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Evaluation of structural stability, soil properties, quality and quantity of organic materials in soils of different history

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ABSTRACT

Land use practices influenced soil nutrients, quality and quantity of organic materials. The soil used for the present study according FAO are classified as; Dystric nitosol from Oko, Orthic acrisol from Anaku, Orthic luvisol from Omor and Gyleic luvisol from Achalla. The land use system studied were forested (10 years) and cultivated soils. 0-25cm depth soil samples collected were air dried, sieved and used for soil properties determination. Results findings showed significant differences among the soil parameters tested. The percentage decrease in OM and CEC content in cultivated soils compared to forest soils varied from 31.9% - 64% (OM) and 10.96% - 33.94% (CEC). The Ca + Mg/Al^{3+} + H^+ ratio was observed higher in forested soils and ranged between 4.33 – 90 as against the range between 3.38 – 11 recorded in cultivated soils. C/N ratio varied 10.3 – 10.15 (Forested), 6.54 – 9.98 (Cultivated) and N/P 1.36 – 1.41 (Forested), 1.39 – 1.41 (Cultivated) respectively. C/P varied from 13.81 – 14.27 (Forested) and 9.24 – 13.87 (Cultivated). Particulate organic materials tested all decreased following cultivation. Correlation matrix showed organic matter to be highly positively significantly ($P < 0.01$) correlated with OC, N and available P with N. The findings from this study proved that continuous cultivation cause depletion of soil nutrients, structural stability and the integrity of the soils. Thus, judicious and protective plan have to be employed in soils of southeastern, Nigeria that is so fragile to ensure food security.

Keywords: Food security, soil management, soil sustainability, soil mineralogy, soil erosion

1. INTRODUCTION

Farmers in a bid to meet up food demand clear more virgin land in search of fertile soil. The implication is the degradation of agricultural soils and this pose a serious threat to food production. Land use changes such as continuous cultivation and its unsustainability according to Liu et al., (2022), Nweke and Ilo, (2019) are major contributor to soil degradation. They cause changes in soil ecosystem functions and magnitude of this changes varies from one location to another. Alterations in particle size, porosity, hydraulic conductivity, bulk density etc. were used by some workers to infer changes in soils with virgin land conversion to arable land through cultivation. Fearnside and Barbosa, (1998), Lal and Kimble, (1997), noted that clay content decreases due to selective erosion due to forest conversion.

Cultivation break down soil aggregates and OM binding agents thus, making the soil aggregates easier to be eroded by the forces of denudation. Top soil layer loss through erosion affect plant nutrient recycling and microbial activity. The spatial distribution of soil nutrients in the agricultural field is a factor of land use management practices (Li et al., 2022; Liu et al., 2022; Gomiero, 2016). Sometimes the farmers continue on this part without adequate input returns leading to land degradation. Soil aggregation improve nutrient availability and physical properties like aeration, water infiltration and retention and water use efficiency (Yuan et al., 2012). Long time soil fertility depends on the OM content accumulation and turn over OC and N. Cultivation had harmful effect on soil properties important to food production.

With cultivation as noted by Elliot, (1986) soil micro aggregates and particles may form macro aggregates through the action of temporary transient agents. Forest soils through its OM dynamics improves soil aggregation and nutrient cycle compared to cultivated soils and transfer of OC into deeper soil horizons. Kaiser et al., (2002) reported that the forest subsoil has about 45% of the SOC of the soil particle. This fraction they are noted to be bound to clay particle, forming micro aggregates to < 20μm in diameter. Virgin soils ensures significant sequestration of new C and stabilizes old carbon pools associated with formation of soils stable micro aggregates affected by silt and clay content (Del-Galdo et al., 2003). The authors equally observed that forest increases the SOC by 25% in the surface soil.

Tropical soils react poorly to continuous cultivation due to high rainfall intensity that result to higher erosion as the soils are unable to hold much water. Micro aggregates are faster and more easily eroded by erosion processes than lager macro aggregates (Šimanský, 2011). Aggregation as noted by Wang et al., (2010) can only be made when there is limited loss of finer particles and cementing agents. Vegetation cover has useful effect on the stability of soil aggregates Burri et al., (2009), because the addition of plant residues accelerates the formation of a more stable aggregates, Martinez et al., (2008) and OM enhance the formation of stable aggregates (Nweke, 2015; Vásquez et al., 2010).

The binding action of humus root exudates and by products of soil organisms contribute to the formation of stable aggregates in soils and significant correlation of OC with aggregate stability. Though in some cases soil OC may be only moderately or weakly correlated with aggregate stability (Holeplass et al., 2004). Nweke, (2015) opined that the decline of food production in Nigeria may be attributed to the famers inability to identify and replenish nutrient lost in the soil following different land use systems with a view of managing the soil according to their capability and limit. Hence the essence of this study is to evaluate the structural stability, soil properties, quality and quantity of organic materials in soils of different history in southeast, Nigeria.

2. MATERIALS AND METHODS

Site Description

The study locations (Achalla, Anaku, Omor, Oko), are in Anambra state and within the same agro – ecological zone of south eastern Nigeria. Omor and Anaku are found in Anambra north senatorial zone of Ayamelum local government area of Anambra state. Areas lies between latitude 06 281N to latitude 06 71N and longitude 06 551E to 06 441E. The study area has a tropical savannah, April to October and November to March are wet and dry periods respectively. The vegetation is grassland with scattered trees and under growth. On subsistence level farming activity is done with wooden implement such as hoe and machete. Information from farmers in Omor and Anaku revealed that they practice shifting cultivation. Cocoyam (*Colocasia Spp*.), cassava *(Manihot Esculenta*), maize (*Zea Mays*), okra (*Abelmoschus Esculentus*), melon (*Citrilus Viligaris*) and rice (*Oryza Sativa*), are major crops grown by farmers in the area.

Also, information from the indigenes of Omor and Anaku, showed that the forest has never been cleared, cultivated or burnt for more than 10 years. Oko is well known for agriculture, the major food crops include assorted vegetables, yam, cassava, cocoyam, plantain, oranges and maize. Oko is one of the towns in Anambra south senatorial zone of Orumba north local government area of Anambra state. It lies between Latitude 06 371N to latitude 06 51N and Longitude 07 751E to 07 881E. It consists of tropical zones, wet and dry climate with high rainfall of about 1600-1800mm and temperature of 32^{o}C. Information gathered showed that the forested land has been kept fallow over decades. Achalla is the capital of Awka north, a local government area in Anambra state.

Area lies between Latitude 06 201N to latitude 06 41N and Longitude 06 591E to Longitude 06 191E. Mixed cropping is mostly practised in Achalla and the crops include rice, cassava, yam, vegetables, pigeon pea and fruits. The study area has a tropical savannah with wet and dry climate having high rainfall of 1386mm and temperature of 34°C. The farmers practice shifting cultivation and the forests have been there for more than ten years. The soils sampled for this study are classified according to FAO soil taxonomy as Dystric Nitosol, Orthic Acrisol, Orthic Luvisol and Gyleic Luvisol (Federal Department of Agriculture and land Resources, 1985). The location, classification, land use type and treatment symbol are explained in (Table 1).

Table 1 Location, classification, and land use type

Location	Classification		Parent Material	Treatment Symbol	Land use Type	Dominant Vegetation /Cropping system
	USDA	FAO				
Oko	Rhodoxic Paleudult	Dystric Nitosol	Sand Stones	NOK (F) NOK (C)	Forested Cultivated	Acacia sp Plantain, Cassava
Anaku	Oxic Haplusults	Orthic Acrisol	Sand Stones	AAN (F) AAN(C)	Forested Cultivated	Mangifera indica Rice, Melon
Omor	Aquic Paleustulf	Orthic Luvisol	Shale mixed with sand stones	LOM (F) LOM(C)	Forested Cultivated	Treculia africana Rice, yam
Achalla	Typic Tropaqualf	Gyleic Luvisol	Shale	LAC (F) LAC (C)	Forested Cultivated	Elaeis guinensis Rice, vegetable

Laboratory Method

Soil samples from 0 – 25 cm depth were collected in duplicate from cultivated and forest lands. The different locations were selected based on the identification of virgin forests, with corresponding cultivated land and relatively with the same slope. At every sampling location, samples were taken in duplicates and were air-dried at room temperature and then sieved through a 5.00mm sieve. Clods were carefully crushed by hand along lines of natural cleavages to pass through the sieve. The samples were shaken mechanically for 10minutes and further sieving was carried out where necessary. All soil samples were in three replicates.

Particle size Analysis

The principle of Bouyocous hydrometer method, described by Day, (1965), was used to evaluate particle size distribution of the soil samples. The principle involves the dispersion of soil sample with Calgon (sodium hexametaphosphate). 20g of the soil samples were soaked in Calgon for 24 hours and later transferred to mechanical stirrer for mechanical agitation for 30 minutes before the hydrometer reading.

Aggregate Stability Evaluation

Mean weight diameter of dry aggregates (MWDD)

The Kemper and Chepil, (1965) method were used to determine the mean weight diameter of dry aggregates. The method involved vibrating horizontally on a mechanical shaker for 10 minutes, 250g of dry soil (previously sieved through a 5.00mm mesh) on top of a nest of sieve having diameters 2, 1, 0.5 and 0.25mm and determining the mass of aggregate on each sieve that fails to break down. The mean weight diameter of dry aggregate (MWDD) was computed thus;

MWDD = Xi di. -------------------- equation 1

Where;

MWDD = mean weight diameter of dry aggregates

Xi = mean diameter of each ith size fraction

di = proportion of total sample weight occurring in the corresponding ith size fraction.

Mean-weight diameter of wet aggregate (MWDW)

The method of Kemper, (1965) was used to determine the mean-weight diameter of wet aggregates. In accordance with the procedure, 40g of soil was pre-soaked for 5 minutes on the topmost sieve of diameter as 2,1,0.5 and 0.25mm. It was vertically oscillated for 20 minutes at the rate of one oscillation per second. The resistant aggregate was oven-dried and their masses recorded.

The mean-weight diameter of wet aggregates (MWDW) was computed as follows;

$$MWDW = X_i W_i \text{------------------------------ } 2$$

Where;

MWDW = mean-weight diameter of wet aggregates

X_i = mean diameter of each size fraction.

W_i = proportion of total sample weight occurring in the Corresponding size fractions.

State of Aggregation (SA)

$$SA = \frac{\text{Wt. of water stable aggregate} - \text{Wt. of sand}}{\text{Wt. of sample}} \times 100 \text{ -------------- } 3$$

Degree of Aggregation (DA)

$$DA = \frac{\text{Wt. of water stable aggregate} - \text{Wt. of sand}}{\text{Wt. of sample} - \text{Wt. of sand}} \times 100 \text{ -------------- } 4$$

Water Stable Aggregates (WSA)

$$WAS = \frac{M_{a+s} - M_s}{M_t - M_s} \times 100 \text{ ----------- } 5$$

Where;

M_{a+s} = mass of resistant aggregate plus sand (g)

M_s= mass of the sand fraction alone (g)

M_t = total mass of sieved soil (g)

Colloidal Stability

Middleton, (1930) procedure was used. The procedure involved the determining the percentage silt + clay in water-dispersed samples (A) and that in sodium resin-dispersed samples (B). The index (A/B x 100), known as the dispersion ratio (DR), is a measure of the ability of the aggregates to resist breakdown upon contact with water molecules. From this study, 20g sample from each aggregated fraction was soaked in either water or sodium hexametaphosphate solution for 24 hours, followed by shaking on a mechanical shaker for 30 minutes at 10 revolutions per minute. The dispersed silt + clay was determined by the hydrometer method.

Determination of Physicochemical Properties of the soils.

Organic Carbon

Walkley and Black, (1934) method as modified by Allison, (1965) was used to evaluate organic carbon (OC). The procedure involved the oxidation of the soil organic matter with potassium dichromate ($k_2Cr_2O_7$) using concentrated sulphuric acid (H_2SO_4) and the percentage organic carbon found by titrating with 1N ferrous ammonium sulphate solution. Organic matter was then determined by multiplying the determined percentage organic carbon by the conventional Van Bemmeler factor of 1.724.

Available Phosphorous

Determination was by Bray and Kurtz, (1945) method using 0.03N ammonium fluoride and 0.1N HCl. The available phosphorous was read off from standard curve after obtaining the optical density from a photo-electric colorimeter.

Total Nitrogen

The kjedahl method Bremer, (1965) using $CuSO_4$ and Na_2SO_4, catalyst mixture was used to determine total nitrogen. The ammonia from the digestion was distilled with 45% NaOH into 2.5% Boric acid. Total nitrogen was then determined by titrating with 0.05N HCl.

pH Determination

The soil pH was determined in both water and 0.1N potassium chloride (KCl) solution using soil: liquid ratio of 1:2.5. After stirring for 30 minutes, the pH value was read off using a Beckman Zeromatic pH meter (Peech, 1965).

Exchangeable Acidity

Determination was by titrimetric method using 1N KCl extract (Mclean, 1965).

Exchangeable Bases

The method described by Chapman, (1965), as complexometric titration method was used to evaluate Ca and Mg, while Na and K was obtained from 1N NH 4OH solution using the flame photometer.

Cation Exchange Capacity

The Chapman, (1965) principle of neutral ammonium acetate of 0.1N KCl solution was used to counter leach the soil sample and the KCl leachate was titrated with standard 0.IN NaOH solution to determine the cation exchange capacity (CEC).

Base Saturation

This was calculated by dividing the sum of bases (Ca, Mg, Na and K) by the cation exchange capacity (CEC) and multiplying the quotient by 100.

Base saturation = $\frac{Total\ exchangeable\ base}{Cation\ exchange\ capacity}\ x\ \frac{100}{1}$

Particulate Organic Matter (POM)

In determination of particulate organic matter, a dispersed 50g of soil sample was used. The soil was wet sieved in order to reduce variation in soil structural properties resulting from air or oven dry soil. 2mm, 250 and 50µm mesh sieves was selected because the particulate organic matter was defined as having diameters ranging between 50-250µm. The 2mm mesh collect root litters and coarse sand particles to medium sand. The 250µm mesh collects fine sand particle and partly degraded plant residues. The 50µm mesh collects silt particle and POM and passes clay particles, soil microbes and associated organo-mineral complexes (humic substances). Based on particle size only, this procedure was a quick approximation of particulate organic matter fraction.

Particulate Organic Carbon (POC)

Particulate organic carbon was determined by the sulphuric acid and aqueous potassium dichromate ($k_2Cr_2O_7$) mixture. After complete oxidation that involve heating of solution Nelson and Sommers, (1982), the unused or residual k2Cr2O7 (in oxidation) was titrated with ferrous ammonium sulphate. The difference between added and residual $k_2Cr_2O_7$, gave a measure of particulate organic C content of the soil.

Calculation;

$$\%\ \text{organic carbon} = \frac{\text{T x 0.2 x 0.3}}{\text{Sample Weight}}$$

$$\%\ \text{carbon} = \frac{(0.003x0.2)(Vb-Vs)x100}{Weight\ of\ sample}$$

Where: Vb = volume in ml of 0.2m ferrous ammonium sulphate used to titrate residual.

Vs = volume in ml of 0.2m ferrous ammonium sulphate used to titrate sample solution (oxidized solution)

w = mill equivalent weight (weight sample)

Particulate Organic Nitrogen (PON)

Particulate organic nitrogen was determined by the sulphuric acid and aqueous potassium dichromate ($k_2Cr_2O_7$) mixture. After complete oxidation that involve heating of solution Nelson and Sommers, (1982), the unused or residual $k_2Cr_2O_7$ (in oxidation) was titrated with ferrous ammonium sulphate. The difference between added and residual $k_2Cr_2O_7$, gave a measure of organic N content of the soil.

Calculation;

% organic nitrogen = $\frac{\text{T x 0.2 x 0.3}}{\text{Sample Weight}}$

% nitrogen = $\frac{(0.003x0.2)(Vb-Vs)x100}{Weight\ of\ sample}$

Where: Vb = volume in ml of 0.2m ferrous ammonium sulphate used to titrate residual.

Vs = volume in ml of 0.2m ferrous ammonium sulphate used to titrate sample solution (oxidized solution)

w = mill equivalent weight (weight sample)

Particulate Organic Phosphorous (POP)

Particulate organic phosphorous was determined by the sulphuric acid and aqueous potassium dichromate ($k_2Cr_2O_7$) mixture. After complete oxidation that involve heating of solution Nelson and Sommers, (1982), the unused or residual $k_2Cr_2O_7$ (in oxidation) was titrated against ferrous ammonium sulphate. The difference between added and residual $k_2Cr_2O_7$, gave a measure of organic P content of the soil.

Calculation;

% organic phosphorous = $\frac{\text{T x 0.2 x 0.3}}{\text{Sample Weight}}$

% phosphorous = $\frac{(0.003x0.2)(Vb-Vs)x100}{Weight\ of\ sample}$

Where: Vb = volume in ml of 0.2m ferrous ammonium sulphate used to titrate residual.

Vs = volume in ml of 0.2m ferrous ammonium sulphate used to titrate sample solution (oxidized solution)

w = mill equivalent weight (weight sample)

Data Analysis

The data generated from the study was subjected to simple linear correlation, to identify which intrinsic and dynamic properties that influenced the physicochemical characterization most. Data generated from the study were subjected to analysis of variance (ANOVA) and significant differences among treatment means were separated using least significant difference (LSD).

3. RESULT AND DISCUSSION

Particle size distribution of the soils

The result presented in Table 2 showed the particle size distribution of the soils studied. The particle size varied with the soil history. Sand and clay fractions were more observed in cultivated soils and silt in forested soils, probably because of low OM content of the soils that makes the cultivated less stable compared to forested soils. While silt/clay ratio value was high in forested soils of AAN (f) and NOK (F), it was low in LAC (F) and LOM (F). The variations observed with particle size distribution may be associated with land use history of the soils (Table 1) and the duration of cultivation (Nguyen et al., 2024; Bufabo and Elias, 2020; Nanganoa et al., 2019). Denton et al., (2017) observed higher sand fractions in arable land under cultivation and tree crops by 76.2% and 71.5%, silt and clay particles higher in grazing land by 27.2% and 10.64% respectively compared with fallow land.

Texture is an inherent property of soils; textural observation may be associated to accelerated weathering due to continuous disturbance of the soil during farm activities. The soils of LAC and AAN both forested and cultivated showed similar textural class of sandy loam. This suggests according to Foth, (1990) homogeneity of soil forming processes and soils similar in parent materials. Indicting also that land use history did not affect the texture of the soils. The dominant sand fraction may be associated with sand stone parent material (Table 1), this, according to give rise to soils with high sand particle content. The silt/clay ratio of greater than 0.32 in all the studied soils confirmed the young age of the soils. Asomoa, (1973) reported that young parent material usually has silt/clay ratio greater than 0.25.

Table 2 Particle size Distribution of the 0-25cm depth of the soils (%)

Treatment	Sand	Silt	Clay	Silt / clay ratio	Textural class
LAC (F)	71.6	11.0	17.4	0.63	Sandy loam
LAC (C)	66.7	13.3	20	0.67	Sandy loam
AAN (F)	65	20.2	15.7	1.29	Sandy loam
AAN (C)	70	11.5	18.5	0.62	Sandy loam
NOK (F)	45.3	35	19.7	1.78	Loam
NOK (C)	67	14.2	18.8	0.76	Sandy loam
LOM (F)	32.7	22.3	45	0.50	Clay
LOM (C)	43.2	21.7	35.1	0.62	Clay loam

F=forested, C= cultivated, LAC= Luvisol at Achalla, AAN= Acrisol at Anaku, NOK= Nitosol at Oko, LOM= Luvisol at Omor.

Chemical properties of forested and cultivated soils

The chemical properties of the forested and cultivated soils studied showed significant ($P<0.05$) differences among the soils (Table 3), except for the results of soil pH (both in water and KCl), K and Na. The pH of the cultivated soils shows more acidity content than forested soils. The recorded value of most parameters in cultivated soils (OM, C/N, C/P, CEC and Ca + Mg/Al^{3+} + H^{+}) were low compared with forested soils. At the same time, values of Na, K, and Ca/Mg ratio did not follow any particular order. K was found to be higher in cultivated soils of LAC, AAN, but higher in forested soils of NOK and LOM respectively, in like manner, base saturation value showed higher content in cultivated soils relative to forested soils. The percentage decrease in OM and CEC were in the order of 64% LAC, 31.9% AAN, 38.50% NOK for OM respectively, and for CEC, 20.14% LAC, 10.96% AAN, 33.94% NOK respectively.

While percentage increase in base saturation content of the cultivated soils in comparison with the forested soils showed variation of 5.36% LAC, 64.35% AAN, 29.12% NOK, 9.89% LOM (BS) respectively. The high acidity value recorded in cultivated soils could be attributed to leaching of the exchangeable bases following cultivation. The depletion of the tested parameters in cultivated soils relative to the forested soils align with the earlier studies of (Denton et al., 2017; Oviasogie et al., 2017). The low pH content observed in cultivated soils may be due to their silica-rich parent material (Ojanuga, 2006). The pH values of both forested, and cultivated soils, however, is within 5.5 – 6.5 considered optimum for the release of plant nutrient (Nweke and Nsoanya, 2013). The C/N, C/P and N/P ratios of the soils studied were less than 20 for all the locations.

The implication of these ratios is that it may favor N and P mineralization in these soils. Brady and Weil, (2002) reported that C/N ratio less than 20 favor N mineralization. The dominance of Ca in the exchange site and the least lost from the exchange complex may have contributed to the increased Ca/Mg and Ca + Mg/Al^{3+} + H^{+} ratio recorded in cultivated soils and forested soils respectively. The result of CEC and OM content of the soils have proved that soils with low OM can have low CEC value as recorded in cultivated soils relative to forested soils in all locations. The observed increase in Na and K content of cultivated soils in some locations simply suggests structural instability of the soils.

Table 3 Chemical properties of the forested and cultivated soils

Treatment Symbol	pH H_2O	pH KCl	OM %	C: N ratio	C: P ratio	N: P ratio	K cmolkg-1	Na cmolkg-1	CEC cmolkg-1	Base saturation %	Ca: Mg ratio	Ca + Mg: Al^{3+} + H^{+} ratio
LAC (F)	6.0	5.6	12.10	10.03	14.04	1.4	1.24	2.24	9.73	56	4.02	7.3
LAC (C)	5.6	5.4	4.30	9.96	13.83	1.39	1.85	3.31	7.77	59	5.96	3.83
AAN (F)	6.0	5.8	12.10	10.03	14.04	1.40	1.60	2.37	10.86	41.8	1.07	12.46
AAN (C)	5.5	5.2	8.24	9.98	14.09	1.41	1.79	2.0	9.67	68.7	8.53	3.38

NOK (F)	6.5	6.2	8.91	10.15	14.27	1.41	1.48	2.05	10.9	57.7	2.33	90
NOK (C)	6.0	5.7	5.48	9.96	13.87	1.39	1.12	3.03	7.20	74.5	19.8	56.4
LOM (F)	5.6	5.3	5.22	10.4	13.81	1.36	NS	NS	15.16	46.5	1.67	4.33
LOM (C)	5.5	5.2	7.31	6.54	9.24	1.41	1.35	1.70	16.77	51.1	1.28	11.75
Mean	5.84	5.55	7.96	9.63	13.40	1.22	1.62	2.55	11.01	56.91	5.58	23.68
LSD0.05	NS	NS	1.3	0.28	0.08	0.02	NS	NS	2.18	10.89	0.98	4.17

F=forested, C=cultivated, LAC= Luvisol at Achalla, AAN= Acrisol at Anaku, NOK=Nitosol at Oko, LOM = Luvisol at Omor. LSD = least significant figure, NS = not significant.

Structural Stability of the Soils

The structural stability of the soils assessed by different indices (Table 4) showed variations and significant ($P<0.05$) differences among the soils. The recorded values for MWDD and colloidal stability showed higher value in forested soils than cultivated soils except for NOK (MWDD), where cultivated value is higher than the forested value. While the value of MWDW, showed cultivated soils to be higher than the forested soils. The exception is the LOM and LAC, where cultivated soil value was low compared with the forested soil value. The percentage increase in dry aggregate stability (MWDD) of cultivated soils in comparison to the forested soils were; 19.90% (LAC), 47.66% (AAN), 118.51% (LOM) respectively. With this value AAN tend to be more stable than the other soils, also the result showed a contrary view that aggregate stability is reduced by cultivation. The result recorded might be attributed to increased OM content in these cultivated soils (Table 3), because aggregate stability is known to decrease in low SOM concentrations.

Though MWDD is not very sensitive in detecting differences among various land use types compared to MWDW. The relative decrease following cultivation for the soils of LOM and LAC concerning MWDW was 13.83% and 85% respectively, while the relative percentage increase due to cultivation for AAN and NOK were 35% and 45.65% respectively. The percentage value of LOM and LAC simple indicated that the aggregates disintegrated faster when they come in contact with water. This necessitates higher variability compared with MWDD (dry sieving). So, for the soils of LOM and LAC, the mean weight diameter of wet aggregates (MWDW) is very sensitive in detecting the disintegration in stability between the forested and cultivated soils. A similar observation was made by in four Nigeria soils. The lower value obtained in cultivated soils relative to forested soils for colloidal stability probably means that there was no decrease in the aggregate stability of these soils following cultivation.

But the higher value recorded indicates less structural stability of the aggregates. Further the higher value recorded for aggregate stability in cultivated soils contrary to what is expected could be attributed to the less OM (Table 3), Fe and Al oxides and clay contents of these soils. Aggregate stability according to Miquel and Norton, (1994) is mainly dependent upon OM, clay, Fe and Al oxides contents. The result of SA and DA showed decreased value in cultivated soils of LAC, LOM and NOK for DA, while cultivation did not affect the state of aggregation (SA) of NOK soil. The nature of the results obtained from SA and to extent DA and WSA simply suggests that the soils are more prone to disintegration when wet of which can be associated with the texture of the soils. Nweke et al., (2023) found soil texture to be a decisive factor that controls aggregate stability of soils.

Table 4 Aggregate stability indices

Treatment Symbol	MWDD mm	MWDW mm	Colloidal Stability %	SA %	DA %	WSA %	Mean
LAC (F)	2.35	0.8	81.4	11.5	39.6	33	-
LAC (C)	1.96	0.12	77.4	4.25	25.3	35	-
Mean	2.16	0.46	79.4	7.88	32.45	34	26.06
AAN (F)	1.58	0.24	87.7	3.25	31.7	37.2	-
AAN (C)	1.07	0.37	66.6	10	40	34	-
Mean	1.33	0.31	77.15	6.63	35.85	35.6	26.15
NOK (F)	2.87	0.25	86	9	64	38	-
NOK (C)	3,2	0.46	73.3	9	28.5	35	-

Mean	3.04	0.36	79.65	9.0	46.25	36.5	29.13
LOM (F)	3.16	0.94	76.5	10.5	31.8	31	-
LOM (C)	1.48	0.81	70	2.1	62.6	35	-
Mean	2.32	0.88	73.25	6.3	47.20	33	27.16
LSD0.05	NS	NS	3.69	2,09	11.05	1.89	-

MWDD = mean weight diameter dry, MWDW = mean weight diameter wet, SA= state of aggregation, DA= degree of aggregation, F=forested, C= cultivated, LAC= Luvisol at Achalla, AAN= Acrisol at Anaku, NOK= Nitosol at Oko, LOM= Luvisol at Omor.

Particulate organic material content of forested and cultivated soils

The recorded result in Table 5 showed that cultivation decreased the value of POM, POC, and PON in cultivated soils except for LAC soil. While for POP value, cultivation had no effect in AAN and LOM soils. The percentage decrease in POM, POC and PON following cultivation in AAN, NOK and LOM were; 8.25%, 35.14%, 6.18% (POM), 44.09%, 38.68%, 5.69% (POC) and 8.33%, 33.10% 6.82% (PON) respectively. The implication of this result suggested that the accumulation of OM, OC and ON were higher in forested soils than in the cultivated soils, indicating that the parameters are very sensitive to cultivation. Litter fall and plant roots supply OM and plant nutrients, hence the essence of increased value of the parameters in forested soils relative to the cultivated soils. However, the sandy nature of these soils (Table 2) simply implies that POM/POC may have low colloidal protection (Table 4) and may have consisted mainly of partially humified plant residues.

Particulate OM, OC, and ON is very much necessary to soil OM turn over and as such sensitive to land use type or farm management practices. Sequiera et al., (2011) reported POM to be important to SOM turn over and responds faster to soil management changes than the total SOM and passive fractions. While Steize et al., (2014) noted that soils under forest with large quantity of litter return have a higher proportion of POM. And as well higher proportions of POC, PON and POP. Gosling et al., (2013) in their studies indicated that the history of OM addition and inclusion of fallow are the primary factors controlling the POM content of agricultural soils. Permanent vegetation in addition is also an essential sources of organic N (ON) and therefore, will have long term effect on the transport of N as well as P on biogeochemical systems of these soils. The importance of organic N in soil ecosystems are well documented in the works of (Ozel et al., 2010; Lee and Wexler, 2013).

The particulate organic P value recorded in these soils may be attributed to absolute low content of P in the studied soils or probable due to P sorption by Fe and Al phosphates that are noted in the soils of the studied area as a result of higher acidity nature of the soils. The ratio results (POC/PON, POC/POP and PON/POP) recorded in these soils that varied with the soil history can closely be associated with the chemical composition and pool size of POM. POM controls the mineralization of the parameters (C, N and P). The POM a readily decomposable food for soil microbes is a dynamic pool for the availability of the parameters leading to their more significant mineralization in soils. The difference in POM, POC, PON, and POP compositions associated with the history of these soils (Table 1) with regards to the source of the plant residues and their decomposition may have influenced the properties of POM and thus the mineralization of the nutrients (C, N and P).

Table 5 Particulate organic material content of forested and cultivated soils meq/100g soil

Treatment Symbol	POM	POC	PON	POP	POC/PON	POC/POP	PON/POP
LAC (F)	5.38	3.12	0.31	0.02	10.06	156	15.5
LAC (C)	9.31	5.40	0.54	0.03	10	180	18
Mean	7.35	4.26	0.43	0.03	10.03	168	16.75
AAN (F)	14.43	8.37	0.84	0.05	9.96	167.4	16.8
AAN (C)	13.24	4.68	0.77	0.05	6.08	93.6	15.4
Mean	13.84	6.53	0.81	0.05	8.02	130.5	16.1
NOK (F)	10.36	6.36	0.63	0.04	10.1	159	15.75
NOK (C)	6.72	3.9	0.39	0.02	10	195	19.5

Mean	8.54	5.12	0.51	0.03	10.05	177	17.68
LOM (F)	7.60	4.39	0.44	0.03	9.98	146.33	14.67
LOM (C)	7.13	4.14	0.41	0.03	10.10	138	13.67
Mean	7.37	4.27	0.43	0.03	10.04	142.17	14.17
LSD0.05	2.04	2.16	NS	NS	-	-	-

POM= particulate organic matter, POC= particulate organic carbon, PON= particulate organic nitrogen, POP= particulate organic phosphorous, WSA = Water stable aggregate, F=forested, C= cultivated, LAC= Luvisol at Achalla, AAN= Acrisol at Anaku, NOK= Nitosol at Oko, LOM= Luvisol at Omor.

Correlation matrix between the soil parameters

The correlation matrix of the soil parameters in Table 6 showed that OC, N and available P is highly significant ($P<0.05$) and positively correlated with OM. Also, N and available P are highly ($P < 0.01$) correlated with OC and available P correlated significantly ($P < 0.01$) and positively with N. The silt showed negative but significantly ($P < 0.05$) correlated with sand. Particulate organic N (PON) and particulate organic P (POP) correlated positively and highly significant ($P < 0.01$) with particulate organic carbon (POC). Every other soil parameter in Table 6 showed non-significant correlation, but in some cases positive and negative correlations were recorded with varied r- values. Nweke et al., (2023) made similar observation with four different soil classes in southeast, Nigeria.

The results of correlation matrix of the soil parameters, generally may have been influenced by a lot of factors which are not limited to the history of the soils, texture, OC content, clay content, Fe and Al-oxides content, silt + clay distribution, OM content, nature and type of microbes, moisture content, physical and chemical composition of the soils. Khurshid et al., (2006) noted that soil structure and aggregation are strongly influenced by cultivation related practices. Nweke and Ijeh, (2017) emphasized the importance of physical and chemical components of the soils as this creates changes (positive or negative) in the relationship between the tested parameters.

Table 6 Correlation matrix showing relationship between soil particles

	sand	silt	clay	OM	OC	N	Avail. P	POM	POC	PON	POP	SA	DA	WSA
Sand	-	-	-	-	-	-	-	-	-	-	-	-	-	-
silt	-0.7299*	-	-	-	-	-	-	-	-	-	-	-	-	-
clay	0.08647	0.029694	-	-	-	-	-	-	-	-	-	-	-	-
OM	0.355746	-0.02914	0.032508	-	-	-	-	-	-	-	-	-	-	-
OC	0.315041	0.059347	0.037125	0.994332**	-	-	-	-	-	-	-	-	-	-
N	0.137747	0.107923	0.384532	0.903057**	0.901087**	-	-	-	-	-	-	-	-	-
Av..P	0.134355	0.108179	0.370014	0.907265**	0.904873**	0.999823**	-	-	-	-	-	-	-	-
POM	0.470841	-0.33462	-0.03877	0.07905	0.044573	-0.04013	-0.04567	-	-	-	-	-	-	-
POC	0.422658	-0.44378	0.046439	-0.30299	-0.32874	-0.36903	-0.3794	0.817227	-	-	-	-	-	-
PON	0.48228	-0.3428	-0.03487	0.062781	0.028289	-0.0575	-0.0631	0.998598	0.827294*	-	-	-	-	-
POP	0.379673	-0.36511	-0.08733	0.091774	0.041816	-0.00653	-0.00927	0.963017	0.74628**	0.965051	-	-	-	-
SA	-0.03259	-0.03645	-0.59203	0.169379	0.192339	-0.05503	-0.04899	-0.284	-0.07404	-0.29379	-0.3214	-	-	-
DA	-0.46455	0.655752	0.592174	0.192365	0.259057	0.49469	0.485776	-0.37246	-0.29525	-0.38366	-0.42577	0.003843	-	-
WSA	0.167442	0.484262	0.433937	0.260772	0.319681	0.315476	0.307836	0.246092	-0.00361	0.249975	0.112525	-0.49519	0.379037	-

*. $P < 0.05$ **. $P < 0.01$.

4. CONCLUSION

From the present study it was found out that higher content of most tested parameters was more observed in forested soils compared to the cultivated soils, showing that cultivation influenced the recorded values of the parameters. However, the structural stability of the soils tested with different indices revealed that cultivated soils relative to forested soils did not have lesser stable aggregates. And when in contact with water did not disintegrate faster than those of the forested soils. The particulate organic materials of the soils were relatively low and sensitive to cultivation. This may constitute a threat to soil productivity, crop production and food security in tropical soils of Nigeria, where cultivation is the principal land use.

The correlation matrix of OM with OC, N and available P was positive and highly significant ($P<0.01$) this also applies to OC with N and available P, and available P with N contents of the soils. Other soil parameters tested revealed non-significant but, in some cases, correlated positive or negative. Generally, the study demonstrated that cultivation influenced the soil properties studied. Therefore, adequate management of cultivation practices in these soils will be an integral to increasing soil OM stocks reduce its losses and a precondition to improving the productivity of these soils.

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Author Contributions

Nweke Ikechukwu Aloysius: The head of the team, initiator of the research work and the author of the paper.

Nwosu Tochukwu Victor: Field data collection, literature review, laboratory analysis.

Okafor Maduabuchi John Bosco: Field data collection, literature review

Madueke Chike O: Assisted in laboratory analysis of the soil and statistical analysis of the data generated

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Ethical approval

Not applicable.

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Data and materials availability

All data associated with this study are present in the paper.

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