Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Evaluation Of Selected Soil Structural Properties of Different Land Uses In Oforola, Imo State, Nigeria

[1] Enyioko C.O, [1]Akande O. S, [2]Kamalu O. J. And [3] Nwokocha C.C

[1] *Department of Soil Science Technology, Federal College of Land Resources Technology, Owerri, Imo State.*

[2]*Department of Soil and Crop Science, University of Port Harcourt, Rivers State.*

[3]*National Root Crops Research Institute, Umudike Abia State.*

ARTICLE INFO

Article history:
Received May 19, 2019
Received in revised form July 30, 2019
Accepted September 21 2019
Available online December 20, 2019

Keywords:
Agro-wastes
Evaluation,
Production
Suitability
Rice.

Corresponding Author'S E-mail Address:

chimexa@yahoo.com. +2348068611483

https://doi.org/10.36265/njss.2019.290205

ISSN-1597-4488 cpublishingrealtime.

ABSTRACT

This study centered on evaluating selected soil structural properties of different land uses in Oforola, Imo State, Nigeria. Soil samples were collected from six different land-use types, namely, secondary forest, bush fallow, bare plot, cassava cultivated plot, oil palm plantation, and grassland vegetation. Soil auger was used to collect soil samples from each of the land use types at two (2) depths (0 – 15 cm and 15 – 30cm). The samples from each land use at different depths were composited, mixed thoroughly and sub-sample, and analyzed in the laboratory for selected physical and chemical parameters. The data were analyzed statistically using GENSTAT software Ver. 8.2 in Completely Randomized Design (CRD). The soils of the study area were principally sandy, with sand accounting for more than 65% of the inorganic mineral fragment in the soil at 0 – 15 cm depth and 15 – 30 cm depth. Land use effect on the dispersion ratio (DR) was significant ($P \leq 0.05$) at the 0 -15 cm and 15 – 30 cm depth. However, oil palm plantation recorded significantly ($P \leq 0.05$) higher dispersion ratio at the 0 – 15 cm depth. Bulk density was highest (1.57 g/cm3) in grassland vegetation and lowest in secondary forest and bush fallow (1.25 g/cm3). The bulk density values for bare plot, cassava cultivated plot and oil palm plantation were 1.51 g/cm3, 1.35 g/cm3, and 1.29 g/cm3, respectively. The total porosity of the soil was significantly higher in secondary forest (51.84%). Total porosity values for bush fallow, Cassava cultivated plot, oil palm plantation, bare plot, and grassland vegetation were 51.83%, 48.38%, 50.97%, 42.36%, and 40.08%, respectively. The proportion of water stable aggregates were significantly ($P \leq 0.05$) influenced by the various land-use types. On the average, secondary forest and bush fallow had higher water-stable aggregates of various sizes compared to the cassava cultivated plot that had moderate water-stable aggregates. The least water-stable aggregates of various sizes were recorded in grassland vegetation and oil palm plantation. The mean weight diameters were significantly ($P \leq 0.05$) influenced by various land-use types. Low mean weight diameter was observed for oil palm plantation, grassland vegetation and cassava cultivated plots. Based on the findings of the study, secondary forest and bush fallow land-use types possessed the most stable structural properties and also showed optimal impact compared to other land uses in Oforola soils, Imo State, Nigeria

1. Introduction

In Sub-Saharan Africa, soils are characterized by low crop productivity (Eswaran, 2007), and are subject to severe degradation due to inappropriate land-use practices (Lal, 2009; Igwe, 2003) and seasonal changes (Singer and Munns, 1999). Several researchers (Emadiet al., 2008;Enyiokoet al., 2017;Tellenand Yerima, 2018) have documented that land use practices have led to changes in the soil physicochemical properties, especially aggregate stability, water-stable aggregates, and micro-aggregate stability. While studying the effects of land use on soil, Aluko, and Fagbenro (2000), observed increased pH and organic matter for soils under *Gmelina aborea* compared to soils under *Pinus canaborea, Treculia africana*, agroforestry and fallow. They also found increased phosphorus (P) in fallow compared to other land use types. Akamigbo and Asadu (2001)reported marked changes in morphological, physical and chemical properties, which accelerates pedogenic processes, and decline in fertility of soil under traditional use when contrasted with forest land. Ahukaemereet al. (2012) also found significant differences in soil properties.

Soil structure is a crucial factor in soil fertility and agricultural productivity and thus has great ecological importance. The influence of soil structure on crust formation, root penetration, soil water and air movement, CO2 emission, erosion, nutrient retention, and biological activity is well known. Soil structure, in turn, depends on the interaction of soil type, aggregating agents, soil management, and environmental conditions (Tisdall and Oades, 2002; Mucheet al.,2015)).

Soil structure relates to the physical state of the soil complex, and the indices of soil structure comprise properties such as bulk density, soil texture, aggregate stability, infiltration, clay dispersion, mean weight diameter, water suitability aggregate, micro suitability aggregate and porosity (DEFRA, 2006). Although the dynamics of terrestrial ecosystems depend on natural cycles, they can be directly modified by human activities (e.g., land-use/cover change) (IPCC, 2000). Land use change causes environmental changes that affect soil fertility. All of these changing processes contribute to soil degradation, which has become a major ecological problem. In their natural states, forests, grasslands and meadows have good soil structure and are rich in soil organic carbon (SOC), but their conversion to arable land usually leads to deterioration of the structure and then rapid erosion (Six et al., 2008). Soil structure often deteriorates together with SOC. Soil structure deterioration has local, regional and global effects on economics, the quality of the environment and resource sustainability; moreover, it induces soil compaction and a decline in SOC (Lal, 2001). Increasing the intensity of cultivation can reduce C-rich macro-aggregates and increase C-depleted micro-aggregates, resulting in an overall loss of SOC (Six et al., 2000). Also Poor mean weight diameter arising from different land sue types can lead to unstable aggregates which disintegrate during rainstorms. Dispersed soil particles arising from low soil mean weight diameter can fill surface pores, and a hard physical crust can develop when the soil dries, thereby leading to soil fertility reduction (IFOAM, 2002). Because of this, it becomes vital- to study the effect of different land use types on soil mean weight diameter, water suitability aggregate, and micro-aggregate stability. There are different types of land uses like recreational land use, agricultural land use, and construction based land use (Herrick et al.,2001). However, for the purpose of this study, cassava farm, secondary forest, bush fallow, bare plot, and oil palm plantation will be the land uses types of interest. The objectives of the study were to determine the micro and macro-aggregate stability indices of Oforola soils under different land use types, to compare the aggregate stability indices of the soils, and to make recommendations based on the findings of the study.

2.0 Materials and Methods

2.1 Description of the Study Area

The study was conducted in Oforola Owerri West, Imo State. Oforola lies between latitudes 60 30′ and 50 54′N and longitudes 60 57′ and 70 43′E. The study area is located within the humid tropical climate, having a mean annual rainfall range of 2000 to 2250 mm. The mean annual temperature ranges from 270–280C and relative humidity varywith seasons from 80–90% in the rainy season and from 60- 80% during the dry season. The rainy season is bimodal; having peaked in July and September and a dry spell in August. The dry season is usually accompanied by a dry cold harmattan period, which prevails during the month of December and January (FDALR, 2005). The soils are derived from coastal plain sands of sedimentary origin and are highly weathered and dominated by low activity clay minerals (Akamigbo, 2000; Ufotet al., 2001). The soils have low contents of organic matter, base status, and water storage capacity, and are highly susceptible to accelerated erosion and degradation (Enwezoret al., 2001).

The native tropical rainforest vegetation has been almost completely replaced by a secondary forest of predominantly wild oil palm trees of various densities of coverage, and woody shrubs as Chromolaenaodorata (Siam weed) and various grass undergrowth. The land use patterns in the area are dominantly the fallow, and continuous cropping systems and the major food crops grown are cassava, yam, maize, and vegetables.

2.2 Sample Collection

Soil samples were collected from six different land use types, secondary forest, bush fallow, bare plot, cassava cultivated plot, oil palm plantation, and grass vegetation. The samples were collected using systematic random sampling from each of the land use pattern. Soil auger was used to collect soil samples from each of the land use pattern at three (3) different depths: 0 – 15 cm and 15 – 30cm. The samples from each land use at different depths were composited, mixed thoroughly, and sub-sampled. The soil samples collected were stored in sampling bags for onward laboratory analysis.

2.3 Laboratory Analysis

Mean Weight Diameter

The samples for the determination of mean weight diameter were collected from 0 -15 cm to 15-30cm soil depth in each of the land use type. The soil samples were dried at room temperature and pre-sieved through a 4mm sieve before determining the mean weight diameter (MWD) index according to the procedure suggested by Kemper and Chepil (1965). In this method, 20g of the <4mm air-dried aggregates were placed on the top of a nest of four sieves of diameters 2,1,0.5 and 0.25mm and soaked in distilled water for 10mins. The sieves and their contents then oscillated vertically for 20 times along a 4cm stroke at the rate of one oscillation per second. The aggregate retained on the sieves were oven-dried at 1050C and their weights recorded. The weights of the <0.25 mm fraction were obtained by difference. The respective dry masses were used to compute the MWD as:

Where Xi = arithmetic mean diameter of the I = 1

Moreover,1 sieve openings (mm)

Wi = proportion of the total sample weight (uncorrected for sand and gravel) occurring in the fraction (dimensionless), and n = total number of size fractions.

Particle size distribution was measured by the hydrometer method (Day, 2005).

This was preceded by two pre-treatment techniques aimed at removing some known aggregating agents.

2.4 *Water Stable Aggregates*

Water stable aggregates of the 2mm size air-dry samples were determined using a nest of the sieve of 2, 1, 0.5, and 0.25mm in diameter as described by Kemper and Rosenau (1986).

2.5 *Micro Aggregates Stability*

The indices of micro-aggregate stability were calculated using the relationship stated below.

Dispersion Ratio (DR) = (%silt + % clay (H2O)) / (%silt + %clay (Dispersed));

Aggregated silt and clay (ASC) = (%silt + %clay (Dispersed)) – (%silt + %clay (H2O);

Clay dispersion Index (CDI) = (%clay (H2O) / %clay (Dispersed)) x 100;

Clay flocculation Index (CFI) -=(%clay (Dispersed) - % clay (H2O) / %clay

(Dispersed) x 100; or (1 - %clay (H2O) x 100).

Higher values of WSA > 0.5 mm, ASC and CFIIndices imply greater stability.

Whereas Higher values of WSA < 0.5mm, DR, and CDI imply lower stability (Igweet al., 2009).

2.5 *Macro Aggregate Stability*

The WSA >0.25mm were used to assess macro-aggregate stability. Whereas the percentage aggregate < 0.25mm measured the unstable aggregate.

Bulk density and Total porosity

Undisturbed soil core samples were taken from all the land use plots at 2 depths (0-15 cm and 15-30 cm). The samples were used to determine the bulk density (BD), according to Blake and Hartge (1986).

Total porosity (PT) was obtained from bulk density (dB) values, with assumed particle density (dP) of 2.65 g/cm3, as follows:

PT = 100 (1- dB/ dP)

2.6 *Data Analysis*

The data were statistically analyzed using GENSTAT Software Ver. 8.2 for a Completely Randomized Design. Significant treatment means were separated using F-LSD at P <0.05 probability level, according to Obi (1986).

3.0 Result and Discussion

Effects of Land Use on Particle Size Distribution and Erodibility Factors

Laboratory results showing the comparison of effects of land use on the particle size distribution and erodibility factors for soils depth of 0 -15 cm and 15 – 30 cm is as shown in Table 1 below:

3.1 *Particle Size Distribution*

The particle size composition of soils in the six land use types is as shown in Table 1. The soils are principally sandy; with sand accounting for more than 65% of the inorganic mineral fragment in the soil at 0 – 15 cm depth and 15 – 30 cm depth. At the 0 – 15cm depth, the proportion of sand was higher in all the land uses except in grass vegetation plots which recorded lower sand content (70.27%).

Conversely, at the 15 – 30cm depth, There was a significant difference (P <0.01) in sand content under soils of different land use types. Bare plots and oil palm plantation recorded significantly the highest percentage of sand, while the least percentage sand content (65.27%) was obtained from cassava cultivated plots. The sand content of the soils decreased with increasing depth except in the bare plot where the sand contents for 0 – 15 cm depth and 15 – 30 cm depth was the same (73.93%). The high percentage of sand in all the land use patterns could be attributed to the geology of the area. The geology of the area is coastal plain sands which are characterized by sandy soils over a vast expanse of land (Akamigbo and Ukaegbu, 2003).

The amount of silt and clay in the different land use types was small compared to the value obtained for sand. At the 0 -15 cm depth, silt contents were higher in the bush fallow land use types (5.33%) and did not differ significantly with values obtained from other land uses except in oil palm plantation with a percentage silt content of 3.00%.. Similar results were obtained at 15 – 30 cm soil depth, except that bare plots, oil palm plantation and secondary fallow plots recorded lower silt contents that ranged from 3.00% – 3.33%. Silt content was the same at 0 – 15 cm depth and 15 – 30 cm depth for bush fallow and oil palm plantation. The silt content of secondary forest, reduced with depth from 4.33% in 0 -15 cm depth to 3.33% in 15 – 30 cm depth. There was also a reduction in the silt content in the soil of bare plot with increasing depth. The silt content of the cassava cultivated plot increased from 4.00% at the 0-15 cm depth to 4.67% at the 15-30 cm. The increase in silt content in the bush fallow, cassava cultivated plot and the grass vegetation could be attributed to the development of soil cover, which helps to suppress soil erosion. Grass vegetation(26.40%)and cassava cultivated plots (24.73%) resulted in significantly (P < 0.05) higher clay content at the 0 -15cm depth than other land use types which did not differ significantly with each other.

On the other hand, bare plots had lower clay content (21.07%) than different land use types which did not differ significantly in their clay contents at 15 - 30 cm soil depth.

Table 1: *Mean comparison of the effects of land use on the particle size distribution and flood factors (silt:clay ratio) for soils depth of 0-15 cm and 15 – 30 cm*

Particle size	Soil depth	Land use						
		SF	BF	BP	CCP	GV	OPP	LSD(0.05)
Sand (%)	0 – 15cm	73.93	74.27	73.93	75.87	70.27	75.93	2.55*
	15 - 30 cm	69.93	67.93	73.93	65.27	67.93	71.93	2.05**
Silt (%)	0 – 15cm	4.33	5.33	4.33	4.00	3.67	3.00	2.22*
	15 - 30 cm	3.33	5.33	3.00	4.67	5.00	3.00	1.92*
Clay (%)	0 - 15cm	21.73	20.40	21.73	24.73	26.40	21.07	2.10*
	15 - 30 cm	26.73	26.73	21.07	27.40	26.73	25.07	4.15*
Si:Cl ratio	0 – 15cm	0.20	0.26	0.20	0.16	0.14	0.14	ND
	15 - 30 cm	0.12	0.20	0.14	0.17	0.19	0.12	ND
DR	0 – 15cm	0.29	0.29	0.32	0.29	0.28	0.39	0.06*
	15 - 30 cm	0.31	0.29	0.29	0.22	0.30	0.27	0.09*
ASC (%)	0 – 15cm	19.00	20.33	20.33	22.00	22.33	14.67	4.19*
	15 - 30 cm	20.00	21.67	20.33	28.00	19.33	19.67	4.19*
CFI (%)	0 – 15cm	71.10	65.60	67.88	72.90	74.02	66.62	3.69**
	15 - 30 cm	73.74	74.51	75.18	76.53	74.45	71.79	3.15**

, = Significant at 5 and 1% probability levels, respectively; NS = Not significant at 5% probability level.*

SF= secondary forest, BF= bush fallow, BP= bare plot, CCP= cassava cultivated plot, GV= grassland vegetation, OPP= oil palm plantation, SCR= silt clay ratio, DR= dispersion ratio, ASC= aggregated Silt + Clay, CFI= clay flocculation index, CDI= clay dispersion index, ND = Not determined.

There was a marked increase in clay content with increase in soil depth in all the land use types except in bare plots where there was a reduction with increase in soil depth. Silt:clay ratio, which is an index of flood hazard showed that at 0 – 15 cm depth, there was no flood incidence as the ratio obtained in all land use types were < 1.

3.2 Land use type and micro-aggregate stability.

The effects of land use type on micro-aggregate stability indices [(dispersion ratio (DR), aggregated silt and clay (ASC), and clay flocculation index (CFI)] at 0 – 15 cm and 15 – 30 cm are presented in Table 1. Using the LSD value of 0.06 at $P < 0.05$ for comparing the DR of the six land use types at 0 – 15 cm soil depth, it is shown that grass vegetation, secondary forest, bush fallow and cassava cultivated plots recorded significantly lowest DRs, while highest DR value of 0.39 was obtained from oil palm plantation land use. According to Igweet al. (1999), lower values of DR imply greater aggregate stability. At a lower soil depth (15 – 30 cm), there appeared to be a reversal of DR values across the land uses. This was most pronounced in oil palm plantation where there wasa 31% reduction in DR value at 15 – 30 cm depth, suggesting greater stability at a lower depth.

Significantly ($P < 0.05$) higher values of ASC values were obtained in all land use types at 0 – 15 cm, except in oil palm plantation where ASC value was lower (14.67%). However, at 15 – 30 cm soil depth, higher values of ASC were obtained compared to values in 0 – 15 cm depth, except in bare plots where values were same and in grass vegetation where there was a 13% reduction in ASC value

(19.33%). Clay flocculation index (CFI) increased with increase in soil depth in all the land uses studied. This suggests greater aggregate stability in the land uses at 15 – 30 cm soil depth. Significantly higher CFI values were recorded in cassava cultivated plots (72.90% and 76.53% at 0 – 15 cm and 15 – 30 cm depths, respectively) and grass vegetation plots (74.02% and 74.45% at 0 – 15 cm and 15 – 30 cm depths, respectively). This may be attributed to higher clay contents recorded in these land use types and depths relative to others. Canasveraset al. (2010) reported that clay particles were considered as agents of aggregation because of their high specific surface area, high CEC and consequently, high chemical and physical activities

3.3 Land use type and selected soil physical properties

Bulk density

The effect of land use on soil bulk density is as shown in Table 2. Bulk density was significantly ($P < 0.05$) highest (1.57 g/cm3) in grassland vegetation land use and lowest in secondary forest and bush fallow (1.25 g/cm3). The bulk density values for the bare plot, cassava cultivated plot and oil palm plantation were 1.51 g/cm3, 1.35 g/cm3, and 1.29 g/cm3 respectively. The slaking, siltation and compaction of soil in cassava cultivated plot, bare plot and oil palm plantation may have led to the high bulk densities recorded in the plots relative to secondary forest and bush fallow plots. Ahukaemereet al. (2012) equally recorded consistently higher bulk density in continuously cultivated land than in oil palm plantation. Akamigbo (2000) and Onweremaduet al. (2009) reported similar results on bulk density in continuously cultivated lands. The range of bulk densities across the land use types appears not too compact to limit plants roots penetration and water and air movement. This suggests the existence of loose soil conditions in the study land use types, and hence, good structure.

3.4 Total porosity

Effect of land use on total porosity of the soil is as shown in Table 2. The total porosity of the soils, in general, varied with bulk density. Accordingly, total porosity increased as the bulk density decreased. The total porosity of the soil was significantly ($P < 0.05$) highest in secondary forest (51.84%), bush fallow (51.83%) and oil palm plantation (50.97%). Lower values of total porosity were obtained in grassland vegetation (40.08%) and bare plots (42.36%). This inverse relationship that exists between bulk density and total porosity seemed to agree with literature.

3.5 Water stable aggregates

Water stable aggregates remaining after sieving in water is a true reflection of the ability of the aggregates to resist breakdown and dispersion due to water forces. The results in Table 3 show that land use type significantly influenced water-stable aggregate sizes, except for 1 – 0.5 mm aggregate size. On the average, secondary forest and bush fallow had greater water-stable aggregates of various sizes when compared to the cassava cultivated plot that had moderate water-stable aggregates across various water-stable aggregate-sizes. The least water-stable aggregates of various sizes were recorded in grassland vegetation and oil palm plantation. For Aggregate sizes >2.00 mm, Secondary forest had significantly ($P < 0.05$) highest water-stable aggregate fraction (2.82) which did not differ significantly with values obtained in the bare plot (0.92), cassava cultivated plot (0.88) and oil palm plantation (0.98). Bush fallow and grassland vegetation had aggregate size > 2.00 mm of -1.05 and -4.18. At 2 – 1 mm aggregate size, bush fallow land use recorded significantly the highest aggregate size (2.43) followed by the secondary forest (0.80). However, bare plots recorded the least value of -1.81. There was no significant difference ($P > 0.05$) in the proportion of aggregate size 1 - 0.5mm in the various land use types. The proportion of aggregate size 0.5 - 0.25 mm were 1.40, 1.18, 0.81, 0.93, 0.23, and 0.18 for the secondary forest, oil palm plantation, bare plot, bush fallow, cassava cultivated plot, grassland vegetation, respectively. Water stable aggregates < 0.25mm was significantly influenced by land use. Significantly ($P < 0.05$) highest values of aggregates < 0.25 mm were obtained in bush fallow (1.81) and secondary forest (1.79). The lowest value of 0.24 was recorded in grassland vegetation and oil palm plantation. A comparative analysis of all the land use types studied showed that aggregates > 0.5 mm resisted breakdown and dispersion due to water force most in secondary forest. The high proportion of water-stable aggregates in secondary forest and bush fallow might have been the result of the accumulation of organic matter throughleaf litter deposition and root biomass that greatly enhanced the formation and stabilization of

Table 2: *Mean Comparison of effects of land use on selected physical properties of the soils*

Land use	Bulk density (g/cm^3)	Total porosity (%)
Secondary forest	1.25	51.84
Bush fallow	1.25	51.83
Bare plot	1.51	42.36
Cassava cultivated plot	1.35	48.38
Grassland vegetation	1.57	40.08
Oil palm plantation	1.29	50.97
LSD (0.05)	0.05*	2.92*

** = Significant at 5% probability level.*

soil aggregates (Silva and Mielniczuk, 1997).

4 Summary

The study was conducted to evaluate selected soil structural properties on different land uses of Oforola, Imo State, Nigeria. Soil samples were collected from six land use types; secondary forest, bush fallow, bare plot, cassava cultivated plot, oil palm plantation, and grassland vegeta-

Table 3: *Mean Comparison of effects of land use on different water-stable aggregate sizes of the studied soils.*

Land use	**> 2.00 mm**	**2 - 1.00 mm**	**1 - 0.5 mm**	**0.5 - 0.25 mm**	**< 0.25 mm**
Secondary forest	2.82	0.80	0.88	1.40	1.78
Bush fallow	-1.05	2.43	1.10	0.81	1.81
Bare plot	0.92	-1.81	0.13	0.93	1.17
Cassava cultivated plot	0.88	0.30	5.13	0.23	1.58
Grassland vegetation	-4.18	0.34	-0.50	0.18	0.24
Oil palm plantation	0.98	0.38	-0.50	1.18	0.24
LSD (0.05)	2.68*	0.05**	NS	0.15**	0.05*

*, ** = Significant at 5 and 1% probability levels, respectively; NS = Not significant at 5% probability level.

Table 4: *Mean Comparison of effects of land use on different mean weight diameter of the studied soils*

Land use	**>2.00 mm**	**>2.00 mm**	**2 - 1.00 mm**	**1 - 0.5 mm**	**0.5 - 0.25 mm**	**<0.25 mm**
Secondary forest	Secondary forest	0.74	7.35	8.46	2.08	0.17
Bush fallow	Bush fallow	0.82	4.39	4.97	5.90	1.77
Bare plot	Bare plot	1.52	6.16	8.40	2.09	0.61
Cassava cultivated plot	Cassava cultivated plot	0.05	4.72	9.08	3.67	1.27
Grassland vegetation	Grassland vegetation	0.03	7.61	6.74	3.01	1.38
Oil palm plantation	Oil palm plantation	0.09	6.07	7.12	3.97	1.56
LSD (0.05)	**LSD (0.05)**	**0.05***	**0.04****	**0.05****	**0.04****	**0.05***

*, ** = Significant at 5 and 1% probability levels, respectively.

5 Conclusion

The study has shown that the effect of land use types on soil structural properties is no more a myth. It showed that the effects of the different land-use systems on soil aggregates and their mean weight diameter are evident in cassava cultivated plot, grassland vegetation and oil palm plantation which may implicate soil organic matter, root biomass, and limited microbial activity. Conversely, higher water-stable aggregates were observed in secondary forest and bush fallow, which is an indication of high soil organic matter, root biomass, and increased microbial activity.

References

Ahukaemere, F. Onweremadu, EU, Ndukwu, BN, and Ohiri, (2011). Variability in Particle-size Distribution of Soils as Affected by Crude Oil Spillage. International Journal of Soil Science, 2009; 1 (I): 104-109.

Ahukamere F. Solomon, D., J. Lehmann, M. Tekalign, F. Fritzsche, and W. Zech, (2012). Phosphorus forms and dynamics as influenced by land use changes in the sub -humid Imo Staten highlands. Geoderma105: 21-48.

Akamigbo, F. (2000) Sustainability evaluation of biodiesel from Jatropha curcas L., Ph.D.Thesis (Unpublished), Katholieke Universiteit, Belgie. PP. 8-9. Adebowale, K.O.,Adedire, C.O. (2006). Chemical composition and insecticidal properties of the underutilized Jatropha curcas L. seed oil. African Journal of Biotechnology, 10:901- 906.

Akamigbo, F.O.R, and, Asadu,C.L.A (2001). The influence of parent materials on the soils of Southeastern Nigeria, East Afr. Agric & Forest, Jour.48: 81-91.

Akamigbo, G., and Ukaegbu,G.(2003). Agrochemistry and soil science. TOM. 18: 392p.

Aluko, A.P, and Fagbenro, J.A.(2000). The role of tree species and land use systems in organic matter and nutrient availability in degraded Ultisol of Onne, Southeastern Nigeria. Proc.Annual Conf, Soil Sci Soc. Nig. Ibadan, Oyo State. Pp 89-292

Blake, G. R., and Hartge, K. H. (1986). Bulk density. In: Klute. A.(Ed.). Methods of SoilAnalysis, Part I. Physical and Mineralogical Methods. 2ndedn. Am. Soc. Agron.,Madison, W. I. p 363.

Canasveras F. TamiratTsegaye. (2010). Vertisols of the Central Highlands, Imo State Characterization, Classification, and Evaluation, of the Phosphorus status. MSc Thesis, Alemaya University

Day F. (2005) Uptake of heavy Metals by Jatropha curcas L. planted in soils containing sewage sludge. American Journal of Applied Sciences, 7(10):1291-1299.

DEFRA (2006) Physical Test for Monitoring Soil Quality. In: Doran, J.W., and Jones, A.J., Editors. Methods for Assessing Soil Quality. PP.123- 141. Retrieved on October 23, 2011, from http://soilquality.org/indicators/bulkdensity.html

Emadi, M.,Baghernejad, M., Hamed, F, and Mahboub, S. (2008). Effect of Land Use Change on Selected Soil Physical and Chemical Properties in North Highlands of Iran. Journal of Applied Sciences, 8: 496-502.

Enwezor, W.,Adesodun, J.K. and Odejimi, O. E. (2001). Carbon-nitrogen sequestration potentials and structural stability of a tropical Alfisol as influenced by pig-composted manure. International Agrophysics, 24:333 -338. Adonis-Habib, B.S. (2005). Pore size distribution of Friona soil series under different hydraulic loadings. MSc. Thesis (unpublished), Texas Technology University.

Enyioko, C. O., Akande. S. O., Nwite, J. N., and Kamalu, O. J. (2017d). Straw Mulch Levels and Selected Soil Physical and Chemical Properties of Oforola, Imo State, Nigeria. Int'l Journal of Agric. And Rural Dev. Volume 20(2): 3216-3221.

Eswaran, G. (2007). Bulk density methods of soil analysis, part 1, physical and mineral method (Ed. A Klute). PP. 363 – 382.

Eze, G. (2000). Land use dynamics, soil conservation and potential for use in Metu area, Illubabor region, Imo State. African Studies Series A13, GeographicaBernensia, Berne, Switzerland. 119p.

Federal Department of Agricultural Land Resources (2005). Litterfall and decomposition trend of Jatropha curcas L. leaves mulches under two environmental conditions. Agriculture and Biology Journal of North America, 2(3):462-470.

Herrick, D., Sánchez, M., M. Soriano, G. Delgado, and R. Delgado, (2001). Soil quality in Mediterranean mountain environments: effects of land use change. Soil Sci. Soc. Am. J. 66: 948-958.

IFOAM (2002) Soil physical quality part i: Theory, effects of soil texture, density, and organic matter, and effects on root growth. Geoderma, 120:201-214.

Igwe, C. A., Akamigbo, F. O. R., and Mbagwu, J. S. C. (1999). Chemical and mineralogical properties of soils in Southeastern Nigeria, in relation to aggregate stability. Geoderma92: 111 – 123.

Igwe, H. (2003) Tillage effects on sediment and soluble nutrient losses from a Manry silt loam soil. Journal of Environmental Quality, 19:683-686.

IPCC (2000).Special Report on Emissions Scenarios, IPCC, Cambridge University Press, Cambridge, UK, 2000. pp. 570.

Kemper, W. D, and Rosenau, R. C. (1986). Aggregate stability and particle size distribution. In: Klute, A (Ed.) Methods of soil analysis. PartI, physical and mineral methods, Madison W.I.P, 425-428.

Lal, R. (2001) Soil degradation by erosion. Land Degradation & Development, 12, 519-539.

Muche, M., Kokeb, A. and Molla, E (2015). Assessing the Physicochemical Properties of Soil under Different Land Use Types. J Environ Anal Toxicol 5: 309.

Obi, I. U. (1986). Statistical methods of detecting differences between treatment means. Deptof Crop Science, The University of Nigeria, Nsukka, Nigeria. SNAAP Press Nig. Ltd.Enugu. 45 pp.

Onweremadu, E. U., G. Murty d. Saikh, H., Varadachari, C. and Ghosh, K. (2009) Changes in carbon, nitrogen, and phosphorus levels due to deforestation and cultivation. A case study in Simplipal National Park, India. Plant Soil 200: 137-145.

Silva, I.F. and Mielniczuk, J. (1997). Ação do sistema radicular de planta naformação e estabilização de agregados do solo. R. Bras. Ci. Solo, 21:113-117.

Singer, M.J., and Munns, D.N. (1999). Soils An Introduction. 4thEdn., Prentice-Hall Inc., New Jersey.

Six F., Beare, M.H., and Bruce, R.R. (2008). A comparison of methods for measuring water-stable aggregates. Implication for determining environmental effects on soil structure. Geoderma, 56:87-104.

Tellen,V.A.,and Yerima,B. P. K. (2018). Effects of land use change on soil physicochemical properties in selected areas in the North West region of CameroonEnvironmental Systems Research, Volume 7, Number 1, Page 1

Tisdall H. and Oades (2002) Rainfall-induced soil surface sealing. Vadose Zone Journal, 3:570-591. Babaji,