



## Review on Revised Universal Soil Loss Equation (RUSLE) using GIS Application

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### ABSTRACT

Soil erosion is an environmental, economic and social problem recognized universally, which the world is facing in the 21st century. It leads not only to severe land degradation and soil productivity loss, but the danger also threatens the well-being, stability and health of all facets of society, and rural areas sustainable development in particular. According to recent evaluations over 80% of world's agricultural land is afflicted with moderate to severe erosion with exacerbated loss of productivity. Because of this and population expansion, the global per capita food supply is presently waning. Estimation of soil erosion loss and assessment of soil erosion risk becomes a pressing task by many nations before implementing soil preservation practices. There is now a huge published literature on the relevance of the Revised Universal Soil Loss Equation (RUSLE) in blend with Geographic Information System (GIS) technology for predicting soil loss and erosion risks in diverse regions. This review paper assesses the current literature on the combined application of RUSLE and GIS, exploring new developments in deriving the five RUSLE components. This literature review shows that using the traditional RUSLE in mapping out soil erosion in large watersheds poses challenges due to the cost, labour and time involved. The amalgamation of GIS technology with RUSLE has improved the effectiveness of estimating spatial distribution and scale of erosion risk with practical costs and better accuracy.

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### INTRODUCTION

Soil erosion is the process in which the surface layer of the weathered rock is loosened and carried away by running water or wind (Angima, *et al.* 2003; Jahun, *et al.* 2015). The most dominant agent of erosion is water where the course includes detachment, then transportation and finally deposition of particles (sediment) by impact of raindrop and flowing water (Julien, 2002). Erosion usually takes place when soil is left exposed to rain or wind energy, whereof making raindrops hit exposed soil with enormous energy and easily displaces the soil particles from the earth surface (Merritt, *et al.* 2003). Studies have discovered that eroded soils are one of the main problems in agriculture and natural resources

managing. It reduces soil efficiency, fills the reservoirs and pollutes the streams (Fangmeier, *et al.* 2006). A different resultant effect is decline in landscape beauty, a threat to food security, swell in the probability of flood in flood plains, loss of aquatic biodiversity in rivers and lakes, reduced quality of water by pollution and eutrophication (Bewket, and Teferi, 2009; Wang, *et al.* 2002). It also causes air pollution through the emission of gases such as nitrous oxide, carbon dioxide and methane (Cox, and Madramootoo, 1998).

Soil erosion is one of the environmental problems facing the world in the 21st Century, upsetting human society, universally recognized as a serious hazard to the wellbeing of human (Abidin, and Ayob, 2012). It is considered the

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second rife environmental problem the world suffers from, after population growth According to Angima, *et al.* (2003). Ownegh, (2003) reported that in the tropics, soil erosion becomes a very serious problem as it is accompanied by a very serious environmental impacts that are dangerous to life.

A recent appraisal by Wardafo, (2011) shows that over eighty per cent of the world's expanse of agricultural land suffers from moderate to harsh erosion which leads to loss of productivity. Coupled with population growth, this therefore, leads to the present fall in global per capita food supply. Further, 85% of the land degradation in the world is connected with soil erosion, most of which happened since the end of Second World War, causing a 17% cut in crop output (Angima, *et al.* 2003). Khosrokhani and Pradhan, (2013) and Pradhan *et al.* (2012) upheld that in world countries like Malaysia, intense rainfall is usually experienced, which causes landslides and soil erosion especially in steep areas where gigantic developments occur, as a result of heavy pressure from urban and agricultural development. In the past 40 years or so, thirty per cent of the world's arable land has turned unproductive due to erosion (Merritt, *et al.* 2003). With this rebelation therefore, we can aptly say that erosion poses a great challenge to human existence, since it adversely affects food production. Therefore, this poses the need for countries to guarantee timely and accurate assessment of risks. It is also pertinent to estimate of fast the soil erodes before effecting any conservation strategies (Jahun, *et al.* 2015).

As a result of the nature of erosion process, its control requires a quantifiable and qualitative assessment of possible soil erosion on a specific site, and the knowledge of cropping system, terrain, soils, and management practices. Thus, it can instrument a few farms or catchments to obtain the desired and requisite data, but to study every location on the Earth's surface in detail is not feasible. Instead, prognostic or predictive tools are required to be applied. Models of erosion can fulfill this function (Morgan, 2011). Erosion models can be applied as prognostic tools for evaluating soil loss, when and where erosion is

stirring, and as tools for studying erosion processes and their connections, and for setting research priorities according to (Nearing, *et al.* 1994).

Numerous soil erosion and sediment transport models have been developed around the globe to help estimate scales of sediment and nutrient transportation under diverse land use systems. Essentially, research identifies three types of model - the conceptual models, the empirical models, and the physically-based models (Merritt, *et al.* 2003). The Universal Soil Loss Equation (USLE) and the Geographic Information System (GIS) based USLE are some of such models. Further research and empiricism have led to an improvement of the USLE model. The upgrades equations developed on the USLE model are such the likes of the Areal Nonpoint Source Watershed Environmental Resources Simulation (ANSWERS) by Beasley (Ahmad, 2013), the Modified Universal Soil Loss Equation (MUSLE) by Williams (Ahmad, 2013), the Revised Universal Soil Loss Equation (RUSLE) by Renard (Renard, *et al.* 1997) and the Unit Stream Power – based Erosion Deposition (USPED) by Mitsova (Mitsova, *et al.* 1996; Abdul Razad, *et al.* 2012). In their inputs and requirements, complexity, the ways in which the processes are represented, the rate of intended use and the types of output information they render, these models, however, differ significantly.

## LITERATURE REVIEW

### **Revised Universal Soil Loss Equation (Rusle)**

USLE came up as a leading model, and has been generally used equally in United States and the world over, in both agricultural and hilly watersheds due to its simplicity of getting parameters (Teh, 2011; Jahun, *et al.* 2015). As cited in Teh, (2011), the model was first developed by Wischmeier, and Smith, (1978) by collecting data of soil erosion in 21 States in US, analyzing and assessing differing dominating factors of soil erosion, and introducing USLE to assess soil erosion by water. USLE predicts the long-term average and annual scale of erosion on a field slope based on crop system, topography, soil



type, rainfall pattern, and management practices (Kouli, *et al.* 2009).

Therefore, all-inclusive research on soil erosion by water has been carried out using the model for many decades now. The model was then enhanced and replaced by the revised edition now identified as RUSLE by more data, and accommodating recent research outcomes, to further enhance its ability to, by integrating information that through research of last 40 years Renard, *et al.* (1997) has been made available, make a prognosis of water erosion. Still today, RUSLE is widely used, and in addition, the combination of GIS techniques and remote sensing with models of soil erosion, such as RUSLE, proved to be an efficient and effective approach for determining the degree and spatial distribution of erosion by researchers. GIS is a tool efficient in integrating various datasets and assessing ever changing system like soil erosion (Jahun, *et al.* 2015). The aim of this paper is to review the current state of erosion assessment and GIS applications in the literature. This will include: 1) the traditional application of the RUSLE model in assessing erosion, 2) the application of GIS and remote sensing techniques in forecasting and estimating the magnitude and spatial distribution of erosion at catchments or regional scales using RUSLE.

### **Geographic Information System (GIS) for Soil Erosion Modeling**

The risk of soil erosion differs spatially sequel to heterogeneous geology, topography, geomorphology, land cover, soil types, and land use (Peter, *et al.* 2012). Conventionally, the RUSLE model was developed to assess the risk of soil erosion for watersheds that are of small local-scale. However, with the spatially pervasive occurrence and rushing of the soil erosion progression and problems of water quality, traditional RUSLE application now becomes expensive and the predicted result reliability becomes questionable. In addition, soil erosion spatial distribution mapping becomes often problematic using the traditional RUSLE model (Lu, *et al.* 2004). The dawn of GIS is able to handle these spatially variable data efficiently and easily.

The estimation of soil erosion with GIS techniques drastically cuts costs and enhances accuracy (Peter, *et al.* 2012). State-of-the-art GIS gives the essential mapping and interpolation methods to generate a database, which encompasses all datasets input for erosion modelling. GIS is considered most fitting for the handling of huge amounts of data. It scales down time and costs for getting access to and handling a database (Peter, *et al.* 2012). De Roo *et al.* (1996) described even additional advantages of GIS, such as the complex input maps production, and the combination of soil, land cover and land use information. With GIS techniques, it makes easier the computation of rates of soil loss for alternative land management scenarios.

### **Rusle Factors Methods of Estimation in GIS Environment**

The application of RUSLE in GIS frameworks has been used in various situations such as large-scale watersheds, mountainous tropical watersheds, in areas with distinct wet and dry seasons, in agricultural watersheds, and also in areas with dynamic changes like agricultural farmlands inland cover patterns, and developments. The RUSLE model consists of 3 main databases: 1) Survey and climatic database that contain information such as monthly precipitation and temperature and contours that is required for the computation of the erosivity factor plus the steepness factors and slope length (LS). 2) Crop database which contains information required for estimating the surface cover factor (C). 3) The soil data contains information of soil survey and soil characterization, which is responsible for scaling the soil erodibility factor (K) (Jahun, *et al.* 2015).

RUSLE calculates the loss caused by average annual soil erosion by considering five factors as defined in Eq. 1 (Renard, *et al.* 1997). Hinging on a plethora of literature, the universal methodology of applying RUSLE is to calculate each of the factors in the model. There have been developed by previous researchers several techniques for estimating the factors, ranging from remotely sensed satellite images, geological maps, use of climate data, soil and, empirical

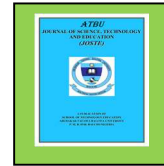
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formulas and digital elevation model (DEM) gotten from various sources (Jahun, *et al.* 2015). The techniques applied to generate the model factors and results obtained are described in the following sections of this article.

$$A = RKLSCP \dots \dots \dots (1)$$

where; A = predicts rill soil loss and prolonged time average of annual sheet and, t ha- 1 yr- 1, R = rainfall-runoff erosivity factor, MJ mmha - 1 h - 1 yr- 1, K = soil erodibility factor, Mg h MJ - 1 mm - 1, L = slope length factor, S = slope steepness factor, % C = cover and management factor and P = support practice factor.

### RAINFALL EROSIIVITY FACTOR (R)

This is the budding ability of rain to induce soil erosion; it dependent on the physical character of rainfall; these factors are Rainfall intensity, Drop size distribution, Terminal velocity and Wind velocity (Lal, 1990). In erosion estimation by RUSLE, R factor is the mainly the significant parameter which is the battering effect of raindrops on the surface of the soil, leading to the detachment of soil particles. This is as suggested by several researchers, and in many rainfall site stations of the world, its correlation with soil loss is high (Fu, *et al.* 2006; Jebari, 2009).

The universal procedures applied by researchers in estimating the erosion factor involve using data of observed historical rainfall, as well as the application of several different formulas, which depend on the existing conditions of an area. The R factor estimation poses a challenge in data poor areas or in situations extremely sparse climate stations (Kurt, 2011). Wischmeier and smith propounded the following empirical equation for ascertaining the total amount of kinetic energy in a storm (E) to be used to kick off the motion of sediment particles as;

$$E=916+331 \text{ [(log)] } _{10} I \dots \dots \dots (2)$$

where: E = foot-tons per inch and I = intensity of the storm in inches per hour.

Renard, *et al.* (1997) demonstrated that in order to obtain precise R factor, EI30 needs to be determined over a number of years for multiple

stations sited at the area of the study site with continuous records and the most excellent equation for R factor was propounded by Wischmeier and Smith, which is shown in Eq. 3 below (Teh, 2011).

$$R = \frac{1}{n} \sum_{j=1}^n [\sum_{k=1}^m (EI_{30})_k] \dots \dots \dots (3)$$

where: R is Rainfall erosivity factor, E is the total storm kinetic energy (MJ/ha), I30 is equal to the maximum 30 minutes' rainfall intensity, j means the index for the count of years used to calculate the average, k stands for the number of storms in each year index, n is the number of years required to calculate average and m is the each year number of storms

To calculate rainfall energy and maximum 30 min rainfall intensity (EI30), continuous rainfall intensity data are required. It is suggested to get rainfall data of at least 20 years so as to contain the natural climatic variation (Teh, 2011). But since such data are not obtainable for many places in the world, researchers have put forward methods to approximate rainfall erosivity from data for annual precipitation, and the studies have shown good connection between the factors for multiple locations around the world (Lee and Heo, 2011). Fu *et al.* (2006) developed a comparable R factor (Req) for Inland Pacific Northwest region in USA by attempting to relate the R factor linearly with the local annual precipitation (Pr) see Eq. 4.

$$R_{eq} = -823.8+5.21P_r \dots \dots \dots (4)$$

where: R<sub>eq</sub>= Equivalent R factor for unique climatic condition and P<sub>r</sub> = annual precipitation (mm)

Another analogous equation put forward by Bols (1978) cited in Teh, (2011) also faced similar setting of bare climate data when evaluating risk of erosion in Indonesia in a particular watershed for computing the R value as shown in Eq. 5 below, where P is the annual precipitation in mm.

$$R = \frac{2.5P^2}{100(0.07+0.78)} \dots \dots \dots (5)$$

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Mikhailova et al. (1997) developed an equation relating their determined R-factor to both elevation and mean annual precipitation in Honduras. In their study, they first established link between R-factor and each one of the other two parameters. Their linear equation for R as a function of P is depicted in Eq. 6. Their relationship was very good.

$$R = -3172 + 7.562P \dots\dots\dots(6)$$

where R =  $M_j \cdot \text{mm}/(\text{ha} \cdot \text{hr})$  and P = precipitation/year (mm)

Torri, et al. (2006) detected a similar linear relationship between annual rainfall (mm) and rainfall erosivity in Italy as seen in Eq. 7.

$$R = -944 + 3.08P \dots\dots\dots(7)$$

where R =  $(M_j \cdot \text{mm}/\text{ha} \cdot \text{yr})$  and P = precipitation/year (mm)

Furher, Renard and Freimund (1994) developed a method for estimating R-values for stations that lack rainfall intensity data that is for long-term. After analyzing R-factor that is available from isoerodent maps and the precipitation data per year, Eq. 8 and 9 were suggested for determining the R factor:

$$R = 0.04830P^{1.610}$$
$$P < 850 \dots\dots\dots(8)$$

$$R = 587.7 - 1.219P + 0.004105P^2$$
$$P > 850 \dots\dots\dots(9)$$

where R stands for annual rainfall erosivity (MJ, mm, ha<sup>-1</sup> H<sup>-1</sup> Year<sup>-1</sup>) and P meaning annual precipitation (mm).

Since the present RUSLE version needs input in U.S. customary units, values resulting from the equations should be divided by 17.02 to get the value in units of hundreds of tons. ha<sup>-1</sup>. Year<sup>-1</sup> (Ahmad, 2013). Renard and Freimund, (1994) equations above were used to calculate R factor. The R factor for each data point and the average annual rainfall and are put into ArcGIS and are spatially interpolated by the use of the

Ordinary Kriging method that are found in the ArcGIS of Spatial Analyst toolbox.

Estimation of the annual rainfall erosivity by the use of the Modified Fournier Index (MFI) has been put forward when only data for monthly precipitation are obtainable, and this is defined by Eq. 10 (Arnoldus, 1977).

$$MFI = \frac{\sum_{i=1}^{12} p_i^2}{p_1} \dots\dots\dots(10)$$

where: P = mean annual rainfall depth (mm) and P<sub>i</sub> = mean rainfall amount for month i (mm)

Also, for a time of N years, MFI which is then referred to as MFI<sub>N</sub> defined as (Foster, et al. 1991):

$$MFI = \frac{1}{N} \sum_{j=1}^N \sum_{i=1}^{12} \frac{p_{ij}^2}{p_j} \dots\dots\dots(11)$$

where: MFI<sub>N</sub> is Modified Fournier Index, P<sub>i,j</sub> = rainfall value in particular month i of the year j and P<sub>j</sub> stands for total rainfall for the particular year.

The link between MFI and R factor indicated better adjustment, which follows an exponential distribution (Ferro et al. 1999). The R factor values can possibly be estimated from the MFI by the use of the following eq. 12.

$$R = aMFI^b + \varepsilon \dots\dots\dots(12)$$

where: a and b stand as empirical parameters, and e, a random, normally distributed error.

This equation was used by Kouli, et al. (2009) in Greece in Crete watershed purposely to estimate MFI for 35 rainfall gauge stations. The factor for erosivity was then estimated on the basis of the determined MFI by the use of Kriging interpolation method and this was shown to range from 3020–3687 MJ mm/ha year<sup>-1</sup> to 2353–3019 MJ mm/ha year<sup>-1</sup>. The same formula was used by Pradhan et al. (2012) in their study of the relationship of soil erosion with events of landslide in Malaysia.

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**Soil Erodibility Factor (K)**

Soil erodibility factor (K factor) can best be described as the soil's inclination to erode. This is dependent on the properties of the local soil (Jebari, 2012) and it has relationship with the integrated effect of rainfall, runoff and consequent infiltration on soil loss. The K factor estimates the propensity of surface materials or soil particles to detachment and transportation by rainfall and runoff input (Renard, *et al.* 1997). To determine the K factor, Wischmeier and Smith, (1978) suggested a simple procedure estimating five soil properties such as sand, percent organic matter, soil structure and permeability and silt. The best methods in estimating these soil properties as input to K factor are testing of the site of interest and field sampling (Yitayew, *et al.* 1999). Nomograph method is subsequently used to determine K factor from the characteristics of soil found through sampling. Nonetheless, the shortcoming of this method is its time consuming and laboriousness (Jahun, *et al.* 2015).

The general trend in researchers is utilizing obtainable soil maps in areas of availability of soil maps from government departments in hardcopy format to digitize them and produce a vector coverage map. The different soils are then grouped into classes extracted from sources like the Agricultural Handbook as suggested by Jahun, *et al.* (2015) or the Food and Agricultural Organization soil classification system as in use by Millward, and Mersey, (1999). Then a raster map is produced by converting the vector soil map by the use of ArcGIS tool. Ozcan *et al.* (2008) used the USLE and GIS method in their research in Kazan watershed in Turkey, where they calculated soil loss of agricultural watershed. The soil map so generated of the Kazan watershed showed high soil erodibility of close to 88.9%, containing very fine sandy textures and silt loam soil within the watershed (Jahun, *et al.* 2015).

For the watershed, to estimate the K factor, the soil map will serve as the base for deriving the layer of erodibility factor. Within the watershed, K factor values are allotted to corresponding soil types, and the K factor is

derived by the use of Eq. 13 as proposed by Renard *et al.* (1997).

$$K = 0.0034 + 0.0405 \times \exp \left[ -0.5(\log D_g + 1.659/0.7101)^2 \right] \dots\dots\dots (13)$$

$$D_g = \exp \left( \sum f_{i,m} \left( \frac{d_i + d_{i-1}}{2} \right) \right) \dots\dots\dots (14)$$

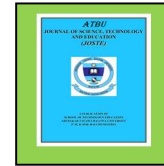
where:  $d_i$  = represents the maximum diameter (mm),  $d_{i-1}$  is the minimum diameter (mm), and  $f_i$  stands for the matching mass fraction for each of the particle size of silt, clay and sand.

Kouli *et al.* (2009) used this formula in their research for predicting erosion scale with RUSLE in a GIS framework in Greece in Chania watershed. A rasterized layer of K was generated and the outcomes indicated that the values of erodibility range from 0.02 ton ha MJ<sup>-1</sup> mm<sup>-1</sup> in very large areas of sandy soil to 0.04 ton ha MJ<sup>-1</sup> mm<sup>-1</sup> for loamy and silt loamy soils of the research area. Their findings also indicate that the highest values of K factor happen to be spatially correlated with the areas that revealed 104eogene and quaternary sediments.

**Topography/Slope Factor (LS)**

Topography influence on soil erosion is accounted for by RUSLE LS factor, which puts together the effects of slope length factor (L), and steepness factor of slope (S) (Kim, 2006). This shows that any increase in the slope length (L) results in corresponding increase in soil erosion per unit area as a result of the surface runoff progressive accumulation on downslope direction. With slope steepness (S) increase, the velocity and surface runoff soil erosion also increase (Ahmad, 2013). Slope length is accordingly defined as the distance from the point of overland flow origin to the point where either the gradient of the slope decreases enough where deposition begins, or the flow is concentrated in a defined channel (Renard, *et al.* 1997). The steeper and longer the slope, the more the speed and increase of water, and the higher the risk of erosion (Mushtak, 2003; Kim, 2006).

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The universal procedure adopted by several studies for estimating topographic effect on erosion is computing both factors (L and S) jointly. These days, with GIS technology, researchers have adopted the use of DEM for generating data of topography. DEM is extracted from existing or digitized contours with clearly known interval. Many formulae are there capable of computing topography. Many researchers have used the technique proposed by Moore, and Burch, (1986). This technique requires accumulation of flow and steepness of slope, as shown in Eq. 15.

$$LS = \left( \text{Flow accumulation} \times \frac{\text{cell size}}{22.13} \right)^{0.4} \left( \frac{\sin(\text{slope})}{0.0894} \right)^{1.3} \dots \dots \dots (15)$$

For ArcGIS, Bizuwerk *et al.* (2008) indicated that the K factor is used in single index, which shows the soil loss ratio as Eq. 16 (Bizuwerek *et al.* 2008) defined for ArcGIS purpose shown below:

$$LS = \left( \frac{X}{22.1} \right)^M (0.065 + 0.045S + 0.0065S^2) \dots \dots \dots (16)$$

where X = slope length (m), S = slope gradient (%) and M = coefficients given in Table 1.

**Table 1:** M value for LS factor

M Value	Slope (%)
0.5	>5
0.4	3-5
0.3	1-3
0.2	<1

The values of X and S are derived from DEM. In order to calculate the value of X, flow Accumulation is derived from DEM upon conducting the processes of Fill and Flow Direction in ArcGIS.

$$X = \text{flow accumulation} \times \text{cell value} \dots \dots \dots (17)$$

By substituting X value, LS equation is going to be:

$$LS = (\text{Flow accumulation} \times \text{cell value} / 22.1)^M (0.065 + 0.045S + 0.0065S^2) \dots \dots \dots (18)$$

Slope (%) is also derived directly from DEM by the use of the same software (Teh, 2011). The m value varies from 0.2-0.5 dependent of the slope as shown in Table 1.

Further, Moore *et al.* (1993) as cited in Abdul Razad, *et al.* (2012) developed a method for determining topography data with 20m contour intervals, and this was used to breed flow direction and flow accumulation for the catchments and L the factor computed as Eq. 19

$$L = 1.4 \times ((\text{Flow Accumulation} \times \text{Cell Size}) / 22.13)^{0.4} \dots \dots \dots (19)$$

Flow Accumulation is the number of cells released by the flow path, and Cell Size is the length of the computational grids. S Factor is computed using a formula by Moore *et al.* (1993) as cited in Abdul Razad, *et al.* (2012).

$$S = \left( \frac{\sin(\text{slope})}{0.0896} \right)^{1.3} \dots \dots \dots (20)$$

Duplication of the S Factor and L Factor will create the LS Factor which for a specified land is a topographic factor.

Lim *et al.* (2005) developed a GIS integrated prototype version of the Sediment Assessment Tool for Effective Erosion Control (SATEEC) to render a GIS interface that is easy-to-use to approximate sediment yield and soil erosion with no additional contribution data apart from those for the USLE model. They used the method developed by Moore, and Burch, (1986) in the SATEEC prototype to calculate the topography factor from DEM by giving an upper bound of slope length of 122 m. Even though the prototype was not validated in their study, it renders results that are acceptable.

Kouli *et al.* (2009) used a technique that is similar to RUSLE, such that Arc- Info Grid was put into use to compute steps of flow path build on iterative slope-length accumulation. Each slope value was designated in each 20m cell of the grid

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surface of the watersheds. Results showed that the topography factor ranged from zero in a flatter zone to 118 at steeper slopes. Results also point that extended areas of steep slopes happened to be prone to harsh erosion as compared to smaller scales which showed less propensity to erosion.

**Vegetative Cover and Management Factor ©**

Vegetation cover is considered one of the most important factors in stopping soil erosion, and the most difficult to calculate over wide geographic areas Abidin, and Ayob, 2012); Ahmad, 2013; Teh, 2011). Ground cover may tend to drive away the raindrop erosive power before hitting the soil surface, thus making the rainwater to reach soil surface by stem flow and drop of leaves which are not capable of detaching apart soil particles. The C factor stands for the influence of vegetation canopy and ground covers in cutting down soil loss (Alejandro and Kenji, 2007). In general, as we increase the protective canopy of land cover, soil erosion falls (Lee, 2004).

Nevertheless, the most widely applied technique for deriving the surface cover factor these days is by employing remote sensing methods in the production of land use/cover classifications from satellite images. Lu *et al.* (2004), in their research in the Brazilian Amazonia of mapping soil erosion risk, based their approximation of surface cover on fraction images from spectral mixture study (SMA) of Landsat ETM+ image. By the use of Eq. 21, the C factor was calculated on the supposition that abundant vegetation cover leads to less soil loss, and the matching higher losses are as a result of lesser vegetation cover. Notwithstanding, they caution that in the process of developing the C factor, there remains the need to calibrate results obtained using local (reference) data at the time of image acquisition, as surface characteristics is captured.

$$C = \frac{f_{soil}}{1+f_{gv}+f_{shad} +f_{gv}+f_{shade}} \dots\dots\dots (21)$$

where:  $f_{soil}, f_{gv}, f_{shape}$  = values of soil, green vegetation and shade end members and Values of

$f_{soil}, f_{gv}, f_{shape}$  parameters start from 0 to 1 and their total sum equals 1.

The Normalized Difference Vegetation Index (NDVI) happens to one of the mostly used methodical processes to determine the C factor by the use of remote sensing for soil erosion evaluation over large geographic or regional area. It has been explored for mapping the C factor linking it to USLE and RUSLE in regression (Lu *et al.* 2004). NDVI shows the energy reflected by the earth for different conditions of surface cover types and is derived from the Eq. 22 for LandSat-ETM. NDVI values apply the use of 2 bands: visible band (band three or two of LandSat ETM) and the infrared band (band four of LandSat ETM), and the index values starting -1.0 from +1.0. When the estimated spectral response of the earth surface becomes very similar to both bands, the NDVI values approach zero. A large variation between the 2 bands results in NDVI values at the boundaries of the data range (Kouli, *et al.* 2009). Vegetation that is growing actively signify a high reflectance within the Infrared portions of the spectrum (Band 4, Landsat TM), as compared with the portion that is visible (red, Band 3, Landsat TM), therefore the NDVI values for actively growing vegetation is positive. NDVI values for very low vegetative surface cover range from -0.1 to +0.1, while clouds and water bodies indicate a minus or zero values (Kouli, *et al.* 2009).

$$NDVI = \frac{LTM4-LTM3}{LTM4+LTM3} \dots\dots\dots (22)$$

Kouli *et al.* (2009) made use of the NDVI technique to get the C factor in their prediction study of soil erosion in Greece. The derivation of C factor surface was from NDVI values by the use of Eq. 23 as recommended by Van der Knijff, (2000). The results appeared to be realistic indicating that forest areas had C values nearing 0 while for rocky terrain approaching 1. They also showed that the slope values predicted for the arable lands are affected by management practices and crop type.

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$$C = e^{-\alpha\left(\frac{NDVI}{\beta-ND}\right)} \dots\dots\dots (23)$$

where: NDVI = Normalized Difference Vegetation Index, Alpha ( $\alpha$ ) = 2, and Beta ( $\beta$ ) = 1 parameters that estimate the shape of curve relating to C factor and NDVI

Pheerawat *et al.* (2012) applied the remote sensing method in their study on soil erosion risk in Thailand. They made use of satellite pictures of landsat 5 (TM) in 1990, and landsat 7 of 2010, to recognize land use patterns of study area by the use of Segmentation Classification of IDRISI Taiga software (Clark Labs, Clark University, USA). Recent works by Mitasova, *et al.* (1996) also used the remote sensing procedure in their works on erosion and landslide research in Malaysia. They used SPOT 5 images of 2005 and 2010 with 10m spatial resolution to get the C factor from a land cover map.

#### Support Practice Factor (P)

Conservation and management support practice factor (P) used in RUSLE happens to be a dimensionless ratio explaining the ratio of loss of soil with support practice that are very specific to matching soil loss with downslope and upslope tillage (Jahun, *et al.* 2015; Renard, *et al.* 1997; Teh, 2011; Reshma and Uday 2012). These practices in essence affect erosions by adjusting the flow patterns, steepness, or direction of surface runoff, and by cutting the rate of runoff (Kim, 2006; Ahmas, 2013; Renard, *et al.* 1997).

Support Practice Factor (P) ranges from 0 to 1, which is equal to 1 when land is directly plowed on the slope, and the value is less than 1 when the conservation practice adopted reduces soil erosion. Contouring and terracing are common and effective support practices on the field level. The effects of terracing are bear on the hill slope gradient and length, because it accordingly reduces the hill slope length. The generally adopted approach for estimating the conservation factor is by developing empirical equations. Fu *et al.* (2006) used the Wenner method suggested by Lufafa, *et al.* (2003) in China to derive the conservation factor value as given by Eq. 24. The equation only needs a slope which

can be easily extracted from available DEM. Based on the equation, the value of P factor can be applied in surroundings where there is less or no conservation and management practices. Khosrokhani and Pradhan (2013) applied this equation, in their appraisal of soil erosion in Kuala Lumpur city, in order to obtain P values ranging from 0.2 to 2.58. The areas with greater slope were assigned the highest values, while minimum values are matched with regions with lower slopes.

$$P = 0.2 + 0.03S \dots\dots\dots (24)$$

Where S = slope grade (%)

#### Total Soil Loss

The relevance of the RUSLE equation is to separate each variable and measure its erosional effect in such a way that the end product of the values considered of all the variables in effect gives the amount of soil loss in the field under examination (Kim, 2006; Ahmad, 2013; Abdul Razad, *et al.* 2012). To determine the overall loss, the five surfaces of the watershed that are gridded were aggregated by the use of GIS implements to produce soil erosion potential and risk map.

Typically, the map is classified into many risk levels-ranging from low to very high risks. In their study in Katsina area, Adediji *et al.* (2010) found that soil loss ranged from moderate to levels of severe risk. Additionally, Lu *et al.* (2004), in their study of Brazilian Amazonia detected that soil loss ranged from very low to low risk levels. Kouli *et al.* (2009) in the Crete watershed got that there was a high correlation between steepness of slopes and poor surface cover in the watershed. Abdul Razad, *et al.* (2012) in their use of RUSLE in the relatively small watershed of Chenderoh Catchments in Malaysia broke the soil loss into classes in the watershed. They realized that the average rate of erosion was 299,960 tons/yr or the equivalence of 3.0 tons/ha/yr. These amounts indicate that Chenderoh catchments witnessed low erosion rate.

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## CONCLUSION

This review shows that the GIS is a system that captures, stores, integrates, analyzes, manages and visualizes data that are connected to coordinates or locations (Omar, 2010; Ahmad, 2013). The amalgam of GIS technology with erosion models like the RUSLE has over the years improved the efficiency for determining spatial distribution and magnitude of erosion risk with effective costs, easier and better accuracy as compared to the traditional RUSLE computation, as acknowledged by several researchers (Gibbs, *et al.* 2003; Neshat, *et al.* 2014; Fu, *et al.* 2006). Soil erosion risks vary spatially because of assorted topography, geology, geomorphology, soil types, land cover and land use. GIS can handle these spatially variable data with ease and efficiently, Therefore, RUSLE computation in GIS environments is an effective approach for estimating soil loss in a given watershed.

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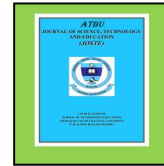
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