# Impact of Different Land Uses on Soil Erodibility Assessed using selected Indices in Awka, Southeastern Nigeria

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K E Y W O R D S

*Erodibility,*
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* C O R R E S P O N D I N G A U T H O R

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A B S T R A C T

*Land use is considered to be one of the drivers of many processes of environmental change that includes erosion. The impact of land use on soil erodibility were evaluated at Nnamdi Azikiwe University, Awka. Five land use types (forest land, rice farm, cassava farm, grassland and plantain farm) were used for this study. Soil samples were collected from each of the land use in five (5) replicates at 0-20 cm depth. Collected samples were subjected to laboratory analysis. Selected erodibility indices such as dispersion ratio (DR), clay dispersion index (CDI), clay flocculation index (CFI), clay ratio (CR) were used to assess land use impact on soil erodibility. Results obtained were subjected to data analysis using analysis of variance and Pearson's correlation analysis. Soils of the studied area were generally acidic and had a sandy loam texture. Bulk density and aggregate stability were higher under rice farm. Moisture holding capacity was higher under grassland and lower under plantain farm. Higher organic carbon, CEC and available phosphorus were obtained under grassland when compared to other land use types. The higher the dispersion ratio (DR) and clay dispersion index (CDI), the higher the ability of the soil to disperse while the higher the clay flocculation index (CFI), the better aggregated the soil becomes. Higher CFI was obtained under cassava farm while plantain farm had the highest CR value. This study encourages land use practices that improve the physical and chemical conditions of the soil so as to reduce susceptibility to erosion.*

## INTRODUCTION

Soil erodibility is an estimate of the ability of soil to resist erosion based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved structure have a greater resistance to erosion (Dexter, 2004). Erodibility is the resistance of the soil to both detachment and transport (Emeka, 2014) and it varies with soil textures, aggregates, stability, shear strength, soil structures, infiltration capacity, soil depth, bulk density, soil organic matter and chemical constituents. The erodibility of soil is a function of land use as it affects the stability of soil aggregates. Inherent soil properties could influence the behaviour of soils therefore understanding of soil properties is important in determining the use to which a soil may be put (Amusan *et al.*, 2006). The physical properties of soil deteriorates with change in land use especially from forest to arable land ; however research has shown that land use influence structural stability more than intrinsic soil properties and that percolation stability of soil increased with increase in soil organic matter content ( Mbagwu and Auerswald, 1999). Land use is defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Ufot *et al.*, 2016). Changes in land-use due to urbanization, agricultural expansion, deforestation, and monoculture productions have led to an accelerated and spatial increase in erosion. Therefore, understanding the effects of land use system on soil attributes is vital for enhancing food security and environmental quality (Igwe and Obalum, 2013). Dispersion ratio, clay dispersion index, clay flocculation index have been reported to be good indices for estimating soil erodibility based on soil characteristics (Oguike and Mbagwu, 2009; Igwe, 2005) and are very important in regulating soil losses and soil quality (Kalhorw *et al*., 2017).

## MATERIALS AND METHODS

### Site Description

The study was conducted in Nnamdi Azikiwe University, Awka Southeastern- Nigeria. It is located in Awka South Local Government Area of Anambra State and lies within latitude $06^{0}12^{1}$N and $06^{0}25^{1}$N and longitudes $07°7^{1}$E and $07^{0}11^{1}$E. The geologicaI formation that underlies Awka are the Imo shale and Ameki Formation. The soils are continuously cultivated with cassava, yam, maize and rice. Most of the original rainforest vegetation have been lost due to clearing and human settlement. Awka has rainy and harmattan climatic conditions. The cumulative annual mean rainfall is about 2553.07mm (Omoja *et al.,* 2021). It has an average mean temperature of about 28 $^{o}$C and an average relative humidity of about 84 %.

### History and features of the land use types studied

The study sites comprised of five (5) land-use types which include Rice farm (RF), Grassland (GL), Plantain plantation (PP) and Forested land (FL). The rice farm lies within latitude $6°15^{1}$N and longitude $7°07^{1}$E; it has been in use for over 6yrs for cultivation of rice. Cassava Farm lies within latitude 6° $15^{1}$N and longitude $7°06^{1}$E; this farm has been in use for over 4yrs for cultivation of cassava. Grassland lies within latitude 6° $14^{1}$N and longitude of $7°07^{1}$E. Species of grasses found there were Oat grass, thatching grass, Burgrass, and Corngrass. Plantain farm lies within latitude 6° 211 N and longitude 7° 071 E; this has been in use for plantain farming over 4 yrs. Forested Land is at the mapped site of Forestry and Wildlife Department; it lies within latitude $6°22^{1}$N and longitude $7°07^{1}$E. The forest land had been under forest management for more than 20yrs. Some trees found in this forest area includes; Bamboo (*Bambusa vulgaris*), palm trees (*Elaeis guineensis*) and velvet fruit (*Dialium guineense*).

### Soil sampling and handling

Prior to soil sampling a reconnaissance visit was made to identify the land use types. Soil samples were collected in Five (5) replicates from each of the land use type at 0 -20cm soil depth and this was used for chemical analysis. Core samplers of about 5cm was used to collect soil samples undisturbed and was used for physical analysis. Collected soil samples were bagged, labelled accordingly and air dried for onward laboratory analysis.

### Laboratory analysis

The following Soil physical and chemical analysis were carried out.

i. Particle Size Distribution: The hydrometer method as described by Gee and Or 2002 was used to determine the particle size distribution of the samples. Textural class was determined using textural triangle.

ii. Soil Bulk Density: The bulk density was determined by core method as described by Grossman and Reinsch (2002).

iii. Moisture content: The gravimetric method of determination of soil moisture content was used and calculated using the equation

$$\text{GMC} = \frac{W2 - W3}{W3 - W1} \times 100 \qquad \dots\dots\dots\dots\dots (1)$$

Where Mc is the Moisture content, W1 is the Weight of container, W2 is the Weight of container and sample and W3 is the Weight after oven drying.

iv. Aggregate Stability: Soil Aggregate stability was determined using wet sieving method of Kemper and Rosenau (1986).

v. Soil pH: Soil pH was measured electrometrically by glass electrode in pH meter in both KCI (1 N) and distilled water suspension using a soil: liquid ratio of 1: 2.5 (International Institute for Tropical Agriculture, 1979)

vi. Soil organic carbon will be determined using the wet dichromate oxidation method of Walkley and Black (1934). Organic matter will be calculated by multiplying the value of organic carbon by a factor of 1.724 (Van Bemmelen factor).

vii. Total Nitrogen (TN): This was determined by the Kjeldahl digestion method according to Jackson (1965).

viii. Available phosphorus: This was determined using Bray II method according to Olsen and Sommer, (1990).

ix. Cation Exchange Capacity (CEC): This was determined by 1N ammonium acetate extraction method.

Determination of Erodibility Indices: Soil erodibility indices was evaluated by the method

of Dong *et al*. (1983) as computed in the following formula:

$$\text{(i) Dispersion Ratio (DR)} = \frac{\text{\% Silt + \% clay in water}}{\text{\% Silt+ \% clay in calgon}}$$

$$\text{(ii) Clay Flocculation Index (CFI)} = \frac{\text{\% clay (calgon) - \% clay in water}}{\text{\% clay in calgon}} \times 100$$

$$\text{(iii) Clay Dispersion Index (CDI)} = \frac{\text{\% clay in water}}{\text{\% clay in calgon}} \times 100$$

$$\text{(iv) Clay Ratio} = \frac{\text{\% Sand + \% Silt in calgon}}{\text{\% clay in calgon}}$$

**Statistical analysis**

Data collected was subjected to analysis of Variance using GENSTAT software (12th edition) to compare the impact of land use on soil erodibility. Significant difference between the means was separated using Duncan's multiple range test at 5% probability level. Pearson's correlation analysis was used to determine the relationship between selected indices and soil properties.

**RESULTS AND DISCUSSION**

**Physical properties of soil under different land uses.**

The results of the physical properties of soil under different land uses are shown in table 1. The particle size distribution showed that rice farm had the highest mean sand content of 723 g/kg while forest land had the lowest mean sand content of 591g/kg. Forest land had the highest mean silt content of 320g/kg while cassava had the lowest mean silt content of 150 g/kg. Cassava farm had the highest mean clay content of 164 g/kg while plantain farm had the lowest mean clay content of 64 g/kg. Sand particle dominated the soils of the area and belongs to sandy loam textural class. Higher sand contents obtained in soils of different land uses suggests low CEC, leaching of nutrients and can encourage soil erodibility on exposure to high rainfall. Plantain farm had the lowest mean soil BD of 1.30g/cm³ while Rice farm had the highest mean soil BD of 1.94g/cm³. The higher BD obtained in rice farm could be due to the impact of repeated tillage operations over a period of time. Grassland had higher water holding capacity of 11.67 when compared to other land uses. The aggregate stability of soils of the different land uses ranged from 0.35%-0.42%. Aggregate stability of soils of the land uses studied were generally low and could be due to low soil organic matter and sandiness of the area. According to Kay *et al*., (1999) a level of soil organic carbon of 2.0% to 2.5% is considered necessary to maintain good aggregate stability and is considered to deteriorate rapidly when SOC falls below 1.2% to 1.5%.

**Table 1:** Physical Properties of Soil under different land use types

| Land Use | Depth (0-20cm) | B.D $g/cm^3$ | M.C% | Aggregate stability | SAND g/kg | SILT g/kg | CLAY g/kg | Textural Class |
|---|---|---|---|---|---|---|---|---|
| Forest Land (RF) | | $1.93^b$ | $9.23^a$ | $0.37^a$ | $591^a$ | $320^b$ | $79^a$ | SL |
| Cassava Farm (CF) | | $1.75^b$ | $9.12^a$ | $0.41^a$ | $687^a$ | $150^a$ | $164^b$ | SL |
| Grassland (GL) | | $1.74^b$ | $11.67^b$ | $0.35^a$ | $654^a$ | $280^b$ | $70^a$ | SL |
| Plantain Plantation (PP) | | $1.30^a$ | $9.09^a$ | $0.38^a$ | $652^a$ | $280^b$ | $64^a$ | SL |
| Rice Farm (RF) | | $1.94^b$ | $9.90^{ab}$ | $0.42^a$ | $723^a$ | $180^a$ | $93^{ab}$ | SL |

Note: B.D= Bulk density, M.C= moisture content

**Chemical properties of soils under different land uses**

Soil pH was generally acidic and ranged from 4.50 – 5.83. However, the acidity varied amongst the different land use types; the acidic nature of the soils as observed was more a reflection of the nature of the parent material (coarse textured, strongly leached, low fertility) than the effect of land use. The results of this study corroborates with the studies of (Opara-Nadi *et al*., 2010, Nwosu *et al., 2016*) that reported similar results. There were 0.69, 0.62, 1.32, 0.81 and 0.95 of organic carbon obtained respectively in forest land, cassava farm, grassland, rice farm and plantain farm. Grassland had the highest organic carbon content of 1.32% while cassava farm had the lowest organic carbon content of 0.62%. Organic matter content is used to judge soil quality and degradation. According to Pieri (1991); critical levels of SOM Index less than 5% shows loss of soil structure and susceptibility to erosion, 5% - 7% shows unstable structure and risk of soil degradation, when greater than 9%, it shows stable structure. Results obtained from the land use types studied showed the susceptibility of the soil to erosion. Total nitrogen content as observed in the soils of the area studied ranged from 0.05%-0.11% and are generally low; this could partly be attributed to the predominantly sandy texture of the soil as well as an indication of nutrient loss at the epipedon as suggested by Nwosu *et al., (*2020). The total nitrogen content in soils of the land use types studied were below the critical value of 0.15% for soils of Nigeria as revealed by Chude *et al.,* (2011). Soils under grassland had the highest CEC mean value of 6.16 cmol/kg while soils under plantain farm had the lowest CEC mean value of 5.11 cmol/kg. Landon (1991) rated CEC value of >40 cmol/kg as very high concentration, 25-40 cmol/kg as high , 15-25 cmol/kg as moderate ,5-15 cmol/kg as low and <5 cmol/kg as very low. The result showed that forest land, cassava farm, grassland, plantain farm and rice farm had 1.87 mgkg-1, 1.22 mgkg-1, 4.45 mgkg-1, 1.55 mgkg-1 and 1.83 mgkg-1 of available phosphorus respectively. Highest value of available phosphorus was obtained in grassland while the lowest value was obtained in cassava farm.

**Table 2:** Chemical properties of soils under different land uses

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| Land Use | Depth (0-20cm) | pH ($H_2O$) | O.C (%) | T.N (%) | CECEC(cmol/kg) | Avail p (mgkg-1) |
|---|---|---|---|---|---|---|
| Forest Land (RF) | | $4.50^a$ | $0.69^a$ | $0.06^a$ | $5.78^a$ | $1.87^a$ |
| Cassava Farm (CF) | | $5.68^c$ | $0.62^a$ | $0.05^a$ | $5.15^a$ | $1.22^a$ |
| Grassland (GL) | | $4.71^{ab}$ | $1.32^b$ | $0.11^b$ | $6.07^a$ | $4.45^b$ |
| Plantain Plantation (PP) | | $5.83^c$ | $0.81^a$ | $0.07^a$ | $5.11^a$ | $1.55^a$ |
| Rice Farm (RF) | | $5.28^{bc}$ | $0.95^a$ | $0.08^a$ | $6.16^a$ | $1.83^a$ |

CO.C= organic carbon, T.N= Total Nitrogen, C.E.C= Cation exchange capacity

**Selected erodibility indices under different land uses**

Results of soil erodibility under land use types are shown in table 3. Highest DR mean value of 0.64% was obtained under Plantain farm while cassava farm recorded the lowest with mean value of 0.37%. Cassava farm had the highest CFI value of 51.11% while plantain farm had thethe lowest CFI value of 16.14%. Soils high in CFI are well aggregated and will not easily disperse in water. Highest CDI mean value of 83.86% was obtained under plantain farm while the lowest was obtained under cassava farm. Soils with high DR and CDI are known to be structurally weak and can easily erode. Also, the high value of DR with low CFI indicates low resistance of soil aggregates to the breakdown by water. Clay ratio measures the amount of binding due to clay. Highest CR mean value of 15.49% was obtained under Plantain farm while the lowest mean CR value was obtained under cassava farm. Higher CR indicates lower binding influence due to clay and therefore higher susceptibility to erosion.

**Table 3:** Selected erodibility indices under different land use types

| Land Use | DR% | CFI% | CDI% | CR% |
|---|---|---|---|---|
| Forest Land (RF) | 0.55ab | 28.53a | 71.47a | 13.05a |
| Cassava Farm (CF) | 0.37a | 51.11a | 48.89a | 8.26 a |
| Grassland (GL) | 0.45ab | 17.76 a | 82.24 a | 15.21 a |
| Plantain Farm (PF) | 0.64b | 16.14 a | 83.86 a | 15.49 a |
| Rice Farm (RF) | 0.42ab | 37.07 a | 62.93 a | 11.41 a |

Note: DR= dispersion ratio; CDI= clay dispersion index; CFI= clay flocculation index, CR=clay ratio.

**Relationship between erodibility indices and selected soil properties**

The results in table 4 showed that CR and CDI had a significant positive correlation(r= 0.436*, r=0.431*) with sand. DR, CDI and CR correlated negatively (r= -0.403*, r=-0.805*, r=-0.810*) with clay while CFI had a significant positive correlation (r=-0.805*) with clay. CFI correlated positively(r = 0.427* r = 0.056) with BD and OC. The sign of the coefficient indicates the direction of the relationship. If the coefficient is positive, it means both variables tend to increase or decrease together whereas when negative it shows that one variable tends to increase as the other decreases.

Table 4. The relationship between erodibility indices and selected soil properties

| Soil properties | DR | CFI | CDI | CR |
|---|---|---|---|---|
| **Sand(g/kg)** | 0.121 | -0.431* | 0.431* | 0.436* |
| **Clay(g/kg)** | -0.403* | 0.805* | -0.805* | -0.810* |
| **Silt(g/kg)** | 0.18 | -0.16 | 0.16 | 0.16 |
| **B.D (g/cm3)** | -0.11 | 0.427* | -0.427* | -0.414* |
| **pH ($H_2O$)** | -0.196 | 0.292 | -0.292 | -0.298 |
| **CEC(cmol/kg)** | -0.039 | 0.007 | -0.007 | 0.001 |
| **O.C (%)** | -0.244 | 0.056 | -0.056 | -0.042 |

CEC= Cation exchange capacity; OC= organic carbon; DR= dispersion ratio; CDI= clay dispersion index; CFI= clay flocculation index, CR=clay ratio.

## CONCLUSION

Based on the study; land use influenced some soil properties and erodibility. Bulk density and aggregate stability were higher under rice farm when compared to other land use types. Organic carbon was more under grassland and lower under cassava farm. High CFI indicates the level of aggregation of the soil and was in the order CF>RF>FL>GL>PP while high CR indicates high susceptibility of soil to erosion. CR of soils under different land uses were in the order PP>GL>FL>RF>CF. soils of the studied area are susceptible to erosion. Therefore, it is important that management practices and measures that incorporates and retains organic matter especially within the top soil should be practiced to prevent erosion.

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