erosion and degradation not only decrease land productivity, but can also result in major downstream or off-site damage than on-site damage. Deforestation, wastelands and indiscriminate usage of cultivable lands have collectively induced soil erosion resulted in ecological imbalances. Soil erosion, generally associated with agricultural practices in tropical and semi-arid countries, leads to decline in soil fertility, brings on a series of negative impacts of environmental problems, and has become a threat to sustainable agricultural production and water quality in the Taluk. It has been estimated that in India about 5334 m-tonnes of soil are being removed annually due to various reasons (Narayan and Babu, 1983; Pandey et al. 2007).

Thus, soil erosion is one of the most critical environmental hazards of modern times. Vast areas of land now being cultivated may be rendered economically unproductive if the erosion of soil continues unabated. Information on the factors leading to soil erosion can be used as a perspective for the development of appropriate land use plan. Simple methods such as the universal soil loss equation (USLE) (Wischmeier and Smith 1978), the modified universal soil loss equation (MUSLE) **(**Williams 1975**),** or the revised universal soil loss equation (RUSLE) (Renard et al. 1997) are frequently used for the estimation of soil erosion from watershed areas. The use of GIS methodology is well suited for the quantification of heterogeneity in the topographic and drainage features of a watershed. The objectives of this research were to map erosion prone areas in the Kothagiri Taluk by using RUSLE and GIS techniques for the discretization of the Taluk into small grid cells and for the computation of physical characteristics of these cells such as slope, land use and soil type, all of which affect the processes of soil erosion in the different subareas of Kothagiri taluk. Further GIS methods are also used to estimate the soil erosion in individual grid cells. The area selected for the present study includes the most popular tourist centre in Tamil Nadu. The gathering of very large crowd over a short period of time in an ecologically sensitive area has resulted in various environmental problems. Though most of the study area is covered with forest, the area has under gone changes in the forest/land use and causes environmental degradation. Since majority of tourist prefers the traditional forest route, lower order forests face degradation and destruction. Hence, the present study was carried out with an objective to assess the annual soil erosion rate and develop a soil erosion susceptibility map for Kothagiri Taluk using RUSLE and GIS techniques, which in turn can be used as a scalable model.

II. STUDY AREA

Kothagiri Taluk is located in Nilgiri district, which is a mountainous terrain in the North West part of the Tamil Nadu. The area has a mountainous character. The Taluk is highly undulating and exhibits the typical highland topography of Western Ghats, with a mean elevation of 1326 m above msl and a general northeast terrain slope. The topographical elevation values vary between 431m to 2629m. The study area covers 425.49 kms and lies between latitudes 11° 10' 00"N to 11° 42' 00" N and longitudes 76° 14' 00" E to 76° 02' 00" E (Figure. 1) and located at 70 km Northwest of Coimbatore city in Tamil Nadu. The study area receives rainfall both in southwest and northeast monsoons. The study area receives an annual average rainfall of 3046 mm and exhibits a wet climatic condition with a mean minimum and maximum temperature of 20.5° C and 30.7° C, respectively. The climate of the Kothagiri area is temperate and salubrious throughout the year. The pronounced wet seasons are during the north-east monsoon in October and November. The northeast monsoon is moderate, contributing nearly 40 percent of rainfall. Geologically, the area falls in the Precambrian terrain and charnockite and gneiss are the major rock types with lateritic over burden. Geomorphologically, the Taluk is characterised by steep structural hills, denudational hills, narrow gorges, intermontane valleys and precipitous escarpments with thick vegetation. The soil texture is gravelly clay followed by gravelly clay loam, which is well drained with very low permeability. The drainage pattern of the area is dendritic types are found in the study area.

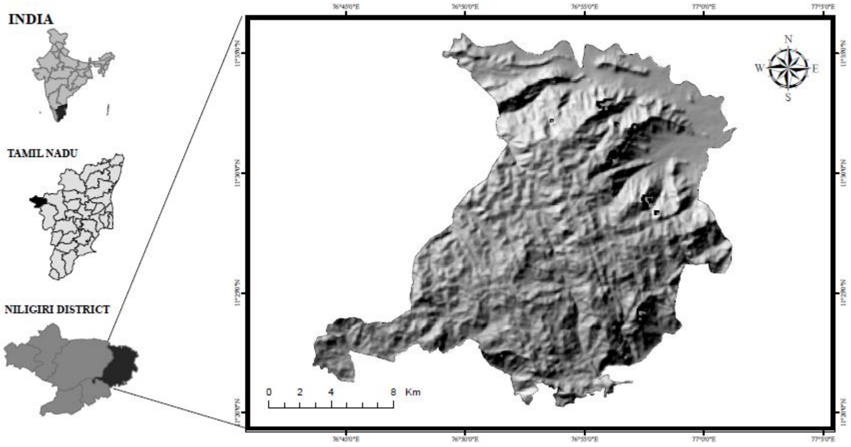

Figure 1: Study area location map

III. METHODOLOGY

The emergence of soil erosion models has enabled the study of soil erosion, especially for conservation purposes, in effective and acceptable level of accuracy. To estimate soil erosion and to develop optimal soil erosion management plans, many erosion models, such as Universal Soil Loss Equation/Revised Universal Soil Loss Equation (USLE/RUSLE), Water Erosion Prediction Project (WEPP), Soil Erosion Model for Mediterranean Regions (SEMMED), Areal Non-point Source Watershed Environment Response Simulation (ANSWERS), Limburg Soil Erosion Model (LISEM), European Soil Erosion Model (EUROSEM), Soil and Water Assessment Tool (SWAT), Simulator for Water Resources in Rural Basins (SWRRB), Agricultural Non-point Source pollution model (AGNPS), etc. were used in regional scale assessment. Each model has its own characteristics and application scopes (Boggs et al., 2001; Lu et al., 2004; Dabral et al., 2008). The dominant model applied worldwide to soil loss prediction is RUSLE, developed by Wischmeier & Smith (1978) because of its convenience in application and compatibility with GIS. The base map was prepared using Survey of India (SOI) toposheets on 1:50 000 scale. Remotely sensed data pertaining to IRS-P6, LISS-III digital data have been used for the study. Soil map of the study area was taken from District Soil Division, Coonour. Daily rainfall data for the year 2013 is collected from Metrological department Chennai. The toposheets covering the study area were scanned in TIFF format and imported in the ArcGIS 9.2 software where geo-referencing was done. The geo-referenced image of toposheets was used as background image for all on screen digitizing. The taluk boundary has been delineated by the District map. Scanned soil map was digitized based on grouping of soil properties. The contour map was prepared of digitized contour lines at 20m interval and combined with a rasterized spot height map for generating a Digital Elevation Model (DEM) and classified it. The RUSLE has been widely used for both agricultural and forest watersheds to predict the average annual soil loss by introducing improved means of computing the soil erosion factors (Wischmeier and Smith, 1978; Renard et al., 1997). The methodology used in the present work was the implementation of RUSLE equation in a raster GIS environment for the calculation of specific factors and annual soil loss of the area under investigation.

The climatic and terrain factors which are used in the equation were derived from rainfall data collected from Indian Meteorological Department (IMD) Chennai, satellite image, soil texture map of soil survey organization, Tamil Nadu and Survey of India (SOI) toposheets. IRS-P6 LISS-III digital data of the year 2012 with resolution of 23.5 m was used for assessment of vegetation parameters in the area. SOI toposheets were used to create the digital database for the boundary, drainage network and contour map (20 m intervals) of the study area.. The cell size of all the data generated was kept in to 20 m x 20 m, in order to make uniform spatial analysis environment in the GIS. This equation 1 is a function of five input factors in raster data format: rainfall erosivity; soil erodability; slope length and steepness; cover management; and support practice. These factors vary over space and time and depend on other input variables. Therefore, soil erosion within each pixel was estimated with the RUSLE. The entire analytical methodology follows the steps shown in Fig. 2. First, grid cell of rainfall, soil units, combined slope length and steepness and land use and practice management were prepared. Computed values for R, K, LS and CP were encoded into the respective units of the respective coverage.

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V. THE RUSLE MODEL

To one side from rainfall and runoff, the rate of soil erosion from an area is also strongly dependent on its soil, vegetation and topographic characteristics. In real situations, these characteristics are found to vary greatly within the various subareas of a Taluk. Therefore needs to be discretized into smaller homogeneous units before making computations for soil loss. A grid-based discretization is found to be the most reasonable procedure in both process based models as well as in other simple models (Beven 1996; Kothyari and Jain 1997). For this study, a grid-based discretization procedure was adopted. The 25 m grid size was adopted for discretization because it should be small enough so that a grid cell encompasses a homogeneous area. The dominant model applied worldwide to soil loss prediction is RUSLE, because of its convenience in application and compatibility with GIS (Millward and Mersey. 1999; Jain et al. 2001; Lu et al. 2004; Jasrotia and Singh, 2006; Dabral et al. 2008; Kouli et al. 2009; Pandey et al. 2009; Bonilla et al. 2010). Although it is an empirical model, it not only predicts erosion rates of ungauged areas using knowledge of the local characteristics and local hydroclimatic conditions, but also presents the spatial heterogeneity of soil erosion that is too feasible with reasonable costs and better accuracy in larger areas (Angima et al. 2003).Soil loss was computed based on RUSLE in GIS environment using ERDAS IMAGINE and ARCGIS Packages. The entire analytical methodology follows the steps shown in Figure. 2. First, grid cell of rainfall, soil units, combined slope length and steepness and land use and practice management were prepared. Computed values for R, K, LS, C and P were encoded into the respective units of the respective coverage. This coverage was overlaid and soil loss rate was calculated as per RUSLE equation (Eq (1)). These were further grouped into five major groups to show the erosion severity in relation to the spatial distribution and their aerial extent. RUSLE (Revised Universal Soil Loss Equation), was developed by Renard et al. (1997); it keeps the USLE form, being improved the methods for calculating the terms of the mathematical equation. The RUSLE has been widely used for both agricultural and forest mountains to predict the average annual soil loss by introducing improved means of computing the soil erosion factors (Wischmeier and Smith. 1978; Renard et al. 1997). This equation is a function of five input factors in raster data format: rainfall erosivity; soil erodability; slope length and steepness; cover management; and support practice. These factors vary over space and time and depend on other input variables. Therefore, soil erosion within each pixel was estimated with the RUSLE. The RUSLE method is expressed as:

$$E = R.\ K\ .LS\ .C.\ P \qquad (1)$$

where E is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t ha-11 y-1); R is the rainfall-runoff erosivity factor (mm ha-11 h-11 y-1); K is the soil erodability factor (t ha h ha-1 mm-1); LS is the slope length and steepness factor (dimensionless); C is the cover management factor (dimensionless, ranging between 0 and 1); and P is the erosion control (conservation support) practices factor (dimensionless, ranging between 0 and 1).

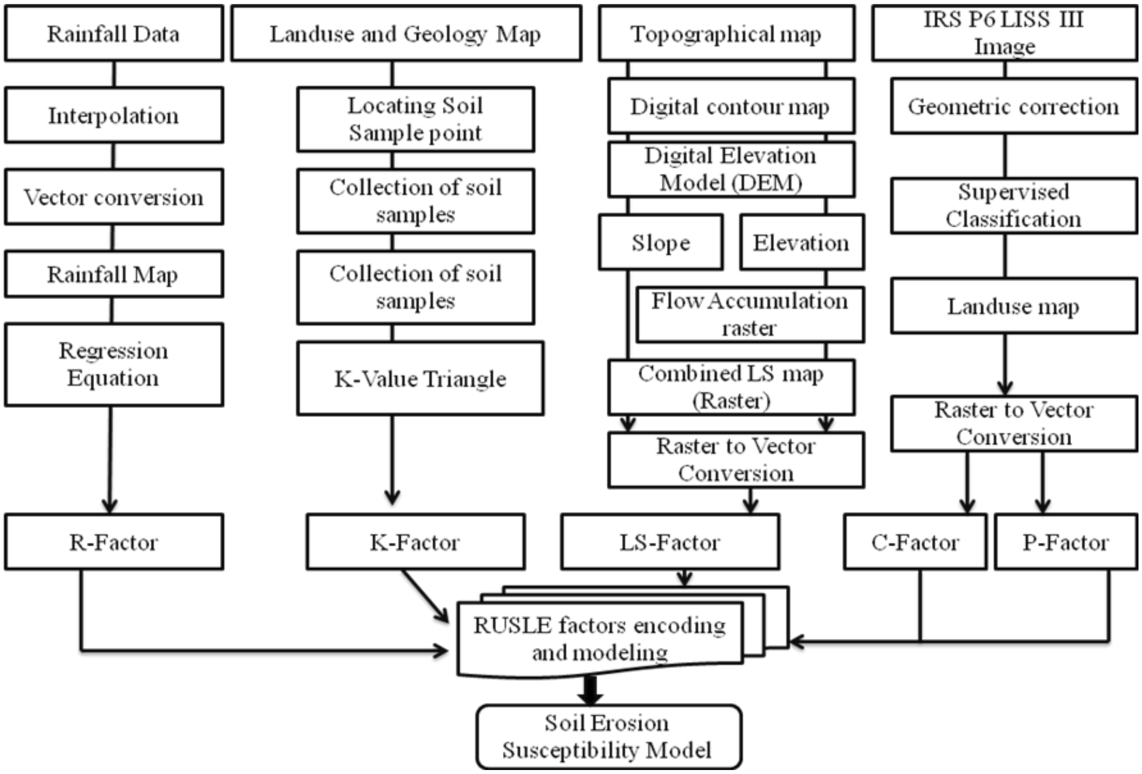

Figure. 2 Flowchart of the study for estimating soil erosion susceptibility map using the RUSLE-GIS mode

A.Rainfall Erosivity Factor (R)

Rainfall is a driver of soil erosion processes and its effect is accounted for by the rainfall-runoff erosivity factor (R) in the RUSLE equation. The R-factor accounts for the effect of raindrop impact and also shows the amount and rate of runoff associated with precipitation events. The R factor is computed as total storm energy (E) time the maximum 30-min intensity (I 30), or EI, and is expressed as the rainfall erosion index (Renard et al. 1997). Rainfall data for the Kothagiri Taluk were obtained from the Meteorological Department Chennai. Rainfall related data for the catchment spanned a period of 10 years. Rainfall data were imported into ArcGIS since all the weather stations had geographical co-ordinates. Annual and monthly rainfall data for the Kothagiri obtained over 12 years were used to calculate the R-factor in this study. The equation below developed by Wischmeier and Smith (1978) was used in the computation

$$R = \sum_{i=1}^{12} 1.735\ X\ 10^{\left(1.5 \log \frac{Pi^2}{P} - 0.8188\right)} \qquad (2)$$

Where Pi is the monthly amounts of precipitation and p is annual precipitation. The annual summation of Pi2/p is called the Fournier equation. In recent years, a number of interpolation methods have been developed in GIS that are suitable to model rainfall erosivity. Interpolation methods available in most GIS software include the inverse distance weighting (IDW), Kriging, Spline polynomial trend, and natural neighbour methods. In this study, the rainfall erosivity values for the different stations were used to interpolate a rainfall erosivity surface using the IDW technique available in ArcGIS 9.2. The IDW interpolation method was selected because rainfall erosivity sample points are weighted during interpolation such that the influence of rainfall erosivity is most significant at the measured point and decreases as distance increases away from the point. The IDW interpolation method is based on the assumption that the estimated value of a point is influenced more by nearby known points than those farther away (Weber and Englund 1992, 1994). In other words, the assigned weight is a function of inverse distance as represented in the following formula (Lam 1983).

$$f(x,y) = \frac{\left\lfloor \sum_{i=1}^{12} w\,(di) Zi \right\rfloor}{\sum_{i=1}^{N} w\,(di)} \qquad (3)$$

Where f (x,y) is the interpolated value at point (x,y); w(di) is the weighting function; Zi is the data value at point I; and di is the distance from point (x,y). The interpolated values of any point within the data set are bounded by min (zi) < f(x,y) < max(Zi) as long as w(di) > 0. The IDW interpolation method has been widely used on many types of data because of its simplicity in principle, speed in calculation, easiness in programming, and credibility in interpolating surfaces (Lam 1983)

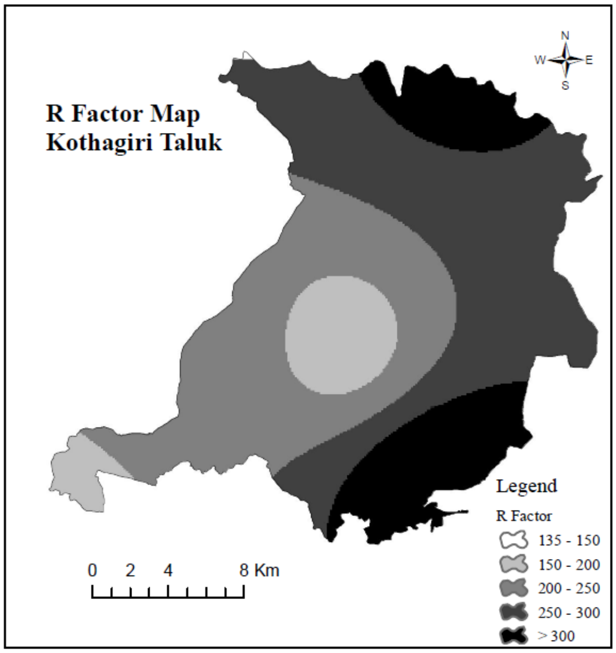

Figure 3: Rainfall-runoff erosivity factor (R)

Figure 3 shows the R factor map of the Kothagiri. The average annual R factor ranged from 150 mm ha-1 h-1 year-1 to 450 mm ha-1 h-1 year-1. The R values for the Kothagiri, Ooty and Mettupalayam ranged from 52 to 316, 30 to 280, and 30 to 550 mm ha-1 h-1 year-1, respectively. There was more rainfall erosivity in the south and south east than in the southwest because rainfall erosivity is closely related to precipitation, which increases from south to north in the Taluk (Figure. 3).

B. Soil Erodibility Factor (K)

Soil erodibility factor (K) in the RUSLE equation is an empirical measure which expresses the inherent susceptibility of a soil to water erosion as determined by intrinsic soil properties. The K factor is rated on a scale from 0 to 1, with 0 indicating soils with the least susceptibility to erosion and whilst 1 indicates soils which are highly susceptible to soil erosion by water. The factor is defined as the rate of soil loss per rainfall erosion index unit as measured on a standard plot. A digital soil classification coverage captured from a soil map by the District geotechnical division was supplied by the National Bureau of Soil Science (NBSS), Nagpur for integration into the RUSLE computation. Soil forms present in the area include the loam, clay, clay loam and sandy loam. Small amounts of stable and well structured soils derived from dolerite are also found in the upper part of the Taluk. The topsoil is highly vulnerable to erosion due to the dispersive character of the soils inherited from the underlying geology and is further exacerbated by the removal of vegetation. The loam and sandy loam soil forms of the lithic soil group and clay loam and clay soils of the oxidic soil group are, however, the most widespread soil types and were used to obtain a general characterization of the soil erodibilities in this study. These soils are predominately sandy loams and sandy clay loams. Fieldwork was conducted to collect soil samples to determine the particle size distribution where the loam, clay, clay loam and sandy loam soils are the dominant soil types. A total of 15 random samples were collected for each area with the dominant soil type; a soil map was used to determine the spatial distribution of the soil forms in the field. The co-ordinates for the soil sampling locations were collected using a Global Position System (GPS). Soil erodibility was calculated using Eq. 4 developed by Wischmeier and Smith (1978). The equation effectively describes soil erodibility as a function of the complex interaction between sand, silt, and clay fractions in the soil and other factors such as organic matter, soil structure and profile permeability class. In general, soils become less erodible with decrease in silt content, regardless of corresponding increases in the sand or clay fraction (Wischmeier and Smith 1978).

$$K= [(2.1 \text{ x } 10-4(12 - OM)\ M1.14 + 3.25\ (S-2) + 2.5\ (P-3))/7.59 \text{ x } 100] \qquad (4)$$

Where K = soil erodibility factor (ton h MJ-1 mm-1), OM is soil organic matter content, M is product of the primary particle size fractions, M = (%silt + %very fine sand) x (100 - %clay), S is soil structure code, P is permeability class. The average soil erodibility for each soil type was computed and added to the soil classification shape file database in ArcGIS 9.2 software. The shape file was subsequently converted to a 20 m grid of soil erodibility. Areas dominated by loam, clay, clay loam and sandy loam forms were assigned a K value of 0.202, 0.232, 0.256 and 0.311, respectively. Different soil types are naturally resistant and susceptible to more erosion than other soils and are function of grain size, drainage potential, structural integrity, organic content and cohesiveness. Erodability of soil is its resistance to both detachment and transport. Because of thick forested nature of the Taluk, detailed field surveys of soils in the area were not possible. So a generalized soil texture map collected from the soil survey organization, Tamil Nadu, was used for the preparation of K factor map and the soil types are grouped into four major textural classes viz. loam, clay, clay loam and sandy loam. Each soil type was associated with a K factor assuming that the same soil type has the same K factor throughout the study area. The K factor map (Figure 4) was computed with the reclassification methods of the GIS.

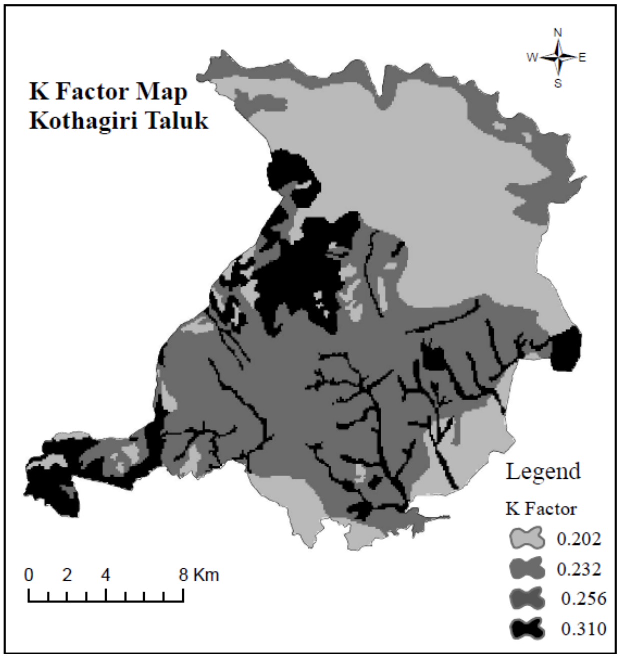

Figure 4: K factor map

C. *Slope-Length (L) And Slope Steepness (S)*

L factor, which is the function of ‘slope length’ along with the S factor (slope steepness), represents the topographical factor commonly expressed as LS factor. Many researchers have used these two L and S factors as the combined LS factor. Slope length, defined as ‘‘the distance from the point of origin of overland flow to either the point where the slope decreases to the extent that deposition begins or the point where runoff enters well defined channels’’ (Wischmeier and Smith 1978), is one of the difficult parameter to compute when estimating soil erosion unless an empirical field study is conducted.. S factor is basically the function of the slope gradient. The slope steepness factor (S) relates to the effect of the slope gradient on erosion in comparison to the standard plot steepness of > 10 %. The effect of slope steepness is greater on soil loss compared to slope length. For this study, the combined LS factor was computed by means of ArcGIS spatial analyst extension. Twenty meter DEM (digital elevation model) of the study area was prepared by 20 m interval digitized contour from 1.50,000 scale topographic map of Survey of India. Topographic analysis was carried out using terrain analysis of ERDAS. Grid theme of elevation and slope prepared by 20 m DEM was used for preparing combined LS factor data of the study area. Combined LS factor was estimated using flow accumulation theme. The flow accumulation, which denotes the accumulated upslope contributing area for a given cell, was calculated by summing the cell area of all upslope cells draining into it. Computation was done from DEM using the watershed delineation tool available in hydrological modeling extension in arc view spatial analyst. This study uses a method proposed by Desmet and Govers (1996) to calculate the L and S factors. Besides inter rill and rill erosion, Desmet and Govers (1997) note through field observations that the two-dimensional approach of the RUSLE considers ephemeral gully erosion as a product of flow convergence. In this procedure, the RUSLE is adapted to a two-dimensional landscape in which the upslope length is substituted by the unit contributing area which is defined as the upslope drainage area per unit of contour length. A 20 m DEM created using contours was used to derive topographic variables such as slope length and steepness. The combined LS factor for the watershed was calculated and its spatial distributions in the different spatial gradients of the watershed were presented.

$$LS = (\text{Flow accumulation x Cell size}/22{:}13)0{:}4 \text{ x sin slope}/0{:}0896)\ 1.3 \qquad (5)$$

Where flow accumulation denotes the accumulated upslope contributing are 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. Figure 5 depicts the map of the LS factors, which ranged from 0.00 in the flat areas in the western part of the Taluk to 24.01 in the high-lands (elevation approximately 2,436 m) in the northern, northeastern, and southern parts of the study area, which had the steepest slopes, the greatest variability in elevation, and large LS values. The LS values were highest in the areas where the river forms deep valleys. These areas were mostly located in the upper part of the Taluk and also in the east and in the south (Figure 5) .

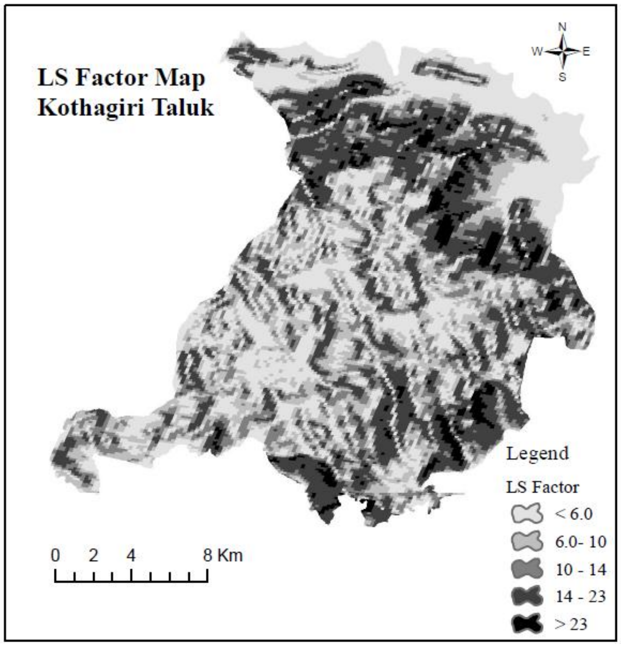

Figure 5: LS factor map

D. Cropping – Management Factor (C)

Cover Management Factor (C) factors that can be used to control soil loss at a specific site. The Cover Management Factor (C) represents the effect of vegetation and management on the soil erosion rates (Renard, Foster, Weesies, McDool, & Yoder, 1997). Cover Management Factor (C) is the ratio of soil loss of a specific crop to the soil loss under the condition of continuous bare fallow. The amount of protective coverage of a crop for the surface of the soil influences the soil erosion rate. C value is equal to 1 when the land has continuous bare fallow and have no coverage. C value is lower when there is more coverage of a crop for the soil surface resulting in less soil erosion. The crop management factor was calculated mainly from literature review, since there was not local data available regarding this factor. Based on the land use/cover classified image of Kothagiri Taluk, similar ecosystems were searched on different bibliographical sources and therefore assigned to the ones existing in study area. The search was orientated to those areas with similar geographical settings. 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 (Pitt 2007). The land cover and management (C) factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith 1978). A good estimation of the cover factor which only accounts for the vegetation cover can be derived rapidly from satellite imagery. Satellite imagery acquired during the rain season are more suitable for this application given that soil erosion is most active and vegetation cover is at its peak during this season. The effect of vegetation cover as a control on soil erosion is well established. Vegetation is regarded as the second most critical factor after topography used to derive the NDVI by computing the ratio (Band 4 - Band 3)/(Band 4 + Band 3). The NDVI is highly correlated with the amount of green biomass, and can therefore be applied successfully to provide information relating to the green vegetation variability. Studies by Van der Knijff (2000) and van Leeuwen (2003, 2005) provide a more refined and reasonable estimation of the C-factor using the NDVI. The IRS ID LISS III image was accurately rectified and terrain corrected using satellite which applies the geoference available in the ERDAS Imagine 9.1. The following equation was used to derive the C-factor in this study.

$$C = exp\left[-\alpha \frac{NDVI}{(\beta - NDVI)}\right] \qquad (6)$$

Where a and b parameters determine the shape of the NDVI curve. Reasonable results are produced using values of $\alpha = 2$ and $\beta = 1$.

Vegetated areas usual have NDVI values much greater than 0.1 while values less than 0 rarely contain vegetation and relate to non-photosynthetic materials such as water and bare soil (Figure 6). A lower vegetation threshold of 0.05 was set, below which vegetation was envisaged to be absent. The ability of NDVI in estimating vegetation cover was confirmed in the field through extensive ground truthing.

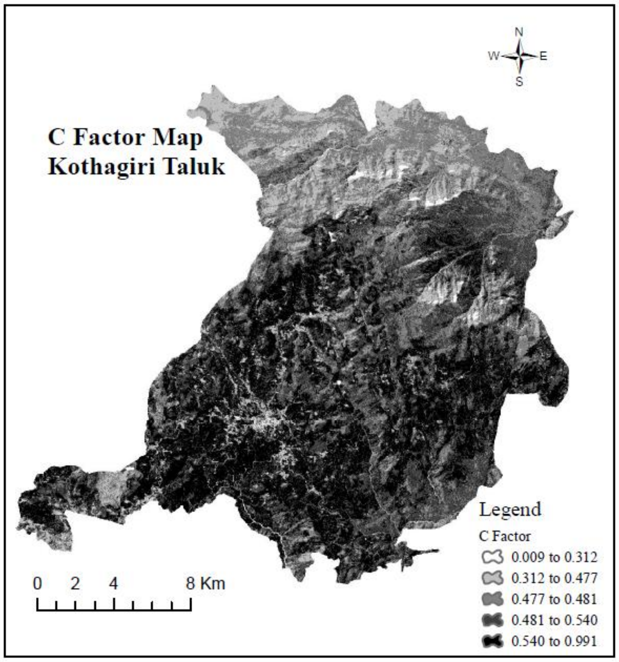

Figure 6: C factor map

E. Support Practice Factor (P)

The support practice (P) factor is the ratio of soil loss using a specific support practice to the corresponding loss with upslope and downslope tillage (Renard and others 1997). The conservation practice P factor is an important consideration of the RUSLE model. The support practice factor is defined as the ratio between soil loss with a specific support practice and the corresponding loss with upslope and downslope tillage. Renard and Forster (1983) explain that support practice essentially affects soil erosion through altering the flow pattern, gradients, or direction of surface runoff and by reducing the amount and rate of runoff. Information regarding conservation was obtained through field observations in the study area using a GPS. As in most agricultural lands in Taluk, agricultural practices in the study area consist of upslope and down slope tillage without any conservation support practices, such as contouring or terracing. In this study, remotely sensed data have been used to estimate the P factor distribution based on LULC classification results (Millward and Mersey 1999; Reusing and others 2000), assuming that the same land covers have the same P factor values. An LULC map of the Kothagiri Taluk derived from the IRS ID LISS III full frame satellite images acquired on June 5, 2012 (route path 102 row 66,65), with a spatial resolution of 23.5-m, was used as the base map for determining the P factors. The digital image processing software ERDAS-Imagine was used to digitally interpret the satellite imagery. Reference data for classifying LULC in the study Taluk were collected from soil maps, aerial photographs, forest maps, and field studies. After synthesizing all of the information, the study area was classified into 10 LULC classes as follows: (1) Dense Foresrt, (2) Orchats, (3) Tea Plantation, (4) Vegetable cultivate areas, (5) Sholas, (6) Rangelands , (7) Forest Plantation, (8) Builtup lands. The supervised classification method (maximum likelihood) was used to extract the LULC classes as described by Lillesand and Kiefer (2000). The P factors used in this study were adopted from previous studies (Nalina 2014) that determined land classes using satellite data (Table 1). The accuracy assessment is generally compiled in the form of a confusion matrix in which the columns depict the number of pixels per class for the reference data, and the rows show the number of pixels per class for the classified image. From this confusion matrix, a number of accuracy measures, such as the overall, the user's, and the producer's accuracy, can be determined. The overall accuracy is used to indicate the accuracy of the entire classification (i.e. the number of correctly classified pixels divided by the total number of pixels in the error matrix), whereas the other two measures indicate the accuracy of individual classes. The user's accuracy is regarded as the probability that a pixel classified on the map actually represents that class on the ground or reference data, whereas the producer's accuracy represents the probability that a pixel on reference data has been correctly classified (Stehman and Czaplewski 1998). In our case, the overall classification accuracy was found to be 86.21 %, whereas the user's accuracy and producer's accuracy were 89.3 %, and 92.6 %, respectively. After creating the LULC map of the study area, the P factors for the land classes were entered as attributes and C factor map of the Kothagiri Taluk was generated using the reclassification method in the GIS. To remove the P factor from the soil erosion estimates, P was set equal to one as suggested by Wischmeier and Smith (1978). These conservancy zones were assigned a P factor of 0.03, (Figure 7) reflecting stringent conservation practice in these areas.

Table 1 .Average soil Loss from different landuse of Kothagiri Taluk.

Landuse	**Crop Management Factor (C)**	**Area (Km^2)**	**Soil Loss ($t\ ha^{-1}\ yr^{-1}$)**	**Losses (%)**
Crop land	0.3	63.14	65.3	55.35
Dense Forest	0.04	87.811	4.6	3.90
Built-up Land	0	43.107	16.6	14.07
Tea Plantation	0.16	68.175	7	5.93
Sholas	0.3	33.709	6.32	5.36
Range lands	0.08	75.337	10.32	8.75
Orchats	0.42	9.259	2.4	2.03
Forest plantations	0.21	44.958	5.43	4.60

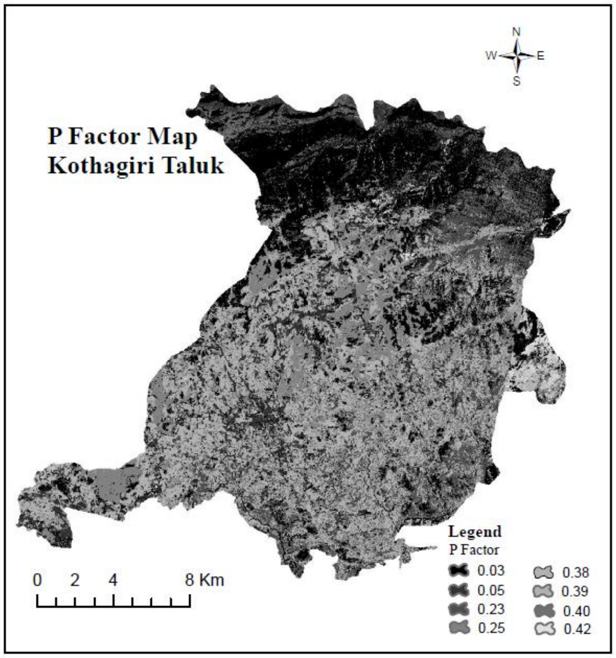

Figure 7: P factor map

V. RESULTS AND DISCUSSION

Soil erosion is still a serious problem in the Western Ghats of Kothagiri Taluk, and attempting different methods to evaluate soil loss at the watershed scale is necessary for sustainable land use and comprehensive Talukal development. RUSLE is often used to estimate average annual soil loss from an area. RUSLE model in GIS environment is a relatively simple soil erosion assessment method. ArcGIS 9.1 software was used to generate the spatial distribution of the RUSLE factors. The four factor layers (R, K, LS, and C) were all converted into grids using a 20-m data set of the Kothagiri taluk in the same reference system. Subsequently, these grids were multiplied in the GIS as described by the RUSLE function. Thus, the annual soil loss was estimated on a pixel-by-pixel basis, and the spatial distribution of the soil erosion in the studied taluk was obtained. To adopt the RUSLE, large sets of data starting from rainfall, soil, slope, crop, and land management are needed in detail. In developing countries all the necessary data are often not available or require ample time, money, and effort to prepare such data sets. RUSLE is a straightforward and empirically based model that has the ability to predict long term average annual rate of soil erosion on slopes using data on rainfall pattern, soil type, topography, crop system and management practices. In the present research, annual soil erosion rate map was generated for Kothagiri Taluk, a mountainous area, which represents most of the terrain characteristics of Western Ghats. Soil erosion mapping was modeled within Kothagiri Taluk, integrating the RUSLE with GIS. To predict average annual soil loss caused by sheet and rill erosion from the study, the parameters used in the RUSLE equation depend on soil characteristics, topography and landuse of the area. Based on this analysis, the amount of soil loss in the Taluk varies 0.54 to 27.11 t ha-1 yr-1. As shown in Figure. 9, the average annual soil loss of the Kothagiri has been found out to be 15.74 t ha-1 yr-1. A spatial location of the high soil erosion areas has been identified in this study. It also reveals that the potential soil loss is typically greater along the steeper slope and poor vegetation cover area. The Range land and dense forest of the Taluk are shown to be the least vulnerable to soil erosion. Tea plantation and sholas show medium soil loss. Other high soil erosion areas are dispersed throughout the Taluk and are typically associated with the landuse classes which have high erosion potential. In the higher elevation ranges, isolated pockets of open forest and dense forest have been cleared for agriculture, tea estates and horticultural crop lands. In this study, the highest amount of soil loss has been identified in the range lands and agricultural lands. Also urbanization and construction of roads in this area have affected the topography and increased the soil loss. This area has to be given special priority for the implementation of erosion control measures.

Potential annual soil loss is estimated from the product of factors (R, K, LS, C and P) which represents geo-environmental scenario of the study area in spatial analyst extension of Arc GIS software. The average soil erosion rate estimated for the upland of the Taluk ranges from 0.54 to 27.11 t h-1 y-1. Soil erosion rate calculated in these studies are found to be appropriate and matching. The results were also compared with the studies carried out in areas having similar geo-environmental and rainfall characteristics (Bacchi et al. 2000; Mati, 2000; Shiono et al. 2002; Lee and Lee, 2006; Yuksel et al. 2008; Adediji et al. 2010) and were found to be comparable with an annual average soil erosion rate of 12.63 t h-1 y-1. The assessed average annual soil loss of Kothagiri Taluk was grouped into different classes based on the minimum and maximum values and the spatial distribution of each class is presented in Figure 9. The grouping of different soil erosion severity zones was carried out by considering the field conditions. The results presented in Table 2 show that about 42% and 28% of the study area is classified as low potential erosion risk to very low potential erosion (3-5 t h-1 y-1, < 3 t h-1 y-1), while rest of the area is under moderate to very high erosion risk. In terms of actual soil erosion risk, the study area has 17% moderate (5-10 t h-1 y-1), 8.28 % (10 t h-1 y-1) high and 3.54 % (>20 t h-1 y-1) erosion risk levels. The spatial pattern of classified soil erosion risk zones indicates that the areas with high erosion risk are located in the east, and northwest part of the study area, while the areas with low erosion risk are in the north and south of the study area (Figure 8).

Table 2 : Soil erosion severity zones with erosion rate and area covered.

Soil erosion classes	Rate of Soil Loss **(t ha^{-1} yr^{-1})**	Area (km^2)	**Losses (%)**
Very High	>20	15.06	3.54
High	10- 20	35.23	8.28
Moderate	5-10	76.02	17.87
Low	3-5	179.12	42.10
Very Low	< 3	120.06	28.22

The results indicate that (as in Figure 9) erosion risk was generally low across all the LULC classes. However, traces of High erosion are available in the moderate forest class. From visual interpretation of the various factors, this was found to be due to the high erodibility of the soil group (Clay loamy) that intersects the sections of the moderate forest LULC Class. Also the forest class falls within the high rainfall zones of the study area which may contribute to high erosion within the forest cover class.

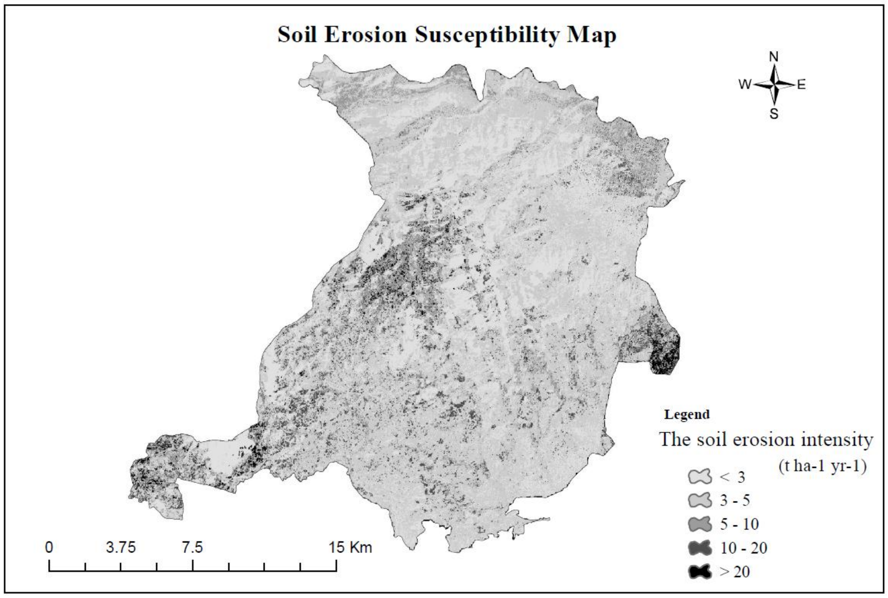

Figure 8: Soil erosion Susceptibility map

V. CONCLUSION

In this paper, a soil erosion model at Kothagiri Taluk with the integration of RUSLE and GIS tools has been developed to estimate the annual soil loss. Different components of RUSLE were modeled using various mathematical formulae to explore the relationship between erosion susceptibility, slope and LULC maps. The erosion map produced was then categorized into five different erosion risk classes. According to this model, approximately in 70 % of the Taluk has very low erosion risk to low erosion risk and 17% moderate erosion risk. But erosion risk is high and very high on 8.28 % and 3.54% respectively. Higher soil erosion was found to occur in the mid part of the study area. The soil texture in the affected area is coarse loamy to loamy skeletal. Hence soil detachment is higher. The very high and moderate erosion were found to be distributed mainly within the areas of high slope gradient and also sections of the moderate forest LULC class. The results indicated that areas within the cropping areas LULC class have a high erosion risk and this was due to the presence of an intersecting high erodibility soil group. This will improve the accuracy of the LULC maps and DEMs generated for land slopes calculations. It should be emphasized that the areas producing more erosion would need special priority for the implementation of soil erosion control measures. The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the entire Taluk. The ways of evaluating soil losses even with the lack of direct observation data presented in this paper could be useful for the land use decision makers in other part of the world. The soil loss map can be further classified into soil erosion susceptibility map. It can be used to identify the locations, where alternative soil conservation practices would be best applied. In general, it is clear from the results of this study that the developed model is beneficial for the rapid assessment of soil erosion susceptibility.

ACKNOWLEDGMENT

The authors would like to thank Dr. S. Anbazhagan and Dr. R.Subramanian for the helpful discussions, encouragements and their valuable criticism and constructive comments on the draft paper. The author is grateful to anonymous reviewers whose valuable comments and suggestions helped to consolidate and strengthens this article.

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