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# **Soil Vulnerability Assessment of Afikpo South Local Government Area, Ebonyi State, Nigeria**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors OE and OOO designed the study, performed the statistical analysis, wrote the protocol and Author ONV wrote the first draft of the manuscript. Authors OOO and ONV managed the analyses of the study. Authors COA and JMM managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Remote Sensing and Geographic Information System (GIS) integrated with the Revised Universal Soil Loss Equation (RUSLE) was adopted to estimate the rate of annual soil loss in Afikpo South Local Government. This is important due to the fact that agriculture is the main source of livelihood in the area. The RUSLE factors were computed using data such as rainfall from NIMET, Soil from FAO, elevation from SRTM and Landsat 8 OLI from USGS. The data were used as input in a GIS environment and the annual soil loss was generated using the RUSLE equation. The result shows that the average annual soil loss ranges from 0 to 155, 858 ha/ton/yr. It was also observed that soil

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erosion was predominant in the southern part of Afikpo South LGA due to the presence of steep slopes in the area. The study serves as preliminary documentation for planning, conservation and management of soil resources in the Local Government.

*Keywords: Soil vulnerability; estimation; RUSLE; Afikpo South; Nigeria.*

## 1. INTRODUCTION

Soil erosion is just the efficient expulsion of soil, including plant nutrients, from the land surface by the different operators of denudation. It happens in several parts of Nigeria under various land, climatic and soil conditions. Be that as it may, the level of event shifts extensively from one part of the nation to the other [1]. Similarly varied are the components in charge of the commencement and advancement of erosion, just as the sorts that exist in several parts of the country.

Soil erosion is a major ecological problem in southeast Nigeria [2]. Soil erosion leads to soil deterioration, and this coupled with improper land use practices becomes increasingly devastating [3]. Massive and expanding gully erosion is prevalent in five states which include Anambra, Imo, Abia, Ebonyi and Enugu. The root causes of the gully erosion are complex with climate change amplifying the challenge [4]. Erosion menace has destroyed buildings, farmlands, landmarks, ancestral burial sites, economic trees and Social infrastructures. Soil erosion poses a serious threat to food production [5]. In Afikpo South Local Government Area of Ebonyistate, there is a decrease in agricultural productivity due to soil erosion effect. The situation has become critical with an increase in population, urbanization, deforestation and intensified rainfall. There is a need for policies that encourage soil retention strategies, land-improving investments and better land management [6]. Causes of gully erosion have been traced to poor land management coupled with a lack of innovation and awareness measure [7,8]. The study was aimed to estimate the rate of annual soil loss in terms of Revised Universal Soil Loss Equation (RUSLE) in Afikpo South Local Government region using remote sensing and Geographic Information System (GIS) techniques. This is important due to the fact that agriculture is the main source of livelihood in the area.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Afikpo South Local Government Area (LGA) is located between longitude 7°40' E to 7°53'E and latitude 5°41' N to 5°57' N (Fig. 1). Afikpo South is historically known as Edda. It is the homeland

of Edda people an Igbo subgroup. Its administrative headquarters is at Nguzu Edda. Edda is bordered by Unwana to the east, Akaeze to the west, Ohafia to the south and Amasiri to the north. The basic occupation in the LGA is farming and fishing. Afikpo South LGA covers a total of 330 km<sup>2</sup> in an area with a population of 157,072 according to the 2006 Nigeria population census. The climate is characterised by two distinct seasons; the dry and rainy season. The rainy season is oppressive and overcast. The dry season is muggy and mostly cloudy. According to Koppen and Geiger, the climate of Afikpois classified as Aw with an average temperature of 27.2°C and an average annual rainfall of 2022mm. Afikpo South landscape features lush vegetation with parklands and short tress added to a litter of woodlands and forests.

### 2.2 Data

Rainfall data for Afikpo South LGA was acquired from the Nigerian Meteorological Agency (NIMET) for the period of 1985 to 2015. The rainfall data were analysed to derive the average annual rainfall for the LGA.

Landsat 8 imagery was acquired from the United States Geological Survey (USGS) imagery distribution platform. The Landsat imagery was acquired on the 15<sup>th</sup> of January, 2015. The study area was extracted from the large dataset. The imagery was used to generate the vegetation cover for Afikpo South LGA.

Shuttle Radar Topography Mission (SRTM) imagery was acquired from the United States Geological Survey (USGS) distribution platform. The SRTM image was used to delineate the slope length and slope steepness of Afikpo South LGA.

Soil data was acquired from the Harmonised World Soil Database (HWSD) by the Food Agriculture Organisation (FAO).

## 3. METHODOLOGY

### 3.1 Soil Erosion Modelling by Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) is an empirically based soil erosion model developed by [9]. The soil loss (A) due to water erosion per

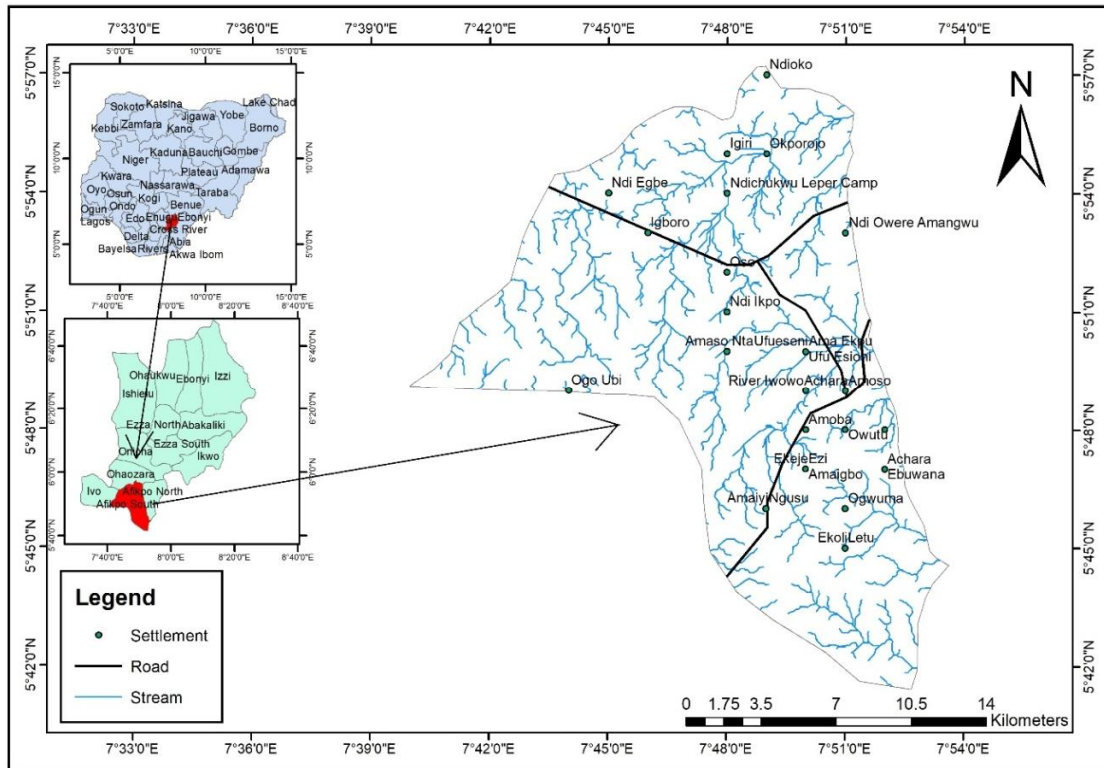


Fig. 1. Map of Afikpo South LGA-study location

unit area per year ( $\text{Mg ha}^{-1} \text{ yr}^{-1}$ ) was quantified using USLE following equation:

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

Where A is the average soil loss due to water erosion, R the rainfall and runoff erosivity factor ( $\text{MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$ ), K the soil erodibility factor ( $\text{Mg h MJ}^{-1} \text{ mm}^{-1}$ ), L the slope length factor (dimensionless), S the slope steepness factor (dimensionless), C the cover and management practice factor (dimensionless), and P the support practice (dimensionless).

### 3.2 Rainfall-Runoff Erosivity Factor (R)

The rainfall erosivity factor (R) is a representation of the potential of rainfall to erode soil particles [10] The R factor reflects the effect of long term average of rainfall intensity on soil erosion [7].

### 3.3 Soil Erodibility Factor (K)

Soil erodibility factor (K factor) is the soil loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6ft (22.1m) length of uniform 9% slope in

continuous clean-tilled fallow [11]. Soil erodibility factor measures the susceptibility of soil particles or surface materials to transportation and detachment by the amount of rainfall and runoff input [8]. K factor takes into account the integrated effect of rainfall, runoff and infiltration on soil loss [9]. K factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport due to raindrop impact and overland flow shear forces [12].

### 3.4 Topography Factor (LS)

L factor is the function of slope length and S factor is the function for slope steepness. The both which is written as LS factor is used to represent the topographical factor effect on soil erosion. The effect of topography on soil loss is accounted for by the LS factor. Slope length is defined as the distance from the point of origin of overland flow to either the point where the slope decreases to the extent that deposition begins or the point where runoff enters well-defined channels [7]. The slope length factor determines the concentration of water. The greater the slope length of a field, the greater the concentration of water and runoff [13]

### 3.5 Cover Management Factor (C)

The cover and management factor indicates how vegetation cover, cropping and management practices affect soil erodibility. Cover Management Factor (C) is the ratio of soil loss from a particular site with a specified cover and management to soil loss from a standard unit plot [9]. This simply means the ratio of soil loss of a specific crop to the soil loss under the condition of continuous bare fallow [8]. This value includes the effects of cover, crop sequence, productivity level, length of the growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms.

### 3.6 Conservation Practice Factor (P)

Support practice factor is the soil loss ratio with a specific support practice to the corresponding soil loss with up and downslope tillage [8]. Farmers tend to plough their farmlands without engaging in soil conservation practices such as contouring, striping and terracing and this leads to higher P value. Lower P values would be attained if conservation practices are been carried out by farmers. These practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff [14].

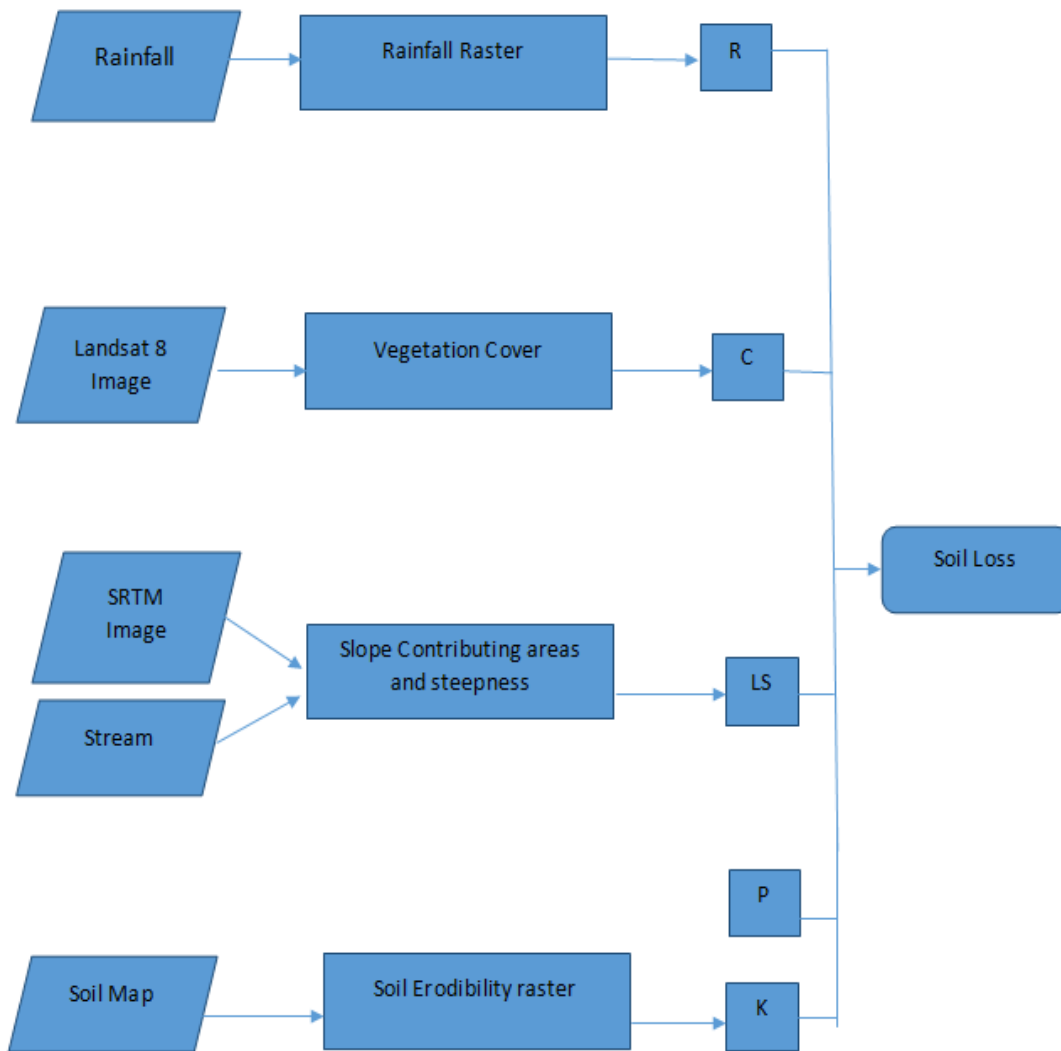


Fig. 2. RUSLE flow chart

#### 4. RESULTS AND DISCUSSION

##### 4.1 RUSLE Erosion Modelling

###### 4.1.1 Rainfall-runoff erosivity factor (R)

NIMET precipitation data for 1985 – 2015 was acquired for Afikpo South LGA. The average precipitation was calculated for the 30 years period. The average precipitation in Afikpo South LGA for the 30 years period is 2385.39mm. The calculated average precipitation value was fitted into the R factor formula:

$$R = 0.5 * P * 1.73 \text{ (in Metric unit) [15]}$$

The R factor was calculated as 2063.36 and this represents the rainfall regime within Ebonyi state.

###### 4.1.2 Soil erodibility factor (K)

The soil types identified within the Afikpo South LGA includes; Dystric Nitosols and Dystric Gleysols. The soil properties were used to classify and compute the erodibility factor within the study area. Table 1 shows the K factor each

soil type in Afikpo South Local Government. Fig. 3 shows the map of the K factor for each soil type. The K factor is computed with the following equation:

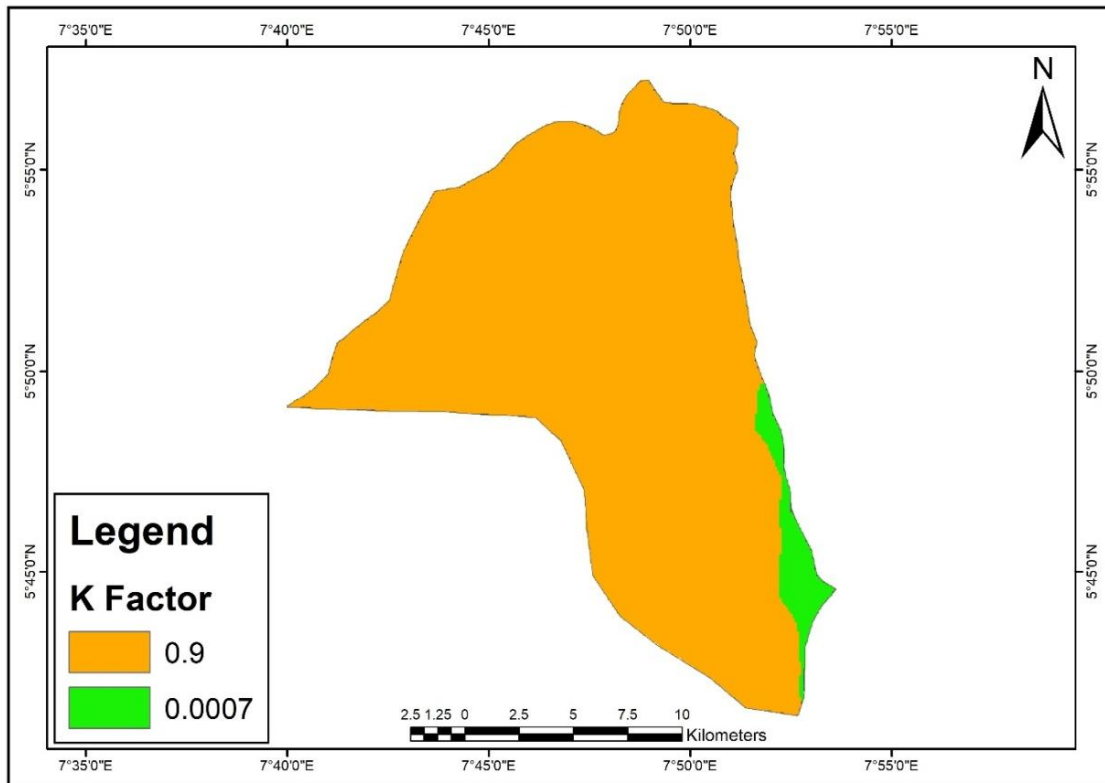
$$K = 27.66m^{1.14} \times 10^{-8} \times (12-a) + 0.0043 \times (b-2) + 0.0033 \times (c-3)$$

Where;

- K = Soil erodibility factor (ton/hr/haMJmm)
- m = (Silt% + Sand%) x (100 – clay%)
- a = % organic matter
- b = Structure code: 1) very structured or particulate, 2) fairly structured, 3) slightly structured and 4) solid.
- c = Profile permeability code: 1) rapid, 2) moderated to rapid, 3) moderate, 4) moderated to slow, 5) slow, 6) very slow

**Table 1. Shows the K factor for each soil type in Ebonyi State**

Soil type	K factor
Dystric Nitosols	0.9
Dystric Gleysols	0.0007



**Fig. 3. Map of the K factor**

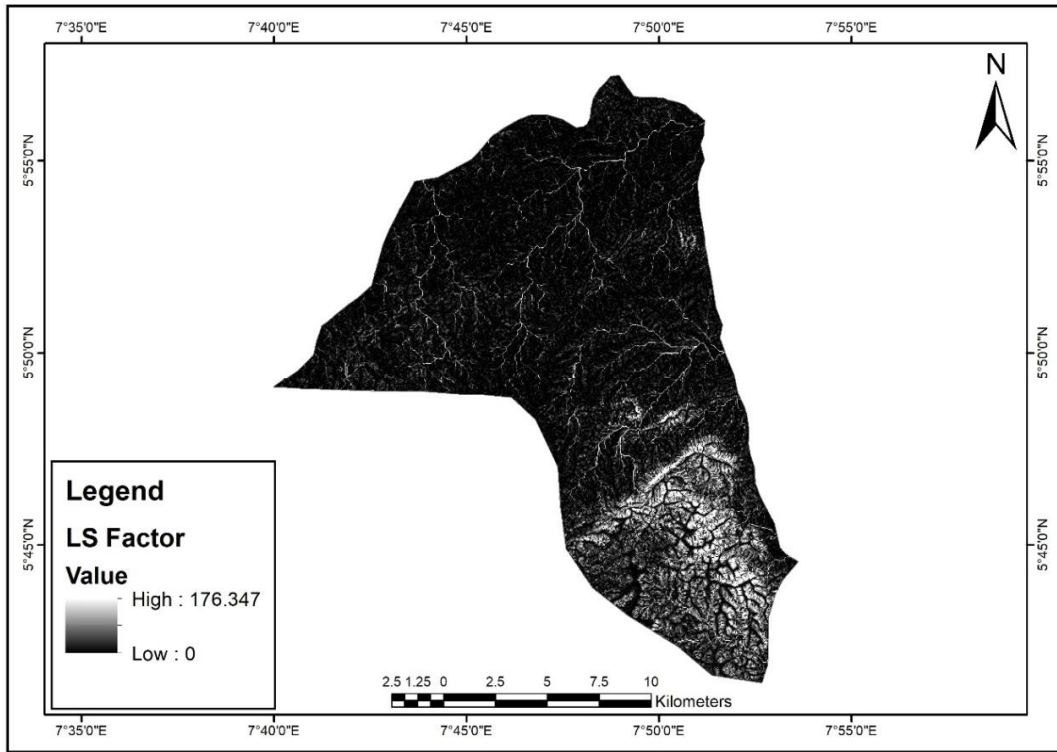


Fig. 4. Map showing LS factor

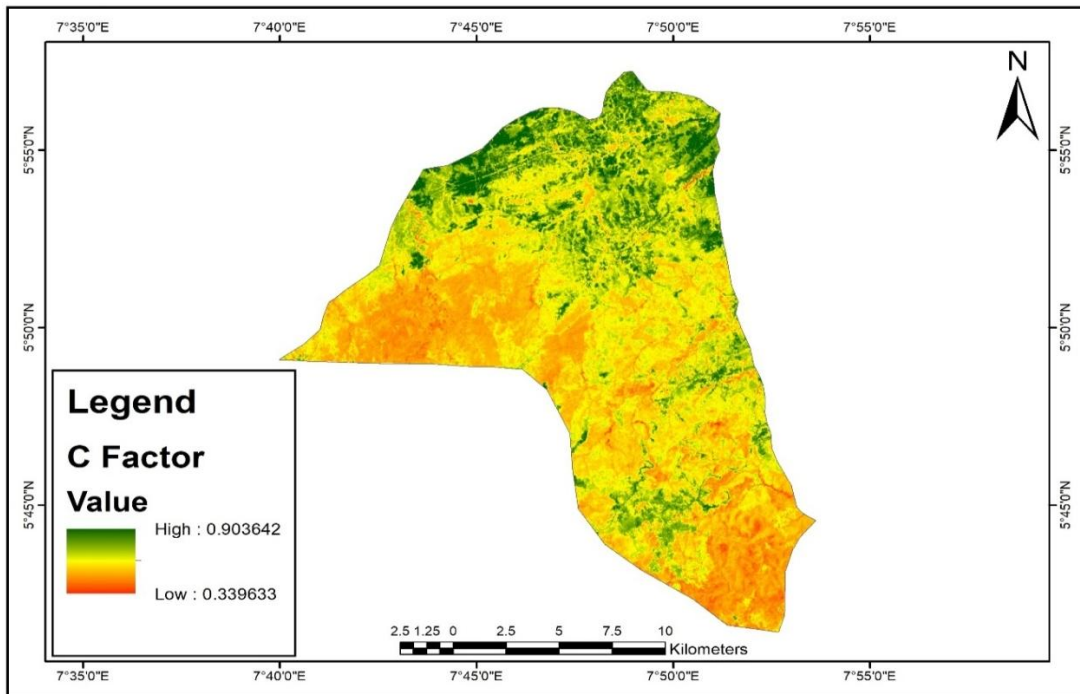


Fig. 5. Map of C factor

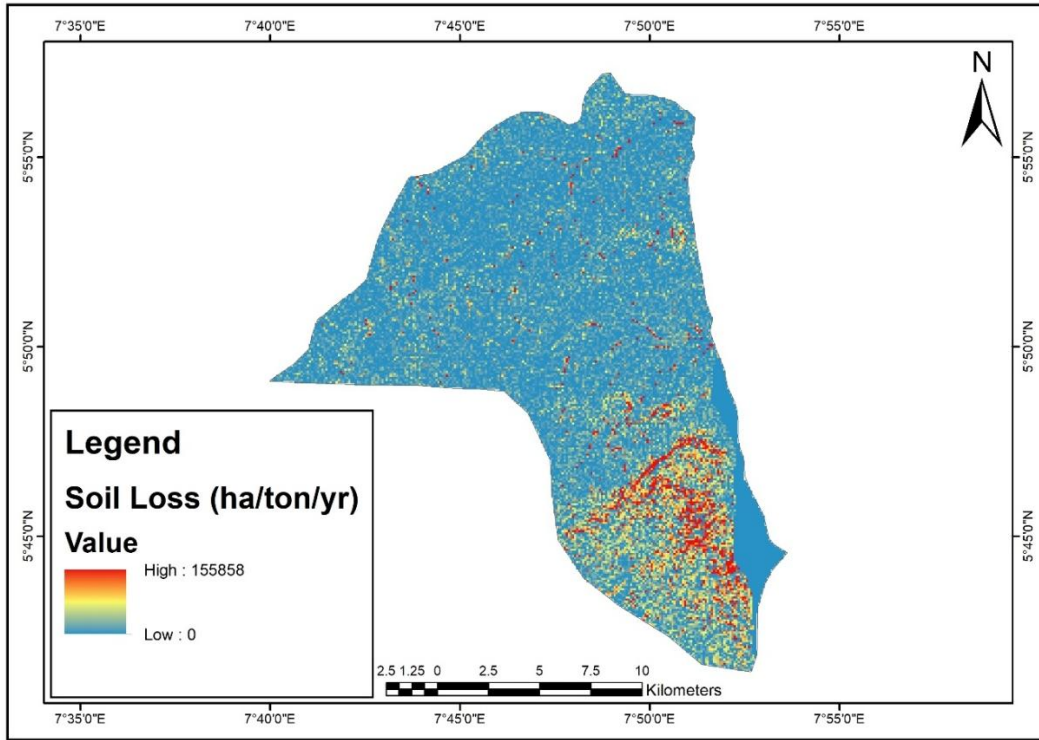


Fig. 6. Map of soil loss in Afikpo South LGA

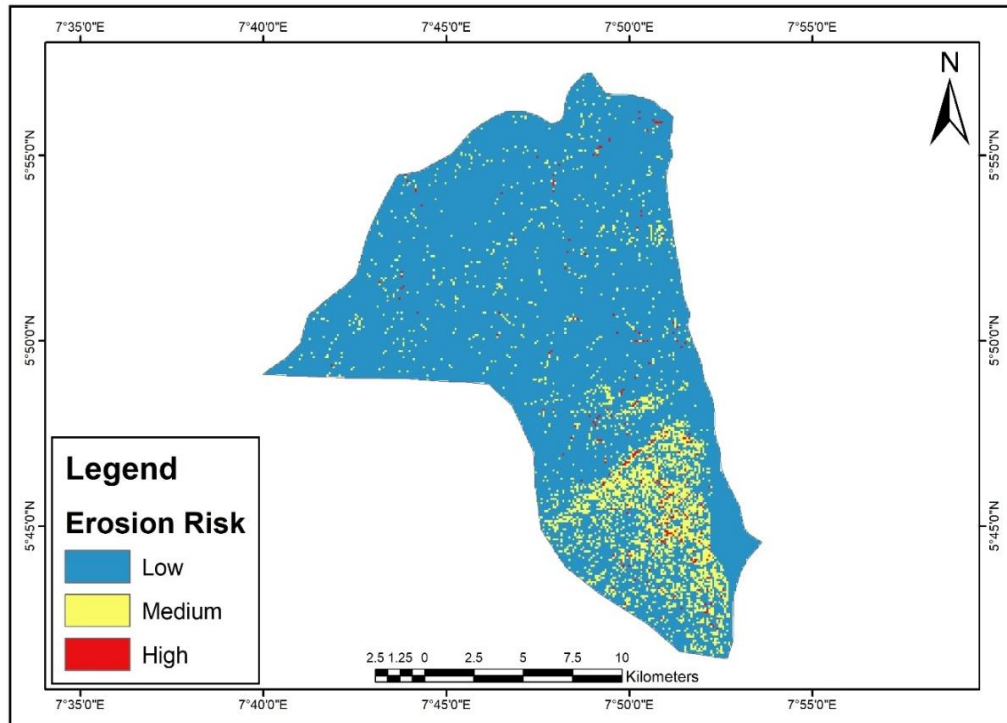


Fig. 7. Afikpo South LGA soil erosion risk map

#### 4.1.3 Topography factor (LS)

The steepness factor (S factor) accounts for the influence of slope steepness or elevation on erosion. The steeper and longer the slope, the higher is the risk for erosion. The combined effect of slope length and steepness gives the rate of soil erosion. Fig. 4 shows the map LS factor. The map indicates that the slope steepness is dominant in the southern parts of Afikpo South LGA.

#### 4.1.4 Cover management factor (C)

C factor shows the relationship between erosion on bare soil and erosion observed under a cropping system. It expresses the protection of soil by cover type and density [16]. The C factor was generated using NDVI, a vegetation health indicator, in the following equation;

$$C = \exp \left[ -\alpha \frac{NDVI}{(\beta - NDVI)} \right]$$

Where  $\alpha$  and  $\beta$  are unit-less parameters that determine the shape of the curve relating to NDVI and the C Factor. This scaling approach gives a better result than assuming a linear relationship and the values of 2 and 1 were selected for the parameters  $\alpha$  and  $\beta$  respectively [17]. The generated C factor ranges between 0.9 and 0.34. Fig. 5 shows the map of the C factor.

#### 4.1.5 Conservation practice factor (P)

P factor accounts for soil loss when specific management practices are carried out. The P value for Afikpo South LGA was set at 1 since there are no specified management practices used in the region.

#### 4.2 Soil Loss

Fig. 6 shows the amount of soil loss in tonnes per hectares per year in Afikpo South LGA. The soil erosion in Afikpo South LGA is spread in patches across the LGA area. The northern part experiences lesser erosion activities. Soil erosion was more prevalent in the southern part of the LGA. The soil loss ranges from 0 to as high as 155,858 ha/ton/yr. Fig. 7 shows the erosion risk Afikpo South LGA. The erosion risk was classified into three; low, medium and high. Low risk covers an area of 297.92km<sup>2</sup>, medium risk covers an area of 29.15km<sup>2</sup> and high risk covers an area of 2.14km<sup>2</sup>.

#### 5. CONCLUSION

Remote Sensing and Geographic Information System (GIS) integrated with the Revised Universal Soil Loss Equation (RUSLE) were applied (Fig. 2) in this study to predict the annual average soil loss rate in Afikpo South Local Government Area, Nigeria. This process can serve as a first step to identifying and mapping of land degradation and its effect. Soil erosion is a major environmental challenge in Afikpo South Local Government area where agriculture is the source of livelihood. Mapping of soil loss in this area is necessary for planning and management of soil resources in the Local Government. The study result indicates that soil erosion was prevalent in the southern part of the local government. In the northern part, there were scattered patches of high and medium risk soil erosion zones. Low soil erosion risk area covers 90.5% of the area, medium soil erosion risk area covers 8.8% of the area and High soil erosion risk covers 0.7% of the total area. It was observed that soil erosion was prevalent in the southern part of the Local Government Area due to the presence of steep slopes which are predominant in the south.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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