Original Research Article

ASSESSING THE EFFECT OF LANDUSE/LAND COVER (1986-2020) ON SOIL LOSS IN ALLUVIUM GEOLOGIC FORMATION USING GEOSPATIAL TECHNOLOGY IN SOUTHERN NIGERIA

Abstract

The occurrence of soil loss is a continuous process and occurs spatially across the earth's surface. The study of soil loss is a necessity for proper understanding of the processes and the rate of soil loss for conservational purpose. Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper Plus (ETM^+)/Operational Land Imager (OLI) image data was acquired for 1986, 2003 and 2020 were used to derive the *C*factor of the RUSLE model while other factors of the model were kept fixed for the years considering their inability to change easily. The RUSLE model was used to determine the trend of the soil loss on the alluvium geologic formation considering their land use/land cover changes for 1986, 2003 and 2020. The rainfall erosivity of the study area had an average of 8201.45$MJmmha^{-1}h^{-1}yr^{-1}$. The soil erodibility index of the soils obtained from Alluvium had an average of 0.150tons MJ^{-1} hmm^{-1}. The slope length and steepness factor of the study area range from 0 to 2.574. the crop cover factor of for 1986 range from 0.52 to 0.87, 2003 range from 0.52 to 0.87 and 2020 range from 0.62 to 0.92. No active field conservation was found out within the study area as described by Wischmeier and Smith. The results obtained show that 1986, 2003 and 2020 had a soil loss of 1966.3, 2167.85 and 3361.14 $tonha^{-1}yr^{-1}$ respectively.The results show that the study area is experiencing an increased trend of soil loss. This result can serve as guide into understanding the past and current rate of soil loss for soil resource planning and management

Keyword: AlluviumGeologic Formation, Land use/land cover, Revised Universal Soil Loss Equation (RUSLE),Rainfall Erosivity, Soil Erodibility.Soil Erosion.

1.0 Introduction

Soil erosion is considered as a continuous process and occurs spatially on the earth's surface (Okorafor *et al.*, 2017; Elsawwaf and Williems, 2012). It is considered as a global threat to the environment due to its onsite and offsite Impact (Boardman andPoesen, 2006; Wang *et al.*, 2018). Theuse of Landsat imageries in determining the crop cover factor of the empirical model through the land use/land cover has enabled the estimation of soil for the past and present. This has become a necessity for the proper understanding of the soil loss pattern and adequate management planning.

Soil loss is known to be caused by several factors that works together simultaneously to cause soil loss such as; rainfall erosivity *R*, soil erodibility *K*, slope length and steepness *LS*, landcover *C*and land management *P*(Wischmeier and Smith, 1978; Aga *et al*., 2018).For soil erosion to occur there be rainfall erosivity which is known as the ability of rainfall to cause soil loss and soil erodibility is the ability of the soil to resist the sudden impact of the erosive event to cause detachment of the soil particles (Almaaitah *et al*., 2018). It is being been exacerbated by the slope length and steepness, landcover and land management practices (Nearing *et al.,* 2017; Wischmeier and Smith, 1978).

Several models have been adopted in soil loss study such as; the conceptual model such as Agricultural Non-Point Source Model (AGNPS) (Abdelwahab *et al.*, 2018) and Soil Water Assessment Tool (SWAT)(Dutta and Sen, 2018); empirical model includes Universal Soil Loss Equation (USLE)(Tsegaye *et al*., 2015) and Revised Universal Soil Loss Equation (RUSLE)(Thomas *et al*., 2018); physical based model which include Pan European Soil Risk Assessment (PESERA)(Li *et al.,* 2020) and Water Erosion Prediction Project (WEPP) (Meinen and Robinson, 2021).TheUSLE/RUSLE of the empirical model is the most used model worldwide in predicting soil loss and has been considered as a soil conservation and planning tool (Tsegaye *et al*., 2015;Thomas *et al*., 2018). TheUSLE/RUSLE model quantifies soil loss as a product of six factors working simultaneously to cause soil losssuch as the *R*,*K*,*LS*,*C*,*P*(Reinard and Freimund, 1994; Wischmeier and Smith, 1978;Tsegaye *et al*., 2015;Thomas *et al*., 2018)

Several studies have been carried out on soil loss within the study area. Fashae *et al*(2013) carried out soil loss study on wasteland in uyo. Udoumoh *et al.*,(2018) studied the impact of gully sites on the properties of the soil and its erodibility. Ogbonnaya and Johnbosco, (2018) studied the impact of geologic of geologic formation on soil erodibility in Anambra, Nigeria. Essien and Okon (2011) carried out a research using the number of rain days, rainfall amount, intensity and erosivity on soil loss and gully development in Uyo. Udoh and Akpan (2015) carried out a study on the characteristics and classification of soils as influenced by their parent materials. Akpan and Uwah (2018) studied the impact of land use systems and parent materials on soil quality indicators in soils of Akwa Ibom state. Uzoma and Onwuka (2018) carried out a field study in Ikpe Ikot Nkon of Akwa Ibom state on aggregate stability of different agricultural land use system.

The application of GIS and remote sensing in modelling soil loss has encouraged the rampant use of the empirical modelin predicting soil loss based on their compatibility and ease of usage(Abdelwahab *et al.,* 2018; Pancholi *et al.,* 2015). The use of remote sensing data such as satellite imageries has enabled the retrieval of the landuse/landcover over the years and has enabled the estimation of the soil loss based on the land use pattern previously and currently for proper understanding of the soil loss based on the land use pattern within the study area.

Theuse of satellite thematic imageries has been found to be useful in estimating the crop cover factor in the USLE/RUSLE model.Therefore, the objective of this research is to determine the soil loss trend in Alluvium geologic formation for 1986, 2003 and 2020 using the satelliteimageries of the respective years.

2.0 Materials and Method

2.1 Study Area:

The location of the study is Akwa Ibom state, Nigeria. The study area is located within the trigonometric boundaries of 4^{o}32’ and 5^{o}33’ north latitude and 7^{o}25’ and 8^{o}25’east longitude. The climate is divided intothe wetanddry season which last from April to October and November to March respectively. The annual total rainfall ranges from 1875mm to 2500mm with a mean annual temperature that varies between 21^{o}c and 29^{o}c and a relative humidity of 60% and 85% (Ogban and Obi, 2010).

2.1.1 Description of the Geologic Formation

The detailed geologic map of the study was obtained from the Cross River Basin Development Authority. The map was scanned, geo-referenced and digitized for the study as shown on Figure 1. Five geologic formations were identified within the study area.Alluvium formation – lithologies consists of sands, silts, clay, shale and gravels as described by (Akpan and Uwah, 2018;Oboh-Ikuenobe *et al*., 2005).

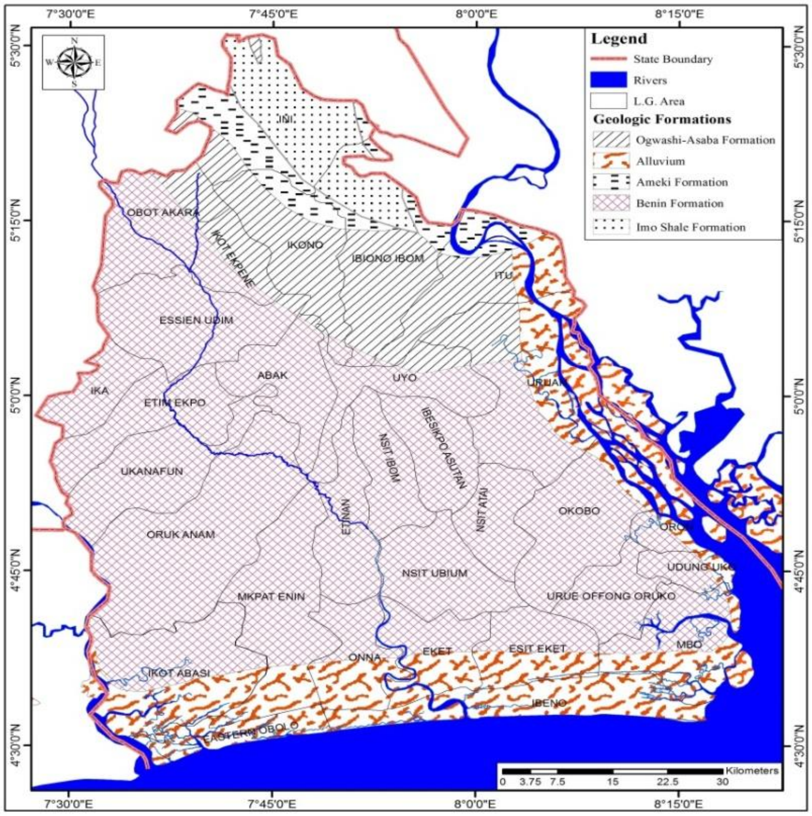

Figure 1: Map of Geologic Formation of Akwa Ibom

Source: Cross River Basin Development Authority

2.2 Methods:

2.2.1 Erosion Modeling

2.2.1.1 Revised Universal Soil Loss EquationModel

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \quad (2.1)$$

Where:

A = is given as the estimated spatial and temporal average soil loss per unit area, which is given as tons/acre/year or tons/ha/year; R = rainfall-runoff erosivity factor ($MJmmha^{-1}hr^{-1}yr$); K = soil erodibility factor (tons MJ^{-1} hmm^{-1}); L = slope length factor; S = slope steepness factor; C = cover-management factor; P = support practice factor

2.3 RUSLE Model Parameter Estimation

2.3.1 Rainfall Erosivity (*R*)

In obtaining the rainfall erosivity index of the study area, a mean monthly rainfall data (rainfall amount) for 34 years (1985 - 2018) was obtained from Nigerian Metrological Agency (NIMET), Oshodi; Lagos. Similarly, a mean monthly data was obtained from the Akwa Ibom International Airport for 9 years (2010 - 2018). The method used in this study is based on the average monthly and annual rainfall to measure rainfall aggressivity using the Modified Fournier Index and determine the rainfall erosivity index *R-values* asdeveloped by Fournier (1960) and modified by Arnoldus, (1980)**.** It is an alternative procedure to estimate *R* in data scarce region(Tahiri *et al*., 2016; Ramzi *et al*., 2018; Andoh *et al*., 2012; Renard and Freimund, 1994; Coman *et al*., 2019). The equation is given as;

$$R = 1.735 \times 10^{(1.5\log F - 0.08188)} \qquad (2.2)$$

$$F = \sum_{i=1}^{12} \frac{P_i^2}{P} \qquad (2.3)$$

R = Rainfall Erosivity (MJmmha^{-1}h^{-1}yr^{-1}); F = Modified Fournier Index; *Pi* = Monthly rainfall (mm); *P* = Total annual rainfall (mm)

2.3.2 Soil Erodibilty (*K*) *Factor*

Soil Erodibilty (*K*) factor is an important field parameter in assessing the risk of soil erosion based on the sand, silt, clay, organic matter, permeability and structural code of the soil (Wischmeier and Smith, 1978; Chadli, 2016). K factor investigates the susceptibility of a soil to loss based on the physico-chemical characteristics of the soil sampled obtained as measured under the standard unit plot criteria. The standard condition is the unit plot, which is given as 22.6m long with a 9% gradient, tilled up and down the hill slope with a continuous fallow system (Chadli, 2016 and Wischmeier and Smith, 1978). The results of the analyzed soil samples in the study area were used for determining the*K*factor as giving by equation 2.4.

$$k = \frac{2.173 \times 10^{-4}\,(12 - OM) \times M^{1.14} + 3.25\,(S - 2) + 2.5\,(P - 3)}{100} \qquad (2.4)$$

Where *OM* is the organic matter (%); S is soil structure class; P is permeability class; M is the aggregated variable derived from the soil textural classification; M = (%Msilt) × (%silt+%sand), and the modified silt (Msilt) is a percentage of grain size between 0.002 and 0.1 mm.

2.3.3 Topographic Factor (Slope length & steepness factor) *LS-factor*

The slope length and slope steepness expresses the ratio of soil loss as defined by Wischmeier and Smith (1978).Slope value was derived from Digital Elevation Model (DEM) of the study area. The values of X and S were derived from DEM. To calculate the slope length (*L*) value, Flow Accumulation was derived from the DEM after conducting Fill and Flow Direction processes by using Arc Hydro tool.

$$LS = (X/22.1)^{m} (0.065 + 0.045\ S + 0.0065\ S)^{2} \quad (2.5)$$

Where;

$$LS = (\text{Flow accumulation} * \text{Cell value} /22.1)^{m} (0.065 + 0.045\ S + 0.0065\ S^{2}) \quad (2.6)$$

L = slope length (m or km); S = slope gradient (%); the value of m varies from 0.2 – 0.5 depending of the slope

2.3.4 Crop management factor (C-factor)

The cropcover management factor which represents the *C*factor in the USLE/RUSLE is used to indicate the effect of cropping and management practices on soil loss rates (Pancholi*et al*., 2015). It showcases the ratio of soil loss under a given crop cover condition to the soil at the base (Morgan, 1995). The *C*factor wasgenerated using the Normalized Difference Vegetation Index (NDVI) obtained fromland use/land cover satellite imageries of the study area (Barakat*et al.*, 2014;Abdo and Salloum, 2017; Rouse *et al.*, 1974).

2.3.4.1 Landsat Imageries Data

A 30 meters resolution dataset of remotely sensed satellite imagery of Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper Plus (ETM^{+})/Operational Land Imager (OLI) image data was acquired for 1986, 2003 and 2020 respectively from the United State Geological Surveys (USGS) were used for the land use/land cover classification and change trend analysis.

2.3.4.2 Image Processing and Data Preparation

The processing of the landsat images for change detection was carried out using ERDAS IMAGINE software. Radiometric calibration and corrections were done during change detection in order to eliminate the image differences as a result of changing atmospheric conditions. Similar method has been carried out by (Eyoh and Uboh, 2015; Essien and Cyrus, 2019; Karar *et al*., 2020).

2.3.4.3 Determination of the C Factor for the Study

The NDVI were calculated using equation (2.7), subsequently, the *C* factor weredetermined using equation (2.8).

NDVI = (NIR – RED) / (NIR + RED) (2.7)

C = 1.02 – 1.21 NDVI (2.8)

2.3.5 Conservation Practice factor (*P* factor)

The conservation practice*P* factor is known as the ratio of soil loss associated with a support practice on croplands to the corresponding loss with up and down slope (Renard et.al., 1997). The different types of agricultural land management practices includes; Strip cropping, Contour farming, and terracing etc.(Wischmeier and Smith, 1978).*P*-factor is ranging from 0 – 1,the value reaching to zero indicates well conservation measures while the value reaching to 1 indicates poor conservative measures. Noactive support practice was found within the study area during inspection.

3.0 Results and Discussion

3.1 Rainfall-Runoff Erosivity of the Study Area

The rainfall amount obtained from the study area depicts a rainfall zone as described by Ezemonye and Emeribe, (2012) and Isaiah *et al*., (2020). Table 1 shows the mean value of the erosivity values obtained from NIMET and Airport metrological. The average rainfall erosivity was estimated from the two weather stations as8201.45MJmmha^{-1}h^{-1}yr^{-1}. This indicates rainfall that is capable of initiating soil loss with a strong erosivity rate (Carvalho, 2008).

Table 1: Mean Value of the Rainfall-Runoff Erosivity for the Study Area

Rainfall Station	**latitude**	**longitude**	**Rainfall Energy** (MJmmha^{-1}h^{-1}yr^{-1})

Airport	4.87499	8.091821	8536.11
NIMET	5.001233	7.9194398	7866.78
Average			**8201.45**

3.2 Soil Erodibility of Alluvium Geologic Formation

The soil erodibility within the study area as indicated an average value of the erodiblity indices of the soils formed from the alluvium geologic formation of the study area as shown on Table 2.The erodibility indices of the soils is given as 0.150 which falls into the group II of the Wischmeier and Smith, (1978) soil erodibility index classification and cited by Emeka-Chris, (2014) it shows that soils form from Alluvium geologic formation are sandy soils that are well grained, similar finding have been observed by Ogban, (2017).

Table 2 Soil Erodibility of AlluviumGeologic Formation

Soil Erodibilty (tons MJ^{-1} hmm^{-1})	**Alluvium**
K $_{\mathbf{Average}}$	0.150184

3.3 Slope Length and Steepness (*LS*) Factor of Alluvium Geological Formation

The slope length and steepness factor was obtained using the slope and flow accumulation of the DEM of the geologic formation. The *LS* factor of the Alluvium geologic formation ranges from 0 to 2.57424 as shown on Figure 2.The value of the *LS*factor indicates that the topography of the geologic formation is relatively plain with moderate slopes and gradients.

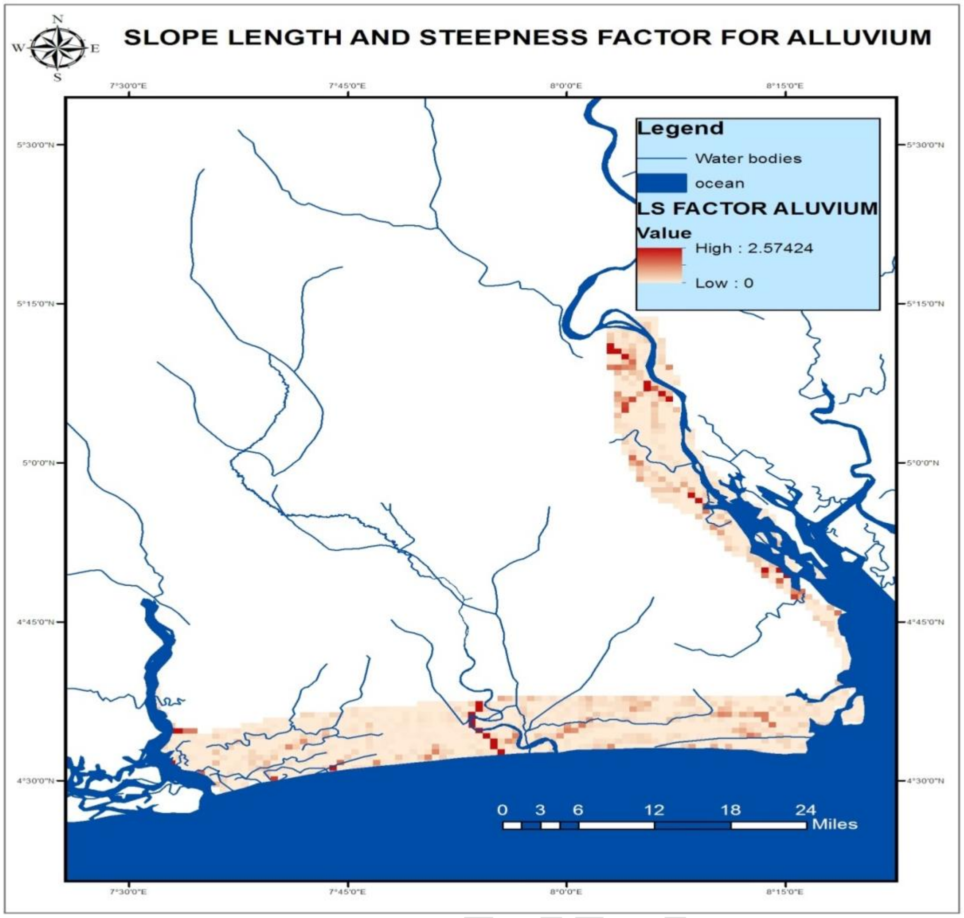

Figure 2: Map of Slope and Steepness Factor of Alluvium Geologic Formation

3.4 Land Use and Land Classification of AlluviumGeologic Formation

Table 3: LULC Spatial Extent in 1986, 2003 and 2020for Alluvium Geologic Formation

SN	**Land Use Land Cover**	**1986 Area (Ha)**	**1986 Area %**	**2003 Area (Ha)**	**2003 Area %**	**2020 Area (Ha)**	**2020 Area %**
1	Water Body	17816.33	12.34	21662.975	15.002	18079.9205	12.521
2	Swamp Forest	80480.77	55.74	62338.55	43.172	43270.1175	29.966
3	Primary Forest	10944.82	7.58	25396.85963	17.588	33190.8075	22.986
4	Secondary forest	12356. 52	8.56	17793.8985	12.323	22936.7925	15.885
5	Cultivated land	18182.12	12.60	10670.68	7.390	14434.9425	9.997
6	Builtup/Bare land	4616.257	3.20	6532.75	4.524	12484.0525	8.646
	TOTAL	**144396.633**	**100**	**144396.633**	**100**	**144396.633**	**100**

Table 2 shows the area occupied by the different land use and land cover identified in Alluvium geological formation for the period covered (1986 to 2020). The total area of land occupied by Alluvium geological formation is given as 144396.63ha. The landuse/land cover changes can be seen as a function of the population growth, urbanization and increase in agricultural activities within the study area. The data shows that more lands are exposed to the vagaries of erosion. Ekpenyong (2013) confirmed that the land use changes across the years and subjects most lands to soil loss degradation. Figure 3 shows the classified landsat imageries of Alluvium geologic formation for 1986, 2003 and 2020.

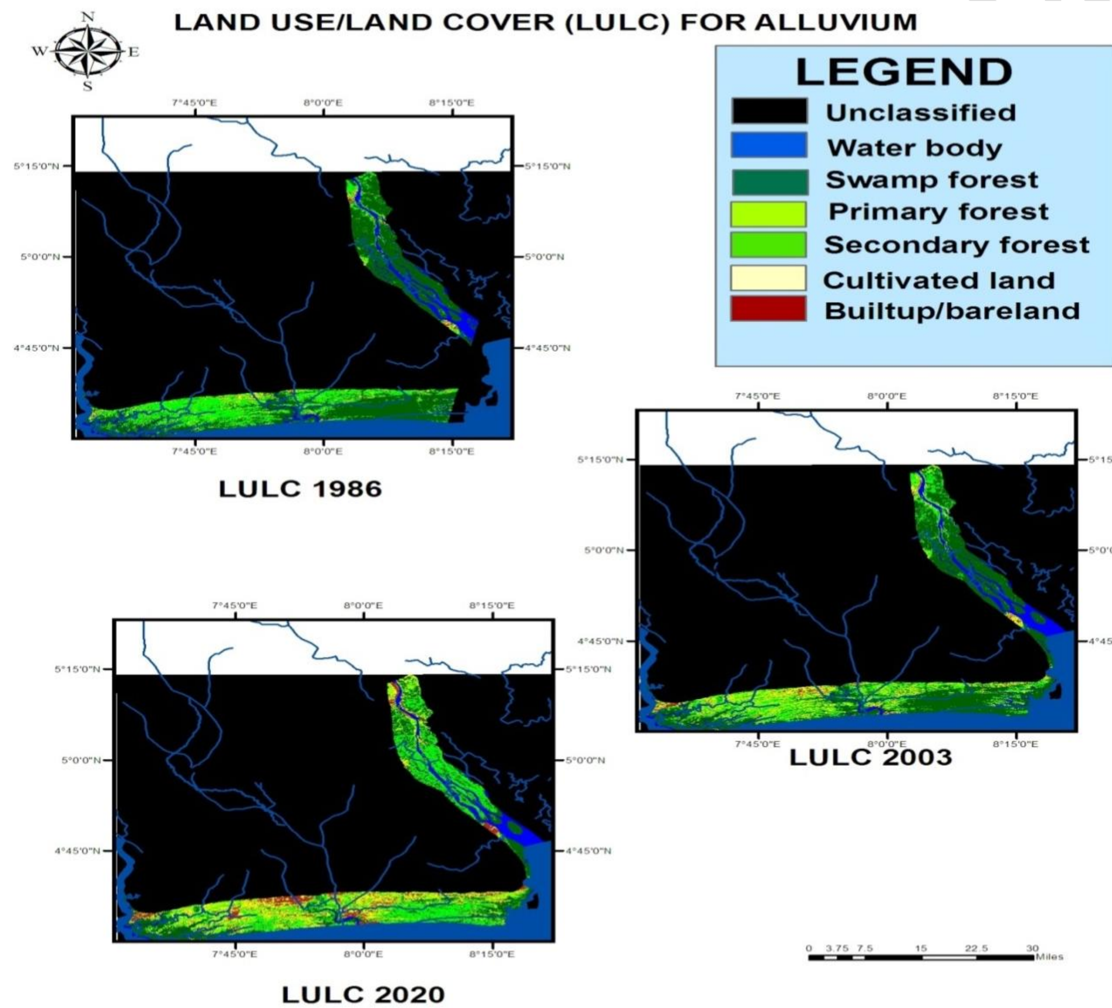

Figure 3:1986, 2003 and 2020 Classified Landsat Image of Alluvium geologic formation of Akwa Ibom state

3.4.1 Crop Management Factor for Alluvium Geologic Formation

The crop management *Cfactor* for Alluvium geologic formation using the NDVI show that the *C* factor values for 1986 range from 0.65 to 0.90, 2003 range from 0.52 to 0.87 while 2020 range from 0.62 to 0.92. Figure 4 shows the spatiotemporal variation of the crop cover management *C* factor within Alluvium geologic formation.

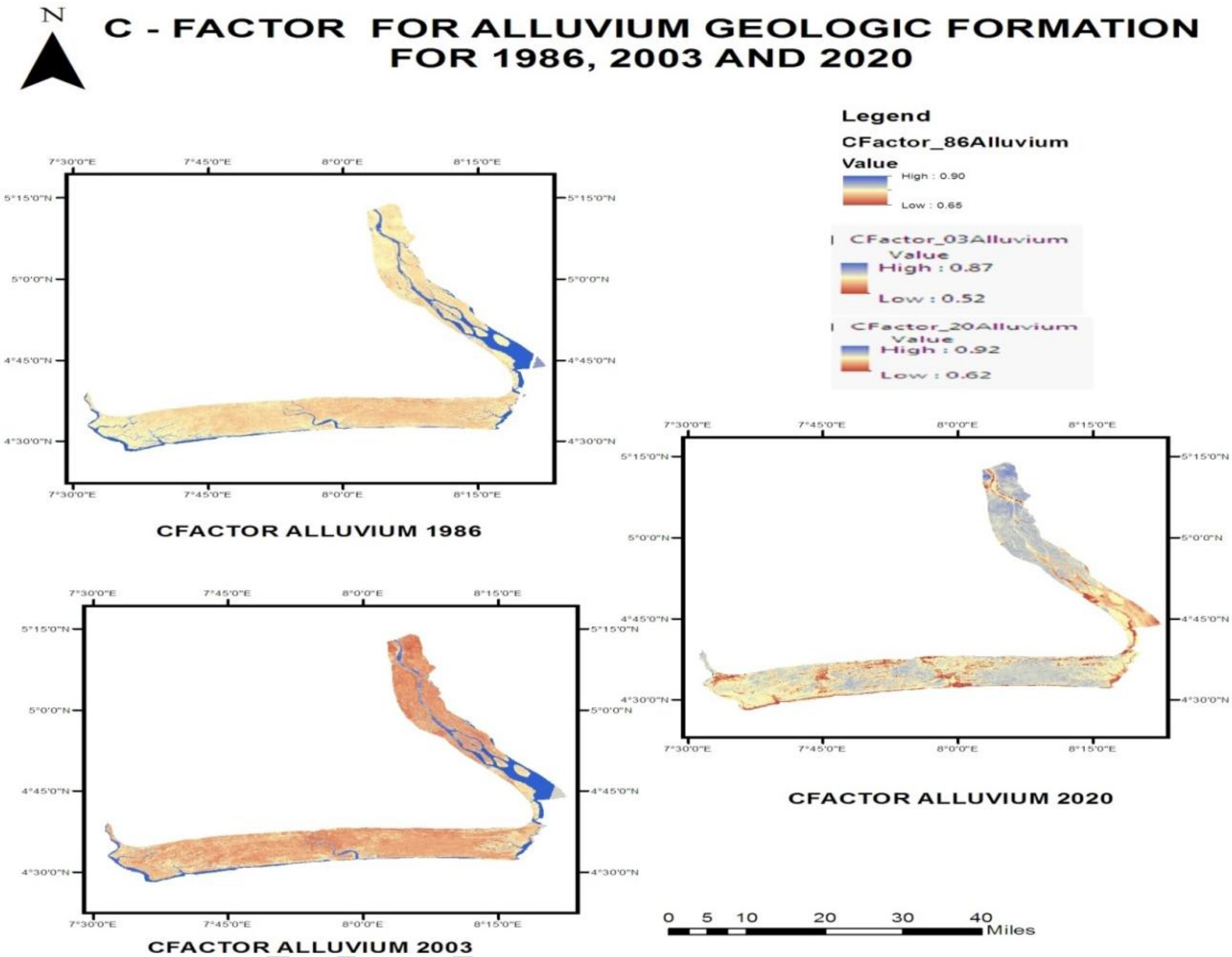

Figure 4: Cover Management Factor for Alluvium Geologic Formation for 1986, 2003, 2020.

3.5 Soil Loss Spatial Pattern for Alluvium Geologic Formation for 1986, 2003 and 2020.

Soil loss spatial pattern of Alluvium geologic formation showcases the past and present soil loss rate within the geologic formation. The years considered were 1986, 2003 and 2020. The results obtained shows that the Alluvium geologic formation had experienced a progressive soil loss across the years. In 1986, the geologic formation had an average annual soil loss ranging from 0 to 1966.3 t h^{-1} y^{-1}. In 2003, the geologic formation had an annual average soil loss of 2167.85 t h^{-1} y^{-1} while 2020 experienced an average soil loss of 3361.14 t h^{-1} y^{-1} annually. The result obtained shows that the geologic formation is experiencing a continuous soil loss (Okorafor *et al.*, 2017; Elsawwaf and Williems, 2012). The high rainfall energy found within the study area has an influence on the rate of soil loss within the geologic formation (). the erodibility index of the type of soils formed from alluvium geologic formation shows soils that are easily eroded which also contributes to the rate of soil loss within the study area. the topography indicates minimal effect on soil loss. From the results obtained from the satellite imageries, it shows that the application of remote sensing is useful in predicting soil loss. The changes on the land cover indicate the impact of population growth, urbanization and increased agricultural has led to an increased soil loss.Figure 5 shows the soil loss of Alluvium geologic formation for 1986, 2003 and 2020.

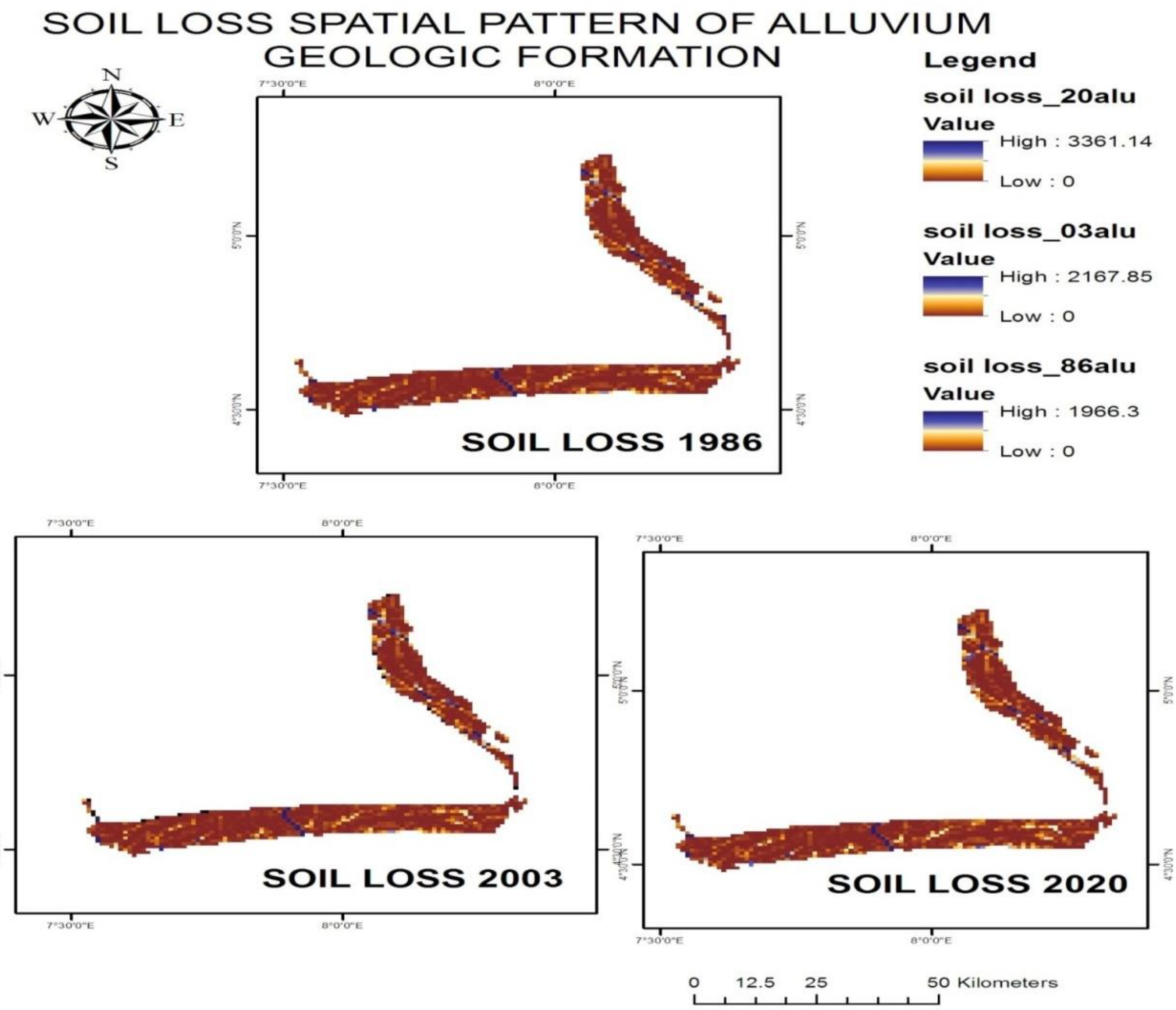

Figure 5: Spatial Pattern of Soil Loss in Alluvium Geologic Formation for 1986, 2003 and 2020.

4.0 Conclusion

Soil loss study has become a necessity in order to understand the rate of soil loss for soil conservational planning. This study focused on the use of remote sensing imageries of the land use/land cover of the study area to understand the past and present land use/land cover pattern for 1986, 2003 and 2020 for soil loss study.The land use/land covers were used to determine the *C* factor of the RUSLE modelusing the NDVI while other parameters of the model were assumed to be constant for the years since they seldom change. The results obtained show the rate of soil loss experienced by the geologic formation across the years. This research proves the importance of the application of geographical information system and remote sensing on soil loss study. The study shows that Alluvium geologic formation is experiencing an increased rate of soil loss across the years as a result of the land use/land cover changes associated within the geologic formation. This study can serve as a guide in soil resource conservation and management.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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