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Original Article

Erosion potentials of soils under different land utilization types in Anambra State, Nigeria

OPEN ACCESS

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ABSTRACT

Soil erosion by water remains a serious ecological challenge in Anambra State that often leads to destruction of farmlands and reduction of area of land available for agricultural activities; hence, the study evaluated soil erosion potential in Awka and Ifite Ogwari areas of Anambra State. Auger and core soil samples were randomly collected from each land use practice (cassava farm, grassland, and rice farm) in three replicates at 0–30 cm depth, after which the collected samples were subjected to laboratory analysis. Significant differences were determined statistically at 5% probability level. The results showed the soils of the studied areas to be acidic. Soils in Awka and Ifite Ogwari, respectively, belonged to sandy loam and clay textural classes. Bulk density ranged from 1.73-2.02 g/cm^3. The highest moisture content (8.81%) was obtained under the rice farm in Ifite Ogwari. Ksat ranged from 0.01-0.04 cm/hr, while MWD ranged from 0.34 - 0.90 mm in both sites. OC ranged from 0.36-1.12% and was highest under the cassava farm in Ifite Ogwari. DOA was higher (29.48%) in grassland of Ifite Ogwari compared to cassava farm of Awka with a value of 24.38%. Characterised by low organic carbon content and loss of structure, the studied areas were found to be erosion-prone; therefore, replenishing the soil organic carbon upon land utilisation is key to improving soil stability.

KEYWORDS: *Agriculture, Aggregate formation, Continuous cultivation, Degradation, Soil erodibility*

INTRODUCTION

Soil is a porous medium composed of soil particles of different sizes and shapes (Ding *et al*., 2014). It plays an important role for mankind by providing the fundamental ecosystem services required for human life primarily for the production of food by providing the environment for plant growth (Sebastian *et al*., 2014). As an important natural resource that comprises of minerals and other constituents is most times threatened by degradation resulting from erosive actions of water. Soil erosion by water is a serious problem in Anambra State that most times lead to destruction and reduction of farmlands for agricultural activities which further creates problems for the population.

According to Levy *et al*. (2001) erodibility is the inherent tendency of soils to erode at different rates due to differences in soil properties. 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

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et al., 2006). Land use influences aggregate stability (Oguike & Mbagwu, 2009) as nutrient removals cause changes in structural stability (Mill & Fey, 2003). Successful agriculture requires the sustainable use of soil resource, because soil can easily loose its quality and quantity within a short period of time for reasons like intensive cultivation, leaching and erosion (Kiflu & Beyene, 2013). Therefore, understanding the effects of land use on soil attributes is vital for enhancing food security and environmental quality (Igwe & Obalum, 2013). For sustainable land utilization, the need for information about soil conditions and current status, level of degradation, changes due to land use patterns and management techniques as well as appropriate conservation measures are important (Tellen & Yerima, 2018) thus the study aimed at understanding how land use cause changes in soil erosion by impacting its influencing properties.

MATERIALS AND METHODS

Description of the studied area

The study was conducted in Awka and Ifite Ogwari areas of Anambra State. Awka lies within latitude $06^0 12'$ N and $06^0 25'$ N and longitudes 07°7 ' E and $07^0 11$ ' E. The geologicaI formation that underlies Awka are the Imo shale and Ameki Formations. The soils are continuously cultivated with cassava, yam, maize and rice. Most of the original rainforest vegetation have been lost due to clearing for human settlement. As per 2022 data from Nigeria meteorological Agency, the cumulative annual mean rainfall of Awka is 2590.6mm. It has an average mean temperature of about 28 ^{o}C and an average relative humidity of about 84%. Ifite Ogwari lies within latitude $06^o 4'$ N and $06^o 60'$N, and longitudes $06^o 57'$E and $06^o 95'$E. It is among the rice producing towns of Anambra State. The soils are of Imo shale geologic formation (FDALR, 1990), the vegetation according to Chukwu (2007) is derived savannah with some patches of rainforest. Two main seasons of dry and wet seasons prevail in this area with an average annual rainfall of 2737.4 mm based on 2022 data by Nigeria meteorological Agency though rainfall onset and cessation period have varied recently. The average temperature and relative humidity of the area is 35^oC and 74% respectively. The major land uses in the area are for agricultural purposes.

History of Land use Practices studied: The rice farms have been under swamp rice cultivation for over 10 years usually planted through broadcasting method; the use of herbicide is common during land preparation. The grasslands have been under grass cover for an estimated period of 3 years and contain species of grasses like oat grass, thatching grass, burgrass, African feather grass in Awka area while in Ifite Ogwari spear grass & bahamas grass dominated the area; The cassava farms have been under continuous cultivation which sometimes is mixed with maize and yam for over 6 years respectively in both sites.

Soil sampling: Auger and core soil samples were randomly collected from each of the land use types in three replicates at 0-30 cm depth. The core sampler measured 5cm by 5cm in both diameter and height. The collected soil samples were bagged, properly labelled, air dried for laboratory analysis. Auger soil samples were used to determine the particle size distribution and selected chemical properties of the soil while the core soil samples were used to determine selected physical properties of soil.

Laboratory Analysis

The hydrometer method as described by Gee & Or (2002) was used to determine the particle size distribution of the samples while the soil texture was determined using the USDA Textural triangle. Bulk Density was determined by core method as described by Grossman & Reinsch (2002). Soil Total Porosity was calculated from the bulk density as shown in this equation:

$$\text{Total porosity (\%)} = 1 - \frac{\text{Bd}}{\text{pd}} \times 100 \qquad (1)$$

Where Bd =Bulk density, Pd =particle density ($2.65 g/cm^3$). Saturated Hydraulic conductivity (k_{sat}) was determined by the constant head permeability procedure according to Young (2001) while Gravimetric Moisture Content was determined by oven drying at a temperature of 105^0C and percentage of moisture in soil calculated mathematically as follows:

$$GMC = \frac{\text{W2} - \text{W3}}{\text{W3} - \text{W1}} \times 100 \qquad (2)$$

Where W1=Weight of the Can, W2=Weight of wet sample + Can, W3=Weight of oven dried sample + Can. 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 . Soil organic carbon was determined using the wet dichromate oxidation method of Walkley and Black (1934) while organic matter was calculated by multiplying the value of organic carbon by a factor of 1.724. Cation Exchange Capacity (CEC) was determined through 1N ammonium acetate extraction method.

Determination of erodibility/aggregate stability properties

The wet sieving technique of Kemper & Chepil (1965) was used to determine:

Mean weight Diameter (MWD) using the equation $\sum_{i=1}^{n} XiWi$ (3)

while Degree of Aggregation was calculated as:

$$DOA = \frac{\text{wt.of water stable aggregate} - \text{wt.of sand} \times 100}{\text{Wt.of sample} - \text{wt.of sand}} \quad (4)$$

Aggregated Clay was computed from the formula**:**

% clay (calgon) - % clay (water) (5)

ie Total clay (TC)-Water dispersible clay (WDC) (6)

Statistical analysis

Data collected was subjected to Analysis of Variance using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Separation of means for statistical difference was done by the least significance difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Results

Particle Size Distribution

From the results obtained (Tables 1), soils under the cassava and rice farms had the highest sand and silt contents with respective values of 66.4% and 27.2% in Awka site while rice farm had the highest clay content with a value of 46.6 % in Ifite Ogwari site compared to Awka site. The sand content under land use types in Awka were higher compared to those of Ifite Ogwari site. The soil in Awka and Ifite Ogwari sites respectively belonged to sandy loam and clay textural classes.

Table 1: Particle Size Distribution under land use types in the studied sites

	Sand (%)		Silt (%)		Clay (%)		Textural Class	
Land Use	**Awka**	**Ifite Ogwari**	**Awka**	**Ifite Ogwari**	**Awka**	**Ifite Ogwari**	**Awka**	**Ifite Ogwari**
Cassava farm	66.4	30.8	24.0	24.0	9.50	45.7	SL	Clay
Grassland	59.1	34.9	26.7	21.8	13.70	42.2	SL	Clay
Rice farm	55.4	30.0	27.2	22.4	17.3	46.6	SL	Clay
LSD (P<0.05)	0.09	0.53	0.59	0.79	0.28	0.41		

Selected Physicochemical Properties of Soils under land use types in the studied sites

As presented in Table 2, grassland and cassava farm had the highest bulk density with values of 2.02 g/cm^3 and 1.90 g/cm^3 respectively in Awka and Ifite Ogwari sites while rice farm had the lowest bulk density values of 1.96 g/cm^3 and 1.73 g/cm^3 respectively in Awka and Ifite Ogwari sites. The bulk density obtained under cassava farm at Ifite Ogwari site was significantly higher when compared to the grassland and rice farm. Rice farm recorded the highest total porosity of 28.38% and 34.57% respectively in Awka and Ifite Ogwari sites while cassava farm recorded the lowest total porosity of 23.23% and 29.47% in Awka and Ifite Ogwari sites respectively. Rice farm in Ifite Ogwari site had the highest moisture content of 8.81% while the grassland in Awka site had the lowest moisture content of 5.47%. Highest Ksat was obtained under cassava farm and grassland in Awka site with respective values of 0.04 cm/hr while the lowest was obtained under rice farm with a value of 0.03 cm/hr. The pH of soil in both sites ranged from 5.16-5.81 indicating strongly acidic to moderately acidic level. Higher organic carbon content (1.12%) was obtained in Ifite Ogwari site compared to Awka. Generally, the organic carbon content as obtained in this study ranged from 0.36-1.12% which was low. Highest CEC value of 4.46 cmol/kg was obtained under cassava farm while the lowest with a value of 4.28 cmol/kg was obtained under rice farm in Awka site. The CEC under cassava farm in Ifite Ogwari site was significantly higher compared to other land use types.

Table 2: Selected physicochemical properties of soil under land use types in Awka and Ifite-Ogwari sites.

Land Use	BD g/cm3		TP		MC	%	Ksat		OC		CEC (cmol/kg)g)		pH	
	Awk	Ifite	Awk	Ifite	Awk	Ifite	Awk	Ifite	Awk	Ifite	Awk	Ifite	Awk	Ifite
Cassava farm	2.00	1.90	23.23	29.47	7.49	7.03	0.04	0.04	0.42	1.12	4.46	7.03	5.81	5.79
Grassland	2.02	1.74	26.30	34.27	5.47	6.87	0.04	0.01	0.50	1.00	4.41	6.59	5.19	5.65
Rice farm	1.96	1.73	28.38	34.57	7.02	8.81	0.03	0.01	0.51	0.36	4.28	4.48	5.35	5.16
LSD (P<0.05)	0.72	0.05	0.38	0.17	0.09	0.12	NS	0.01	NS	0.001	NS	0.004	NS	0.001

Note: Awk- Awka, OC- organic carbon, BD- Bulk density, TP- Total porosity, Ksat- Hydraulic conductivity, CEC- Cation exchange capacity

Selected erodibility/aggregate stability properties of soils under land use types in the studied sites

The results of degree of aggregation, mean weight diameter and aggregated clay in the studied areas are shown in table 3. Highest and lowest DOA values of 29.47% and 24.38% was obtained under rice and cassava farms respectively in Awka site and followed the order: rice farm> grassland> cassava farm whereas in Ifite Ogwari site, the highest DOA value of 29.48% was obtained under grassland and the lowest (24.38%) was obtained under cassava farm which followed the order: grassland> rice farm> cassava-maize. MWD ranged from 0.34-0.90mm in both sites under the land use types however highest MWD of 0.90mm was respectively obtained under rice farm and grassland in Awka and Ifite Ogwari sites. Aggregated clay content under cassava farm, grassland and rice farm in Awka site were 22.96%, 27.85% and 33.30% respectively while in Ifite Ogwari site it was 42.61%, 36.12% and 47.92% respectively for cassava farm, grassland and rice farm. Aggregated clay was significantly higher under rice farm compared to other land use types in Awka site and was in the following order; rice farm> grassland>cassava farm while in Ifite Ogwari site it was in the order; rice farm> cassava farm>grassland.

Table 3: Selected erodibility/aggregate stability properties under land use types in the studied sites

Land use	DOA (%)		MWD (mm)		AC (%)	
	Awka	Ifite Ogwari	Awka	Ifite Ogwari	Awka	Ifite Ogwari
CF	24.38	24.38	0.34	0.34	22.96	42.61
GL	26.66	29.48	0.51	0.90	27.85	36.12
RF	29.47	26.65	0.90	0.51	33.30	47.92
LSD(P<0.05)	0.45	0.24	0.38	0.10	NS	0.05

Note: CF- Cassava Farm, GL-Grassland, RF- Rice farm, DOA- Degree of aggregation, MWD- mean weight diameter, AC- Aggregated clay.

DISCUSSION

The dominance of sand fraction in Awka suggests vulnerability to erosion due to a low binding agent (Osujieke *et al.* 2020) while Parfitt and Salt (2001) reported that higher clay content of soils reduces erodibility. The observed high bulk density in this study could be associated with the tillage operations, level of organic matter content as well as structural breakdown which collaborates with the findings of Akamigbo and Igwe (1990) who observed high bulk density of similar soils due to structural failure. The lower total porosity obtained under cassava farm suggests that the soil's ability to store water was reduced. The higher moisture content in Ifite Ogwari site compared to Awka site could be as a result of textural characteristics of the soil. The lower Ksat values obtained under rice farms at both sites collaborates with the research of Eshett (1994) who reported soils of paddy rice production to usually have low hydraulic conductivity due to puddling and traffic pan formation. Again, the general low Ksat values observed under land use types in this study did not indicate good water transmission and reduction in water logging; this probably could be associated with soils of the studied sites as they are prone to water logging and reduced drainage especially with regards to Ifite Ogwari soils. Nweke and Nsoanya (2015) reported lower Ksat values in similar soils. The observed acidic level of soils under land use types could be a reflection of the parent material from which soils were derived as reported by Nwosu *et al.* (2020) as well as the very high annual rainfall recorded in the region which facilitates extensive leaching of basic cations (Onweremadu, 2007).

The low organic carbon in this study could suggest higher ability of the soil to disperse. According to Fullen and Catt

(2004) soils with <5% organic matter content are highly erodible while Emeh and Igwe, (2018) opined that soil organic matter content critical level of < 2% could lead to decline in soil structural stability. The CEC of a soil shows how well a soil can hold onto and store cations which implies that soils with high CEC values would be able to hold more nutrients than soils with low CEC values. As obtained in this study, CEC values ranged from 4.28-7.03 cmol/kg and could be termed low following the findings of Ubuoh *et al.* (2013) who reported CEC of low to medium with value range of 3.10 – 16.97cmol.kg-[1] in the soils of Ukpor in Anambra State and attributed it to the type of clay mineral present in the soil. Again, Nwosu *et al*. (2020) reported low CEC in the range of 2.23 -4.91 cmol/kg in the soils of Nworie river watershed. Landon (1991) rated CEC values in the range of 5-15 cmol/kg to be low while <5 cmol/kg to be very low.

The higher the degree of aggregation (DOA) the more resistance of soil to the dispersing action of runoff water; this study therefore showed that soils under rice farm in Awka site as well as grassland in Ifite Ogwari site with the highest DOA values were more stable. The significant difference and relative alike in the values of DOA could be associated to the texture of the soils studied which collaborates with the report of Ijeh *et al.* (2019) who found texture to be a strong significant factor controlling the formation and stability of aggregates. Large MWD values often times may indicate higher proportion of water stable macro-aggregate which according to Khormali *et al*. (2009) are likely to have a greater resistance to soil erosion. In line with this, grassland and rice farm soils showed a relatively firm structure compared to cassava farm. Le Bissonnais (1996) reported soil with MWD value of < 0.4 to be very unstable with systematic crust formation, 0.4-0.8 to be unstable with frequent crusting, 0.8-1.3 to be medium with moderate crusting, 1.3-2.0 to be stable with rare crusting and > 2 to be very stable without crusting. Based on this rating and the result of MWD obtained in Awka site; the soils under cassava farm, grassland and rice farm can be classified respectively as very unstable, unstable and medium whereas in Ifite Ogwari site the soils of cassava farm can be classified as very unstable, grassland as medium while rice farm as unstable with possibility of having frequent crusting. Aggregated clay is indicative of the ability of soil particles to be aggregated therefore the higher aggregated clay content obtained in Ifite Ogwari site may suggest more soil stability compared to Awka soils.

CONCLUSION AND RECOMMENDATION

Based on this study, the soils under land use types are prone to erosion and is characterised by moderate to high bulk density, poor water transmission, loss of soil structure as well as low soil organic carbon content. Soil texture and organic carbon have been identified in this study as important factors in aggregate formation therefore due to excessive land utilisation by farmers replenishing the soil organic carbon content is encouraged.

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Authors' Contribution

TVN conducted the field work/study, interpreted the data and wrote the manuscript. IAN supervised the study and proof read the manuscript.

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