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Soil Texture Effects on Soil Characteristics Under Oil Palm (*Elaeis guineensis*) Plantations of Selected Environments in Edo State, Nigeria

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ABSTRACT

The current work was carried out to examine soil texture effects on organic carbon and nitrogen of soils under oil palm (Elaeis guineensis) plantations of selected environments in Edo State, Nigeria. Eighteen soil samples were collected (0–15cm and 15–30cm) from three oil palm plantations. Soil indicators were analyzed using standardized procedures and the data obtained was examined by student t-test. Results of student t-test indicated that there were significant differences between NIFOR versus Hartman and OPC farms versus Hartman Farms for soil pH. Significant differences were also observed for sand contents between NIFOR and Hartman. This study revealed that the low status of organic carbon and nitrogen detected in the soils can be attributed to the textural characteristics of soils in the investigated sites. This study recommends that to improve the deficient status of organic carbon and nitrogen in the soils, crop and residue management strategies should be adopted.

1. INTRODUCTION

Oil palm, *Elaeis guineensis,* (Jacq) is cultivated throughout tropical forest environments where the altitude is less than 200m and rainfall is high. According to Cornel (2001), it is a lowland tree crop with fibrous root system that needs deep soils that are fertile, free from concretions and are well drained. Of all the plants, oil palm produces most oil per hectare and it is a highly traded edible fat and oil in the world accounting for over 48 % of world export (Cornel, 2001; MPPOC, 2005). Oil palm grows on soils that are acid sands, defined by Enwezor *et al.* (1981) as deep sandy loams and loamy sands derived from unconsolidated sand deposits which are generally acid in reaction and having low organic matter content and similar soils derived from sandstones that occur further north. Ezeaku (2013) opines that sustaining soil productivity in agricultural ecosystems is a function of the status of soil quality indicators. Soil texture, organic carbon and nitrogen are vital soil quality indicators that are used as basic determinants of soil quality and are closely related to soil productivity in an agricultural ecosystem (Adeboye *et al.*, 2011).

Soil texture strongly influences nutrient availability and sandy soils show low water holding capacity. Udom *et al.* (2015) emphasize that clay content is a relatively important determinant of organic carbon levels in soils and appears to apply to both cultivated soils and soils under natural vegetation. Sakin and Sakin (2015) noted that good soil texture protect soil organic matter (SOM) from being decomposed by physical, chemical and biological mechanisms. The impact of soil texture on organic carbon and nitrogen as asserted by Christensen (2001) is that their mineralization rates are often lower in clay soils than in coarse-textured soils because of the holding capacity of organic molecules onto surface minerals which seems to be a major mechanism of soil organic-matter preservation. Additionally, soil texture affects nitrogen (N) availability by influencing SOM accumulation. Therefore, variation in soil particle–size fractions exerts significant controls on the stock and turnover of soil organic matter, carbon and nitrogen. Soil texture, therefore, is one of the most stable features of soil and it is a valuable index of other numerous properties that define the agricultural potentials of a particular soil (Ugwa *et al.*, 2016).

Researchers have carried out investigations on soils under oil palm cultivation. Their works were on effects of oil palm cultivation on the properties of soil, soil carbon sequestration in different ages of oil palm plantations, multivariate analysis of soils under oil palm cultivation, suitability assessment of soils supporting oil palm plantations Notable amongst them are; Edokpayi *et al.* (2015), Ukaegbu *et al.* (2015), Nadeesha and Weerasinghe, (2016) and Roslee *et al.* (2016) amongst others. One distinctive feature about these studies is that they did not investigate the effects of soil texture on organic carbon and nitrogen content of soils under different oil palm plantations. Detailed quantitative studies on the effects of soil texture on organic carbon and nitrogen content of soils under different oil palm plantations are scarce. There is the need therefore, to carry out a detailed quantitative study on texture effects on organic carbon and nitrogen content of specific ecosystems. This study therefore, aims to evaluate the effects of soil texture on organic carbon and nitrogen content of soils under different oil palm (*Elaeis guineensis*) plantations of selected environments in Edo State, Nigeria.

2. MATERIALS AND METHODS

2.1. Sampling Sites

A reconnaissance survey was carried out to find out the foremost oil palm plantations in Edo State, Nigeria. Amongst all the oil palm plantations visited, the Nigerian Institute for Oil palm Research (NIFOR) located in Ovia North-east Local Government Area, Oil Palm Company (OPC) Farms in Igueben Local Government Area and Hartman farms located in Uhunmwonde Local Government Area of Edo State, Nigeria were selected for the study (Figure 1). NIFOR sampling site is about 22.39 km from Benin City, the State capital and is located at an elevation of 70 m above sea level. The area is situated in the tropical rainforest belt of Nigeria and lies between latitude 6°32'39.213'' N and longitude 5°37 '24.785''E. It is an agrarian town in the tropical rainforest belt. Soils from this area are derived from sedimentary sandstone. OPC Farms' in Igueben about 30km from Ubiaja, Esan south east Local Government Area. It lies between latitude 6°35'9.976''N and longitude 6°16'21.606''E. The vegetation of Igueben is a transition zone between rainforest zone and southern wooded savannah. It is situated at 332 m above sea level. The dry season lasts between November and early March while the rainy season lasts between March and late October with a peak at July and a break in August. It is also an agrarian town. Igueben soil overlies colluvium derived from false sandstone. Hartman Farms is located in the latitude 6°31'3.273''N and longitude 5°50' 56.847''E. The area falls within the rainforest zone of Edo state and has a hot humid tropical climate. The climate is characterized by seasonal rainfall to high relative humidity. The soils are derived from sandstones.

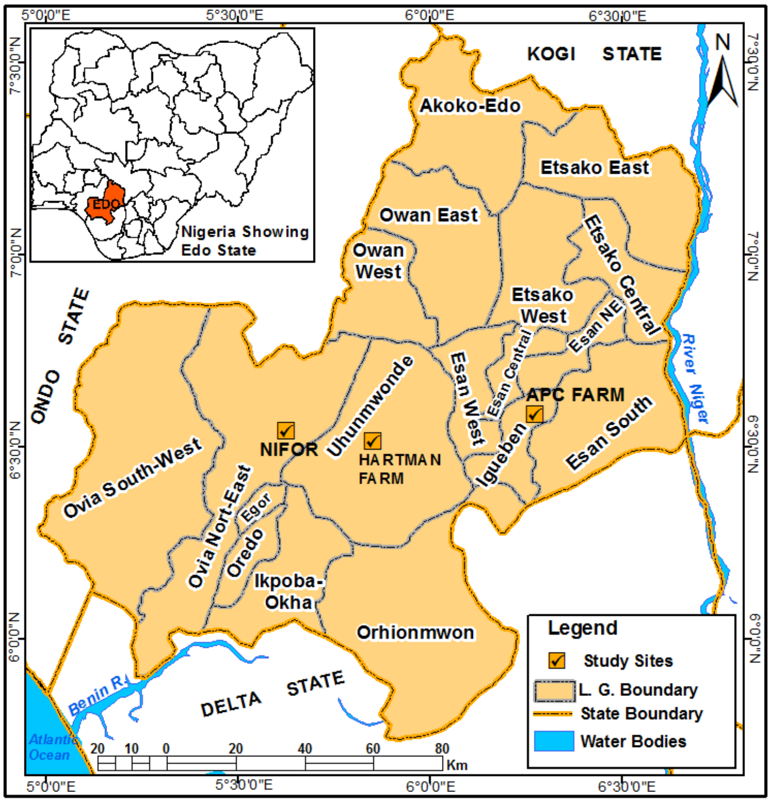

Figure 1: Map of Edo State showing location of study sites

2.2. Soil Sampling

Soil samples were randomly collected using a soil auger at a depth of 0-15cm and 15-30cm from each sampling point. These depths were preferred because apart from being the zones of active changes in the soil during cropping, roots of plants are concerted at these depths (Orobator and Odjugo 2015). These soil layers are important for tillage and water retention. In each of the three oil palm plantation sites, six soil samples (0-15cm and 15-30cm depths) were collected, thus a total of 18 soil samples were collected for the study. The sampling points were geo-referenced with handheld Global Positioning System (GPS) receiver to co-ordinate the referenced points. The samples from each sampling point were stored in polythene bags, labeled accordingly and air dried at room temperature. They were crushed and passed through a 2 mm sieve for the determination of the particle size analysis of soil fractions and organic matter, organic carbon, nitrogen and soil pH. During the collection of the soil samples, dead plants, furrow, old manures, wet spots, areas near trees and compost pit were excluded in order to minimize variations which may arise because of the dilution of soil organic matter (SOM) due to mixing through cultivation and other factors.

2.3. Statistical Analysis

This study adopted both descriptive and inferential statistics. Descriptive statistics includes tables, range and means whereas inferential statistics reflects student t-test. Student t-test was used to test for significant differences of pH, organic carbon, nitrogen, organic matter, sand, silt and clay between NIFOR and OPC, NIFOR and Hartman, as well as between OPC and Hartman farms respectively.

2.4. Laboratory Analysis

The particulate size analysis was determined by hydrometer method using sodium hexametaphosphate as dispensing agent (Okalebo *et al.,* 2002). Soil pH was determined using a 1:1 soil to water suspension using glass electrode pH meter (Mclean, 1982). Organic carbon was determined by the Nelson and Sommer (1982) method. The organic matter content was obtained by multiplying a factor of percent organic carbon by 1.72. Nitrogen was determined by Micro-kjeldahl method as described by Brookes *et al.* (1985).

3. RESULTS AND DISCUSSION

3.1. Soil Texture

Table 1 shows the mean values of sand with soil depths (surface and subsoil). For NIFOR site, the mean values were 707.1 gkg^{-1} and 535.6 gkg^{-1} in topsoil (0-15cm) and subsoil (15-30cm) respectively. The mean values were 561.3gkg^{-1} for topsoil (0-15cm) and 542.5gkg^{-1} for subsoil (15-30cm) in OPC farms. Similarly, Hartman farms had mean values of 499.3gkg^{-1} for topsoil (0-15cm) and 536.1gkg^{-1} for subsoil (15-30cm) correspondingly. Sand concentration in soils on the topsoil and subsoil of the oil palm plantations are as follows: NIFOR>OPC farms>Hartman farms. Higher values of sand were detected in soil on NIFOR and OPC Farms than in Hartman farms (Table 1). This also account for the significant difference of sand between NIFOR and Hartman ($p = 0.04$) (Table 2). Similarly, the values of sand contents decreased with soil depths in all the different oil palm plantations. The result is not surprising since NIFOR falls within the sedimentary sandstone parent materials. In any ecological zone, sandy soil which is also a coarse textured soil is related to parent material from which it is formed. It could also be as a result of the combined effect of climate and parent material which alter the pedogenesis of the soil. NIFOR area has more amount of rainfall than the other study sites and as such, clay will be translocated to the subsoil than the sand fractions by the process of clay eluviation and illuviation.

Table 1: Mean values of sand with soil depths (surface and subsoil)

Soil parameters	Depth (cm)	NIFOR		OPC FARMS		HARTMAN FARMS	
		Range	Mean	Range	Mean	Range	Mean
Sand (gkg^{-1})	S	689.9-734.6	707.1	495.6-681.5	561.3	495.6-506.8	499.3
	SS	513.5-535.4	535.6	535.4-555.6	542.5	535.4-536.5	536.1
Silt (gkg^{-1})	S	125.0-152.0	138.3	105.0-238.0	176.0	188.0-225.0	142.7
	SS	113.0-236.6	156.7	129.0-229.0	163.7	129.0-199.0	153.7
Clay (gkg^{-1})	S	158.1-165.2	154.6	213.6-255.2	262.7	279.4-305.2	291.3
	SS	250.5-351.6	307.7	215.4-334.5	293.8	264.5-334.5	310.2
Organic carbon (gkg^{-1})	S	19.3-36.2	27.6	21.6-30.6	26.1	22.7-28.2	39.0
	SS	8.10-15.4	10.7	9.40-12.3	9.80	6.80-16.1	10.6
Total Nitrogen (gkg^{-1})	S	1.90-3.60	2.70	2.20-3.10	2.60	2.30-2.80	2.60
	SS	0.80-1.50	1.10	0.80-1.20	1.00	0.70-1.60	1.10
Organic Matter (gkg^{-1})	S	33.2-62.2	47.5	37.1-52.6	44.9	39.4-46.6	44.8
	SS	14.0-26.5	18.4	13.2-21.1	16.8	11.7-27.7	18.4
C/N	S:SS		10:1		10:1		15:1
Soil pH	S	4.91 - 5.48	5.21	4.91 - 5.22	5.11	5.25 - 5.43	5.33
	SS	5.00 - 5.10	5.06	5.04 - 5.08	5.05	5.19 - 5.28	5.22

S=Topsoil (0-15cm), SS= Subsoil (15-30cm)

The mean values of silt with soil depths for NIFOR were 138.3gkg^{-1} for topsoil (0-15cm) and 156.7gkg^{-1} for subsoil (15-30cm). In OPC, the mean values were 176.0 gkg^{-1} for topsoil (0-15cm) and 163.7gkg^{-1} for subsoil

(15-30cm) while in Hartman farms, the mean values were 142.7gkg^{-1} for topsoil (0-15cm) and 153.7gkg^{-1} for subsoil (15-30cm) respectively. Silt concentration in soils on the topsoil and subsoil of the oil palm plantations are as follows: OPC farms>Hartman farms > NIFOR. Correspondingly, relative higher values of silt were discovered in soils from OPC and Hartman Farms than in NIFOR farms. This accounts for the no significant difference ($p > 0.05$) in silt in all the study sites. Silt contents decreased with depth in OPC but increased with depth in NIFOR and Hartman farms. Silt may have undergone transformation into clays to have been so low in NIFOR. The very low silt content at NIFOR confers the sand texture to the soils (Ugwa *et al.,* 2016). Table 1 also reveals the mean values of clay with soil depths. For NIFOR, the mean values of clay were 154.6gkg^{-1} for topsoil (0-15cm) and 307.7gkg^{-1} for subsoil (15-30cm). In OPC, the mean values were 262.7gkg^{-1} for topsoil (0-15cm) and 293.8gkg^{-1} for subsoil (15-30cm) while in Hartman farms, the mean values were 291.3gkg^{-1} for topsoil (0-15cm) and 310.2gkg^{-1} for subsoil (15-30cm) respectively. Clay concentration in soils both on the topsoil and subsoil of the oil palm plantations are as follows: Hartman farms> OPC farms> NIFOR. Similarly, relative higher values of clay were discovered in soil from Hartman Farms and OPC than in NIFOR farms (Table 1). This account for the no significant difference in clay in all the study sites ($p > 0.05$). However, unlike the values of sand, the values of clay increased with depth in all the different oil palm plantations. This infers that sand has a negative reciprocal effect on clay and this explains why clay helps to ameliorate the effects of dry season moisture stress by holding more water than sandy topsoil (Orobator and Odjugo, 2015). Also, one of the striking features of the study sites is that clay is higher in the subsoil than in the topsoil. Generally, soils of the study areas were sandy. However, soils in NIFOR contained higher amount of sand content than OPC and Hartman farms. Hence, there was significant difference of sand between NIFOR and OPC farms as well as between NIFOR and OPC farms ($p < 0.05$). The soil in NIFOR plantations is sandy loam. However, no significant difference of sand was observed between OPC and Hartman farms ($p > 0.05$). This is because the soil texture classes of both OPC and Hartman farms are sandy clay loam (medium textured soils).

3.2. Organic Carbon (OC)

Tables 1 also reveal the mean values of organic carbon with soil depths (surface and subsoil). For NIFOR, the mean values of carbon were 27.6gkg^{-1} for topsoil (0-15cm) and 10.7gkg^{-1} for subsoil (15-30cm). In OPC, the mean values were 26.1gkg^{-1} for topsoil (0-15cm) and 9.8gkg^{-1} for subsoil (15-30cm). Whereas in Hartman farms, the mean values were 39.0gkg^{-1} for topsoil (0-15cm) and 10.6gkg^{-1} for subsoil (15-30cm) respectively. According to Adaikwu and Ali (2013), using the interpretation guide for evaluating soil analytical data showed that the mean values of organic carbon at the subsoil was low but high at the surface horizons at the different oil palm plantation sites. This can be attributed to the sandy nature of the soils in all the study sites. The nature of the soils allows excess surface water to infiltrate which subsequently increases its erosive power. Minase *et al.,* (2016) reported that soil texture plays an important role in carbon storage in the soil and strongly influences nutrient availability and retention. The general low level of organic carbon in the soil of the study areas is generally detrimental to soil fertility and water retention capacity. This tends to increase the vulnerability of soil compaction, which leads to increase in surface water run-off and erosion. Lal (2004) opined that soil organic carbon has a significant effect on chemical and physical characteristics of soil and it is one of the essential components of soil quality assessment.

Organic carbon gives an indication of the organic matter in the mineral soil (Enwezor *et al.,* 1981). As the organic carbon often decreases into the soil depth, so is the organic matter. Organic matter comprises of a fraction of the total mass of most soils, but this dynamic soil component exerts a dominant influence on many soil physical, chemical, and biological properties (Brady and Weil, 1999). The presence of organic matter is of great importance in the formation and stabilization of soil structure. However, soil organic matter content in the soils in all the oil palm plantations is soluble due to the sandy nature of the soils. This is because variation in soil fractions also exerts significant controls on the stock and turnover of soil organic matter (Wang *et al.,* 2016). The coarse (NIFOR) and medium (OPC and Hartman farms) textured soils as observed in the experimental sites predisposes that organic matter is prone to decomposition by destabilizing its aggregates particles. The variation in the soil of the organic carbon is definitely a function of the capacity of these soils to store organic matter.

3.3. Nitrogen

Tables 1 shows the mean values of nitrogen with respect to soil depths (surface and subsoil). For NIFOR, the mean values were 2.70gkg^{-1} for topsoil (0-15cm) and 1.10gkg^{-1} for subsoil (15-30cm). In OPC, the mean values were 2.60gkg^{-1} for topsoil (0-15cm) and 1.00gkg^{-1} for subsoil (15-30cm). However, in Hartman farms, the mean values were 2.60gkg^{-1} for topsoil (0-15cm) and 1.10gkg^{-1} for subsoil (15-30cm) respectively. The mean values of nitrogen at both depths were below 10.0gkg^{-1} to 20.0gkg^{-1} and can be described as low status of nitrogen content at the different oil palm plantation sites (Adaikwu and Ali, 2013). Hence, no significant difference of nitrogen existed between NIFOR and OPC, NIFOR and Hartman as well as between OPC and Hartman farms respectively ($p > 0.05$). This could also be attributed to the sandy characteristics of soils observed in all the oil palm plantations. As a result, the soils will not be able to hold nitrogen. The activities of overflowing water as a result of rainfall are also impactful on soils with high sand contents resulting in minimal undergrowth on its sites (Asawalam and Ugwa, 1993). This reflects the activities of increased leaching of nitrogen occurring in soils under oil palm land use. Nitrogen mineralization rates are often higher in sandy soils. This is because of its poor holding capacity of organic molecules onto surface minerals. According to Kaye *et al.,* (2002), the rate and magnitude of stable N retention may also have implications for stable carbon sequestration in soils. Most mechanisms that promote stable N formation also stabilize soil organic matter. This explains the observed values of both carbon and nitrogen on the soils.

3.4. Soil Reaction (pH)

One striking feature of the experimental sites is that despite their lithological differences, all the values of pH of the surface soils were higher than that of the subsoils. Generally, the soils were acidic. This might be due to the kaolinitic nature of the parent materials of the areas (Ugwa *et al.,* 2016). The mean pH values ranging from 5.11 to 5.33 and 5.05 to 5.22 in the topsoil and subsoil respectively does not pose any serious problem to the nutrients for oil palm husbandry. The soils are favorable for the cultivation of oil palm as nutrient available is within the range of soil reaction (Orobator *et al.,* 2017). It was observed that Hartman farms had both topsoil and subsoil pH values higher than the other oil palm plantations. This accounts for the significant difference of pH between NIFOR- Hartman ($p < 0.05$) and OPC-Hartman ($p < 0.05$). According to Ugwa *et al.,* (2016), this higher pH may be due to high intensity of rainfall at Ehor which leaches basic cations down the profile.

3.5. C/N ratio

Carbon – Nitrogen (C/N) ratio is the ratio percentage of soil carbon to that of nitrogen that defines the relative amount of the elements in the soil. The C/N ratio of the topsoil in the study sites ranged from 10 to 15: 1. However, Tisdale and Nelson (1966) stated that C/N ratio of the stable soil organic matter is between 10 or 12: 1. The soils can be said to be more or less stable. The C/N ratio of Hartman farm topsoil in Ehor area of Edo State is 15:1. This is not surprising as it has a mean of organic carbon of 39.0 gkg^{-1} having its highest value more than NIFOR and OPC farms. This may be due to the soil undergrowth coupled with the high palm fronds in the farm. Higher C/N ratios suggest slower mineralization and greater proportion of lower altered crop remains, whereas lower C/N ratio such as the study sites generally present higher microbial populations as well as more rapid mineralization (Asawalam and Ugwa, 1993).

Table 2: Student t-test of the mean of selected soil nutrients

Soil Parameters	Sample Pairs	t-value	p-value
Soil pH	NIFOR-OPC	0.56	0.30
Soil pH	NIFOR- Hartman	-2.09	0.04*
Soil pH	OPC-Hartman	-6.10	0.01*
Nitrogen	NIFOR-OPC	0.23	0.41
Nitrogen	NIFOR- Hartman	0.22	0.41
Nitrogen	OPC-Hartman	-0.12	0.45
SOM	NIFOR-OPC	0.34	0.37
SOM	NIFOR- Hartman	0.26	0.39
SOM	OPC-Hartman	-0.31	0.38
Sand	NIFOR-OPC	1.69	0.07
Sand	NIFOR- Hartman	2.18	0.04*
Sand	OPC-Hartman	1.11	0.15
Silt	NIFOR-OPC	-1.41	0.10
Silt	NIFOR- Hartman	-1.09	0.16
Silt	OPC-Hartman	-0.36	0.36
Clay	NIFOR-OPC	-1.57	0.08
Clay	NIFOR- Hartman	-1.84	0.06
Clay	OPC-Hartman	-0.76	0.23

SOM =Soil Organic Matter

4. CONCLUSION

Oil palm is mostly grown in acid sands in Nigeria and soil texture generally influences its nutrient availability especially organic carbon and nitrogen contents. The study areas are predominantly sandy as a result of the sandstone parent material. The sand particle predisposes the area to water stress during the dry season. There was no significant difference in the silt content of the areas while clay is higher at the subsoil than in the topsoil. Organic matter is low which tends to decrease due to soil detachment and eventual transportation by the agents of soil erosion. Although, nitrogen is a significant soil quality indicator, the nitrogen content can be described as low in the studied soils. Soil fertility and physical characteristics of the area are some of the limitations for optimum oil palm cultivation. To ameliorate these deficiencies, planting of legumes and incorporation of animal manure to the soils should be embraced.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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