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MAPPING SOIL EROSION VULNERABILITY USING ERODIBILITY FACTORS FOR ANAMBRA AND IMO STATES, NIGERIA

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Abstract

Soil erosion has been at the forefront of the degradation of soils in Anambra and Imo states in southeastern parts of Nigeria. Hence, the study mapped out soil texture types in Anambra and Imo states in order to determine their erodibility factors for soil erosion. The primary data sources involved downloaded satellite imageries of Anambra and Imo states and were analyzed in ArcGIS 10.5 environment. The secondary data sources involved obtaining information from FAO Digital Soil Map of the Word (DSMW) Shapefile (2021) where the zone of interest was captured over the respective area and the soil data layer was clipped to the study area in ArcGIS environment 10.5. The information generated in ArcGIS 10.5 was analyzed to obtain the K-factor (soil erodibility) maps for the study. Results showed soil texture types and spatial extent (km^2) of coarse textured (3.87602 km^2); fine textured (1549.14 km^2); medium and fine textured (1473.65 km^2); and medium textured (1735.51 km^2) in Anambra state. Their respective K factors were 0.20; 0.28; 0.26; and 0.24. The results for Imo state soil texture types and spatial extent (km^2) recorded fine textured (253.23 km^2); medium and fine textured (233.79 km^2); and medium textured (4649.29 km^2). Their respective K factors are 0.28; 0.26; and 0.24. Thus, areas with low values indicate low capacities to withstand soil erosion while areas with high values indicate high capacities to withstand soil erosion. The study recommends amongst others that the government should intensify efforts in financing researches that is geared toward the control and management of erosion in the study area.

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Keywords: Soil erosion, Soil texture types, Soil erodibility factors, Vulnerability, Anambra, Imo

Introduction

Erosion is the transportation of material via the activity of wind and/or water. This is a natural process which has over time shaped the landscape features, such as river valleys and mountain ranges (Costard *et al*., 2012). The rate at which this erosion occurs depends on many factors including the force of wind and water pressure applied and the resistance of the material to which this pressure is applied to (Duan *et al*., 2017). Erosion can result from interflow or surface run-off of water overland, which causes some soil materials to be eroded along the water movement (Issaka and Ashraf, 2017). The eroded soil is easily carried by the flowing water after being dislodged from the ground normally when rain falls or during short, intense storms such as during thunderstorms (Costard *et al*., 2012).

Soil erosion is no doubts one of the greatest problems confronting agriculture worldwide. It is a major threat to the soil resource, soil fertility, productivity, and, lastly to food and fiber production, mainly on farm and range lands. Although the problem is as old as settled agriculture, its extent and impact on human welfare and global environment are more now than ever before (Issaka and Ashraf, 2017). A continuation of high soil erosion will eventually lead to a loss in crop production even though fertilizers and other inputs often result in increased yield in the short term. These problems are referred to as on-site effects of erosion. Soil erosion also leads to environmental pollution. Further downstream, erosion leads to flooding, sedimentation of water reservoirs and poor water quality (Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2015). A decrease in soil quality invariably leads to a decrease in water quality, and often in air quality. These are off-site effects of erosion. One of the most visual forms of erosion is gully erosion. Similarly, just like gully erosion which is the removal of soil from the surface and sub-surface by creating permanent channels greater than 30 centimetres (1 foot) deep (Abdulfatai *et al*., 2014); soil erosion therefore leads to removal of top soil leading to several environmental degradations, like loss of soil nutrient, reduced crop production due to reduction of the surface area for agricultural activities.

The fact that erosion is a natural occurrence is not in doubt, but human activities have aided the rate at which erosion occurs globally. Human activities have in one way or the other influenced soil erosion in Anambra and Imo states. It is noted that, majority of the people are into farming and other developmental activities. Consequently, due to the high rate of rainfall in Anambra and Imo states, most eroded lands have been attributed to high rainfall intensity, topography, and poor engineering and agricultural practices of the people contributing immensely to rate of soil degradation (Omoja *et al*., 2021). Apart from land use activities like agriculture, vegetation

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clearance, intensive harvesting, overgrazing (Giordano *et al*., 2012); soil texture types are also factors to be considered that can influence soil erosion overland (Ofomata, 2015). High erosion risks match with units of weak unconsolidated soil formations in the states (Ofomata, 2015).

The erodibility of the soil is defined as the vulnerability or susceptibility of the soil to erosion (Igwe, 2013). It is a measure of a soil's susceptibility to particle detachment and transport by agents of erosion. Erodibility varies with soil texture, aggregate stability, soil organic matter contents and hydraulic properties of the soil (OMAFRA, 2015). Similarly, large particle sizes are resistant to transport because of the greater forces required to entrain these large particles while the fine particles are resistant to detachment because of their cohesiveness. Aggregate stability and associated indices have been shown to be most efficient soil properties that predict the extent of soil erosion. Erodibility factors of the soil have shown reliable information on the extent and degree of soil erosion (Bajracharya *et al*., 1992). Thus, soil erodibility is dependent on soil texture and properties, topography and land management. Soil textural classifications have significant roles to play in soil detachment; for instance, Balasubramanian (2017) observed that soils texture most prone to soil erosion are those with the largest amount of medium (silt) size particles. Clay and sandy soils are less prone to erosion because they are more compact. Soil texture types are the principal characteristics affecting erodibility of the soil, but structure, organic matter and permeability also contribute (Balasubramanian, 2017). Therefore, due to the importance of soil to agricultural development, food production and livelihoods to the people, the study analyzed the soil textural types in Anambra and Imo states in order to classify them based on their erosion vulnerability levels using their erodibility factors.

The important questions answered by the study are: what are the soil texture types in Anambra and Imo states? What is the spatial distribution (km^2) of the soil texture types in Anambra and Imo states? What are the relative percentages (%) of their soil texture types? What are the erodibility factors of the identified soil texture types in Anambra and Imo states? What are the implications of these findings on soil erosion potentials of the soils in Anambra and Imo states?

Materials and Methods

Description of the Study Area

The study area (Anambra and Imo states) are located geographically within latitudes 4° 47' 35‟N and 7° 7' 44‟N, and longitudes 7° 54‟ 26‟E and 8° 27‟ 10‟E (Figure 1) in the tropical rain forest zone of Nigeria. The area covers about 29095 km^2 which is about 3.19 % of the total area of Nigeria (Anejionu *et al*., 2013). The Geology of the study areas are major factor in gully erosion causation and massive landslides that occur in several communities. The sandy members of the Ajalli Sandstone, Ameki Formation and Nanka Sands are very prevalent to denudation where they become exposed as sandy outcrops (Egboka *et al*., 2019). The study areas are well drained

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and the notable rivers draining the area are Rivers Niger, Imo, Nike Lake, Anambra, Idemili, Njaba, Oguta Lake, Nkisi, Ezu, Oji etc. (Egboka et al., 2019). The forest flora in the southeastern part of Nigeria is the richest and very diverse, with many families in it being represented by small numbers of species ((Hall and Medler, 1975). The population figures for Anambra and Imo according to the 2006 population census were 4,182,032 and 3,934,899 respectively. Anambra State with a landmass of 4,844km^2 has the highest population density (863 people per km^2). The increase in demographic growth in population and urbanization put a lot of stress on the system that may result in some of the environmental disasters of floods, soil and gully erosion, landslides, environmental pollution and contamination all compounded by the incidence of global climate change (Egboka *et al*., 2019).

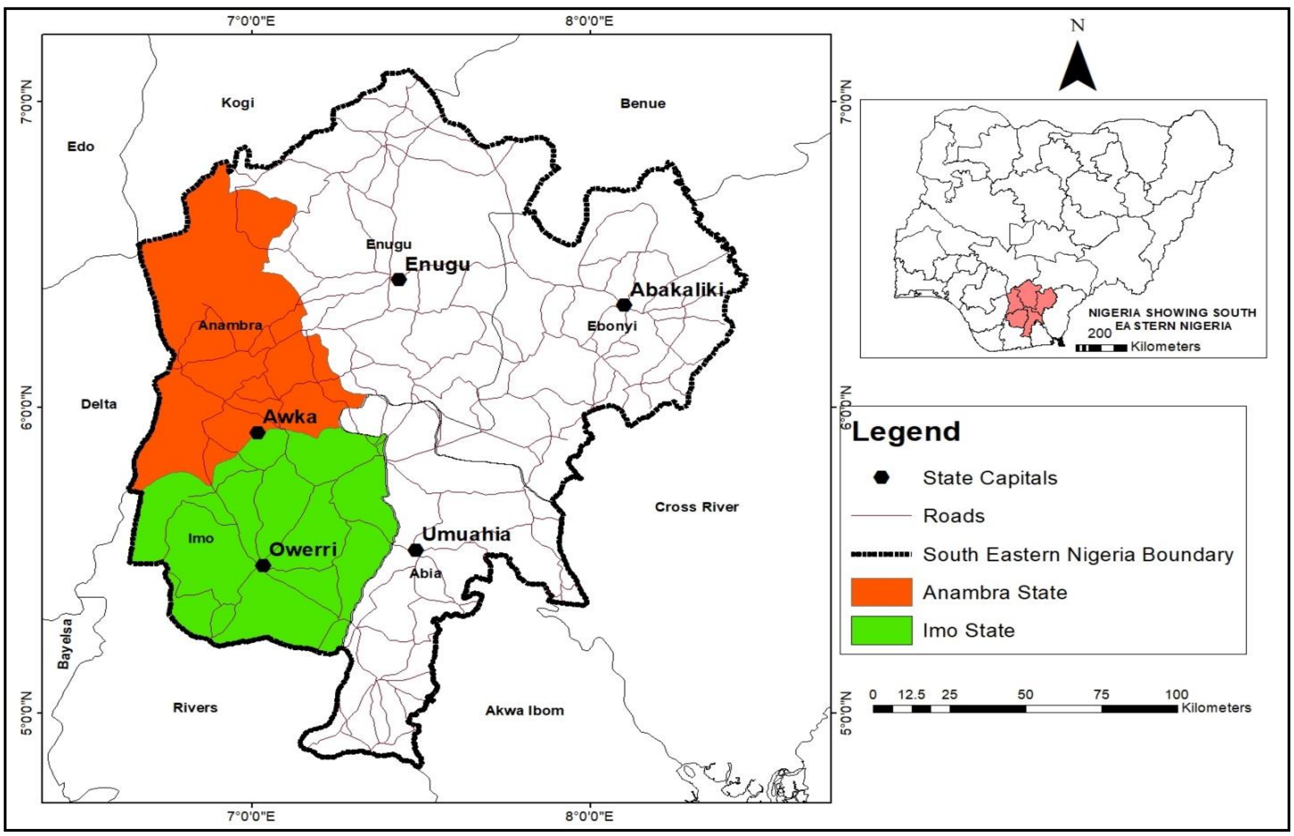

Figure 1: Southeastern States locating Anambra and Imo states (Source: Adapted from Google Earth map 2021)

Data Gathering and Quantitative Data Collection

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Both primary and secondary data sources were used for the study. The primary data sources involved downloaded satellite imageries of the study area and were analyzed in ArcGIS 10.5 environment. The use of global positioning system (GPS) was employed to track the geographic coordinates of points and places of interest to the study as this feat aided the geospatial analysis of the study. The study based on downloaded imageries conducted soil texture/particle size composition for the study. The secondary data sources involved obtaining information on land use erodibility factors which were related with the information determined from the land use analysis. The topographical images of the study area (Anambra and Imo states) were determined using the SRTM (Shuttle Radar Topographic Mission) for image and other analysis (Table 1). The Revised Universal Soil Loss Equation (RUSLE) was employed whereby soil data set which comprised soil survey and characterization information was used to calculate soil erodibility factor (K) for the study. The value K is the soil erodibility index.

Soil erodibility factor which is the K-factor in the RUSLE model reflects the susceptibility of the soil type to erosion, the transportability of sediments, and the amount and velocity of runoff for an appropriate rainfall input. This informed the use of soil textural classes which can determine the rate of infiltration or percolation of runoff in a given area. The soil maps of the region were prepared using FAO Digital Soil Map of the Word (DSMW) Shapefile (2021), where the zone of interest was captured over the respective area and the soil data layer was clipped to the study area in ArcGIS environment 10.5 (Table 1). The soil maps and K-factor values obtained from the literature for each soil type were then used to calculate the soil classes for the study area and then entered into ArcGIS 10.5 and analyzed to obtain a K-factor map. The K-factor values for the corresponding soil groups were used in the analysis.

Table 1: Data Types and Sources

Type of Data	Data Description	Nature of Data	Sources
Digital Elevation Model (DEM)	SRTM DEM for 2021 (0.00083m resolution) Grid Format	Geotiff Raster Format	USGS/NASA SRTM data (Reuter et al, 2007)http://srtm.csi.cgiar.org
Soil Data	FAO Digital Soil map of the World (DSMW)	Shapefile Vector Format	Food and Agriculture Organisation of the United Nations (2021)
Landuse/Land cover	Landsat Imagery	Geotiff Raster Format	United States Geological Survey Earth Explorer (www.usgs.gov)

Source: Researcher’s Field data sources, 2021

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Data Analysis

The descriptive statistical tools of Tables, percentages (%) and Maps were used for data presentation for the study.

Results and Discussion

Soil Texture types in Anambra state

The information for the soil texture types for Anambra state is displayed on Table 2 and Figure 2. The distribution revealed that four (4) soil texture types were identified in Anambra state and these are: coarse textured, fine textured, medium/fine textured and medium textured. It was revealed that coarse textured soils occupied a spatial extent of 3.88 km^2 (0.09%) in the eastern part of the state. The fine textured soils were found within the north-eastern, central and south-eastern parts of the state, and their spatial extent was 1549.14 km^2 (32.53%). The medium/fine textured soils occupy the north-western and south-western parts of the state with a spatial extent of 1473.65 km^2 (30.94%). The medium textured soils were found within the central parts and southern parts of the state. The medium textured recorded a spatial extent of 1735.51 km^2 (36.44%) which was the highest in terms of spatial coverage among soil texture types in Anambra state.

Table 2: Soil Texture Types in Anambra State

Soil Texture	Spatial Extent (sq km)	Percentage (%)
Coarse textured	3.87602	0.09
Fine textured	1549.14	32.53
Medium and Fine textured	1473.65	30.94
Medium textured	1735.51	36.44
Total	4762.18	100.0

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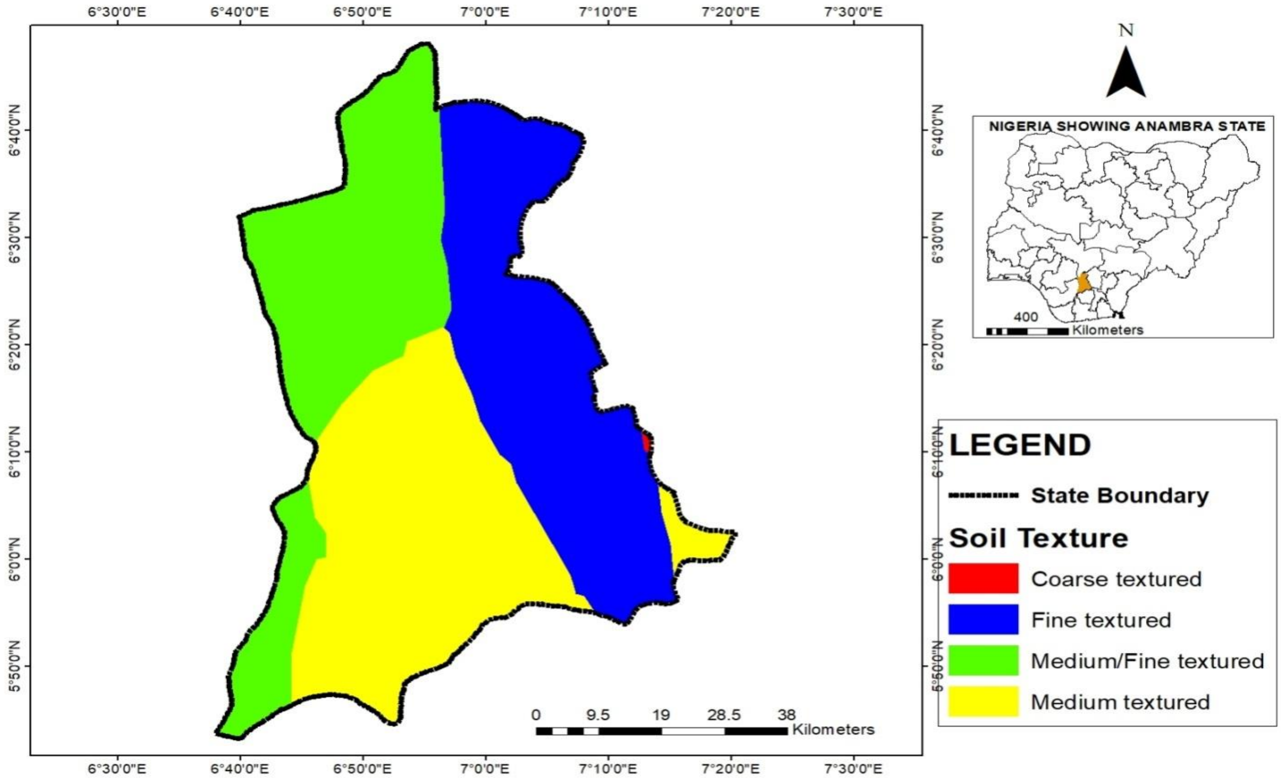

Figure 2: Soil Texture types in Anambra State

Soil Erodibility (K factor) for Anambra state

The soil erodibility from the soil texture types analyzed for Anambra state is displayed on Table 3 and Figure 3. Similarly, soil texture is a combination of sand, silt and clay and they are known as the distribution of mineral particles of less than 2 mm (diameter) based on their sizes. For instance, soil composition of fine particles (clay) have diameter of less than 0.002 mm; soil composition of medium particles (silt) have diameter of between 0.002 mm and 0.63 mm; while soil composition of sandy particles (sand) have diameter of 0.63 mm – 2 mm. The relative percentages (%) of sand, silt and clay are what combine to give soil its texture. The soils most vulnerable to erosion are those soils that contain more of the medium size (silt) particles. However, clay and sand particle sized soils are less prone to soil erosion. More importantly, clay soil particles due to its compactness may influence more surface run-off but due to low infiltration capacity but have high capacity to resist soil erosion. However, the sandy soil with high infiltration capacity may have reduced surface run-off depending on the slope degree, but may eventually give in to erosion when fully saturated.

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The soil erodibility ranged between 0.20 and 0.28 as depicted on Figure 3. Thus, areas with low values indicate low capacities to withstand soil erosion while areas with high values indicate high capacities to withstand soil erosion. In other words, areas that are highly vulnerable to soil erosion are the areas contributing more to average soil loss in the state and vice versa. Thus, based on the classification as adopted from the FAO Digital Soil Map of the Word (DSMW) Shapefile (2021), where the zone of interest was captured over the respective area and the soil data layer was clipped to the study area in ArcGIS environment 10.5 used to produce the K factor based on their different soil erodibility (Figure 3). Therefore, areas within 0.20 and 0.26 have lower capacity levels to resist soil erosion when compared with areas from 0.27 to 0.28.

Table 3: Soil Erodibility (K factor) for Soil Texture Types in Anambra State

Soil Texture	K factor
Coarse textured	0.20
Fine textured	0.28
Medium and Fine textured	0.26
Medium textured	0.24

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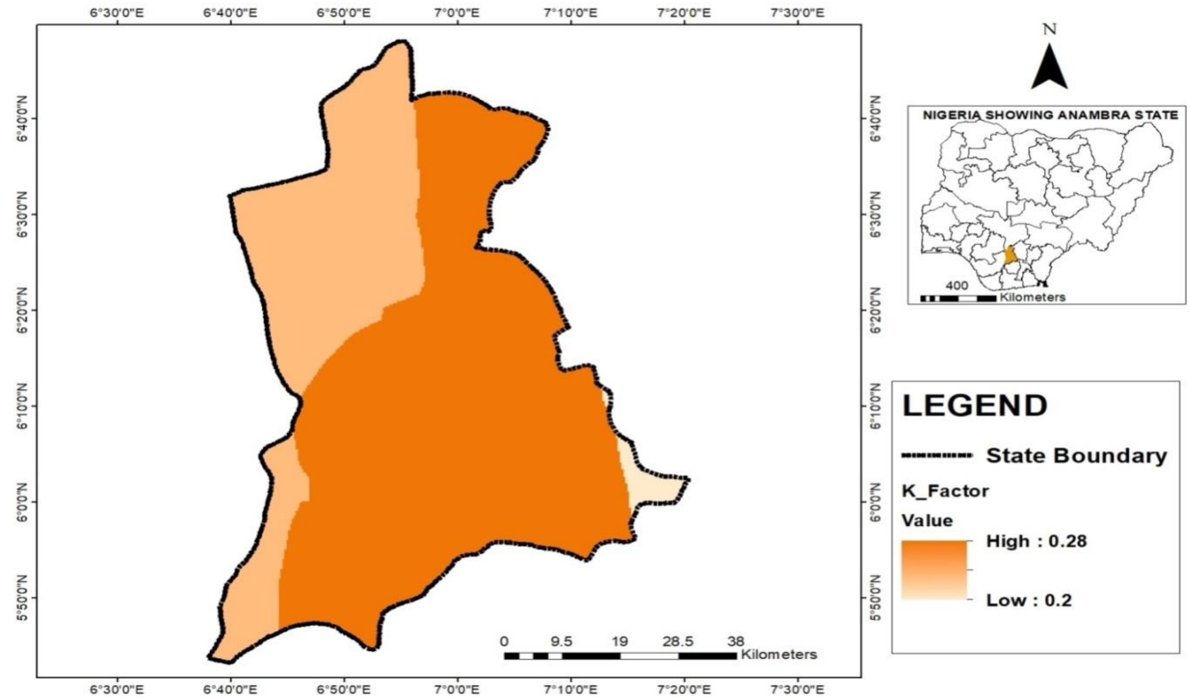

Figure 3: Soil Erodibility (K factor) for Anambra state

Soil Texture Types Computed for Imo state

The information for the soil texture types for Imo state is displayed on Table 4 and Figure 4. The distribution revealed that three (3) soil texture types were identified in Imo state and these are: fine textured, medium/fine textured and medium textured. It was revealed that the fine textured soils were found within the north-eastern part of the state, and the spatial extent was 253.23 km^2 (4.93%). The medium/fine textured soil classification occupied a spatial extent of 233.79 km^2 (4.55%). The medium textured soils occupied the largest portion of the surface and sub-surface soils in Imo state recording a spatial extent of 4649.29 km^2 which is 90.52% of the entire land mass in the state. Therefore, more lands in Imo state is occupied by the medium textured soil types.

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Table 4: Soil Texture Types for Imo State

Soil Texture	Spatial Extent (sq km)	Percentage (%)
Fine textured	253.23	4.93
Medium and Fine textured	233.79	4.55
Medium textured	4649.29	90.52
Total	5130.31	100.00

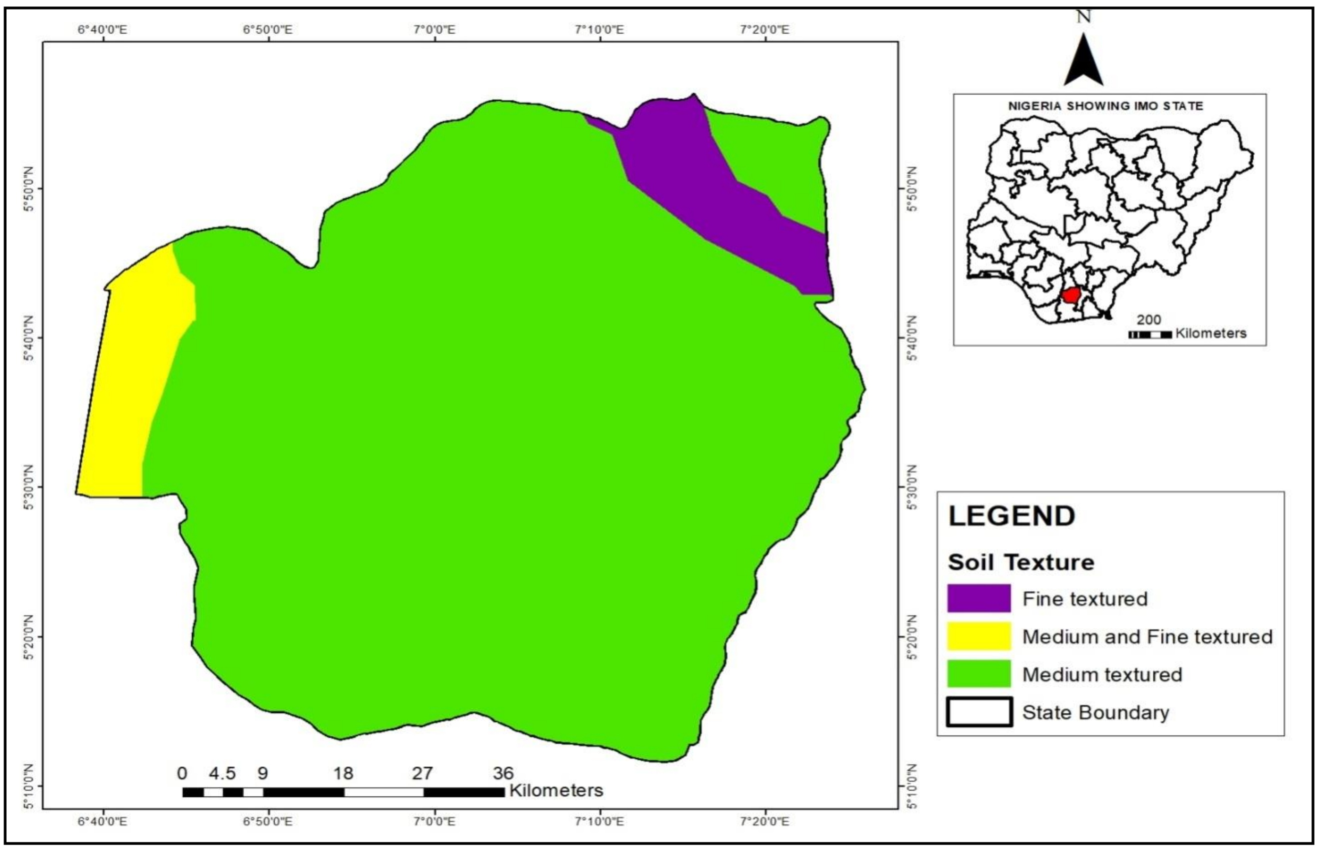

Figure 4: Soil Texture types for Imo State

Soil Erodibility (K factor) for Imo State

The soil erodibility (K factor) from the soil texture types analyzed for Imo state is displayed on Table 5 and Figure 5. The soil erodibility ranged between 0.24 and 0.28 as depicted on Figure 5. Thus, the range of values indicates the levels of vulnerability to erosion which means that areas

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of fine textured and medium/fine textured are not as vulnerable to soil erosion when compared with areas of medium textured in the study area. Therefore, the areas between 0.24 and 0.26 are less vulnerable to soil erosion when compared with areas above 0.26 to 0.28 because the soils in these zones are vulnerable to soil erosion.

Table 5: Soil Erodibility (K factor) for Imo State

Soil Texture	Soil Erodibility
Fine textured	0.28
Medium and Fine textured	0.26
Medium textured	0.24

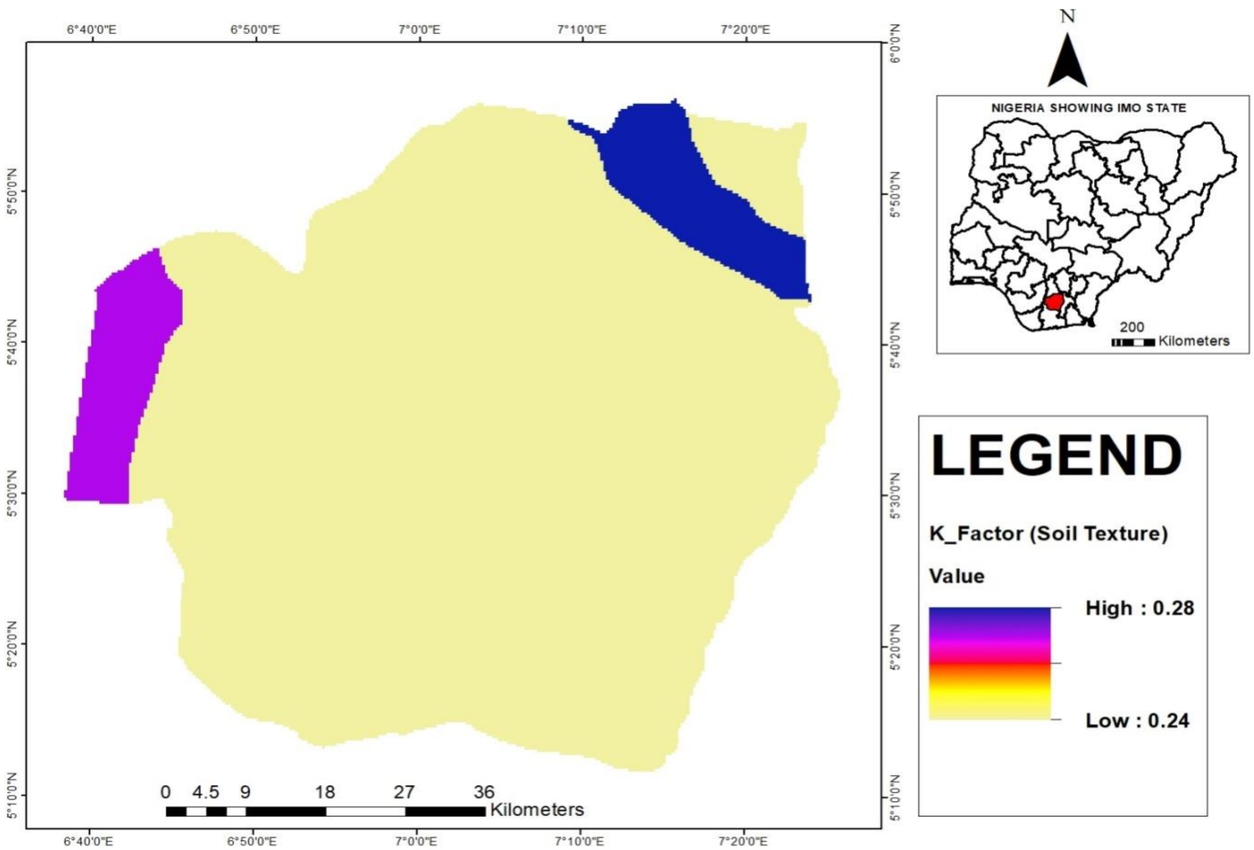

Figure 5: Soil Erodibility (K factor) for Imo State

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Discussion

Finding of the study revealed that the fine textured, medium textured and medium and fine textured soils covered most of the land areas in Anambra and Imo states. Therefore, based on the soil erodibility factor computed, it was revealed that fine textured, medium textured and medium and fine textured recorded K factor ranging between 0.24 and 0.28. The analysis indicated that these soils have higher soil erodibility factor (K factor) which means that they are susceptibility to soil erosion probably due to their low infiltration capacities which favour excessive surface run-off. In other words, their vulnerability levels are high making them more prone to soil erosion in the study area. The earlier findings of Omoja *et al*., (2021) on high rainfall amounts in Anambra and Imo states will therefore put more pressure on these soil texture characteristics forcing more soil detachments and more surface run-offs. These processes have several implications on soil loss due to erosion in Anambra and Imo states (Ofomata, 2011; Osujieke *et al*., 2020). Thus, the soil textural characteristics in Anambra and Imo states are contributing factors to soil erosion. The study therefore agrees with Osujieke *et al*., (2020) that high rainfall intensities and soil characteristics promoting more surface run-off are contributing factors causing soil erosion. These factors are known to influence the extent of soil erosion overtime in the study area (Renard *et al*., 1997). Igwe (2013) concluded that the soil characteristics of the southeastern region of Nigeria are made up highly friable sandstones that yield to erosion. It was further stated that most of the land areas are susceptible areas with unconsolidated sandy formations of weak sandstones and less weak areas of consolidated tertiary sediment formations are highly vulnerable to soil erosion with several gully formations to show for it.

Conclusion and Recommendation

The study was able to map out soil texture types/characteristics and soil erodibility factors for Anambra and Imo states. The findings of the study have shown the spatial pattern of soil texture types as well as their varying vulnerability levels to soil erosion in the study area. The highly vulnerable areas due to their soil characteristics are liable to be eroded especially in the event of flooding in the study area. The study therefore recommends that: due to the ecological problems and rainfall characteristics of the study area, great consideration should be given to cropping systems that will provide maximum protection for soil; the minimal use of tillage systems is therefore advised; conservation tillage practices should be encouraged as this will reduce erosion by protecting the soil surface and allowing water to infiltrate instead of running off; the government should intensify efforts in financing researches that is geared toward the control and management of erosion in the study area; adequate funds should be made available for environmental researches that will provide lasting solutions to the ecological problems promoting erosion in the study area; the creation of enlightenment programmes directed at

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farmers at all levels should be conducted to sensitize them of the dangers of soil erosion and how it can be controlled with zero effect on their agricultural productivity.

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