GIS and RS in Empirical Soil Loss Models
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Soil erosion is a serious worldwide environmental problem that stems from a combination of several factors such as agricultural intensification, deforestation, increasing population, and rainstorms. This phenomenon produces a soil fertility decline, removes soil rich in nutrients and increases natural level of sedimentation in the rivers and reservoirs reducing their storage capacity as well as life span (Amore et al., 2004; Pandey et al., 2007; Bouaziz et al., 2011). Quantify and identify the zones with the highest erosion trend, sediment yield, and sediment deposition are necessary for watershed management policies. For instance, soil conservation measurements can reduce land degradation and assure a sustainable management of soil resources (Amore et al., 2004; Bouaziz et al., 2011). Over time, different empirical models have being developed however, the Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978) is extensively used for prioritization of the watersheds (Pandey et al., 2007). Geographical Information System (GIS) and Remote Sensing (RS) facilitate the data management to estimate the model parameters (Amore et al., 2004; Pandey et al., 2007; Vemu et al., 2010; Bouaziz et al., 2011).

The model calculates the average annual soil loss with its distribution on the basin for given natural and anthropogenic conditions. The USLE is easy to parameterize requiring less data and time to run (Lufafa et al., 2003; Amore et al., 2004; Pandey et al., 2007). USLE has been applied at watershed of different sizes, for example small basin from 28 Km² (Pandey et al., 2007) and watershed with more extension like 4,500 Km² according to Bouaziz et al., (2011). Moreover, USLE has quantified soil loss worldwide. Ethiopia, India, Tanzania, Kenya and Uganda are good examples of countries which had used the model (Lufafa et al., 2003; Vemu et al., 2010; Bouaziz et al., 2011).

By the product of five factors, USLE predicts the soil loss potential for a given site in a long-term average (Amore et al., 2004; Pandey et al., 2007). The limitation of this model is that it does not estimate deposition, sediment yield, channel erosion or gully erosion. (Jain et al., 2001;
Dabral et al., 2008). The factors that represent the influence of climate, soils, topography, vegetation and management are combined in the empirical model (Eq. (1)) as follows:

\[ A = R \times K \times LS \times C \times P \]  

**Eq. (1)**

Where, \( A \) is average annual soil loss rate [tons ha\(^{-1}\) yr\(^{-1}\)], \( R \) is rainfall erosivity factor [MJ mm ha\(^{-1}\) h\(^{-1}\) year\(^{-1}\)], \( K \) is soil erodibility factor [tons ha h ha\(^{-1}\) MJ\(^{-1}\) mm\(^{-1}\)], \( LS \) is slope steepness and length combined in a single index, \( C \) is crop management factor and \( P \) is conservation supporting practice factor (Wischmeier and Smith, 1978; Lufafa et al., 2003; Dabral et al., 2008).

First, the study watershed is delineated with GIS, and then it is divided either into regular grids. For example Dabral et al., (2008) used a grid of 200x200m for their study basin; and Amore et al., 2004 divided the study basin into units where a unique runoff direction exists. (Pandey et al., 2007). Then, a map or thematic layers are created for each factor.

The “R” factor is in function of the falling raindrop and the rainfall intensity data. These data is determined using pluviometers in the study zone. For example, Amore et al., (2004) digitized an isoerodent contours map and interpolated between them to calculate “R” factor. On the other hand, Dabral et al., (2008) used a mathematical correlation to find “R” in function of monthly and annual rainfall data from a rain gauge station. In both cases GIS simplified the procedures and saved time due to its interpolation capabilities and ability to manage data (Lufafa et al., 2003).

The “K” factor depends of particle size, organic matter content and soil permeability class. This parameter can be quantified using an empirical correlation that includes the factors previously mentioned (Dabral et al., 2008). Another method is using digital maps where each class of soil was associated with the “K” factor from government agencies (Amore et al., 2004). GIS is one of the best tools to efficiently manage information layers and operate cells with mathematical models (Vemu et al., 2010).

The LS” factor can be determined with correlations supported by the Digital Elevation Model (DEM) simplifying the procedure complexity (Jain et al., 2001). GIS strengths are the DEM manage and the operation among information layers (Pandey et al., 2007).
Land use or land cover of the study area are required to determine “C” and “P” factors (Pandey et al., 2007). This information can be obtained from the satellite images. RS is essential to manage and process images using programs such as ERDAS-IMAGE, ENVI 4x and Arc GIS 10.2 (Bouaziz et al., 2011). For example, Pandey et al., (2007) classified their study area into eight land use classes using supervised classification method (Maximum Likelihood) and processing an “IRS-1C LISS –III” image with ERDAS IMAGE 8.4 like software. Bouaziz et al., (2011) used the same classification method with Landstat TM image to get land use classes and also to calculate vegetation cover from the Normalized Difference Vegetation Index (NDVI).

The “P” factor is calculated using a mathematical correlation in function of the “C” and “S” factors for each study zone pixel (Lufafa et al., 2003; Dabral et al., 2008). Other researches prefer a value equal to one for zones that do not have conservation practices (Amore et al., 2004; Pandey et al., 2007). As mentioned before, GIS is a powerful tool for operating math models in each cell and provide the output with the thematic map (Nisar Ahamed et al., 2000; Vemu et al., 2010).

After preparing each information layer, the five parameters are analyzed and multiplied into the specified cells using GIS according to the Equation (1) (Pandey et al., 2007). The output is an erosion map indicating in detail the areas of severe, high, moderate and low trend to soil loss (Dabral et al., 2008). Moreover, the area distribution identifies where the management practices and conservation strategies should be intensified (Bouaziz et al., 2011). It is noteworthy that calibration and validation procedures are necessary to optimize the model. These procedures are made using field data, experience of the researcher or previous study data. GIS facilitates data manipulation and repetitive necessary for calibration and validation procedures (Lufafa et al., 2003).

GIS and RS have a significant role in generation, quantification and management of the soil erosion model parameters (Pandey et al., 2007). The GIS and RS evolution have converted the conventional methods; which were tedious, time consuming and difficult to handle. Thank to this technologies we can generate maps that can be easily understood in a faster way. (Jain et al., 2001). The platforms GIS and RS have a promising future with the development of more specialized applications that integrate calculation procedures reducing the computation time and facilitating data management. (Dabral et al., 2008).
Annotated Bibliography


In this paper Amore et al. compares an empirical with a physical soil loss model, Universal Soil Loss Equation (USLE) and Water Erosion Prediction Project (WEPP) respectively. This study is applied to three Sicilian basins with different properties in order to estimate soil erosion due to water. The review shows whether and how subdivision detail affected the total computed soil loss from each basin, using GIS (Arc View GIS 3.1) for three different scales in function of their hillslopes. Amore et al. present how GIS can make soil erosion studies easier and faster, especially in repeated applications. The most interesting in this research is that a finer subdivision is not necessarily needed for a better estimate of eroded soil within the considered range of values (115 Km$^2$ – 570 Km$^2$), although experimental conditions for calibration models may be better defined. Finally, the authors make evident how USLE model allows a good approach in comparison with the WEPP model and the measured sediment volume, specifically for the smaller watershed of 115 Km$^2$.


In this paper Dabral et al. predict the spatial distribution of the average annual soils loss (AASL) for Dikrong river basin. They show how GIS (Arc Info 7.2) and RS (ERDAS IMAGINE 8.7 image processing software) works by generation of USLE parameters (land use, land cover and slopes). Moreover, Dabral et al. evidence the higher versatility, fastness and the accessibility for the creation of database, and detailed analysis with GIS and RSs in comparison to conventional methods. The use of false color composite and supervised classification to generate land use and land cover maps was a great example of GIS and RS capacity. They estimate that the AASL is 51 t ha$^{-1}$ year$^{-1}$ for the years 1988 to 2005 and almost 75% of the watershed area has high erosion risk, which require water and soil conservation measurements.

In this paper Bouaziz et al. analyze the contribution of land use, topography, rainfall, vegetation cover and soil properties in the control soil erosion using RS (ENVI 4.x) and GIS techniques in the basin of the Maleka Wakena (Ethiopia). A high to very high risk of erosion was indicated by the three erosion risk maps obtained with the applied models. Their mapping and modeling method is fast, straightforward and principally fed by remote sensing data, i.e. Landsat ETM+, image was used for land use information by means of supervised classification and also to calculate vegetation cover. The researchers suggest that vegetation cover is the major parameter that determines soil erosion risk level under arid and semi-arid climate. The most interesting section was how GIS and RS provide a flexible tool, applicable for a wide variety of regions.


In this paper Vemu and Udayabhaskar integrate USLE and Watershed Erosion Response Model (WERM) like a tool for Upper Indravati (India) watershed prioritization. They estimate the erosion risk assessment parameter of the catchment to achieve their objective. Vegetation density, slope, drainage density, form factor, circulatory and elongation ratio are used as parameters for watershed prioritization. This paper presents the versatility of GIS and RS to calculate and manage different variables for instance vegetation index, DEM, slopes and moreover the ease of operations among layers of information. The review how GIS (ILWIS) and RS help to classify the study zone was very useful because each subzone has a particular management program in function of its properties and risks. Vemu and Udayabhaskar noted that GIS and RS are subject to data limitations.

In this paper Lufafa et al. merge the GIS and RS facilitates to generate soil erosion map in Lake Victoria basin (Tanzania, Kenya and Uganda). Lufafa et al. stand out the GRID GIS property to do operations and analysis among cells to identify problem areas and adopt the best management practices for each case. The authors also mention the advantage of the GIS and USLE approach to predict soil loss over large areas due to the interpolation capabilities. Moreover, how important is to forecast when there are data limitations and problem of access to the study zone. Lufafa et al. found that the soil loss estimates were about 5 t ha⁻¹ year⁻¹ and corroborate those from field measurements, which is a more realistic indicator in comparison to the previous one. The groundcover was more important than canopy layer according to the authors of this study. Finally, they suggest the model calibration to improve its accuracy.


Morgan and USLE models with support of GIS (ILWIS) and RS (ERDAS) were used in this study to estimate the soil erosion in the subwatershed Siltlarao (India). Jain et al. show how the GIS utilities calculate the components of soil erosion models faster, with more quality and that can be understood better. According with Jain et al. GIS provides an efficient way to the land use management strategies and reduce the soil loss. Morgan et al. is very clear to mention that results of this study are not calibrated and/or validated, being a reason of difference in numerical results with both models. Therefore, qualitative soil loss estimation is preferred for this research instead of quantitative estimation. Their study showed that forested and open scrub areas show less soil loss compared to unprotected areas like fallow lands, which contribute to high soil loss.

Pandey et al. quantify the soil loss on grid using USLE to identify the critical erosion in the basin for planning conservation. They divided a watershed into 200×200m grid cells and estimated average annual sediment yields for each cell of the watershed. Pandey et al. show how GIS (ARC Info 7.2) and RS (ERDAS IMAGINE 8.4) data was able to determinate the spatial distribution of the USLE parameters such as land use and land cover. According to the study, the strength of GIS lies in its ability to handle spatial data and attribute information at a higher level of resolution. Moreover, high-quality output, easy updating capabilities, and the possibility for testing management options made GIS useful for providing the most efficient solution for handling soil erosion problem. They found that the average annual soil erosion for the study area was 3.66 t. ha⁻¹ yr⁻¹.
REFERENCES


