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A Review Approach to USLE and its Derivatives

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Abstract—Soil erosion is an important term of consideration in the processes of watershed development planning. Soil conservation planning and erosion risk mapping, are usually done with the help of erosion models .These models are widely used,all over the world, to estimate the erosion rates and uses mathematical expressions to symbolize the relationships between different variables or factors. Among available soil erosion and Sediment yield models, the universal soil loss equation (USLE), the revised version of USLE (RUSLE), and its modified version (MUSLE) are extensively used in hydrology and environmental engineering for assessment of potential soil erosion and sediment yield. Evaluation of the applicability of soil erosion models for a particular watershed is not very easy, thus it requires a thorough review of the soil erosion models being used in similar or other landscapes. A review of the soil erosion models can assist in verifying the necessity of considering the appropriate parameters in controlling long term soil erosion by adopting a proper soil erosion model in the researches.

Keywords: *Soil erosion Models, USLE, RUSLE, MUSLE.*

1. INTRODUCTION

Soil is the earth's fragile skin cover that holds all life on Earth. It is composed of numerous species that create a dynamic and complex ecosystem and is the most precious resources to human beings. Increased demand for agricultural commodities generates allurement to convert forests and grasslands into agricultural fields and pastures. This transition can actually increase soil erosion beyond the soil's ability to preserve itself. Half of the topsoil on the earth has been lost in last 150 years. Besides erosion, soil quality is affected by some other aspects which include soil compaction, loss of soil structure, nutrient depletion and salinity. These aspects are real and can cause severe issues.

Soil erosion is a slow process that continues nearly unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from croplands may be reflected in reduced crop production, lower surface water quality and choked drainage networks. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent watercourses and lakes.

Erosion broadly involves three distinct actions namely soil detachment, movement and deposition whether it is by water, wind or tillage. Scientific management of soil, water and other resources on watershed are very important to check erosion and rapid siltation in water bodies but is difficult to perform on large and challenging watersheds. Remote sensing applications and GIS can provide convenient solution for the management of soil, water and other resources. Voluminous data gathered with the help of remote sensing techniques are better handled and utilized with the help of Geographical Information Systems (GIS).

In this paper, several soil erosion models have been reviewed like USLE, RUSLE, RUSLE-3D and MUSLE. The aim of this review is to provide a better understanding of the soil erosion models and their adaptability for the determining the accuracy of the results in different areas of the world. These models can be used as predictive tools for assessing soil loss and soil erosion risk for conservation planning.

2. UNIVERSAL SOIL LOSS EQUATION (USLE) AND ITS DERIVATIVES

The Universal Soil Loss Equation (USLE) is an empirical model and used for estimation of annual soil loss over the world, widely within the United States. USLE developed in 1970s by USDA; many modifications have been made in USLE (Kinnell and Risse, 1998). The model has also been modified for taking into account additional information (RUSLE, Renard *et al.*, 1991). While developed for small hill slopes, USLE and its derivatives have been incorporated into many catchment scales for erosion and sediment transport modelling applications.

The USLE uses the following formula for computing the average annual soil loss:

$$A = R \times K \times L \times S \times C \times P$$

Where, A= estimated soil loss per unit area,

R= rainfall erosivity factor,

K= soil erodibility factor,

L= slope-length factor,

S= slope-steepness factor,

C= cover-management factor, and

P= conservation practice factor (Wischmeier and Smith, 1978).

The basic USLE is based on an overland flow and sheet-rill erosion equation and has number of limitations.

The update OF THE USLE is based on an extensive review and is so substantial that the result is referred to as RUSLE—the revised USLE. The Revised Universal Soil Loss Equation (RUSLE) computes sheet and rill erosion from rainfall and the associated runoff for a landscape. As a revision and update of the Universal Soil Loss Equation (USLE), RUSLE incorporates data from rangeland and other research sites to significantly improve erosion estimates on untilled land areas. RUSLE can be used to compute soil loss on areas where significant overland flow occurs, but is not designed for lands where no overland flow occurs.

Some of the improvements in the RUSLE include:

- An expanded erosivity map for the western United States.
- Minor changes in R factors in the eastern United States.
- Expanded information on soil erodibility.
- A new slope length factor
- A sub factor method for computing values for the cover-management factor.
- Improved factor values for the effects of contouring, terracing, strip cropping, and management practices for rangeland.

The RUSLE-3D (Revised Universal Soil Loss Equation-3D) model was implemented in geographic information system (GIS) for predicting the soil loss and soil erosion risk for soil conservation planning. It has been widely used for spatial prediction of soil loss and erosion risk potential (Millward and Mersey 1999; Lu *et al.* 2004; Shi *et al.* 2004;Efe*et al.* 2008).RUSLE 3Dwas being used because it provides genuine results in quality and quantity and for detailed evaluation of the factors affecting erosion. RUSLE a functional model derived from the analysis of intensive soil erosion data has wide application in long-term water erosion prediction as seen in soil erosion modelling.

Modified Universal Soil Loss Equation (MUSLE) model has been developed for estimating the sediment load produced by each storm, which takes into account the volume of runoff not rainfall erosivity. It also has some limitation such as it is not incorporating detachment by runoff and raindrop impact.

3. EXISTING MODEL REVIEWS

A brief review of some popular soil erosion models used in different regions all over the world.

Cohen et al [5] 2004, suggested that with any adopted empirical model, application in new areas requires calibration before results are used for decision support. They evaluated USLE effectiveness for predicting erosion in a small watershed in western Kenya based on 420 geo-referenced ground observations of ordinal erosion class (3 categories) systematically collected from throughout the basin. Association between USLE predicted risk and observed erosion, estimated and classified only 38% sites correctly into three degradation classes and model sensitivity was only 28% for delineating the regions of severe degradation. Graphical modelling was used to identify those USLE risk factors that were conditionally associated with observed loss and then employing only these factors, a logistic regression model, employing only these factors was developed. This result suggests a critical need for efficient ground-based sampling schemes to be used in conjunction with flexible statistical models based on USLE factors for future investments in erosion risk assessment in the tropics.

The pattern of soil erosion in Jamni River Basin examined by Singh et al[13] in 2006 is highly uneven and rugged physiographic disposition coupled with climatic conditions and human mismanagement are major factors responsible for erosion. The coarse soil texture, undulating topography, low organic matter, absence of vegetation cover, and dry farming practices are the main factors which have made these soils highly erodible and are under a critical condition of deterioration with high rate of potential soil loss. They use USLE for the watershed to predict soil erosion and topography is a factor of over-riding importance in determining the rate of soil loss among the USLE parameters. Soil erodibility variations also seem to be influenced by soil management factor. Factor maps of each parameter were integrated to generate a composite map of erosion intensity based on advanced GIS functions. The map is expected to assist in the identification of priority areas of the basin and would thus help in future planning of a watershed and its sustainable development.

Karso watershed of Hazaribagh, Jharkhand State, India was divided into 200 × 200 grid cells byPandey et al [4] in 2007 and average annual sediment yields were estimated for each grid cell of the watershed to identify the critical erosion prone areas for prioritization purpose. A recent emerging technology represented by Geographic Information System (GIS) was used as the tool to generate, manipulate and spatially organize data for sediment yield modelling. Thus, Arc Map and ERDAS IMAGINE image processing software provided spatial data and the USLE was used to predict the spatial distribution of the sediment yield on grid basis of the watershed. The deviation of estimated sediment yield from the observed values of the sediment yield is 1.37 to 13.85 per cent indicating accurate estimation of sediment yield. Thus, GIS and RS can assist in developing management scenarios and provide options to policy makers for handling soil erosion problem in the most efficient manner for prioritization of watershed areas for treatment.

A quantitative assessment of average annual soil loss of Dikrong river basin of Arunachal Pradesh (India) on grid basis was made by Dabral et al [12] 2008, using the well-known USLE to analyse the spatial distribution. The Remote sensing data enable the evaluation of the spatial distribution of the USLE parameters and the average annual soil erosion for Dikrong river basin was found to be 51 t ha/year. About 25.61% of the watershed area is found out to be under slight erosion. Areas covered from moderate to very severe erosion potential zones are 26.51%, 17.87%, 13.74%, 2.39% and 13.88% respectively. Creation of database through conventional methods is time consuming, tedious. They attempted to utilize remote sensing data for generating land use/land cover data which are essential pre-requisites for generation of USLE factors. Thus, remote sensing and GIS helped in generation of parameters for USLE for remote areas of river basins for soil erosion assessment.

Jayarathne et al [9] carried their study with the objective of developing a land degradation assessment model using a geospatial approach in 2010. USLE together with some socio - economic factors were used to develop the model for prediction of land degradation. The computed soil erosion map was coupled with the socio-economic factors on population density, agricultural land to man ratio and land to man ratio to assess the land degradation. The results showed that marginal tea lands are the highest contributor to soil loss in the study area. Accordingly, soil erosion and population density contributed more to the land degradation and a strong negative relationship was found between land degradation and land to man ratio. It is recommended to use multi sensor and multi-spectral remotely sensed data to provide valuable and very important factors in the USLE like C and P to assess soil erosion.

The estimation of soil erosion in the Upper Kangsabati catchment of west Bengal using Universal Soil Loss Equation in a GIS environment and prioritization of catchments was dealt by Biswas et al [18] in 2012.Soil erosion of each of the sub-catchment was estimated from the integrated map and the sub-catchments were prioritized based on the estimation of erosion. It can be inferred from the study that soil erosion estimation using Remote Sensing and GIS technique can be effectively used for prioritization of catchments and this helps in the way the catchments can be taken for treatment for conservation measures**.**

To assess the annual soil loss in Upper South Koel basin**,** Parveen et al [15] uses Universal Soil Loss Equation (USLE) in 2012 and the soil erosion rate was determined as a function of land use, erosivity, topography, soil, and crop management factor using the Universal Soil Loss Equation, with the help of remote sensing and GIS techniques. A quantitative assessment of average annual soil loss was done and the study revealed that area covered under slight to very severe soil loss potential zones are 64.70%, 17.10%, 10.05%, 4.65%, 1.60%, 1.90% respectively. Thus average annual soil loss map will be helpful in identification of priority areas for implementation of soil conservation measures and effective checking of soil loss.

In 2013, Ahmad et al [8] presented the application of USLE model and GIS, for soil loss estimation for the Tandula reservoir catchment area on Tandula River at Balod Tehsil of Durg district of Chhattisgarh State, India .The soil erosion can be controlled effectively if it is predicted accurately under alternate management practices and strategies. The Universal Soil Loss Equation model has been accepted and used most widely all over the world to predict the soil erosion from a watershed. The result obtained has been compared with existing model, Nayak and Khosla’s method and it is observed that USLE with GIS give better result as compared to other two methods.

A Simplified relationship was proposed by Elangovan et al [3] for estimating the erosivity in krishnagiri watershed area in 2011. Data from three locations were used to develop the relationship and one additional station across the watershed for validation. A relationship was established between the rainfall erosivity and depth that can be expressed in a potential form and the difference between the estimated and the observed erosivity is the experimental error. Statistics of the experimental errors are reported as the Mean Absolute Error (34) and the Root Mean Square error (84) for the validation. The regression model and the erosivity map here provided represent a helpful mean for soil erosion assessment and mapping both at watershed and at regional scale.

To identify the estimation of soil loss, prioritization of the micro watersheds and suggestion of best conservation measures for the Nun Nadiwatershed,Naqvi et al [7] employed Revised Universal Soil Loss Equation (RUSLE) model in 2012. About 23 km² area consisting 7 micro watersheds was classified as very high to high priority risk zones and demands immediate attention for purpose of planning and management. Thus the study provides accurate results for soil loss predictionand watershed unit proves helpful for the soil loss based study and its prioritization and management has good potential for soil conservation. It also shows the contribution of adopting effective conservation measures in minimizing the soil loss.

In 2012, Rabia et al [1] aims to quantify the soil loss and to specify the main factor affecting the erosion in the study area applying RUSLE. ArcGIS™ and Excel software were used for all the calculations procedures of RUSLE values and to produce the soil erosion risk map. The final values showed the loss quantity of soil in t/ha/year, ranging from considerably less to very high soil loss rates (223.6 t/ha/y). The data also shows that Topography (LS) factor was the most effective factor followed by the support practices (P) factor in controlling the erosion process. The study showed that stone bands are successful management practice to conquer the soil erosion dilapidation and demonstrates that Remote Sensing and GIS are effective tools in generating spatial and quantitative information on soil erosion studies and risk assessment mapping.

For Pamba sub-watershed, Kerala, a quantitative assessment of average annual soil loss is made by Prasannakumar et al [20] in 2012 with GIS based well-known RUSLE equation considering soil, land use, rainfall and topography. They suggested that spatial erosion maps generated with RUSLE method and GIS can serve as effective inputs in deriving strategies for land planning and management in the environmentally sensitive mountainous areas.

Alkharabsheh et al [11] 2013, aims at assessing the impact of land cover change on the erosion in agricultural areas of northern Jordan. It was achieved by quantifying and analysing the soil erosion in the study area between the years 1992 – 2009 by comparing it with land cover changes. By comparing the change of the erosion risk levels with the land cover change map, it was evident that the main reason for soil erosion change was the abandonment of rainfed crops and their transition to rangelands. The differences in erosion risk of the two years were considerable indicating that changes in land cover affects significantly the soil erosion rate. The main reason for the changes in soil erosion between the LULC types are due to the changes in land cover which are reflected by NDVI, and in turn changing the C factor values which affect strongly the soil erosion.

The RUSLE model was adopted by Tirkey et al[2] in 2013 for estimating the annual average soil loss in the Daltonganj watershed provides satisfactory results and can be used for estimating soil erosion in other similar micro watersheds. The average annual soil loss in the Daltonganj watershed was found to be 69 tons/ha/yr. The maximum area contributing to soil erosion however comprised agricultural lands where rainfed cropping exists. Thus the upland area of the catchment soil conservation measures must be adopted to check soil erosion such as terracing, bunding, agro-forestry techniques, crop rotation etc. The remote sensing data and GIS provide the accurate determination of the spatial distribution of the parameters. Thus, they play a significant role in generation of input parameters for inaccessible areas of the watershed where ground based observations are difficult for the soil erosion modelling.

GIS as a valuable tool has demonstrated by Sharma et al [6] in 2013**,** in assessing soil erosion and assisting the estimation of erosion loss of the micro-watersheds. Remote Sensing and GIS here has been productively used for soil erosion study of all the three micro-watersheds of catchment area of Bisalpur reservoir achieving objective of the study as methodology for simple qualitative soil erosion mapping has been developed using the freely available remote sensing data. The catchment area of watershed and micro-watersheds of Bisalpur dam have been successfully delineated using Remote Sensing and GIS. Qualitative assessment has been done as soil erosion prone areas are identified by studying combined weightage of soil erosion factors. Quantitative assessment has effectively been accomplished by calculating rates of soil loss and developing soil loss severity maps of the study areas using soil loss equation model RUSLE. Comparison of qualitative and quantitative analysis of soil erosion analysis showed that soil erosion can be effectively studied using the two as almost similar results have been produced with a few exceptions.

For prediction of annual soil loss in Findikli Creek watershed, Turkey Recep et al [14] uses the Revised Universal Soil Loss Equation (Version 1.06) to determine the erosion. To determine controlling factors and rate of potential erosion risk, Geographical Information Systems (GIS) based Revised Universal Soil Loss Equation (RUSLE) model was used. The procedure adopted is to calculate six RUSLE factors using distributed GIS data (e.g. soil, land cover, and DEM) to represent the surface attributes and to estimate spatial distribution of soil loss in the study area basin. All factors of the model were calculated for the watershed using local data and factor maps are prepared. Accordingly, five erosion risk classes from low, slight, moderate, high to severe were defined and the mean value of the annual average soil loss was calculated to be 66.5 tons/ hectare/year.

Suresh Kumar et al. [19] aim to assess the spatial pattern of soil erosion risk in PathriRao sub-watershed using RUSLE-3D model in 2013. High resolution remote sensing data (IRS LISS-IV) were used to prepare land use/land cover and soil maps to derive the vegetation cover and the soil erodibility factor whereas Digital Elevation Model (DEM) was used to generate spatial topographic factor. The sub-watershed is dominated by natural forest in the hilly landform and agricultural land in the piedmont and alluvial plains. The study predicted that 15% area has moderate and 26% area has high to very high risk of soil erosion in the sub-watershed.

To estimate the sediment yield due to storm rainfall and runoff at the outlet of the Khanmirza watershed (395 sq.km) in western Iran, SADEGHI et al [17] in 2007, uses the Modified Universal Soil Loss equation (MUSLE) model for six storm events .The applicability of the model was then evaluated by comparison of its estimates with those calculated using the measured sediment data. Their results demonstrated the efficiency of the MUSLE in estimating storm-associated sediment yield except one storm event with a high level of agreement and differences between mean estimated and measured values in the study storm events.

Modified Universal Soil Loss Equation (MUSLE) application was undertook by Arekhi et al [16] in 2010, to estimate the sediment yield of the Kengir watershed in Iyvan City, Ilam Province, Iran. Sediment yield at the outlet of the watershed is simulated for six storm events over the year 2000 and validated. The coefficient of determination has a high value (0.99) which ensures that MUSLE model sediment yield predictions are satisfactory for practical purposes.

Mohamed Rinos et al [10] 2014, proposed that it is clear from their study that modified USLE is a powerful model for the qualitative as well as quantitative assessment of soil erosion intensity for the conservation management. Multi-temporal, multi-sensor and multi-spectral remote sensing data have provided valuable and very important factors like C and P. Thus, GIS has given a very useful environment to undertake the task of data compilation and analysis within a short period at very high resolution. IRS-1D pan data and GPS data can be used for updating the age-old Survey of India topo-sheets, which is the prime source of data for the Geo-coding of images and Digital Elevation Model.

4. CONCLUSION

In the light of the gravity of the problem, the worst affected areas need immediate conservation measures which are important to conserve the land resources for long-term benefits. Otherwise it would result in environmental degradation, some socio-economic consequences in the ecological tract. Thus an area with severe soil erosion requires special priority for the implementation of control measures. In general, it is clear from this study that USLE is the most widely used model for soil erosion estimation all over the world and spatial erosion maps generated with RUSLE method and GIS can serve as effective inputs in deriving strategies for land planning and management even in the environmentally sensitive mountainous areas. Quantitative assessment can also be effectively accomplished by calculating rates of soil loss and developing soil loss severity maps using soil loss equation model RUSLE. Modified USLE is a powerful model for the qualitative as well as quantitative assessment of soil erosion intensity for the conservation management but has its greater implementation in areas like Iran. The accuracy of any prediction depends on the capability of the model to check for effects of the physical phenomena causing the output and the accuracy by which the parameters have been estimated. The most accurate and effective soil erosion model is the Revised Universal Soil loss Equation.

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