Temporal Assessment of Soil Loss in Owerri Using the Revised Universal Soil Loss Equation (Rusle) Model and Geospatial Techniques

Amadi A. K., Amangabara G. T., Owuama C. O.

Abstract— **Temporal Assessment of soil loss in Owerri is a GIS-based time series study which incorporates the Revised Universal Soil Loss Equation (RUSLE) soil erosion model to calculate annual soil loss value and estimate soil erosion linked with precipitation and landuse in Owerri. Five parameters are used in the RUSLE model to estimate soil loss namely rainfall erosivity (R), soil erodibility (K), slope length and steepness factor (LS), cover management factor (C) and conservation practice factor (P). In the GIS environment and application "Flow Length" was used instead of "Flow Accumulation" to estimate the slope length and steepness (LS) factor. The modeling was carried out for year 2000 and 2015, using a LANDSAT remotely sensed data, digital elevation models, rainfall data from the study area, as well as existing soil maps. After running the RUSLE model and analyzing the result maps, no significant change in soil erosion trends or patterns were found, as well as no significant change in precipitation trend and land cover changes during the period 2000 to 2015. The study shows that the average annual soil loss for Owerri was estimated to be 315 t h-1 yr-1 .Rainfall erosivity was 3260.85 MJ mm ha−1 h−1 y−1 in year 2000 and increased to 3355.08 MJ mm ha−1 h−1 y−1 in year 2015 with a corresponding erodibility value of to 0.1302 t h-1 yr-1 in 2000 which increased to 0.1395 t h-1 yr-1 in year 2015. Observations shows that the areas of the study area where the topography is hilly and cut through by streams appear to have high risk of soil loss compared to the western part of the study area and also have a good NDVI analysis.**

Index Terms— **landsat, temporal, assessment, precipitation, parameters, erosivity, erodibility, topography.**

I. INTRODUCTION

Soil is the most integral part of the earth crust, which supports life through agriculture, construction etc. Overtime, this soil has been over exploited and is under pressure as a result of various anthropogenic activities such as deforestation leading to desertification, over exploitation and pollution due to urbanization. Some natural, technological and social disasters have also contributed to soil loss locally and globally, they include; earthquakes, floods, hurricanes, landslides, volcanic eruptions; toxic spills, transportation activities, explosions in industrial plants; riots, acts of terrorism, crowd crushes, etc. According to Millward and Mersey, (1999) and Hoyos, (2005) soil erosion and related land resources degradation have been stated to be significant environmental and socio-economic problems in a lot of countries all over the world. Soil erosion is a natural occurring activity; its significance to humanity depends on a host of factors which include climate, topography, nature of soil, nature of human activities. Soil loss is mainly associated with practices such as farming that do not conserve in-situ, such as deforestation and overgrazing. Some other activities such as mining, urbanization, construction, do not consider hydrological conditions.

According to recent researches and assessments, over 80% of the world's agricultural land suffers from moderate to severe erosion which results to loss of productivity. Due to this and population growth, the global per capital food supply is currently declining. In many parts of the world, surface impacts on soil loss are frequently coupled with off-site impacts related to the increased mobilization of sediments and its transportation to rivers. These off-site impacts include water pollution, degradation of aquatic habitats, reservoir sedimentation, and increased cost of water treatment (Ritchie *et al*, 2003). Soil erosion increased throughout the 20th century, about 85% of global land degradation in the world is connected to soil erosion (Piccarreta *et al*., 2006).

Agents of soil erosion are wind and water, each contributing a significant amount of soil loss each year. Erosion of soil may be a slow process that continues relatively noticed which may lead to extreme top soil loss. According to Deniz *et al.*, (2008) soil erosion caused by water is a serious environmental challenge in many parts of the world. Many researchers e.g. (Stanley and Pierre, 2000; Vanni`ere *et al*., 2003; Piccarreta *et al*., 2006; Szilassi *et al*., 2006; Feng *et al*., 2010) describe soil erosion as a major and common cause of land degradation globally and has been accelerated by improper land use practices over the last several decades.

Moreover, soil moved by erosion carries nutrients, pesticides and other harmful farm chemicals into rivers, streams, and ground water resources hence deteriorating our freshwater sources (Nyakatawa *et al.*, 2001). In Africa, there is an estimate that the decrease in agricultural productivity due to soil erosion ranges from 2 - 40% with an average of 8.2% for the whole continent and with average of 19% of reservoir storage volumes been silted (Andersson, 2010).

Soil erosion situation in the southeastern part of Nigeria has become a very critical situation, due to increased intensity of cultivation and clearing of forests, rapid human population growth and urbanization, watershed configuration, soil type and intense rainstorms which has led to major soil erosion problems. Anejionu *et al*., (2013) stated that, all these have

Amadi A. K., Federal University Of Technology Owerri, Imo State, Department Of Environmental Management
Amangabara G. T., Federal University Of Technology Owerri, Imo State, Department Of Environmental Management
Owuama C. O., Federal University Of Technology Owerri, Imo State, Department Of Environmental Management

devastating impacts and has led to land degradation (gullies), infrastructural damage as well as loss of lives and properties. According to the following researchers (Ezezika and Adetona, 2011; Obiadi *et al*., 2011; Akpokodje *et al*., 2010; Igbokwe *et al*., 2008; Ofomata, 1965) in Anejionu *et al*., (2013); most of these erosion problems currently being experienced, are generating a high level of concern among researchers and the populace.

In recent times, the advent of new techniques or soil erosion models e.g. the application of remote sensing and geographic information system to the study of soil loss prediction offer considerable potentials for developing cost-effective land management practices.

The Revised Universal Soil Loss Equation (RUSLE model) was developed for temperate weather conditions to predict water erosion. It is easier to adapt to tropical climates than other existing models. It is an empirically based model founded on the Universal Soil Loss Equation (USLE) model by Wischmeier *et al*, (1978) but is more diverse and includes databases unavailable when the USLE was developed (Renard *et al*, 1997). The RUSLE model enables prediction of an annual rate of soil erosion for a site of importance for many scenarios involving cropping systems, management techniques and erosion control practices.

GIS (geographic information system) can be used to isolate and query these locations to identify the role of individual variables contributing to the observed erosion potential rate. Remote sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. The use of maps and assessment of erosion prone areas can improve soil conservation. Mbugua (2009) stated that maps presenting the spatial distribution of natural and management related erosion are of great values in the early stages of land management plans, allowing identification of preferential areas where action against soil erosion is more urgent or where the remediation effort will have the highest revenue.

Application of Erosion Models

Several authors have applied Remote Sensing and GIS in their study of soil erosion for example the works of Efthimious *et al* titled "*Soil erosion assessment using the Revised Universal Soil Loss Equation (RUSLE) model and Geographical Information System (GIS)*". This study was conducted at the Agricultural University of Athens, Department of Natural Resources Development and Agricultural Engineering. The main aim of the study was to evaluate the performance of the RUSLE at the Venetikos River catchment. A Geographical Information System (GIS) based approach was applied to take into account the spatial distribution of the models individual factors. SEAGIS I.0 graphical interface (Soil Erosion Assessment using GIS) developed by the Danish Hydraulic Institute (DHI, 1999) as an Arc view extension was used in LS factor calculation, while other factors were calculated by the ArcMap 10 platform.

The result of the study showed that the models performance was evaluated, both annually and inter-annually considering the sediment discharge measurements conducted by the PPC (Greek Public power Cooperation at the catchments) outlet – Greneva Bridge (1965 – 1982). Irrespective of the underestimated results, the RUSLE model performed quite satisfactory, allowing identification of the most susceptible to erosion areas.

Another work done was *"Erosion Sensitivity Assessment of communities in Owerri, Nigeria using GIS and RUSLE model*" this was done in the year 2016, by AC-Chukwuocha et al., of the department of Environmental Technology, School of Environmental Sciences, Federal University of Technology, Owerri, Nigeria. In this piece of work, the researchers integrated some measurable variables such as erodibility index assessed from soil samples, rainfall data, slope length and steepness derived from classified land use of Landsat 7 ETM satellite image. The study was carried out in five (5) communities in Owerri west Local Government Area. The RUSLE and GIS were integrated with these variables to determine the degree of sensitivity of the study area and to identify sub-areas high sensitivity to erosion for mitigation and remediation strategies.

The result reveals that the degree of erosion sensitivity prevalent was observed in the low population density areas with substantive vegetative covers, while areas close to the city recorded very high sensitivity to erosion because of high population density.

According to Adedeji *et al*. (2010) of the Department of Geography, Obafemi Awolowo University Ile-Ife, Nigeria was carried out in Katsina town, Katsina State of Nigeria. The researchers applied *RUSLE model using RS and GIS*. The research focused basically on the use of RUSLE, RS, GIS in identifying areas, been affected by soil erosion and estimating the potential soil loss from the affected area. The Revised Universal Soil Loss Equation parameters were assessed using Satellite Remote Sensing and Geographical Information System with a view to model soil erosion. Data on parameters such as slope factors, crop cover and management practice support were obtained using Digital Elevation Model (DEM) and Landsat ETM+, 2002 of the area.

The integration of these models, were able to identify built up towns degraded forests, farmlands, grassland, bare land and water bodies. The potential rates of soil loss from the classes ranged from 0.0 to 418.10ton/ac/yr. The mean soil loss was put as 17.75ton/ac/yr. On the whole, the study demonstrated that Remote sensing and Geographical Information System are useful tools for modeling soil erosion, evaluating various disturbance alternative and spatial optimization of conservative measures.

Nwakor *et al*., (2015) focused on the estimation of the rate of soil erosion and soil loss potential using RUSLE2 and ARCGIS in the Upper Ebonyi River watershed. The various data sets such as soil data, land use inventory, digital elevation model and climatic data were used to generate RUSLE2 factor values in ARCGIS environment. For the catchment area, local data was used to calculate all factors used in RUSLE2. The result provided several insights on areas to be first conserved based on the severity of soil loss. The study shows that the use of GIS technologies and RUSLE2 model resulted in assessment of soil erosion in a shorter time and at low cost.

Soil erosion in eastern part of Nigeria

Soil erosion a natural occurring process, is related to accelerated erosion, where the natural rate has been significantly increased by human activity. As such soil erosion poses severe limitations to sustainable agricultural land use, as it reduces on-farm soil productivity and causes the accumulation of sediments and agro-chemicals in waterways (Kirkby *et al.*, 2004). It is true to observe that soil erosion is one of the most striking features on the land surface of Southeastern Nigeria, especially in Anambra and Imo States, only rare occurrences of the phenomenon are recorded in some other States of the Federation.

Environmental problems posed by erosion include; challenges to agricultural sustainability, degradation of soil and water quality, and indirect pollution of the environment through the transport of contaminants such as agricultural and industrial waste attached to sediments to other parts of the environment and hydrographic network (Kostadinov, 2002, American Society of Agricultural and Biological Engineers, 2002). The major types of erosion mentioned above occur simultaneously in the southern eastern zone.

The factors of soil erosion in Nigeria resolve into two components: physical (geologic or "natural") and anthropogenic (human or "accelerated"). Studies have revealed that the human component in soil erosion is often exaggerated while the effects of the physical component are usually underestimated. It has been noticed that soil erosion in the country is a result of the so-called "bad farming techniques".

The gully types are the more obvious forms of erosion in the country, mainly because of the remarkable impression they leave on the surface of the earth. They are also a visible manifestation of the physical loss of the land due to erosion. Good examples of gullies are widespread in Nigeria, especially in the Agulu-Nanka, Obioma, Nsukka, Alo, Nnobi, Nnewi, Orlu, Ozuitem, Abiriba, Ohafia, Uruala, Amucha and Uyo areas of Southeastern Nigeria. Other examples, but on a much smaller scale, exist on the Jos Plateau, especially in Heipang around Zaria, in Ankpa and at Auchi.

Much more pernicious and highly detrimental to agriculture is sheet erosion which often goes on unnoticed due to its gradual, constant and uniform action, but which finally results in a complete removal of arable parts of the soil. A report shows that in the region, about 45% is affected by considerable sheet erosion, also, about 20% of the land area suffers severe sheet erosion (Nwilo *et al.*, 2011).

Through this action of sheet erosion, the topsoil is gradually swept clear of its finer elements and plant nutrients, and only coarse, infertile materials are left behind. Wind erosion occurs more generally and more frequently in the extreme northern parts of the country, but is limited in both time and space in other parts. Wind erosion is a major geomorphologic force, it occurs mostly in arid and semi-arid regions. It is also a major source of land degradation, evaporation, desertification, harmful airborne dust, and crop damage, especially after being increased far above natural rates by human activities such as deforestation, urbanization, and agriculture.

There are two primary varieties of wind erosion, which are: deflation, this is where the wind picks up and carries away loose particles; and abrasion, where surfaces are worn down as they are struck by airborne particles carried by wind. Wind erosion is much more severe in arid areas and mostly in times of drought. For example, in the Great Plains, it is estimated that soil loss due to wind erosion can be as much as 6100 times greater in drought years than in wet years. Agricultural practices, deforestation, roads and urbanization, climate change are all human activities which have led to land degradation, sedimentation of aquatic ecosystems, airborne dust pollution. One major environmental problem is soil erosion; this is as a result of the fact that a large sparse of land area which would have been used for infrastructural development and residential area is lost in urban areas while large agricultural land is lost in rural areas (Ehiorobo and Izinyon, 2011). If erosion is not given utmost attention, it could grow from the earliest sheet erosion stage to disastrous gullies which in some cases could lead to landslides (Amangabara, 2012).

Measurement of Soil Erosion

The severe problems of human sustainability have been related to the harmful influence of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems and environments. Prediction of soil loss is often difficult due to the complex interplay of various factors which includes land cover, topography, soil, human activities and other climate. Accurate and timely prediction of soil erosion loss and evaluation of soil erosion risk has become an urgent task. (Mbugua, 2009)

In recent times, land managers and policy makers neglect absolute values of soil erosion loss, rather are more interested in spatial distribution of soil erosion risk. In order to check this, the combined use of Geographic Information System (GIS) and erosion models has been shown to be an effective approach in evaluating and other predicting soil loss. The Revised Universal Soil Loss Equation (RUSLE), amongst other mathematical models used for estimation, is the widely used and the most accepted model to predict the average soil rate from certain area. (Mitasova *et al.*, 1996, Yitayew *et al.*, 1999).

Remote Sensing and GIS in Soil Erosion Assessment

One of the major problems in testing these models is the generation of input spatial data. With the advent of remote sensing technology, deriving the spatial information on input parameters has become more handy and cost-effective (Kalpana, 2006). Besides with the powerful spatial processing capabilities of Geographic Information System (GIS) and its compatibility with remote sensing data, the soil erosion modeling approaches have become more comprehensive and robust.

Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi-temporal satellite images provide valuable information related to seasonal land use dynamics. Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor. Digital Elevation Model (DEM) one of the vital inputs required for soil erosion modeling can be created by analysis of stereoscopic optical and microwave

(SAR) remote sensing data. Remote sensing provides significant source for real-time and accurate data related to land and soil. It enables homogeneous information over large regions, and can therefore greatly contribute to regional erosion assessment (King and Delpont, 1993; Siakeu and Oguchi, 2000). As an account for seasonal variability, multi-temporal satellite images are useful to extract the valuable information associated to seasonal land use dynamics for mapping land use/land cover. It can be used to generate a cover and management factor (C-factor) (Morgan, 1995; Wischmeier and Smith, 1978) which is one of the input requirements of erosion modeling. The factors associated with soil classification such as soil properties, climate, vegetation, topography, and lithology can be potentially mapped with satellite remote sensing (McBratney *et al.*, 2003) to account for spatial differences in erodibility which serve as input data for erosion modeling. Especially optical satellite imagery can be used for soil mapping, mainly through visual delineation of soil patterns (Dwivedi, 2001).

The basic requirement of any hydrologic or geomorphologic studies is a digital elevation model (DEM). DEM enables to derive various topographic attribute such as elevation, slope and aspect etc. Which are essential to analyze watershed physical characteristics (kumar, 2004). DEM data can be extracted from the satellite images of terrain such as stereo optical imagery.

The Importance of GIS in soil erosion

Erosion is a natural geological phenomenon resulting from the removal of soil particles by water or wind, transporting them elsewhere, while some human activities such as agricultural practice, conversion of forest to agriculture etc. would increase erosion rates. Effective modeling can provide information about current erosion, its trends and allow scenario analysis. Substantial efforts have been spent on the development of soil erosion models (Nearing *et al.*, 2005). Soil erosion and degradation of land resources are significant problems in a large number of countries (Lu *et al.*, 2003 and Kim *et al.*, 2005). In addition, simulation models for soil erosion can be used to evaluate alternative land management scenarios in both gauged and un-gauged basins.

Geographic Information System (GIS) is a computerized database management system which enables the user to capture, store, retrieve, analyze, manage, and visualize the spatial data that are linked to the real-world coordinates (ESRI 2005). GIS is enhanced with a set of geospatial tools that can perform statistical analysis, identify relationships, and determine patterns and trends. GIS has been used as early as the 1960's. However, extensive application of GIS in environmental field particularly in hydrologic and hydraulic modeling, flood mapping, and watershed management did not begin until early 1990's (Coppock and Rhind, 1991; Maidment and Djokic, 2000; Moore *et al.*, 1991). Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output, and for interaction with erosion models (Renschler and Harbor, 2002).. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modeling and erosion risk assessment. A GIS can be used to scale up to regional levels and to quantify the differences in soil loss estimates produced by different scales of soil mapping used as a data layer in the model.

II. MATERIALS AND METHODS

Study Area

The study area is located between longitude 6° 56' 45''E and 7° 5' 0''E, and latitude 5° 18' 15''N and 5° 34' 45''N. Owerri is the capital of Imo state. It is the State's largest city, followed by Orlu and Okigwe as second and third respectively. It is set in the heart of Igboland. Owerri consists of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West. It has an estimated population of about 715,800 as of 2015 and is approximately 100 square kilometres (40 sq mi) in area. Owerri is drained by Otamiri and Nwaorie Rivers.

Owerri is a rapid growing urban centre consequent to its designation as the capital of Imo State in 1977, in South-Eastern Nigeria. The general topography of Owerri is fairly flat and its watershed is mostly covered by depleted rainforest vegetation, with mean temperatures of 27°C throughout the year and total annual rainfall exceeding 2500mm (Ezemon

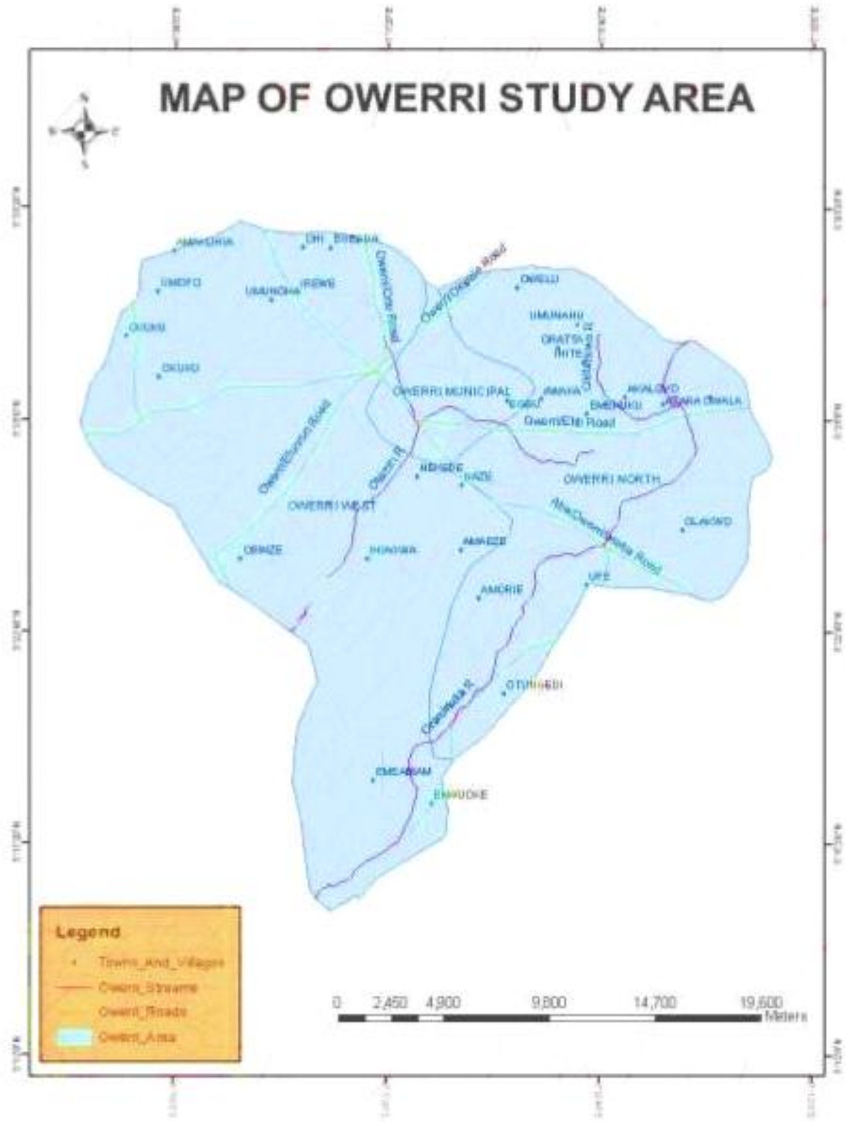

Fig 1.1: Location Map of the Study Area

Climate and Vegetation

Owerri is characterized by high precipitation which causes runoff, leaching of nutrient elements and soil erosion (Onweremadu *et al.,* 2011).This city has a tropical climate. The general topography of Owerri is fairly flat and its watershed is mostly covered by depleted rainforest vegetation, Owerri has its max temperature as 33.4°C with mean temperatures of 27°C throughout the year and total annual rainfall exceeding 2500mm (Ezemonye *et al.,* 2012). Its highest and lowest rainfall was recorded as 19 and 2mm respectively for 2012. The Otamiri River is joined by the Nworie River at Nekede in Owerri, a river about 9.2 km in length.

Relative humidity is high during the rainy season. Tropical rainforest is the dominant vegetation in Owerri area although its density has drastically reduced due to anthropogenic activities such as urbanization, deforestation and agricultural activities. The vegetation is arranged in layers with herbaceous plants forming the forest floor. Oil palm tree (Elaeis guineensis) is the dominant plant species in the area. Rivers Otamiri and Nworie play significant role in the hydrology of the area. Farming and cottage industrial activities dominate the socio-economy of the inhabitants in the area. Farming is common at the banks of rivers. Land preparation ranges from slash-and-burn to slash-and-pack with crops planted on flats and sometimes on ridges. Mixed cropping is common in the area with maize, cassava, leafy vegetables and yams being common in the area.

Owerri has significant rainfall most months, with a short dry season. The climate here is classified as Am by the Köppen-Geiger system. The least amount of rainfall occurs in January. The average in this month is 17 mm. In June, the precipitation reaches its peak, with an average of 363 mm. The temperatures are highest on average in March, at around 27.9 °C. At 25.0 °C on average, August is the coldest month of the year. The variation in the precipitation between the driest and wettest months is 346 mm. The variation in annual temperature is around 2.9 °C.

Soil texture and topography

With the soil map of Imo State, using the United States Department of Agriculture (Peech *et al.* 1947) and Food and Agricultural Organization of the United Nations (FAO 1976) classification systems, there are three classes of soil in Imo. Alluvial soils occupy terrace of the water courses. Basically, the textural class of the soils ranges from loamy sand to sandy clay loam for well-developed soils and loamy sand to sandy loam for soils on alluvial deposits.

Geology

Owerri lies entirely within coastal plain sandstones (Benin Formation) which have a thickness of about 800 m. The Benin formation extends from the west across the Niger Delta and southward beyond the present coastline. It is over 90 percent sandstone with minor shale intercalations in some places. It is coarse grained, gravely, locally fine grained, poorly sorted, sub-angular to well-rounded, and bears lignite streaks and wood fragments. The Benin formation is thus partly marine, partly deltaic, partly estuarine and partly lagoonal and fluviolacustrine in origin (Reyment, 1976). Its age ranges from Miocene to recent. The terrain of the area is characterized by two types of land forms: highly undulating ridges and nearly flat topography. Various structural units (point bars, channel fills, natural levees, back swamp deposits and oxbow fills) are identifiable within the formation indicating the variability of the shallow water depositional medium.

The subsurface geology of the study area fall within Benin formation, but associated with the transition area of Benin to Lignite formation. The lithology consists predominantly of coastal sediments, essentially sand, sand stone and minor clay. The underlying formation consists of mudstone, and clay and lignite series.

Population and Land use

Owerri, last known population is ≈ 715 800 (year 2015). This was 0.393% of total Nigeria population. The people practice shifting cultivation and crops grown on the area are maize, melon, yam, and cocoyam. The area also lies within the rainforest region of Nigeria, which has its peak rainfall within June, July, September and October

Data Sources

The quantitative prediction of soil erosion loss by erosion model such as RUSLE is based on its component factors, which include: Satellite imageries of LandSat 8, Topographic map, Rainfall data, Soil map. These data were obtained from the website of United States of Geographical Survey (USGS), Office of the Surveyor of the Federation (OSGOF), Nigeria Meteorological Agency (NIMET), and Nigeria Geological Survey respectively. The dataset used to predict rate of soil loss using RUSLE model include Digital Elevation Model, Average annual rainfall data, satellite images and soil type map GIS implementation aids to manage and analyze these data. It is therefore imperative to evaluate these data before being implemented. The uncertainties regarding data sources may introduce larger uncertainties in soil erosion estimates; therefore, great attention was paid in evaluating and preprocessing of data sources.

Digital Elevation Model

Digital elevation model (DEM) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. Its data is a digital representation of cartographic information.

The purpose of this data set is to provide a single consistent elevation model for national scale mapping, GIS and Remote Sensing applications and Natural Resource Assessment.

The Topographic map was imported into ArcGIS 10.1, it was geo-referenced, and then digitized with a scale of 1:100 000 to extract the contour lines and it was masked to extract the study area. The DEM will be used to calculate the slope length and steepness factors in the RUSLE model for the purpose of the study.

Rainfall Data

The Nigeria Meteorological Agency (NIMET) has collected most of Nigeria's monthly and annual precipitation data. The data for rainfall data was collected at their gauge station located at the Sam Mbakwe Airport Owerri.

The Climate data include rainfall, relative humidity, solar intensity, wind speed and temperature. All the data can be read as tables by ArcGIS or Excel. Only rainfall data is needed for this study. The mean rainfall depth in millimeters for the target year 2000 and 2015 was extracted from a large data set. The rainfall erosivity factor was estimated by importing the values from the weather station.

Soil Classification Map

The primary source of Soil map for the study area is from Nigeria Geological Survey. The geological and mineral map was imported into ArcGIS 10.1. It was geo-referenced under the WGS84 Coordinate System to give it a spatial attribute and the study area, Imo State was masked from it. Based on the digitized map Owerri has one major soil formation, which is sands and clay (Coastal plains sands) – Plio-pleistocene

Satellite Remote Sensing Images

Landsat images of 2000 and 2015 were used. The spatial resolution of the satellite images are 30metres. All images were geo-referenced under the WGS84 Coordinate System. Detailed information about the used LandSat images is shown in table 1.1. The two satellite images used are expected to be from the same date and period. However, due to heavy cloud coverage in the Southeast region during Summer time, this requirement is difficult to fulfill. The data used in the study area are the best combination which can be found.

Table 1.1. Information about LandSat satellite images

Time	Path/Row	Cloud Coverage	Band
17th December 2000	188/56	<10%	4,3,2
3rd January 2015	188/56	<10%	5,4,3

In the downloaded data, the digital values for red, green and near infrared bands were interpreted following the spectral reflectance characteristics. That means that the satellite image can be used for Normalized Difference Vegetative Index (NDVI) calculation directly in the further processing stage. The NDVI maps indicate the land cover environment. NDVI was thus used to estimate the cover management factor which is one of the components in RUSLE model.

The RUSLE Model

The RUSLE soil erosion model is used to estimate annual soil loss value and estimate soil erosion intensity in a catchment. The RUSLE model is based on the USLE erosion model structure which was developed by Wischmeier and Smith (1978), and improved and modified by Renard *et al.* (1997). Five parameters are used in the RUSLE model to estimate soil loss. They are rainfall erosivity (R), soil erodability (K), slope length and steepness factor (LS), cover management factor (C) and conservation practice factor (P). Referring to RUSLE model, the relationship is expressed as:

$A = R \times K \times LS \times C \times P$

where

A (t ha−1 y−1) is the computed spatial average of total soil loss per year;

R (MJ mm ha−1 h−1 y−1) is the rainfall erosivity factor;

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

LS is the slope length and steepness factor (dimensionless);

C is the land surface cover management factor (dimensionless); and

P is the erosion control or called conservation practice factor (dimensionless).

The methods and formulas for estimating each of the parameters in the RUSLE model are mainly based on three previous studies by Pilesjö (1992), Bamutaze (2010), and Prasannakumar *et al.* (2012). The work flow is shown in the flow chart below in Figure 1.3

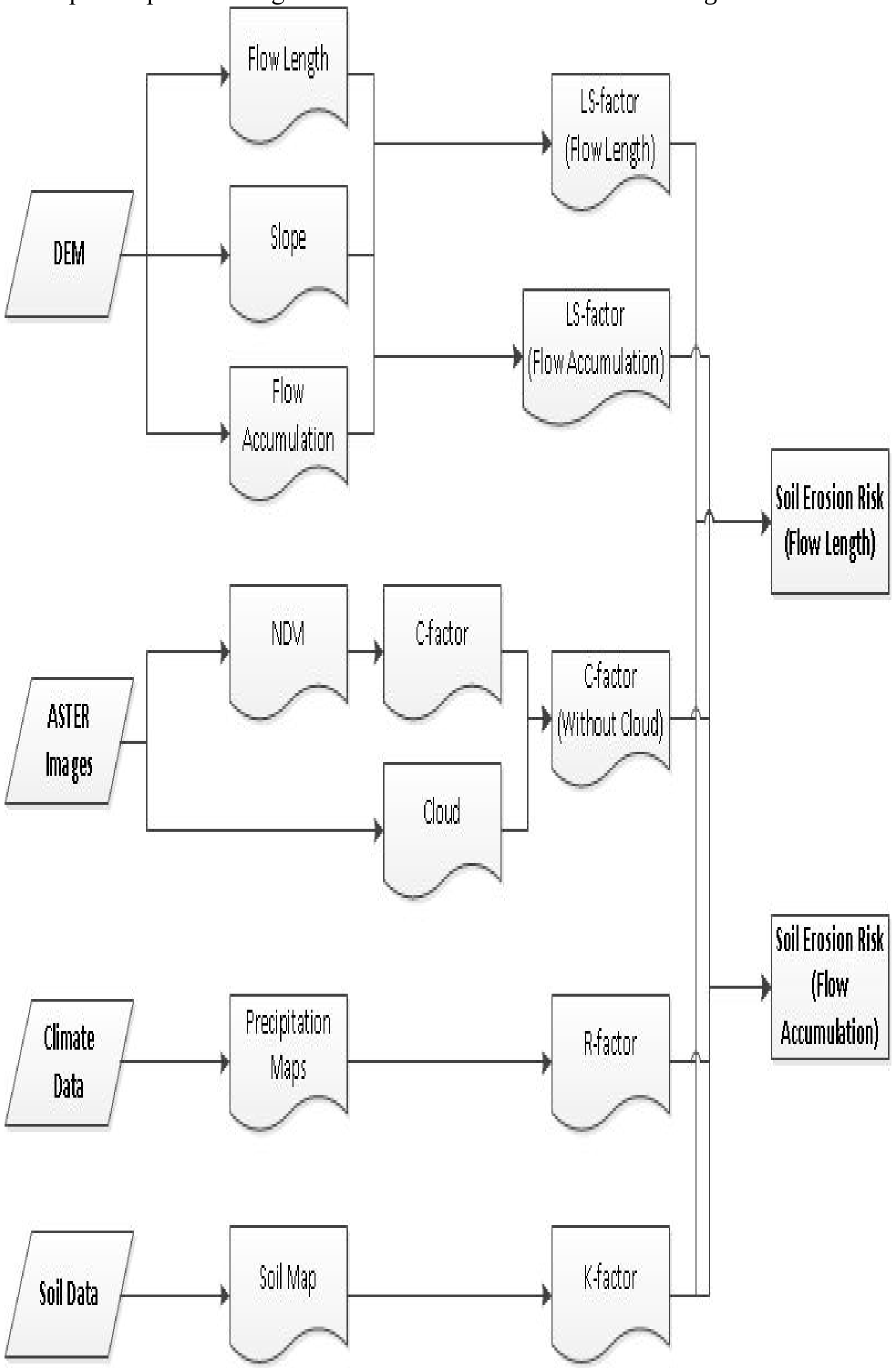

Figure 1.2 Flow chart of RUSLE modeling.

III. RESULT AND DISCUSSION

Rainfall Erosivity Factor (R)

The rainfall erosivity factor indicates the erosive force of a specific rainfall (Prasannakumar et al., 2012). The relationship between rainfall erosivity and rainfall depth developed by Wischmeier& Smith (1978) and modified by Arnoldus (1980) was used to translate the rainfall depth to rainfall erosivity. The calculation formula is as follows:

R

where R is rainfall erosivity value in MJ mm ha−1 h−1 y−1 , Pi is the monthly rainfall in mm; and P is the annual rainfall in mm.

To apply the relationship above, the monthly and annual rainfall depth are required to be prepared in raster format. Thus, the original rainfall data which distributed in daily form from four climate stations was extracted and summed up to monthly rainfall and annual rainfall depth for the two-target years 2000 and 2015. The position of the stations and the corresponding rainfall depth values were imported to ArcGIS as point vector data. Afterwards, Inverse Distance Weighting (IDW) interpolation with second power calculation was applied to create totally 13 rainfall depth maps, 12 monthly and an annual rainfall depth maps, for each of the target years. The relationship developed by Wischmeier & Smith (1978) was used to construct rainfall erosivity maps.

Figs 1.2 and 1.3 below show the spatial distribution of the computed rainfall erosivity for year 2000 and 2015 is given. The rainfall erosivity is up to 3950.4 MJ mm ha−1 h−1 y−1.

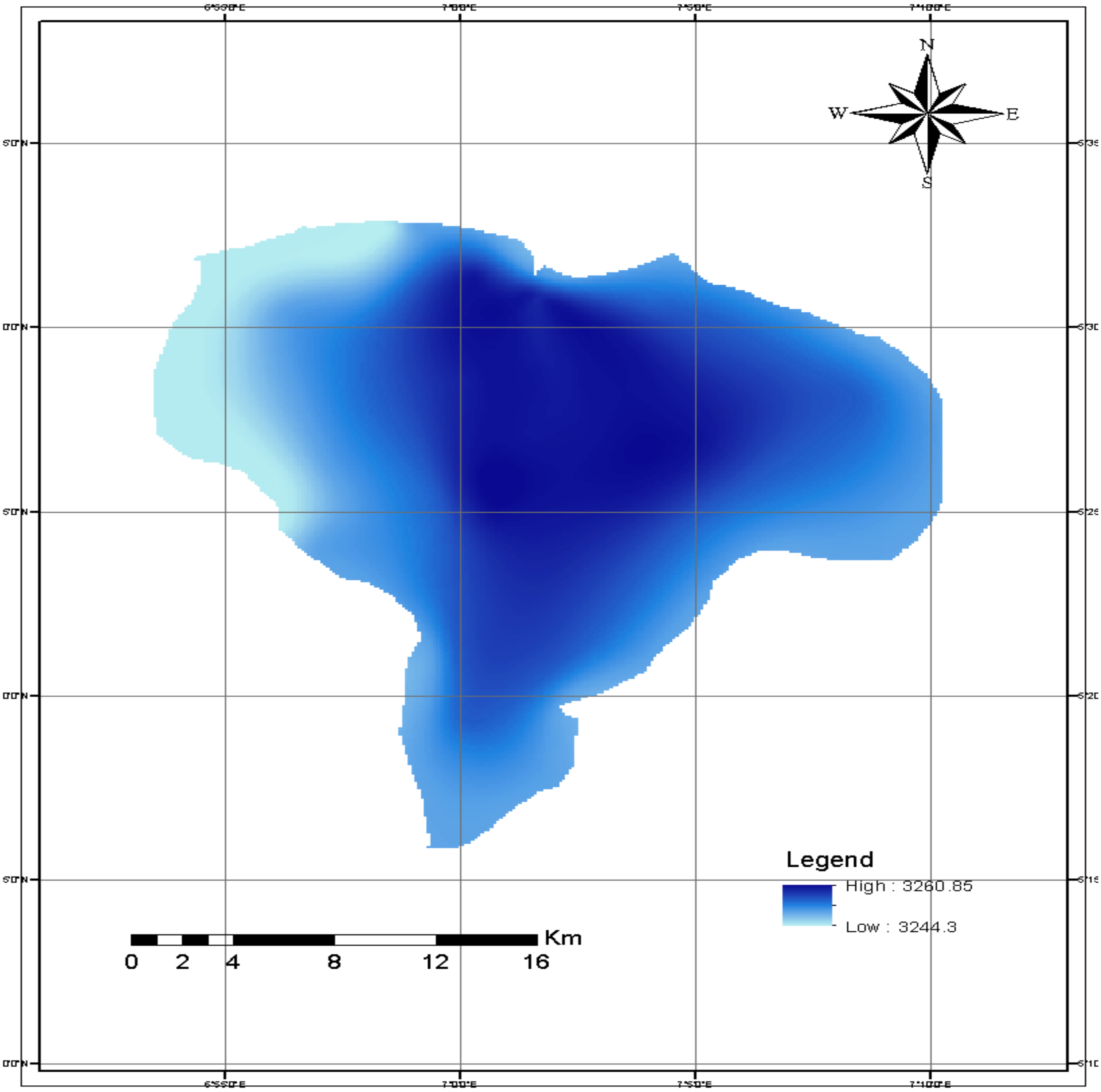

Fig 1.3 Rainfall erosivity map for the year 2000

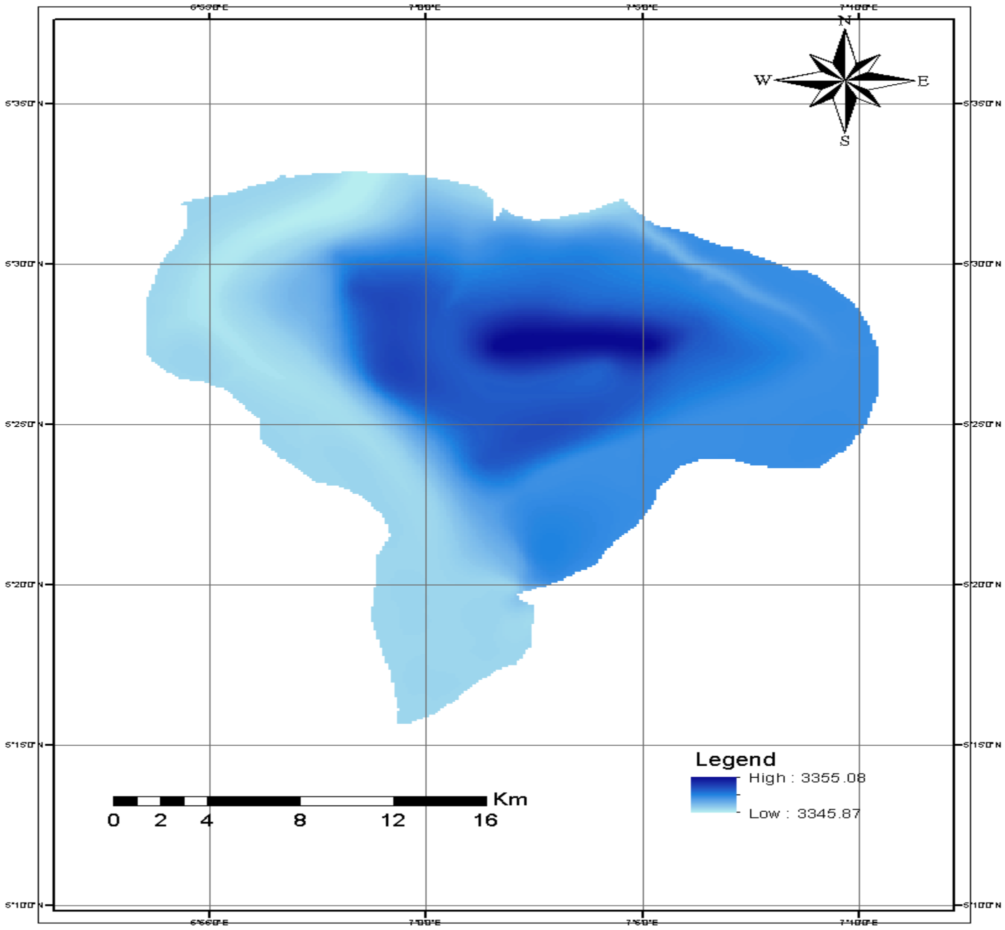

Fig 1.4 Rainfall erosivity map for the year 2015

For the year 2000, the largest amount of rainfall and spatial spread of erosivity was observed to occur at the Owerri Municipal (3260.85 MJ mm ha^{-1} h^{-1} y^{-1}) compared to Owerri North and Owerri West LGAs the rainfall erosivity factor was found to be 3260.85MJ mm ha^{-1} h^{-1} y^{-1}. However, the area of erosivity increased in spatial coverage in 2015 to include Owerri North with an erosivity value of 3355.08 MJ mm ha^{-1} h^{-1} y^{-1}

- **Soil Erodibility factor (K)**

Soil erodibility values were estimated based on the soil classification of the place which is just one type, unlike some areas e.g. Okigwe that has up to six different types. (fig 1.4) Owerri has just one type

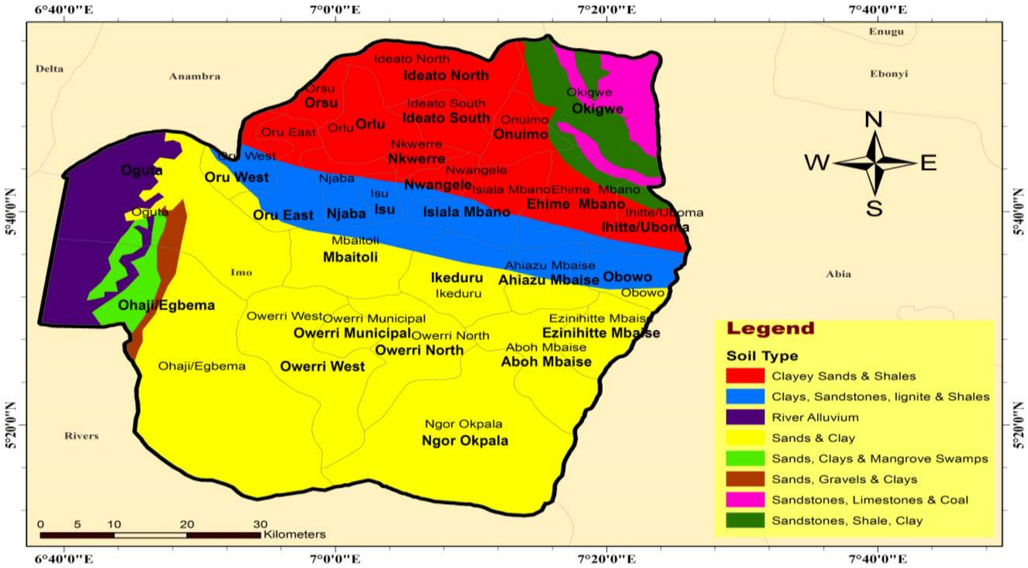

Fig. 1.5: **S**oil type classification for Imo State (Source: Amangabara, 2014)

Different soil types normally have different structure, which influence the intensity of the soil erosion. The soil erodibility K-value indicates the vulnerability and susceptibility of the certain type of soil to detachment by erosion (Hoyos, 2005). The higher erodibility value the soil has, the more erosion will be suffered when the soils are exposed to the same intensity of rainfall, splash or surface flow (Hudson, 1981).

Stewart *et al* (1975) estimates soil erodibility values using the composition of the soil. There are some other professional calculation methods for K-value, but more detailed information is required for different types of soil. In this case, this is the best way the estimated K- value can be estimated due to the limitations from available data. The map of soil erodibility factor is shown in Fig 1.4

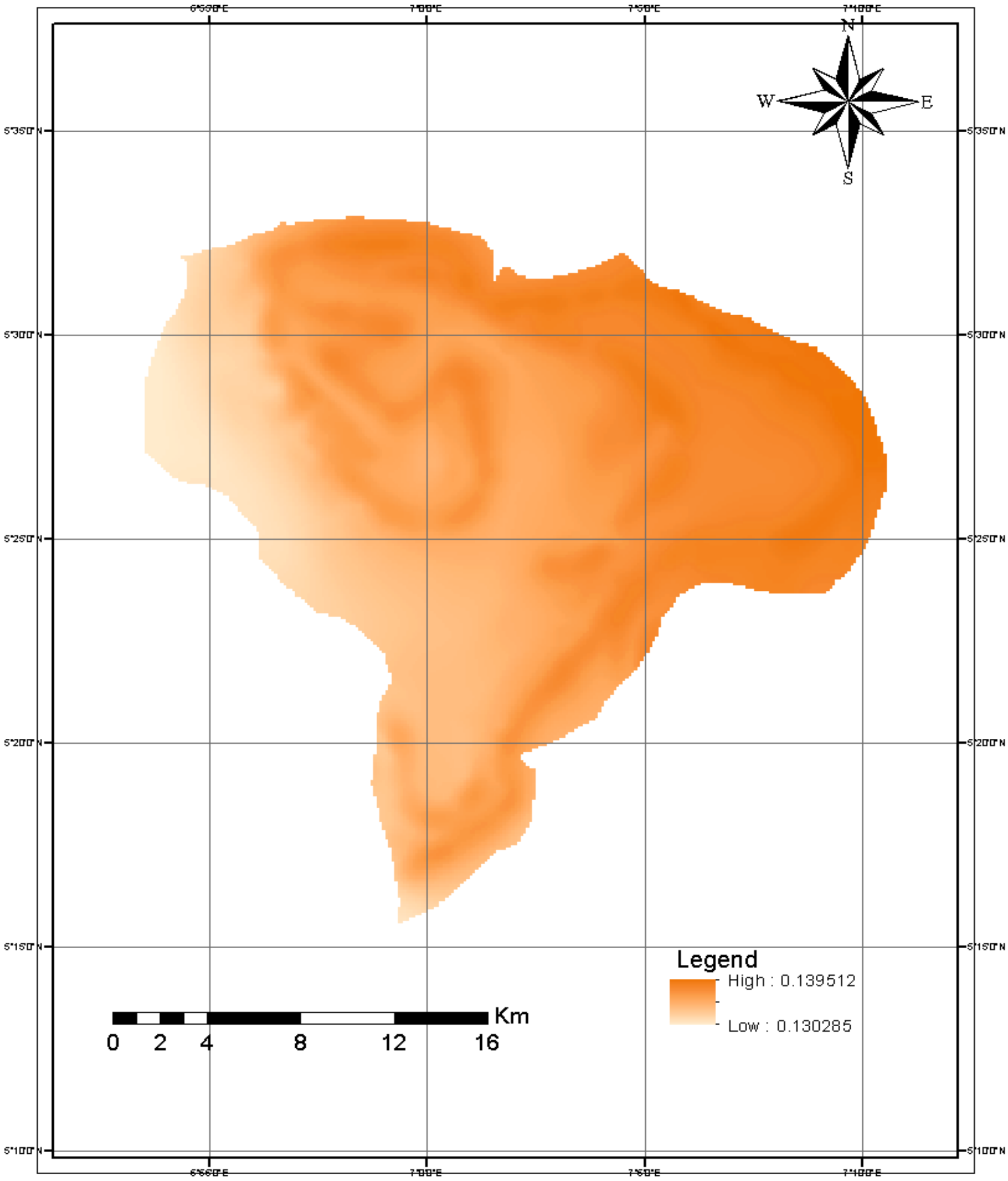

Fig 1.6 The translated soil erodibility (K-value) factor map of the study area.

Fig 1.3 show that soil erodibility values ranged from 0.130285 t ha h ha–[1]MJ–[1]mm–[1] to 0.139512 t ha h ha–[1]MJ–[1]mm–[1] in the Study area. The average K-value for the soil composition in the study area is therefore 0.13. These values were estimated based on the soil map, which contains the soil classification according to soil composition in Soil erodibility factor classification in Stewart *et al.*, (1975).

Slope Length and Steepness Factor (LS)

The slope and steepness factor (LS) is a combination of slope steepness and slope length, to high degree affecting the total sediment yield from site. It is considered to be one of the most challenging to derive (Fu *et al.*, 2005). Prasannakumar *et al.*, (2012) claim that generating the LS-factor also captures factors like compaction, consolidation and disturbance of the soil.

In this study, the flow length was used to calculate the LS-factor, With the help of ArcGIS. The LS factors were estimated applying the equation proposed by Moore & Burch (1986a, b). In the equation, the flow length of upslope cells which contribute to a given cell. In addition, in ArcGIS calculation, flow length is the number of upslope cells which contribute to a particular cell, so they can be replaced by each other in the equation. The relationship is as follows:

$LS = (\text{Flow Length} * \text{Cellsize}/22.13)^{0.4} * ((\text{Sin Slope})/0.0896)^{1.3}$

where LS is the combination of slope length and steepness; Flow length is the accumulated upslope contribution to a cell; Cell size is the resolution of the raster image, and Sin slope is the sin value of the slope in degrees. The estimated LS values based on flow length, varying between 0 and 1, are presented in Fig 1.5 and 1.6

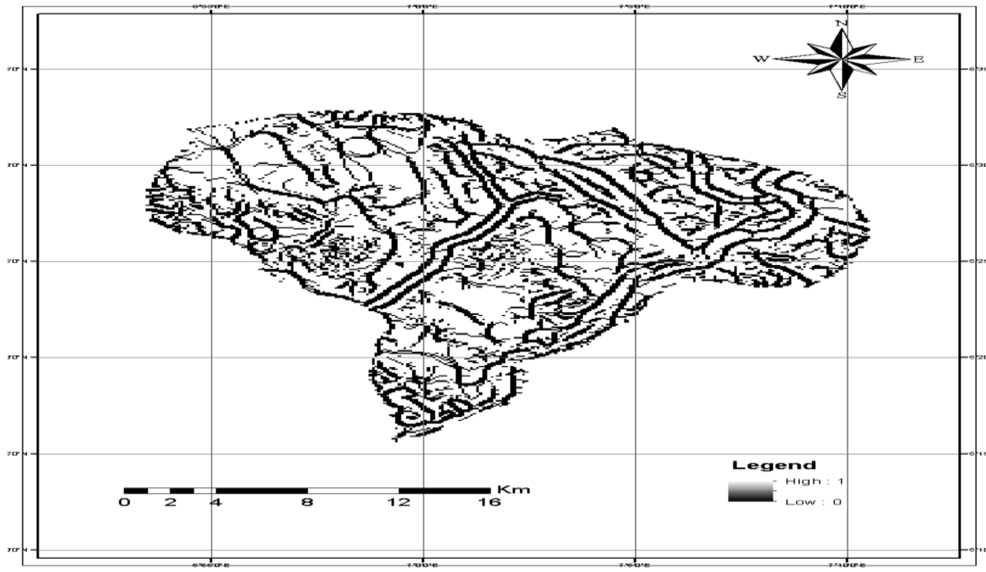

Fig 1.7 Flow length of the study area

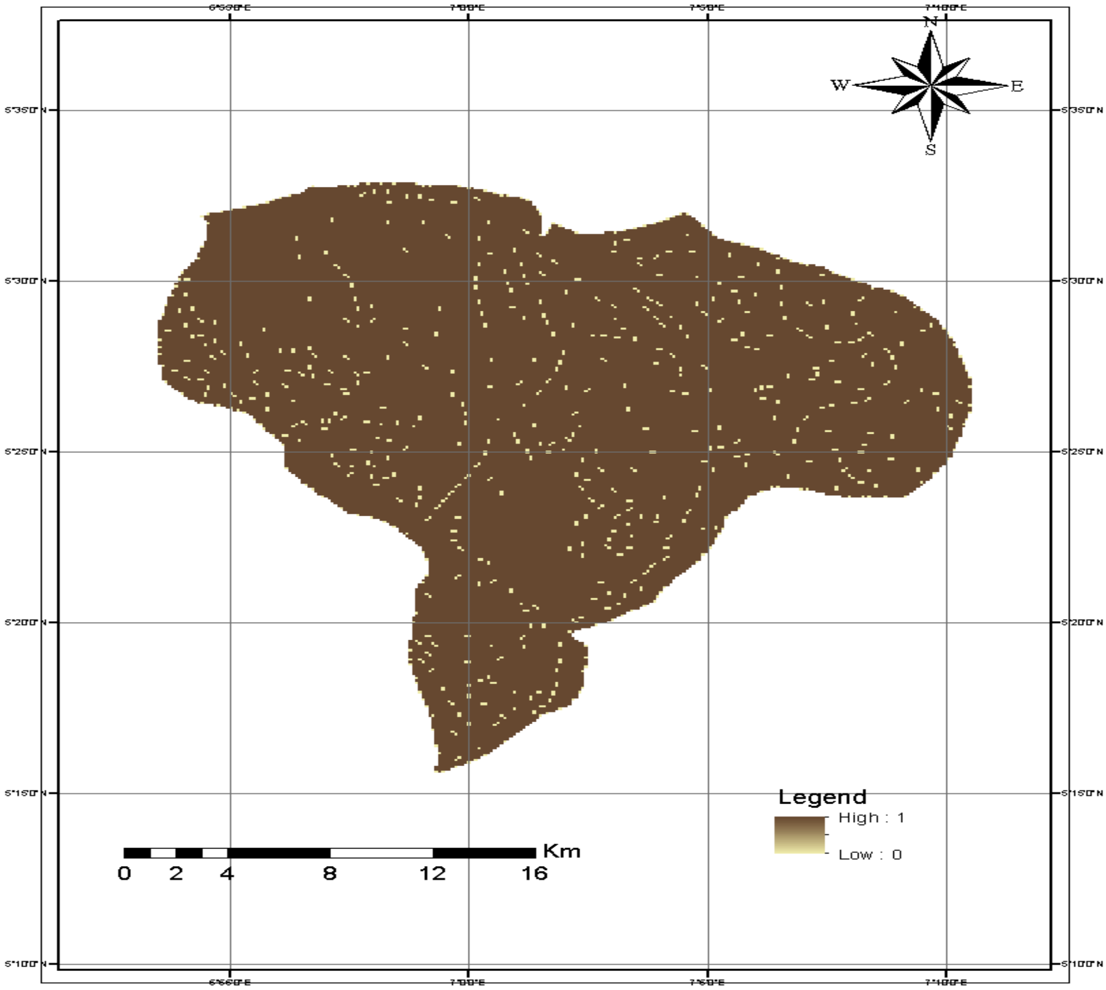

Fig 1.8 LS-factor map obtained by using flow length.

Cover management factor(C)

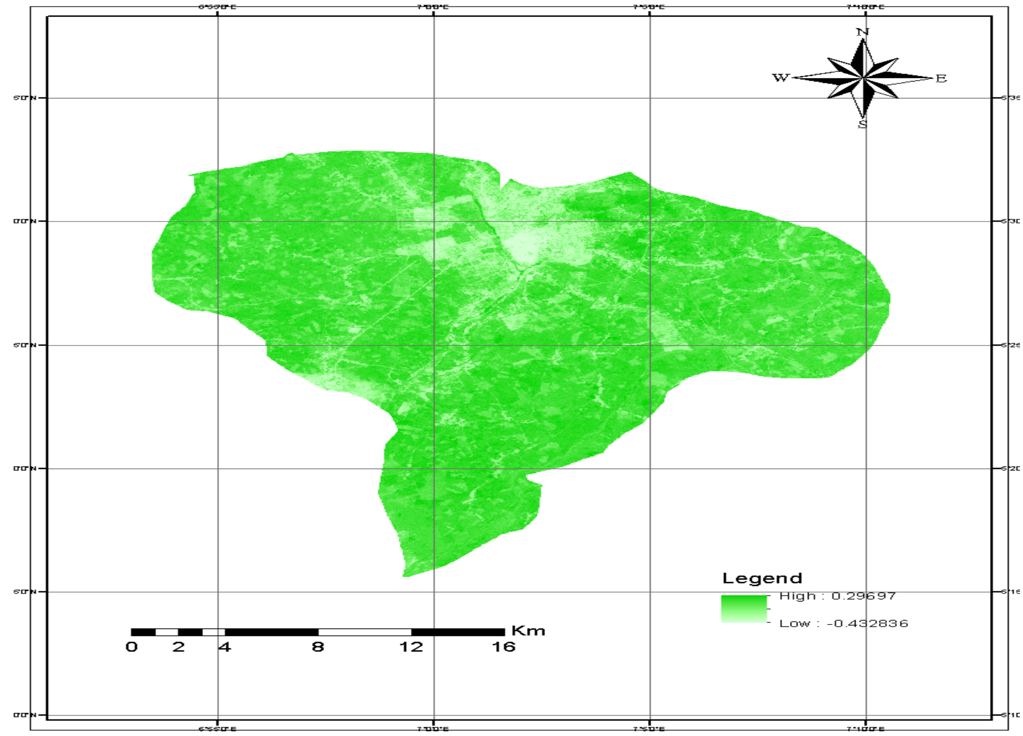

Fig 1.9 Year 2000 NDVI Classification of the Study Area

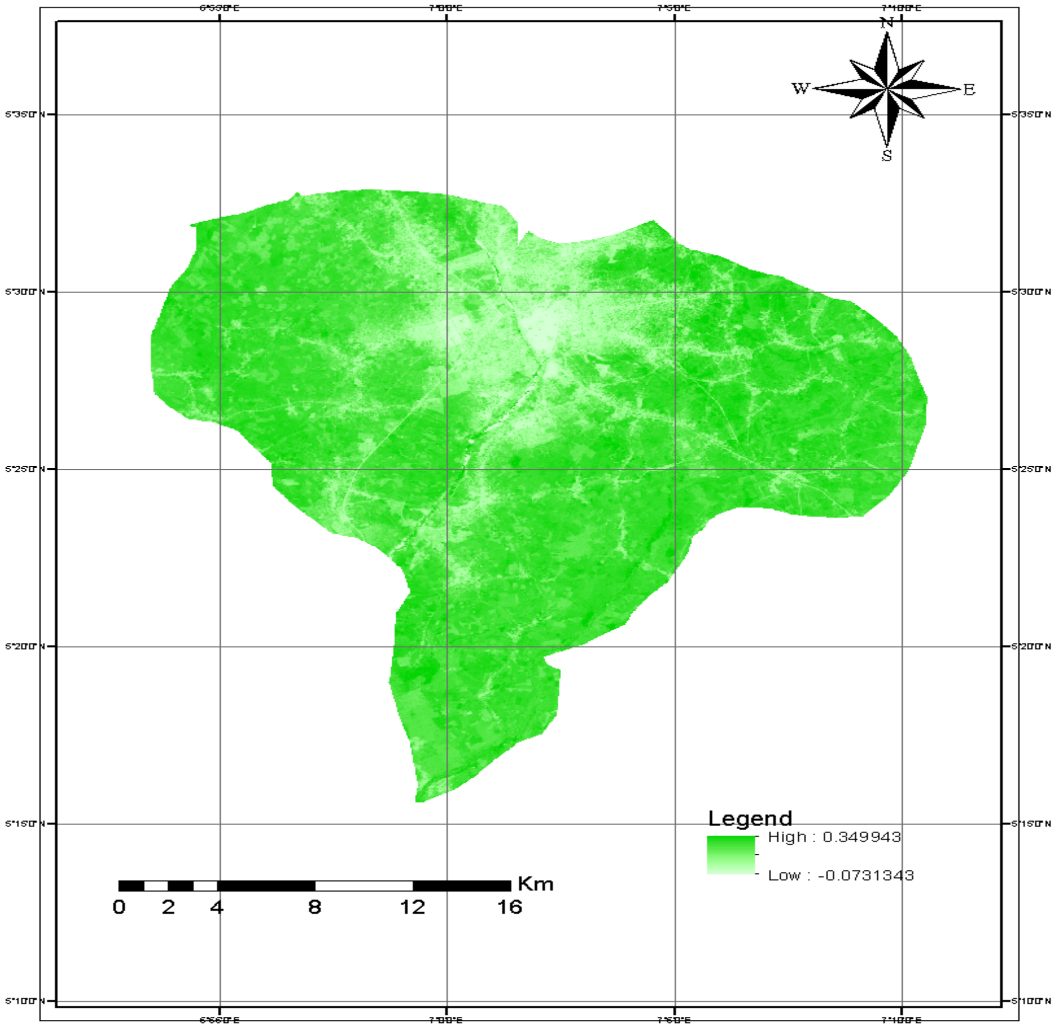

Fig 1.10 Year 2015 NDVI Classification of the Study Area

The cover management factor represents the effect of plants, crop sequence and other cover surface on soil erosion. The value of C-factor is defined as the ratio of soil loss from a certain kinds of land surface cover conditions (Wischmeier and Smith, 1978). According to Prasannakumar *et al*. (2012), the Normalized Difference Vegetation Index (NDVI) can be used as an indicator of the land vegetation vigor and health. In addition, Karydas *et al*. (2009) and Tian *et al*. (2009) state that due to the variety of the land cover patterns, satellite remote sensing data can act as an extremely important role to estimate the C-factor.

In this study, the original satellite images from the year 2015 with the reflectance values in bands green, red and near-infrared, were converted to NDVI for the corresponding years. The NDVI calculation formula can be represented as following:

$$NDVI = \frac{rNIR - rRed}{rRed - rNIR}$$

where rNIR is the reflectance value in near-infrared band;

rRed is the reflectance value in visible red band.

After calculated NDVI, the C-factor can be estimated by applying the relationship used in Zhou et al. (2008) and Kouli et al. (2009):

$$C = \exp(-\alpha * (NDVI/\beta - NDVI)$$

where C is the calculated cover management factor.

NDVI is the vegetation index,

α and β are two scaling factors.

Van der Knijff et al. (2000) suggest that the values for the two scaling factors α and β to be 2 and 1, respectively.

For the year 2000, the C-factor map is shown in Fig 4.7 and for 2015, The C-factor is shown in fig 1.8. By running the formula with the raster calculator tool in ArcGIS, the C-factor maps were obtained. The C-factor map is shown above. The C-factor varies from 0.29 in 2000 to 0.34 in 2015.

Comparing both figures, one can visibly see that it corresponds with Erosivity and other highlighted factors. The city centre (Owerri Municipal) has less NDVI showing a close relationship with other factors i.e as the city is continually urbanized, the vegetation in the area is cleared and exposes the soil to rainfall events and subsequent erosion.

Conservation Practice Factor (P)

The conservation practice factor (P) is also called as support factor. It represents the soil-loss ratio after performing a specific support practice to the corresponding soil loss, which can be treated as the factor to represent the effect of soil and water conservation practices (Omuto, 2008; Renard *et al*., 1997).

The range of P factor varies from 0 to 1. The lower the value is the more effective the conservation practices are. In this study, this conservation practice factor was assigned to the maximum value of one (1) for the entire study area for running the RUSLE model. It is because there are no significant conservation practices detected. In Owerri, most of the conservation practices are tree planting, and can thus be considered to influence the cover management factor (C) (Bamutaze, 2010).

Annual Soil Loss Estimation (A)

To estimate annual soil loss, the five factors were multiplied according to the relationship in RUSLE model. In total three layers with annual soil loss were computed for target years. The soil loss was classified into soil erosion risk maps with five different soil erosion risk levels according to Bamutaze (2010). The threshold for each of the risk level is presented in Table 1.2

Table 1.2 Categorization of soil erosion risk.

Erosion Risk	Threshold
Very Low	Soil Loss $\leq$ 2
Low	2 $<$ Soil Loss $\leq$ 10
Moderate	10 $<$ Soil Loss $\leq$ 50
High	50 $<$ Soil Loss $\leq$ 100
Very High	Soil Loss $\geq$ 100

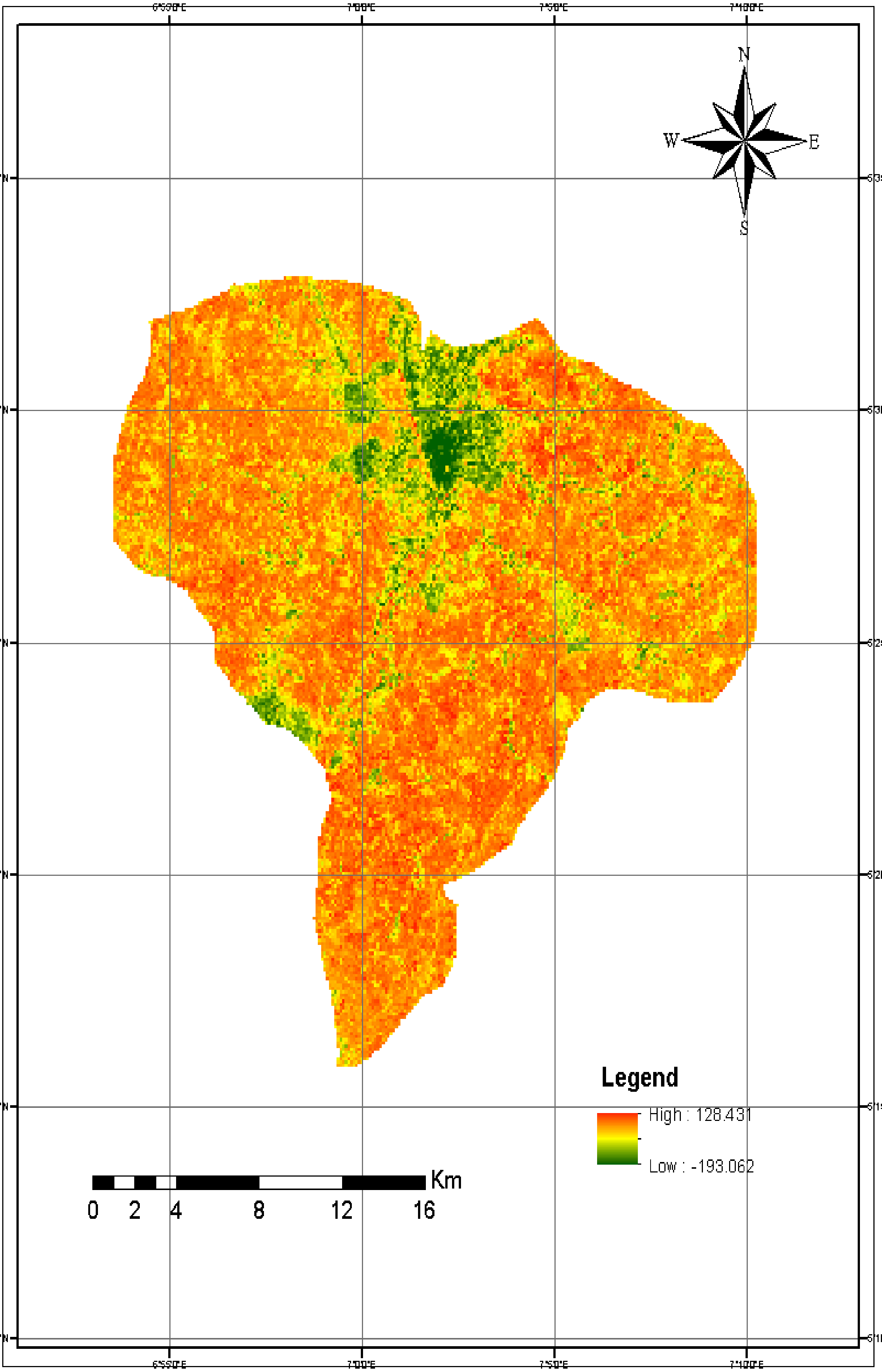

Fig 1.11 Erosion Risk Map for 2000

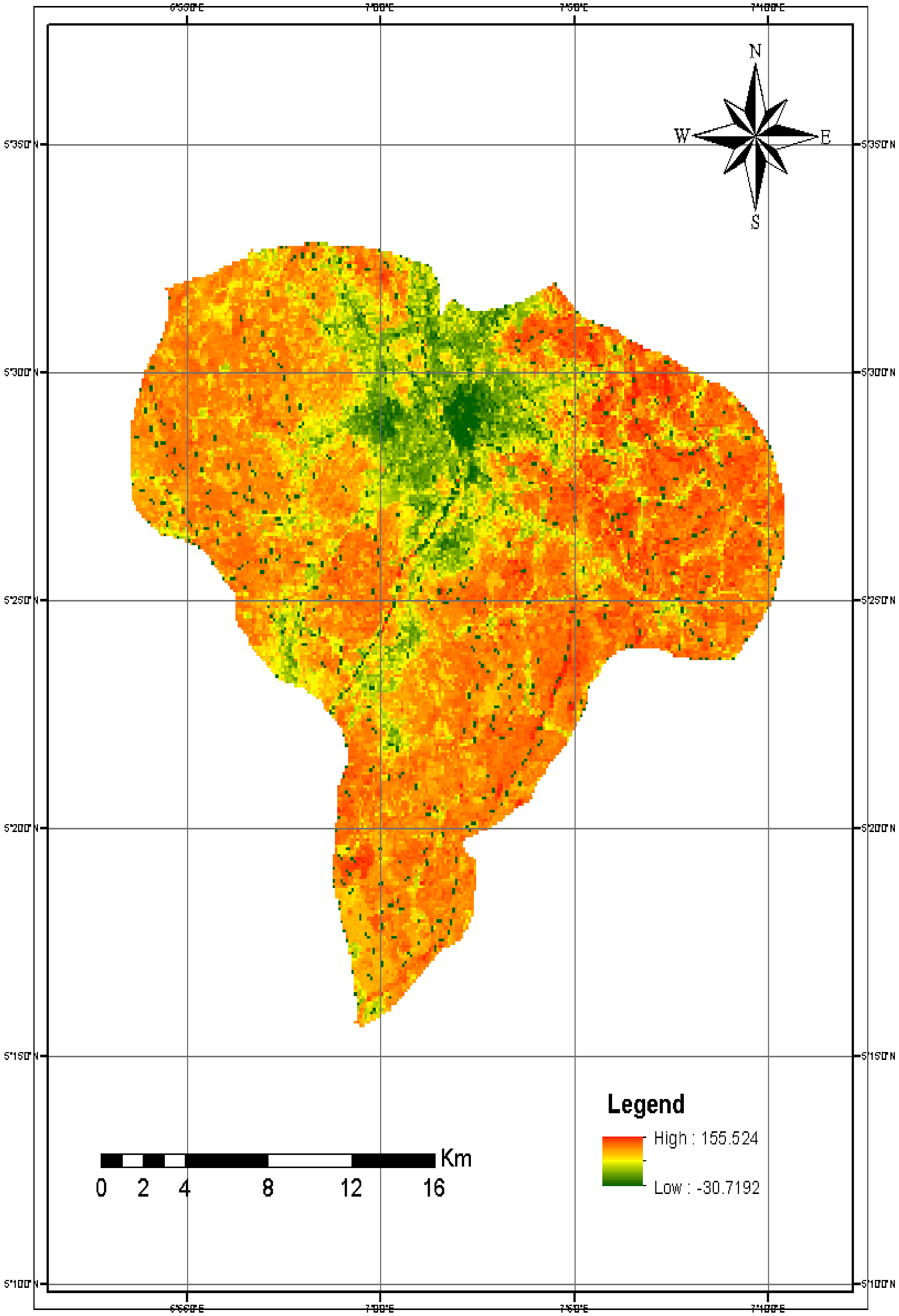

Fig 1.12 Erosion Risk map of the Area 2015

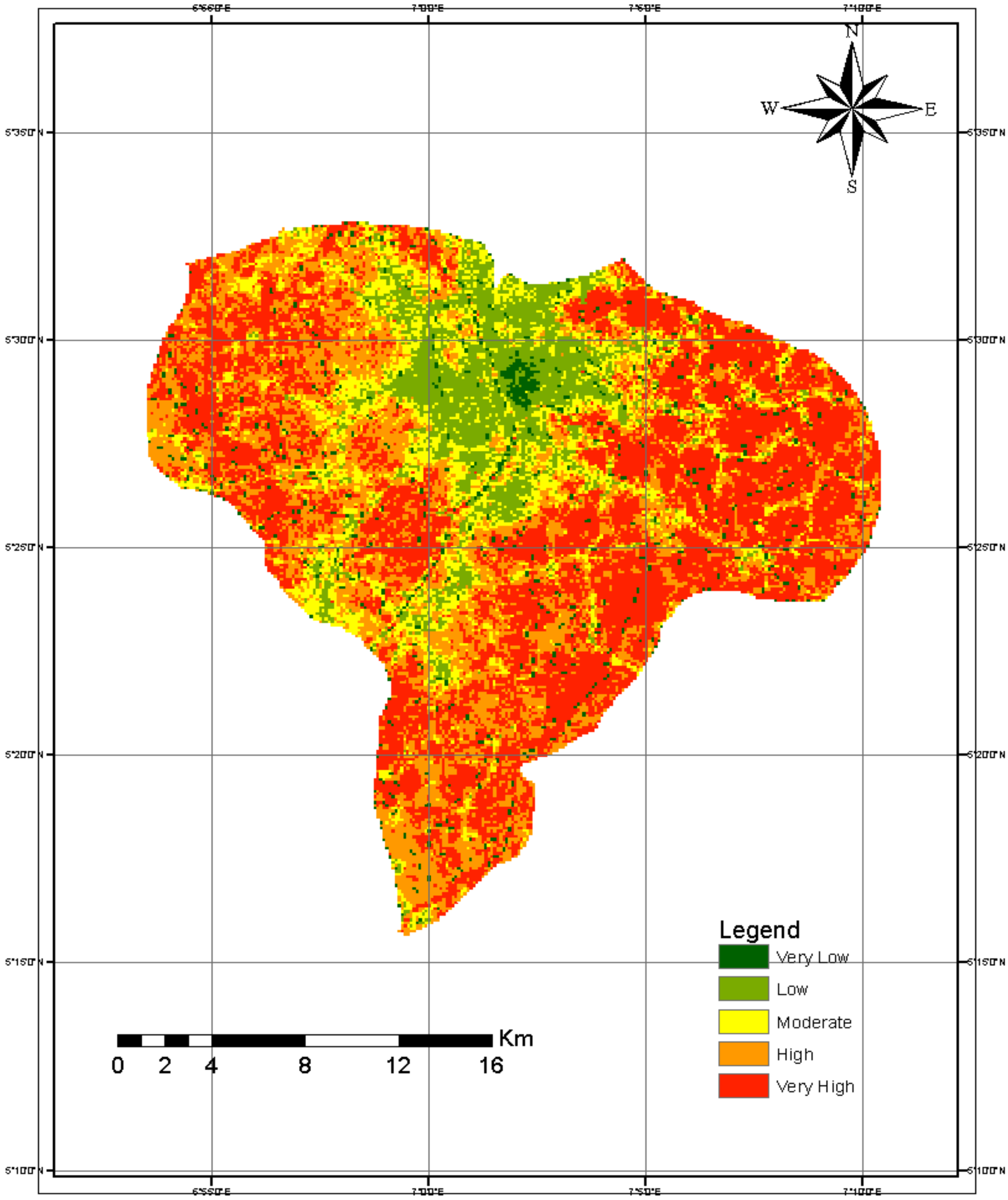

Fig 1.13 Erosion Risk Classification of the Study Area

For the year 2000, the erosion risk map (Fig 1.9), the estimated annual soil loss varies between -193.062 and 129.431 t ha^{-1} y^{-1} Fig4.10 shows that 23.4% of the area has a very high erosion risk, 33.1% a high risk, 46.1% a moderate risk, 11.9% a low risk, and only 5.4% a very low risk of soil erosion.

The result for 2015 (Fig 1.11), the estimated soil loss values vary between -30,7192 and 155,524 t ha^{-1} y^{-1}. The mean soil loss value is 315 t ha^{-1} y$^{-1,}$ which is higher than year 2000. From the histogram, Fig 4.13, 34.1% area is under very high erosion risk, which is less than the year 2000. 11.2% of the area has a very high erosion risk, 22.9% a high risk, 29.1% a moderate risk, 30.8% a low risk, and only 5.9% a very low risk of soil erosion. There is an increase for the area of low and moderate erosion risk compared with year 2000. The coverage percentage of year 2015 is very similar to the situation in 2000.

IV. Conclusions and Recommedations

This study attempts to find soil erosion patterns from year 2000 to 2015 due to climate and landcover changes based on estimating annual soil loss by applying the RUSLE model in Owerri (comprising of the three Local Government Areas, namely Owerri Municipal, Owerri West and Owerri North). The methodologies are based on previous studies by Pilesjö (1992), Bamutaze (2010), and Prasannakumar *et al.*, (2012). Based on the results of analysis, the following conclusions can be drawn.

Firstly, no significant trends in precipitation changes during the last decade are found. Even if there are reports of more intense and increasing amounts of rainfall in the area, this could not be verified, neither through analysis of climate data, nor trends in estimated soil loss.

Secondly, the risk of soil erosion is not significantly different year 2015 compared to year 2000, and also no significant change trends through target years.

Thirdly, no specific change of patterns in soil loss, precipitation and landcover has been found.

Finally, even though there are no significant changes found, the mean annual soil loss values seem more sensitive to precipitation changes.

The results obtained by this study are basically reliable, even if there may be some uncertainties and limitations during the processing of the study. For future studies working on this field, more targets years are suggested to be treated on. Furthermore, for a much better research, better datasets are needed. Thus, the construction and improvement of the database used for environmental analysis are expected to be implemented to reduce the uncertainties and limitations. Hopefully, more studies in this field will be carried out to estimate and solve land degradation problems, provide early warming service for the geologic hazard.

Recommendations.

There is a need to further investigate better ways of deriving the conservation and management factor (P) for better on future studies. Establishment of functional weather stations to collect precipitation data. New research in this area should use satellite data from the same month and in dry time. The reason for this is that not only this period has the most vegetation cover, but also that it is the most serious erosion period due to rains. Target years should be increased. Better construction for the GIS database in this study field will also lead to increase the available data for time series study.

Limitations to the use of RUSLE and GIS in the Study Area

Due to the specific characteristics of study area, finding the data which fulfill the requirement of RUSLE modeling is very difficult. In this study, most of the data are provided by local departments and researchers except for the LandSat remote sensing data. Mainly four key points are highlighted in following the explanation for each of the original data.

Regarding precipitation, only data from one rainfall station in the region was available. The precipitation maps for the entire study area were generated by running IDW interpolation with the data from this one point which was used as multiple stations. Moreover, the location for the only climate station used for interpolation is far from the study area. One can thus expect the interpolated precipitation values to be more accurate if there were more rainfall stations in the study area. If the limitation of the original rainfall data can be solved and more rainfall data available, the uncertainty from R-factor can be significantly reduced.

In the soil map, nine types of soil were detected in the study area, which does not have a good quality. In Nigeria, soil mapping is still at a coarse scale, which also can be treated as a challenge to seek for good soil data. Anyway, with more detailed soil map a more accurate result can be achieved. In addition, the method used to estimate K- factor is according to the composition of the particular type of soil, which can be called as a rough estimation method and it is not accurate enough. In the study done by Xu *et al*. (2012), a more professional K-factor estimation method which refers to Sharpley & Williams (1990) is mentioned and presented. In order to apply this method, more detailed soil parameters are required, for instance, the subsoil sand fraction, the silt fraction, the clay fraction and topsoil carbon content in percentage. With more detailed soil information and using a more accurate estimation method, the K-factor values will be improved.

There are also uncertainties in the cover management factor which was estimated using Landsat satellite images. There are mainly two sources generating the uncertainties, one is related to the temporal distribution of the satellite data, and the other related to cloud cover.

The satellite data is supposed to be from the same month and in the summer time. The reason for this is that not only this period has the most vegetation cover, but also that it is the most serious erosion period due to the rains. However, the rainy season and the climatic conditions result in extremely cloudy weather. It was impossible to find satellite data from the same month for the different paths and rows.

If all the problems mentioned above are solved and taken into consideration, by applying RUSLE model, the uncertainties in the estimated soil erosion results can be reduced significantly. In addition, more and better construction for the GIS database in this study field will also lead to increase in the available data for time series study. Therefore, more detailed and continuous study can be performed.

References

[1] Amangabara, G. T. (2012). Geo-Environmental Hazards and disasters in Africa. Alheri books. PortHarcourt. Pp 5-20

[2] American Society of Agricultural and Biological Engineers. (2002). In Defence of Soil and Water Resources in the United Sttaes: Soil Erosion Research Priorities.http://topsoil.nserl.purdue.edu~flanagan/erosymp/ASAE-position-paper.pdf

[3] Amore E., Modica C., Nearing M.A. and Santoro V.C. (2004). *Scale effect in USLE and WEPP application for soil erosion computation from three Sicilian basins, Journal of Hydrology,* 293 (1-4), 100-114.

[4] Andersson,L. (2010). Soil Loss Estimation Based on the USLE/GIS Approach through Small Catchments- A Minor Field Study in Tunisia. PhD Dissertion, Division of Water Resources Engineering, Department of Building and Environmental Technology, Lund University, Sweden.

[5] Anejionu O.C.D., Nwilo P.C. and Ebinne E.S (2013). Long term assessment and mapping of erosion hotspots in Southeast Nigeria, Remote Sensing for Land use and planning-6448

[6] Arnoldus, H.M.J. (1980). An approximation of the rainfall factor in the Universal Soil Loss Equation. In: De Boodt, M., Gabriels, D. (Eds.), Assessment of Erosion. Wiley, Chichester, UK, pp. 127-132.

[7] Bamutaze, Y. (2010). Patterns of water erosion and sediment loading in Manafwa catchment, Mt. Elgon, Eastern Uganda. Makerere University.

[8] Dwivedi, R. S. (2001). Soil Resources Mapping. A remote sensing perspective, Remote Sensing reviews, 20 (2), 89-122

[9] Edwards, K. (1987). Runoff and soil loss studies in New South Wales: Soil Conservation Service of NSW. Technical Handbook No. 10, Sydney.

[10] Ehiorobo, J.O. and Izinyon, C.O., (2011). " Measurement and documentation for Flood and Erosion Monitoring and control in the Niger Delta States of Nigeria, FIG working week 2011.

[11] ESRI guide to GIS Analysis, Vol. 2. (2005) Spatial Measurements and Statistics.

[12] Environmental System Research Institute. (2005 - 2012). ArcGIS Version 9.2: ArcGIS Desktop Help (Version 9.1).

[13] Ezemonye, M.N. and C.N. Emeribe. (2012) Rainfall Erosivity in South Eastern Nigeria. *Ethiopian Journal of Environmental Studies and Management* 5, 2. http://dx.dio.org/10.43 14/ejesm.v5i2.1.

[14] Ezezika,O.C. and Adetona, O. 2011. Resolving the gully erosion problem in Southeastern Nigeria:Innovation through public awareness and community-based approached. *Journal of Soil Science and Environmental Management,* 2(10), 286-291
[15] Feng, X. M., Wang, Y. F., Chen, L. D., Fu, B. J., and Bai, G. S. (2010) Modeling soil erosion and its response to land-use change in hilly catchments of the Chinese Loess Plateau, Geomorphology, 118, 239–248,.
[16] Fu, B.J., Zhao, W.W., Chen, L.D., Zhang, Q.J., Lu, Y.H., Gulinck, H. and Poesen, J. (2005). Assessment of soil erosion at large watershed scale using RUSLE and GIS: A case study in the Loess Plateau of China. Land Degradation & Development 16, 73-85.
[17] Goldman, S. J., Jackson, K., &Bursztynsky, T. A. (1986).Erosion and sediment control handbook. New York a.o.: McGraw-Hill
[18] Igbokwe, J.I., Akinyede, J. O., Dang, B., Alagac, T., Onoa, M.N., Nnodu, V. C., Anike, L.O. (2008). Mapping and Monitoring of the impact of gully erosion in south eastern Nigeria with satellite remote sensing and Geographic Information System. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.37.B8. Beijing.
[19] Hoyos, N. (2005). Spatial modeling of soil erosion potential in a tropical watershed of the Colombian Andes. Catena 63 (1), 85-108.
[20] Hudson, N. (1981). Soil Conservation. Batsford Academic and Educational. London.
[21] Joan Q.Wu. (2011). WEPP: A Physically-Oriented Hydrology and Erosion Model for watershed Assessment, Management, and Conservation.
[22] Kalpana, O. B. (2006). Soil Erosion Risk Modelling and Current Erosion damage Assessment Using Remote Sensing and GIS Techniques. Pp 11-35
[23] Kim J.B., Saunders P., Finn J. T.(2005) Rapid assessment of soil erosion in the Rio Lempa Basin, Central America, using the Universal Soil Loss Equation and Geographic Information Systems, Environmental Management,36(6)(2005),pp.872-885
[24] Karydas, C.G., Sekuloska, T. & Silleos, G.N. (2009). Quantification and site- specification of the support practice factor when mapping soil erosion risk associated with olive plantations in the Mediterranean island of Crete. Environmental monitoring and Assessment 149, 19-28.
[25] Kinnell, P.I.A. (2005). Raindrop-impact-induced erosion processes and prediction: A review
[26] Kostadinov, S., (2005) Erosion and Torrent Control in Mountainous Regions of Serbia. Preceeding Keynote Paper, International Year of Mountainous Conference. Natural and Socio-economic effects of Erosion Control in Mountainous Regions.
[27] Kouli, M., Soupios, P. & Vallianatos, F. (2009). Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. Environmental Geology 57, 483-497.
[28] Laosuwan, S. Pattanasethanon and W. Sa-Ngiamvibool (2013). Using GIS, RS for Soil Erosion Mapping. Geospatial World Weekly.
[29] Lu, D., Li, G., Valladares, G. S., and Batistella, M. (2004). Mapping soil erosion risk in Rondônia, Brazilian Amazonia: using RUSLE, remote sensing and GIS. Land Degradation & Development, 15 (5), 499-512
[30] Maidment, D.R. and Djokic, D. (2000). Hydrologic and hydraulic modeling support with geographic information systems. ESRI Press, Redlands, CA.
[31] McBratney, A. B., Mendonca, S. and Minasny, B. (2003). On Digital Soil Mapping, Geoderma, 117 (1-2)3-52
[32] Millward, A. A. and. Mersey J. E. (1999). Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed, CATENA, 38 (2), 109-129