*Original Research Article*

# BULK DENSITY OF SOILS FROM OIL PALM AGROFORESTRY SYSTEMS IN KOGI EAST, NIGERIA



**ABSTRACT**

*This study was conducted to assess the bulk density and textural class of soils of selected oil palm agroforestry systems in Kogi East (Ankpa, Dekina, Ofu, Olamaboro and Omala local government areas-LGAs), Nigeria. Random soil sampling was used to collect a total of 100 core samples from the five LGAs (20 from each of the LGA). Soil bulk density was determined using core sampler technique. Data collected were analysed using Analysis of Variance (ANOVA) of GENSTAT Discovery Software. Significant means were separated using Duncan Multiple Range Test at 5 % level of probability. The results revealed that the soil bulk density of the oil palm agroforestry systems in Kogi East, Nigeria were within moderate range of 1.15-1.47 g/cm$^3$. Most of the soils in the studied locations were observed to be sandy clay: Ofu and Olamaboro LGAs were sandy clay while Dekina, Ankpa, Omala were loamy sand, sand, and sandy loam respectively.*

*Keywords: Agroforestry, Soil Physical Properties, Soil Management, Tillage*

## 1. INTRODUCTION

Bulk density of soils within thresholds can contribute to the capacity of the soils to function in terms of soil aeration, structural support, water and solute movement. This implies that bulk density of soils that are above thresholds could lead to impaired soil function. Based on soil texture, ideal bulk density for plant growth are < 1.60, < 1.40, and < 1.10 g/cm$^3$ for sandy, silty, and clayey soils respectively while bulk density that restricts plant growth are >1.80, >1.65, and >1.47 for sandy, silty, and clayey soils respectively (Aubertin and Kardos,1965; Jones,1983; Arshad *et al*., 1996). High values of soil bulk density can result to soil compaction (Al-Shammary *et al*., 2018). Soil compaction can limit biochemical processes and microbial activities, restrict root growth, negatively affect the movement of air and water through the soil profile, decrease plant growth and crop yield including reduction of vegetative cover available to protect soil from erosion (Chaudhari, *et al*., 2013; Keesstra *et al.,* 2016; Al-Shammary *et al*., 2018).

Agroforestry is a land use system that combines agriculture (crops and/or livestock) and forestry (trees and shrubs) on the same land management unit (World Agroforestry Centre, 2102). Agroforestry as an integrated and sustainable land use system can provide food and income for the farmer as well as can contribute to environmental sustainability. Agroforestry systems are source of nutrition as well as additional income for farmers engaged in it - the farmers practicing agroforestry are gainfully employed with reduced level of poverty and enhanced livelihoods. The sales of food crops as well as timber and non-timber products by the farmers in AFS can promote sustainable development (Amadu *et al*., 2020; Elagib and Al-Saidi, 2020; World Agroforestry Centre, 2012). Furthermore, the diversification of farm outputs in an agroforestry system is helpful in the reduction of risks from total crop failure compared to monoculture system in periods of extreme weather events including floods and droughts (Cornell and Miller, 2011). The environmental benefits of agroforestry systems (AFS) include water quality management - the roots of trees in AFS can reduce nitrogen and phosphorus residues in soils and also the reduction in the use of inputs such as fertilizers and pesticides in AFS can reduce water contamination and eutrophication (Pavlidis and Tsihrintzis, 2018); conservation of biodiversity by providing habitat for biodiversity to live and breed (Nair, 2011); soil quality improvement through carbon sequestration, enhancement of soil nutrient cycling, soil structure, soil moisture retention (Pardon *et al*., 2017). Oil palm AFS have been reported to improve soil physical properties such as bulk density (Agriani *et al.,* 2021). On the other hand, the findings of Khasanah *et al.* (2020) and Rahmani *et al.* (2021) revealed that oil palm Agroforestry AFS can provide economic and environmental benefits. This study was conducted to assess the soil bulk density and textural class of soils from selected oil palm agroforestry systems in Kogi East. Knowledge from this study will provide insights on the ability of the soils of the selected oil palm agroforestry systems in Kogi East Nigeria to provide structural support, soil aeration, water and solute movement.

## 2. METHODOLOGY

### 2.1 Study Location

This study was conducted in selected oil palm agroforestry systems in Kogi East (5 local government areas: Ankpa, Dekina, Ofu, Olamaboro and Omala). Study locations were comprised of 4 communities in each LGA. The communities within Ankpa were Odagbo, Oje Elanyi, Ojogobi Olaji, and Okabo. For Dekina LGA, the following communities were selected: Anyigba, Egume, Dekina, and Odu Ogbaloto. The communities selected for Ofu LGA were Ejule, Ochadamu, Ogbulu, and Ugwolawo. Olamaboro was comprised of Ejoka, Igoti-Ade, Ubalu, and Unobe while communities selected from Omala LGA were Ajedibo, Ajomakoji, Odumukpo, and Okugba.

### 2.2 Soil Sampling and Analysis

Random soil sampling technique was employed for the collection of samples. For bulk density, core samplers of known weight, height and diameter were used to collect a total of 100 core samples from the five LGAs (20 from each of the LGA). For particle size analysis, soil auger was used to collect surface samples (0-15 cm depth). Also, a total of 100 samples (20 from each of the LGA) were collected for particle size analysis but were bulked to 60 samples (12 composite samples per LGA). The prepared soil samples were analyzed at the Department of Soil and Environment Management, Faculty of Agriculture, Kogi State University Anyigba for bulk density and particle size distribution.

#### 2.2.1 Determination of Bulk Density

The soil bulk density was determined using core sampler technique. Where samples contained in the core rings of known weight, height and diameter were weighed and the fresh weight recorded, then oven dried at $105^0$C for 24hours which the dried weight were also recorded (Al-Shammary *et al*., 2018). This was earlier explained in detail by Ali (2010) using a calculation sheet (Table 1).

**Table 1: Core method for determining bulk density – A calculation sheet (Ali, 2010; Al-Shammary *et al*., 2018)**

| Sample number | Weight of oven-dried soil core (C1) | Weight of core (C2) | Core size | | | Actual soil sample volume (C4) | Weight of oven-dried soil (C5) ($C5 = C1 - C2$) | Soil $\rho_b$ value (C6) ($C6 = C5/C4$) |
|---|---|---|---|---|---|---|---|---|
| | | | Height ($h$) | Diameter ($d$) | Volume ($\pi d^2 h/4$) (C3) | | | |
| | g | g | cm | cm | $cm^3$ | $cm^3$ | g | $g\ cm^{-3}$ |
| 1 | 160 | 25 | 6 | 5 | 117.8 | 117.8 | 135 | 1.15 |



### 2.2.2 Particle size analysis

A fifty grams (50g) sample of the soil was weighed into a beaker and 50ml of Calgon (35.7g) sodium hexametaphosphate and 7.94g sodium carbonate into 1 litre of distilled water) was added into the beaker. Ten milliliters (10ml) of de-ionized water was added into a beaker. It was stirred and allowed to stand for 30 minutes. It was then transferred into a measuring cylinder and de-ionized water was added to make up to a litre volume. The temperature was measured as $T_1$, the sample was mixed with a plunger ten (10) times and the hydrometer was dropped immediately into the suspension. The reading of the hydrometer was also taken after 40 seconds as $H_1$ and after two hours as $H_2$. At this point, the temperature reading was taken as $T_2$. The percentage sand, silt and clay was determined according to Bauder (1985). The textural classes of the soils were determined using the USDA textural triangle classification system for soil (USDA, 2008).

### 2.3 Statistical Analysis

Data collected were analysed using Analysis of Variance (ANOVA) of GENSTAT Discovery Software. Significant means were separated using Duncan Multiple Range Test at 5 % level of probability.

## 3.0 RESULTS AND DISCUSSIONS

## 3.1 Results

### 3.1.1 Particle Size Analysis of Soils from Oil Palm Agroforestry Systems in Kogi East, Nigeria

Table 2 shows the particle size analysis of soils from oil palm agroforestry systems (AFS) in Kogi East, Nigeria. The results revealed that two locations (Ofu and Olamaboro LGAs) had the same textural class of sandy clay. Soils of Dekina AFS were loamy sand, Omala were sandy loam while Ankpa soils were sand. The sand, silt and clay composition of Ofu were 59.52, 4.28, and 36.20 % respectively. Olamaboro had sand, silt and clay composition of 60.52, 4.28 and 35.20 % respectively while Dekina had 76.02, 3.18, and 20.80 % of sand, silt, and clay respectively. Omala had a composition of 64.12 sand, 22.66 silt and 13.22 % clay while Ankpa had a sand, silt and clay composition of 88.02, 3.96 and 8.02 % respectively (Table 2).

**Table 2: Particle Size Analysis of Soils from Oil Palm Agroforestry Systems in Kogi East, Nigeria**

| Location | Sand | Silt | Clay | Textural class |
|---|---|---|---|---|
| | ← | % | → | |
| Ankpa | 88.02 | 39.60 | 8.02 | Sand |
| Dekina | 76.02 | 3.18 | 20.8 | Loamy Sand |
| Ofu | 59.52 | 4.28 | 36.20 | Sandy Clay |
| Olamaboro | 60.52 | 4.28 | 35.20 | Sandy Clay |
| Omala | 64.12 | 22.66 | 13.22 | Sandy Loam |

### 3.1.2 Bulk Density of Soils from Oil Palm Agroforestry Systems in Kogi East, Nigeria

The results obtained from the assessment of bulk density of soils from oil palm agroforestry systems in Kogi East, Nigeria showed that there was no significant difference in the bulk densities in the soils of the various communities in Ankpa, Dekina, and Omala (Table 3). However, significant differences in soil bulk density were observed in communities within Ofu and Olamaboro LGAs.

**Ankpa Local Government Area:** The values of bulk density of soils from oil palm agroforestry systems in Ankpa were within 1.35-1.42 g/cm$^3$. Odagbo, Oje-Elanyi, Ojogobi Olaji, and Okabo had bulk density of 1.36, 1.42, 1.35, and 1.39 g/cm$^3$ respectively.

**Dekina Local Government Area:** Bulk density of Dekina soils were within 1.27-1.40 g/cm$^3$. Anyigba, Dekina, Egume, and Odu Ogbaloto had bulk density of 1.36, 1.40, 1.27, and 1.40 g/cm$^3$ respectively.

**Omala Local Government Area:** The oil palm agroforestry systems in Omala LGA had bulk density within 1.41-1.47 g/cm$^3$. Ajedibo, Ajomakoji, Odumukpo, and Okugba had bulk density of 1.44, 1.47, 1.41, and 1.45 g/cm$^3$ respectively.

**Ofu Local Government Area:** The bulk density recorded from Ogbulu, Ugwolawo, and Ejule were 1.43 g/cm$^3$, 1.37 g/cm$^3$, and 1.32 g/cm$^3$ respectively in Ofu local government area. There was no significant difference between the soils of the three locations. Although Ochadamu had the lowest Bd (1.23 g/cm$^3$), there was no significant difference between the value and that of Ejule soils (1.32 g/cm$^3$). The oil palm agroforestry systems in Ofu LGA had bulk density within 1.23-1.43 g/cm$^3$.

**Olamaboro Local Government Area**: Bulk density results obtained from soils of Ejoka, Igoti Ade, Unobe, and Ubalu in Olamaboro local government area were 1.38 g/cm$^3$, 1.28 g/cm$^3$, 1.16 g/cm$^3$, and 1.15 g/cm$^3$ respectively. There was no significant difference in the bulk density of Ejoka and Igoti Ade. Lowest and no significant difference in bulk densities were observed in soils in Ubalu and Unobe. Bulk densities of Olamaboro soils were within 1.15-1.38 g/cm3.

**Table 3: Bulk Density of Soils from Oil Palm Agroforestry Systems in Kogi East, Nigeria**

| Local Government Area | Location of Oil Palm Agroforestry System | Bulk Density ($g/cm^3$) | LSD | Statistics Max | Min | SEM |
|---|---|---|---|---|---|---|
| Ankpa | Odagbo | 1.36 | 0.1231NS | 1.494 | 1.175 | 0.0399 |
| | Oje Elanyi | 1.42 | | | | |
| | Ojogobi Olaji | 1.35 | | | | |
| | Okabo | 1.39 | | | | |
| Dekina | Ayingba | 1.36 | 0.1447 NS | 1.509 | 1.152 | 0.0470 |
| | Dekina | 1.40 | | | | |
| | Egume | 1.27 | | | | |
| | Odu Ogbaloto | 1.40 | | | | |
| Ofu | Ogbulu | 1.43a | 0.1256 | 1.520 | 1.092 | 0.0408 |
| | Ugwolawo | 1.37a | | | | |
| | Ejule | 1.32ab | | | | |
| | Ochadamu | 1.23b | | | | |
| Olamaboro | Ejoka | 1.38a | 0.1007 | 1.450 | 1.009 | 0.0327 |
| | Igoti Ade | 1.28a | | | | |
| | Unobe | 1.16b | | | | |
| | Ubalu | 1.15b | | | | |
| Omala | Ajedibo | 1.44 | 0.1397 NS | 1.565 | 1.143 | 0.0453 |
| | Ajomakoji | 1.47 | | | | |
| | Odumukpo | 1.41 | | | | |
| | Okugba | 1.45 | | | | |

**Note:** Means in a column with different letters are statistically significant at 5 % level of probability. NS = Not significant; LSD = Least significant difference; Max = Maximum; Min = Minimum; SEM = Standard Error of Mean.

### 3.2 DISCUSSIONS

#### 3.2.1 Texture of Soils of Oil Palm Agroforestry Systems in Kogi East, Nigeria

Texture is an important soil property as it greatly affects crop production and soil quality – it plays a key role on soil nutrient and water retention including biological processes in the soil (Jaja, 2016; Alotaibi *et al*., 2018; Kurniawan *et al*., 2018). Most of the soils in the studied locations were observed to be sandy clay. The chemical and physical properties of sand soils are low (Hazelton and Murphy, 2016). Sandy soils have low organic matter content (OMC), cation exchange capacity (CEC) and therefore low nutrient retention capacity (Walpola and Arunakumara, 2010). On the other hand, the positive contribution of clay content of soils to soil bulk density have been reported in previous study (Heuscher *et al*., 2005). Nonetheless, soil compaction arising from higher clay content affects the growth, distribution, and function of roots, and crop productivity (Gregorich *et al*., 2011; Gregorich *et al*., 2014).

#### 3.2.2 Bulk Density of Soils from Oil Palm Agroforestry Systems in Kogi East, Nigeria

The results obtained from all the studied locations revealed that the soil bulk density of oil palm agroforestry systems in Kogi East were within the range of 1.15 -1.47 g/cm$^3$ which further indicate that the soils have a range of bulk density required for arable crop production. The critical value of bulk density for restricting root growth varies with soil type – Soil texture (Hunt and Gikes, 1992) but in general, bulk densities > 1.6 g/cm$^3$ tends to restrict root growth (Mckenzie *et al*., 2004). Based on soil texture, ideal bulk density for plant growth are < 1.60, < 1.40, and < 1.10 g/cm$^3$ for sandy, silty, and clayey soils respectively while bulk density that restricts plant growth are >1.80, >1.65, and >1.47 for sandy, silty, and clayey soils respectively (Aubertin and Kardos,1965; Jones,1983; Arshad *et al*., 1996). It is generally desirable to have soils with low bulk density (<1.5 g/cm$^3$) (Hunt and Gikes, 1992) for optimum movement of air and water through the soil as well as suitability for root growth (Cresswell and Hamilton, 2002 ; Mckenzie *et al*., 2004).

## 4.0 SUMMARY AND CONCLUSION

This study was conducted to assess the bulk density of soils from selected oil palm agroforestry systems in Kogi East (5 local government areas: Ankpa, Dekina, Ofu, Olamaboro and Omala). Study locations were comprised of 4 communities in each LGA. Random soil sampling was used to collect a total of 100 core samples from the five LGAs (20 from each of the LGA). The bulk density of soils were determined using core sampler technique. Where samples contained in the core rings of known weight, height and diameter were weighed and the fresh weight recorded, then oven dried at 105$^0$C for 24hours which the dried weight were also recorded. Data collected were analysed using Analysis of Variance (ANOVA) of GENSTAT Discovery Software. Significant means were separated using Duncan Multiple Range Test at 5 %level of probability.

The results of the analysis of the bulk density of the AFS showed moderate values of 1.15-1.47g/cm$^3$. This implies that the soils of the agroforestry systems in Kogi East can enhances soil bulk density for crop production. Most of the soils in the studied locations were observed to be sandy clay: Ofu and Olamaboro LGAs were sandy clay while Dekina, Ankpa, Omala were loamy sand, sand, and sandy loam respectively.

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