**Estimation of Soil Erosion Using Empirical Equation with GIS & Remote Sensing**

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**Abstract**

Soil erosion is the land degradation form, this is natural process that affects landuse, fertility of soil and agriculture productivity, and water availability. This chapter aims the multi-temporal average annual soil loss using USLE, MUSLE, and RUSLE models with Remote Sensing and Geographical Information System. These empirical models used to estimate the annual soil loss.

**Keywords:** USLE, MUSLE, RUSLE, GIS, RS, and Soil erosion.

1. **Introduction**

Soil erosion is a significant problem in India, where more than 70% of the land is in degraded condition. The threat of soil erosion by rapid water and wind is a serious problem for localities in developing countries, especially tropical and subtropical countries. Accelerated soil erosion has adverse economic and environmental effects. Economic impacts are losses of farm income due to reductions in on-site and off-site income and other losses, along with adverse effects on crop and animal production (Harjadi, 2009). The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) reports provide information that land degradation affects various types of 120.72 million ha, and the total geographical area of India is 328.6 million ha, with 82.5 million ha affected by water erosion, 12.4 million ha by wind erosion, 6.7 million ha by salinity and alkalinity, and 18.9 million ha affected by other soil degradation (Sathiyamurthi et al,2023). ). worldwide, the area impacted by rainfall-induced erosion stands at 1094 M ha, with 751 M ha having severe effects; wind erosion affects 549 Mha of land (Lal, 2003).

Erosion may be defined as the process of detachment, transportation, and deposition of soil particles. (Wischmeier & Smith, 1978). The detached particles are transported by erosion agents from one place to another and finally settle at some place, leading to the erosion process. It is initiated by the detachment of soil particles due to the action of rain and wind. Natural erosion may not be harmful. However, clearing natural vegetation and trees for agriculture disrupts the soil's natural protection, resulting in rapid soil detachment and movement. The upper-layer surface of soil is the supporting layer, and this layer is productive, so this layer removes resulting production and productivity losses. Factors affecting soil erosion are mainly rainfall, runoff, wind speed, and crop cover. Soil erosion rates are larger in arid and semi-arid regions due to the high sensitivity of such region to climate and land use change. Soil erosion rates are also reported to be high in Asian countries such as China, India and Afghanistan (Safari et al., 2021). According to Ouyang et al. (2010) the relationship between erosion and precipitation, whether positive or negative, is highly determined by the condition of the ground vegetation cover.

**2 Effects of soil erosion**

Soil erosion has become a worldwide concern for the sustainability of the environment and agriculture. The impact of soil erosion is identified both on-site and off-site. On-site effects are mainly in the agricultural field, which leads to reductions in soil structure, organic matter, soil productivity, low agricultural production, and low income. The loss of nutrients is closely related to erosion, which may result in a loss of soil fertility. These nutrients are very essential, and each nutrient plays a unique role. Increased pollution and sedimentation in downstream streams and rivers are the results of off-site soil erosion, which decreases stream, river, and reservoir capacity and increases flood risk. Waterways may choke, potentially affecting water quality, and most of the environmental issues that the world faces today from soil erosion. The empirical and mathematical both models to predict the soil loss (Wischmeier and smith, 1978). The soil erosion risk finding the USLE and RUSLE models by using GIS provides land users to make better decisions about the usage and conservation of the soil and the ecosystem, by connecting scientific principles to their traditional knowledge. The spatial changes erosion maps produce with USLE or RUSLE model, RS and GIS can provide as inputs in developing strategies for planning of land use, management in the mountainous areas, and environmentally sensitive.

 

**3 We need to measure the risk of soil erosion.**

Watershed areas have been highly disturbed. The present situation is so bad that even termination of exploitation may no longer make possible self-restoration of biological diversity, stability, and productivity of the ecosystems. The relative balance between soil-establishing and depleting processes is extremely important in any production system for achieving long-term sustainability. Soil is the basis of agricultural production, so soil erosion assessment can be useful for regional land evaluation. Measurement of soil loss, erosion rate, and its spatial distribution are key factors for the success of soil erosion assessment.

Spatial and quantitative soil erosion information for a particular region contributes to erosion control, conservation planning, and management of agriculture as well as the environment. Proper identification of affected areas with this type of erosion problem and quantitative soil loss with adequate accuracy is extremely important for the purpose of designing and implementing soil and water conservation practices and appropriate erosion control measures. Researchers have been alarmed by soil dynamics since the middle of the 20th century and developed several.

**4 Why soil conservation is needed**

Soil conservation is the only known way to protect productive areas. In a mainly agricultural country like India, where droughts, famines, and floods cause chronic food scarcity, soil conservation not only improves crop yields but also prevents agricultural land. Large-scale soil and water conservation efforts in India began in 1951. In the earliest phases, soil and water conservation programs were primarily focused on improving agricultural fields with contour bunding. Soil erosion is a critical issue for agricultural sustainability. After decades of research and the availability of effective technical solutions. The slow and limited implementation of soil conservation measures raises questions about the underlying causes. Research indicates that several factors influence the adoption of these measures, but a significant for rapid change in agricultural practices is the presence of clear economic incentives for farmers. Since many conservation practices are cost-neutral, their adoption is less widespread than anticipated. This economic aspect must be considered when developing strategies for effective soil conservation in the Global South, where agricultural systems are poised for substantial transformation in the coming century. It can support these efforts and offer farmers in the Global South a more sustainable future (Govers et al., 2017).

**6 Soil erosion modelling**

Soil loss is commonly assessed through such as land user and expert opinions, field observations, monitoring, measurement, modelling, productivity change estimation, and remote sensing. So, various models have been developed in order to predict soil loss, primarily using empirical, conceptual, and physical models approaches. These models aim to represent and quantify the processes involved in soil erosion, including detachment, transportation, and deposition. The goal is to create tools that can be used for educational planning and legislative purposes (Renchler and Harbor, 2002).

The most widely used models for the estimation of soil losses are:

1. Universal Soil Loss Equation
2. Modified Universal Soil Loss Equation
3. Revised Universal Soil Loss Equation

**6.1 Universal Soil Loss Equation (USLE)**

The Universal Soil Loss Equation (Wischmeier and Smith, 1978) is the mostly used soil loss estimation equation in the world. This equation predicts the annual soil loss (A) for the long term including sheet and rill erosion, using the factors that are associated with rill and sheet erosion, including factors that are associated with vegetation, topography, climate, and soil.

 A = R×K×LS×C×P

Where,

A is the average annual soil loss (t ha−1 year−1).

R is the rainfall erosivity (MJ mm ha−1 h−1 year−1),

K is the soil erodibility factor (t ha h MJ−1 mm−1),

LS is the topographic factor (dimensionless),

C is the cropping management factor (dimensionless),

and P is the practice support factor (dimensionless).

For estimation of the average annual soil erosion rate in a small field with an average length of 22 m and a field slope of 9%, the most popular empirical model is the universal soil loss equation, which is also dependent on the rainfall pattern, soil type, topography, cropping system, and management practices. (Wischmeier & Smith, 1978). USLE, the most widely accepted equation throughout the world, being a lumped empirical model, does not segregate factors that influence soil erosion like plant growth, decomposition, infiltration, soil detachment, runoff, or soil transport.

**Limitations**

1. The model applied only to rill and sheet erosion.
2. The USLE model not calculate sediment deposition.
3. It is empirical model not provide actual soil loss.
4. The model applicable only for average data and is not valid for single storms.

**6.2 Revised Universal Soil Loss Equation (RUSLE)**

The Revised Universal Soil Loss Equation (RUSLE) is the easiest and most widely used equation for the estimation of rates of soil erosion caused by rainfall and associated flow. The RUSLE model (Renard et al., 1997) equates the mean annual soil loss (A) per unit area with the erosivity of rain-runoff (R), erodibility of the soil (K), slope length/slope steepness (LS), cover-management (C), and support practice (P) factors by sheet and rill erosion, which can be computed using:

                                               A= R × K × LS × C × P

where A is mean annual soil loss (t ha-1 yr-1); R is rainfall erosivity factor (MJ ha-1 mm-1); K is soil erodibility factor (t ha h ha-1 MJ-1 mm-1); C is cover-management factor (dimensionless); LS is slope length/slope steepness factor (dimensionless); and P is the support practice factor (dimensionless). The soil erosivity, erodibility, and management factors can be determined from the geomorphological and rainfall characteristics of the area.

The Revised Universal Soil Loss Equation (RUSLE), being land use independent, is an upgrade of USLE. It can be used on cropland, disturbed forestland, rangeland, construction sites, mined land, reclaimed land, military training grounds, landfills, waste disposal sites, and other lands where rainfall and its associated overland flow cause soil erosion (Renard et al., 1997).

In comparison with USLE, the major changes here are the improvement in the calculation of the topographic factor and the value given to the vegetation cover. Also, more advanced computerization is done in the case of RUSLE. It places more emphasis on the fact that surface residues as well as residues incorporated in the soil near the soil surface have the ability to reduce erosion. RUSLE takes into consideration that some portion of runoff is channeled into rills and gullies, but USLE considers runoff to be uniform over the entire catchment. RUSLE takes into account that soil can get saturated with long rains, which leads to reduced infiltration and more runoff, causing erosion. RUSLE takes account of areas with net sedimentation and areas with converging and diverging terrains.

**6.3 Modified Universal Soil Loss Equation (MUSLE)**

Williams (1975) developed the MUSLE by replacing the rainfall erosivity factor in the USLE with a runoff energy factor.

The MUSLE is:

 Y = 11.8(Q × qp)0.56 K×C×S×L×P

Where,

Y = sediment yield (metric t)

Q = runoff volume (m3)

qp = peak runoff rate (m3/sec).

and K, C, S, L, and P are the standard USLE factors for soil erodibility, crop management (cover), slope length-gradient, and erosion control practice.

The MUSLE follows the same format as the USLE, except for the fact that here the runoff factor is introduced, removing the rainfall erosivity factor. For sediment yield prediction, it also optimizes the hydrological procedure. The enhancement of prediction occurred as antecedent moisture content and precipitation intensity were part of the runoff factor (Zhang et al. 2009). The direct conceptual and physical relevance of factors, simplicity, and enormous data base upon which the equation was developed are the main advantages of this equation. Also, its capability to insert management considerations into factor selection is also one of its main advantages. One of the disadvantages is that the equation is an empirical model and does not take into consideration the physical factors that affect the sediment yield. One more limitation of the equation is that in applications for rangelands as well as croplands, the erodibility factors are not well developed.

**7 Estimation of soil erosion using remote sensing and GIS**

Soil erosion measurement on a basin scale is highly complex due to the variation in intensity of rainfall, soil types, land use, and topography. Also, the process of measuring soil erosion is time-consuming, costly, and typically limited to small experimental sites. However, the integration of GIS mapping and satellite remote sensing has proven effective for incorporating spatially varying parameters (Rajkumar et al., 2010). Various studies have using the RUSLE model to estimate mean soil erosion because it requires fewer input parameters, has a straightforward structure, and is compatible with remote sensing and GIS. In the RUSLE model, the annual soil loss was calculated through raster grid spatial analysis of six parameters: precipitation, topograpic, soil type, crop cover, and land management**.**

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