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Assessment of Physical Properties of Soil under Eucalyptus Plantation in Aliko Dangote University of Science and Technology Wudil, Nigeria

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SUMMARY

This research evaluates the physical characteristics of soil beneath eucalyptus cultivation at Kano University of Science and Technology, Wudil, located within the Zoological Garden in Kano State, Nigeria, in 2021. *Eucalyptus* is a genus comprising over 500 species known for their broad adaptability and includes many important timber trees found across extensive areas. The study aims to assess the physical properties of soil in the eucalyptus plantation and to compare these properties with those of soil in adjacent cleared areas. Eucalyptus remains one of the primary tree species cultivated in Wudil, Kano State. Reports indicate several concerning effects associated with eucalyptus cultivation, including the desiccation of water bodies, alterations in soil physical characteristics, nutrient depletion, reduced soil fertility, inhibition of native plant species, decreased forest biodiversity, and lower crop yields in agroforestry practices. While numerous studies in other countries have documented the negative impacts of eucalyptus plantations on soil characteristics, research in Nigeria examining the effects of eucalyptus—used for industrial and agroforestry purposes—on soil physical properties is limited.

Keywords: Soil physical properties, Materials, Reagents, Nigeria

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INTRODUCTION

Eucalyptus is a genus that includes over 500 highly adaptable species, many of which are significant timber trees in Australia, covering extensive areas. In regions where Eucalyptus is cultivated, changes in soil nutrients—specifically nitrogen (N), phosphorus (P), potassium (K), and organic matter—were observed compared to the natural soils of Shore and Robusta forests in Uttar Pradesh. There was a marginal increase in clay and silt levels, coupled with a slight decrease in sand levels. Additionally, bulk density and particle density were somewhat lower, while there was a notable increase in cation exchange capacity, organic carbon levels, and both total and available nutrients beneath eucalyptus tree plantations (Balamurugan et al., 2000). Furthermore, eighty-three percent of surface soil samples and ninety-four percent of sub-soil samples revealed low organic matter levels (< 1%) under areas where eucalyptus trees were planted.

Different forest vegetation is said to exert different influences on soil physical properties. These variations are linked to their ability to cycle cations and the different organic minerals that aid in the decomposition of minerals (Holsten *et* al., 2000). Allelopathic effects of eucalyptus may have implications when other species grow near eucalyptus trees. This is associated with crop yield reduction. Eucalyptus planting is a cause of severe drought. In recent decades, biodiversity and the environment have been significantly degraded in eucalyptus plantation forests.

Though, the impacts of plantations of Eucalyptus on physical characteristics of the soil, and loss of vital soil health, are still uncertain, and conventional scientific conditions are limited on the definite effect of Eucalyptus plantations in terms of soil conditions (soil particle density, soil bulk density, soil porosity, soil particle size distribution). The basis of agroforestry makes it a suitable scientific method for the ecological rehabilitation of degraded land and resource management. The role of tree-based land use systems in soil conservation and in improving the economy of farmers with small farm holdings has been recognized during the last two decades (Chauhan and Dhyani, 1990; Fisher, 1990; Dhyani and Tripathi, 2010). There is, therefore, a risk that certain trees will have a negative impact on the improvement of soil. Such changes in tropical land use, i.e., conversion of forests to agriculture or plantations, may alter some of the physical aspects and the carbon balance, thereby changing the levels of soil organic C and N.

The impact of land-use changes and management, however, have been proposed to be interpreted by soil physical properties as appropriate indicators. Plant cover is known to affect soil properties. For forests, this effect has mainly been assessed in terms of exotic and/or fast-growing forest tree species. indeed it had been claimed that those plantation species used in short rotation as coppiced stands with high biomass removal, e.g. *Eucalyptus* species may have changed the fertility and soil evolution. Eucalyptus plantations have been linked to significant environmental issues. They are known for causing excessive nutrient depletion in the soil, impacting its biological health, and significantly decreasing overall water yields when grown in semi-arid water catchment zones. It is frequently challenging to distinguish the impact of site conditions and management practices from the particular effects of tree species. No individual experiment has been documented in the literature that evaluates all the above-mentioned influences; yet existing data suggest that the impact on soil properties ascribed to specific exotic forest tree species is primarily a result of soil management and agricultural practices (Alban, 1982). The aim of the study is to assess the soil physical properties of Eucalyptus plantation in Kano University of Science and Technology, Wudil zoological garden. And objectives of the study are to assess the soil physical properties of Eucalyptus plantation and to compare the physical properties of soil under eucalyptus plantation and in study area.

MATERIALS AND METHOD

STUDY AREA

The study was conducted at KUST Zoological Garden. The latitude of Wudil Local Government, Nigeria, is 11.794242, and the longitude is 8.839032. The elevation is

422.00 m (www.altitudemaps.com). The study area is predominantly flat, with a maximum elevation change of 8 feet and an average elevation of 1,365 feet above sea level. Seasonal variations in perceived humidity are notable; the muggiest period lasts 6.2 months, from April 18 to October 24, with August 19 being the most humid day of the year. Conversely, the least muggy day occurs on December 27. The rainy season extends for 6.3 months, from April 12 to October 23, characterized by at least 0.5 inches of rainfall over a sliding 31-day period. The peak rainfall during this period typically occurs around August 13, averaging 7.2 inches. Wudil Local Government experiences a hot season lasting 2.2 months, from March 17 to May 24, during which the average daily high temperature exceeds 99°F. The hottest day of the year is April 12, with an average high of 102°F.

The natural vegetation of the area is primarily a savannah type consisting of Sudan and Guinea Savannah. Northern Guinea characterizes the vegetation of the southern part, while Sudan dominates the central and northern parts of the state (Olofin, 2008). Trees are fewer in number compared with grasses and are scattered over expansive grasslands.

SAMPLING PROCEDURE AND DATA COLLECTION

Fifteen soil composite samples were collected at a depth of 0.15 cm using a soil auger. Also, fifteen core sampler samples were collected for bulk density and particle density. The samples were air-dried, crushed gently with pestles and mortar, and then the soil was passed through a 2 mm sieve. The fine particles were used for laboratory analysis, while the core sampler soil samples were oven-dried at 105 °C.

Analytical method

The soil samples were analyzed using standard laboratory procedures. The core sampler was labeled and weighed, and the vertical and horizontal surfaces at the sampling depth were smoothed. The core sampler was pressed into the soil to fill the inner core without causing compression. After removing the undisturbed soil core, the surrounding soil was evacuated. The process began with cutting off both ends of the core sampler and smoothing the edges with a knife. Next, the ends of the cores were supported by placing the core sampler on a disk. To prepare for measurements, the core sample was oven-dried at 105 °C in a WTC Binder Oven for 24 hours until it reached a constant weight.

Bulk Density (g cm^{-3}) = $\underline{ms}$/vs

Ms = cs-c	Vs=3.142r^2h
Ms = mass of soil	Vs =volume of soil
Cs = core sampler and soil	C = core sampler
h = height of core sampler	r^2 = diameter of core sampler

Soil texture

Fifty-one grams of soil were placed into a 600 ml beaker, followed by the addition of 100 ml of Calgon solution and 300 ml of distilled water. The mixture was allowed to soak overnight. Simultaneously, a second sample of the same soil (10 g) was dried overnight at 105 °C, then cooled and weighed to determine its oven-dried weight. The

Calgon-treated sample was dispersed, and the resulting suspension was transferred to shaker bottles, where it was shaken overnight on a rotating shaker. The suspension was then poured into a graduated cylinder, and distilled water was added to achieve a total volume of 1000 ml. After allowing the suspensions to reach room temperature, a plunger was inserted and moved up and down to mix the contents thoroughly. To remove sediment, vigorous upward thrusts of the plunger were applied at the bottom, while rotating the plunger just above the sediment. Following two or three gentle stirrings, the stirring completion time was noted, and a hydrometer was delicately placed into the suspension. Measurements were taken after 40 seconds (HR1), and the temperature was recorded. The hydrometer was then carefully removed, rinsed, cleaned, and dried before being reinserted for another measurement taken after 7 hours (RH2), with the temperature recorded again. The computations were performed as follows.

Sand

$$100-(HR1/WT * 100/1)$$

Clay

$$HR2/WT * 100$$

Silt

$$100-(SAND + CLAY)$$

To find HR1

HR1+(T1-20) * 0.36

To find HR2

HR2+(T2-20) * 0.36

After getting the percentage sand, silt and clay, the soil textural triangle was used to classify the soil.

Soil particle density

Pre-condition the soil samples by drying in a 105°C oven and assess the gravimetric water content of air-dried soil. The water distilled with degassed water was then heated for several minutes and allowed to cool to ambient temperature. The temperature and density of the water, as well as the productivity of algae, were noted. Degassed water was poured into the pycnometer, and a stopper was placed into the pycnometer to ensure that the capillary opening in the stopper was filled. The pycnometer bottle was first dried and then weighed for the calculation. Half the latter’s volume was emptied out, with the pycnometer contents being transferred to another container. Ten grams of air-dry soil was added to the pycnometer, and the weight of the pycnometer and stopper was again recorded. The weight of the oven-dried soil samples was also measured. The pycnometer was then flooded with distilled water, the stopper was returned, and it was checked again to ensure that the capillary was filled. The calculations were performed according to the following formulas.

$$Pd = (\%P * PD) + BD$$

Where,

%p = porosity
Pd = particle density
Bd = bulk density

Soil porosity

The core sampler was identified and weighed, and the untouched vertical and horizontal surfaces at the sampling depth were smoothed. The sampler was then driven into the soil sufficiently to fill the inner core without compressing it. After carefully removing the undisturbed soil core, the surrounding earth was excavated, and the soil beneath was cut away. The ends of the core sampler were trimmed with a knife to ensure they were flush before being placed on a plate to protect the cores. The core sample was then oven-dried in the WTC Binder Oven at 105°C for 24 hours until it reached a consistent weight.The core sampler was removed and placed on the dish to cool and then weighed. 100 ml of water was poured into the dish, and the core sampler with soil was placed in the dish containing the water to determine the amount of pores. The calculation was used to determine the total porosity.

%p = VP/TV * 100

Where

Vp = cws-cs Tv = $3.142r^2h$

Cws = core sampler with wet soil Cs = core sampler with dried soil

STATISTICAL ANALYSIS

The outcomes of the analyses were statistically analyzed using one-way ANOVA, and if the means were significant, they were separated using Duncan's Multiple Range Test (DMRT). Using MS Excel (2010), tables and graphs were created to present and describe the soil physical features of *Eucalyptus* spp. plantations in comparison to the open area.

RESULTS AND DISCUSSION

PARTICLE SIZE DISTRIBUTION

Figures 1, 2 and 3 show the variability in soil textural classes and particle size distribution of soil samples from eucalyptus plantations and open areas. The results showed that Replication I, II, III, and control have particle size distributions of sand 66.96%, silt 17.73%, and clay 15.32%; sand 65.49%, silt 19.19%, and clay 15.31%; sand 54.17%, silt 19.67%, and clay 15.32%; and sand 65.34%, silt 19.34%, and clay 15.32%, respectively.

Broadly, soils from Replications I, II, III, and control could be categorized as sandy-loamy. These strikingly low percentages of clay in the sample soils must be responsible for the low amount of exchangeable nutrients in the soil as well as the overall productivity of the soils (Brady and Weil, 2005). The soil particle size distribution observed in this study was comparable to that reported by Aweto and Moleele (2005). Similar findings were also noted by Balamurugan et al. (2000) and Alem et al. (2010) in soils under *Eucalyptus* spp. plantations.

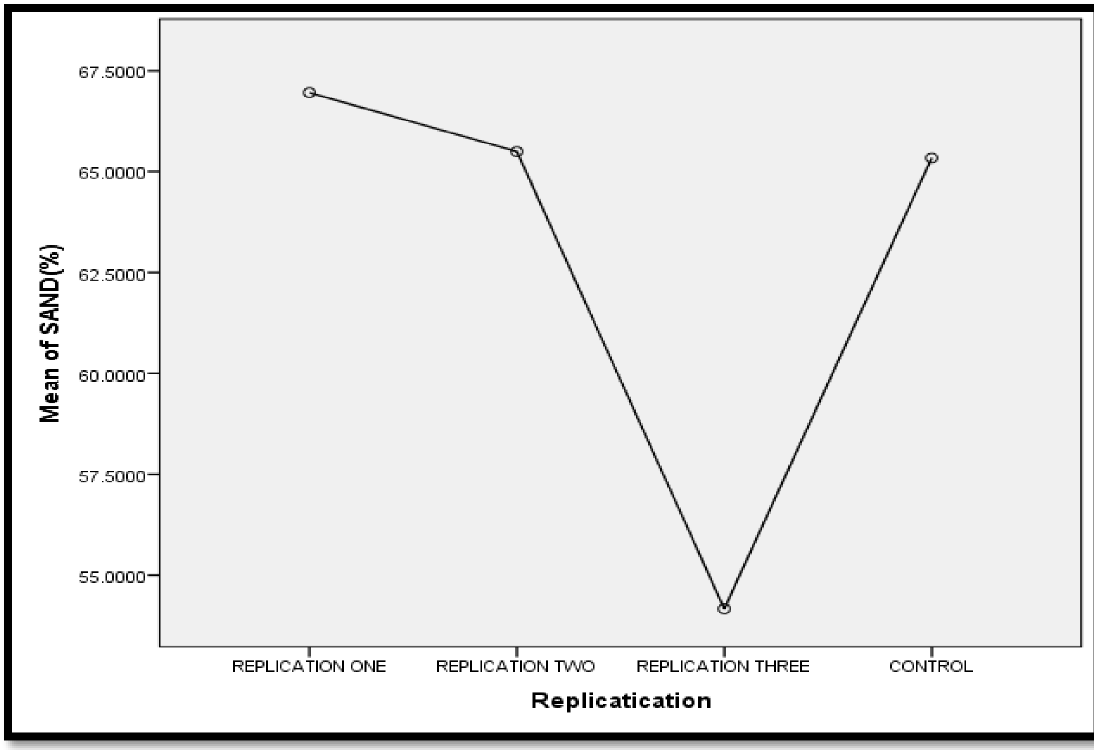

Figure 1: Particle Size Distribution under Replication three (3).

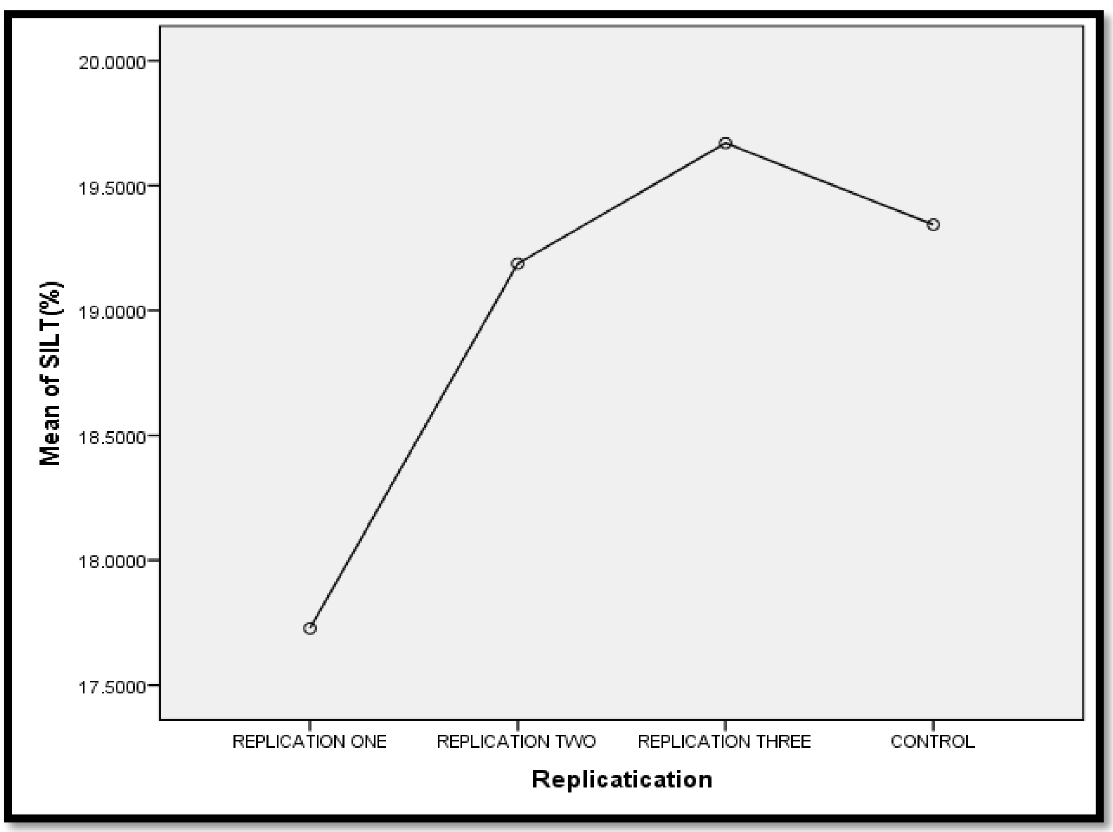

Figure 2: Particle Size Distribution under Replication one (1)

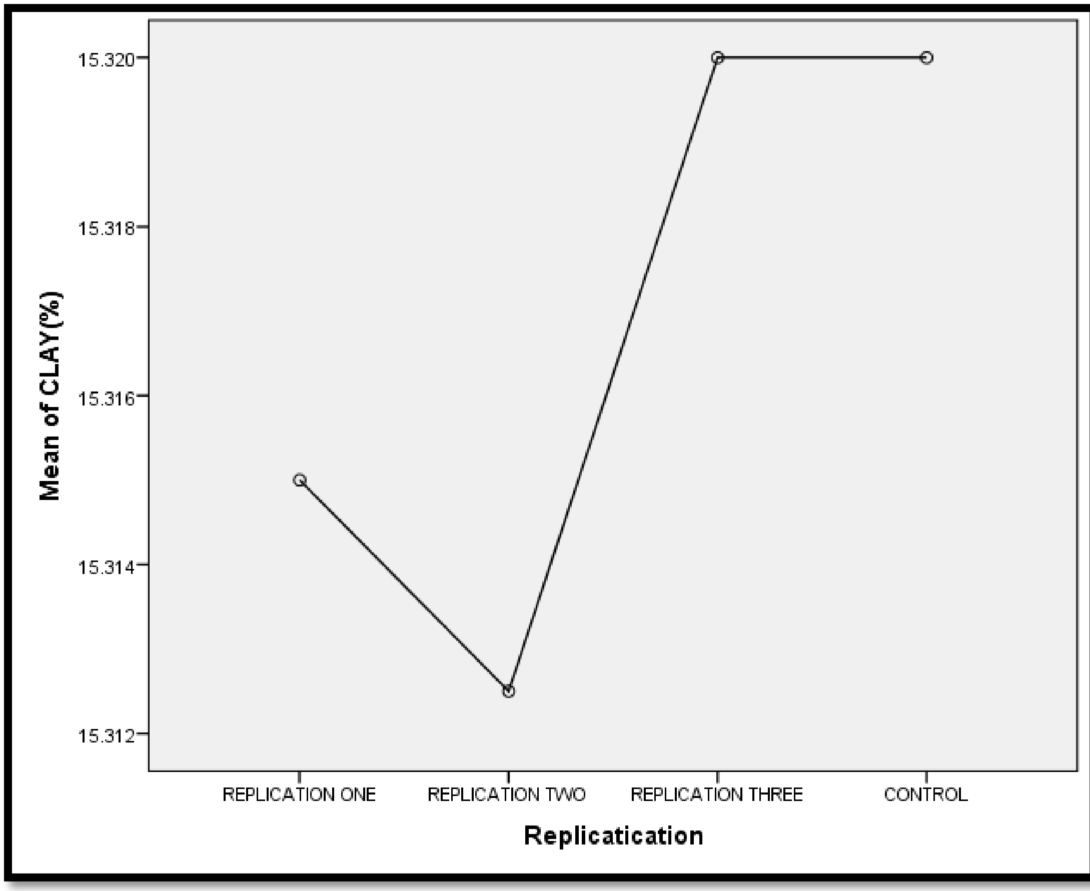

Figure 3: Particle Size Distribution under Replication two (2), note RI: Replication 1, RII: Replication 2, RIII: Replication 3, C: Control.

BULK DENSITY

Table 1 below illustrates the bulk density for replications I, II, III, and the control. Replication III exhibits the highest value at 1.61 g/cm³, while replication II shows the lowest value at 1.42 g/cm³. The typical bulk density value for soil is 1.50 g/cm³. Soil should not exceed this standard limit, as doing so may hinder root development. Replications I, III, and the control have surpassed the typical soil bulk density value, which could impede root growth and result in inadequate air and water movement within the soil (Figure 4). Increased soil bulk density leads to decreased water retention at field capacity, while lower bulk densities indicate reduced compaction and improved water retention (Kakaire et al., 2015). In his research in Minas Gerais, Brazil, Ravina (2012) found that the soil bulk density in *Eucalyptus* spp. plantation areas averaged 1.24 g/cm³, compared to 0.66 g/cm³ in exposed soil areas (0-15 cm) in Brazil. Kolay (2000) notes that the bulk density of fertile natural soils typically ranges from 1.1 to 1.5 g/cm³. The bulk density values observed in this study for both the eucalyptus plantation and the open area fall within this range. However, these findings contradict those of Aweto and Moleele (2005), who reported that *Eucalyptus* spp. plantations significantly increased soil bulk density relative to open lands in Botswana.

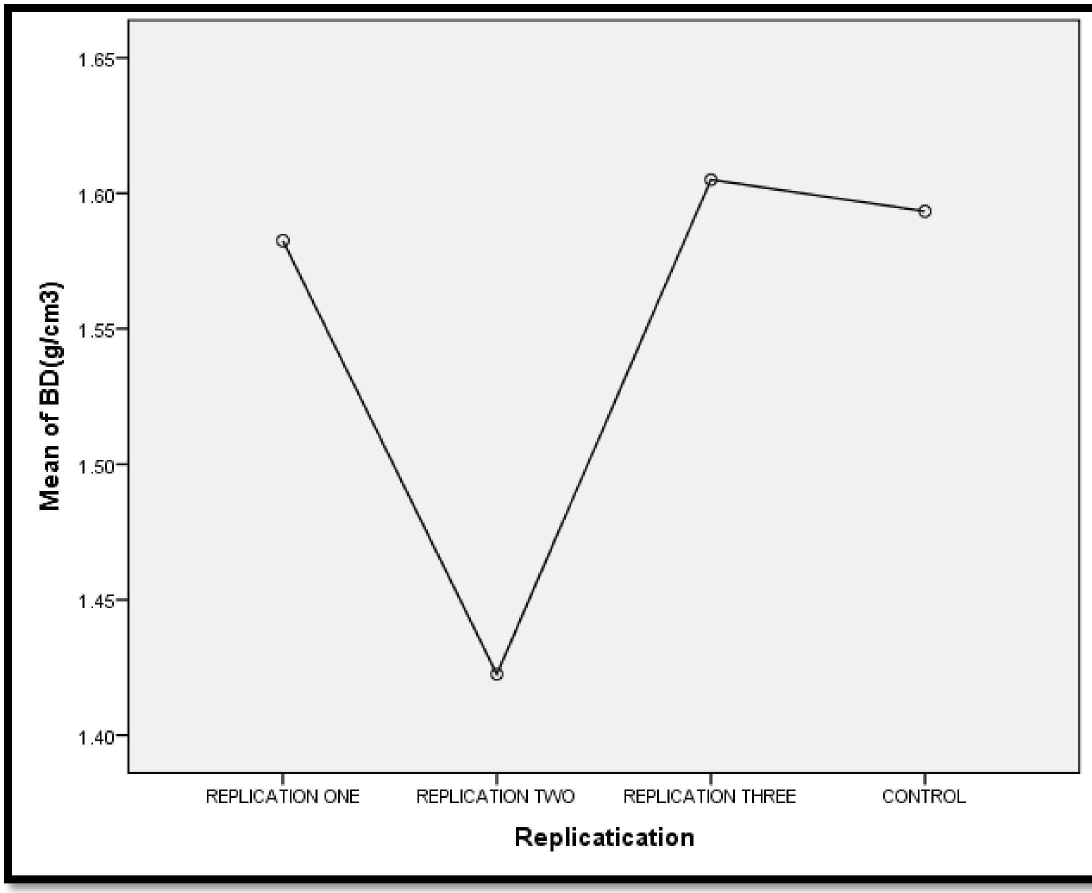

Figure 4: Bulk density showing replication I, II, III and control.

PARTICLE DENSITY

The values of particle density are presented in Table 1 below. The levels detected in the samples are 2.53 g/cm³, 2.30 g/cm³, 2.88 g/cm³, and 2.33 g/cm³ for Replications I, II, III, and Control, respectively (Figure 5). According to the analysis results, there was a significant difference between the sampling sites in terms of chemical composition and structure of the minerals in the soil. Replication III had a significantly higher value than Replications I, II, and Control. Replication III's value is higher than the maximum set limit of 2.60-2.75 g/cm³ by FAO (Ayers and Westcot, 1994; US EPA, 2012). This might be due to high organic carbon content and a large amount of heavy minerals such as magnetite, limonite, and hematite, while the low record of Replication II is due to an increase in organic matter in the soil. These results were similar to the findings of Kumar and Singh (2007).

The result of the analysis showed that there was no significant difference across the replications in terms of %P (Table 1). These values could be considered low, with RI, RII, and Control having percentages of 37.00%, 38.50%, and 32.00%, respectively, while Replication III had the highest percentage of 43.75% (Figure 6). According to the analysis result, there was a significant difference between the sampling sites in terms of total porosity. Replication III had a significantly higher value than Replication I, II, and Control. Replication III values are higher than the maximum set limit, unlike the findings of Dawaki et al. (2013), who found low levels due to particle texture, compaction, structure, and quantity of organic material.

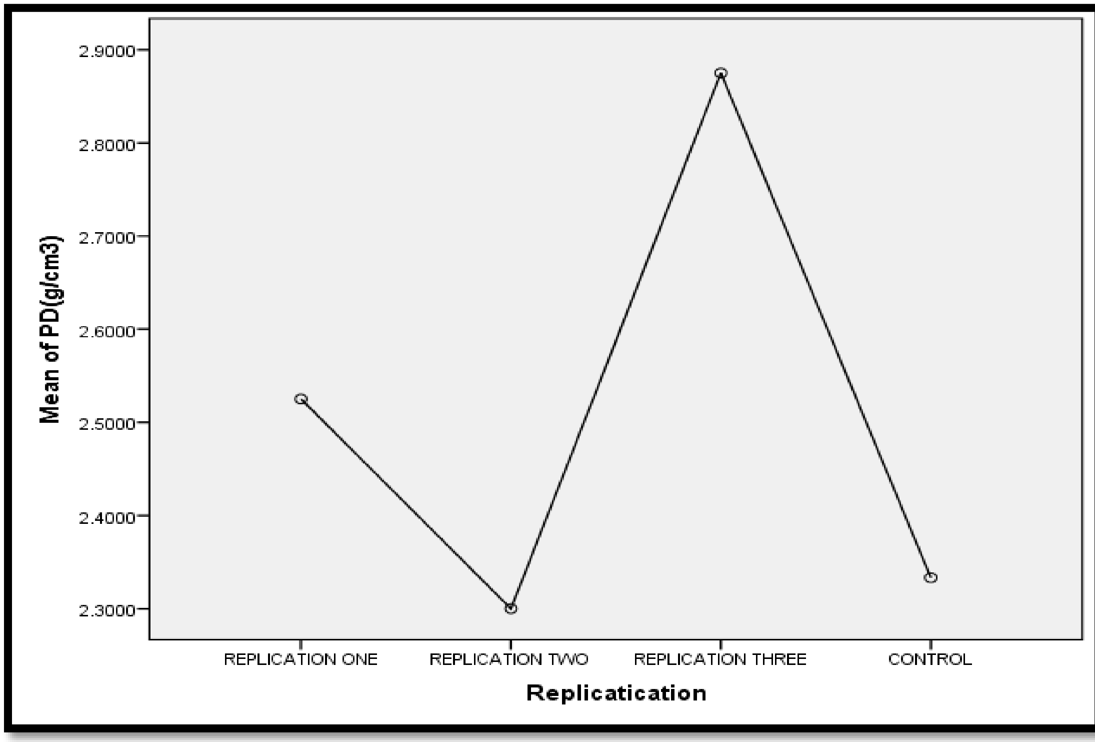

Figure 5: Particle density showing replication I, II, III and control.

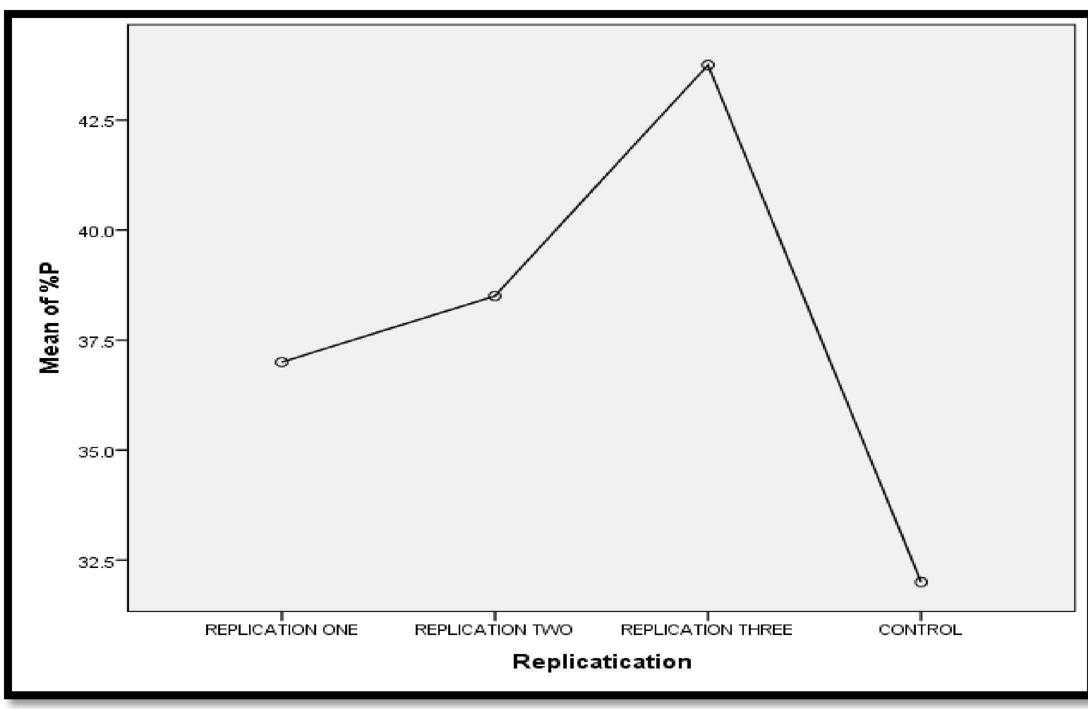

Figure 6: Total porosity showing replication I, II, III and control.

Table 1: This table shows the Bulk Density, percentage porosity, particle density, percentage proportion of Sand, Silt and Clay under Replication I, II, III and Control.

Replication	BD(g/cm3)	%P	PD(g/cm3)	SAND (%)	SILT%	CLAY %
Replication I	1.58[NS]	37.00 [NS]	2.53 [b]	66.96 [NS]	17.73 [NS]	15.32 [NS]
Replication II	1.42 [NS]	38.50 [NS]	2.30 [d]	65.49 [NS]	19.19 [NS]	15.31 [NS]
Replication III	1.61 [NS]	43.75 [NS]	2.88[a]	54.17 [NS]	19.67 [NS]	15.32 [NS]
CONTROL	1.59 [NS]	32.00 [NS]	2.33 [c]	65.34 [NS]	19.34 [NS]	15.32 [NS]

NOTE: Mean values on the column with different super scripts are significantly different ($P \leq 0.05$). Mean ± Standard deviation. Note; NS = Not significant, BD = Bulk Density, P = Total Porosity, PD = Particle Density.

CONCLUSION

The aim of this study was to assess the physical properties of soil under *Eucalyptus* spp. plantations and open areas. This study was conducted at the KUST Zoological Garden, Kano State, Nigeria. The study's results showed that the soils were predominantly sandy loam in both the Eucalyptus plantation and the open area (control). The soil bulk density under the *Eucalyptus* spp. plantation and the open area (control) was significantly higher compared to other soils. The soil bulk density and porosity under the Eucalyptus plantation and open area (control), however, exceeded the standard values; the bulk density was higher, while the porosity was lower for productive soils, which can restrict root growth and impede air and water movement through the soil, as indicated by Kolay (2000). In terms of particle density, the analysis results showed a significant difference between the sampling sites regarding the chemical composition and structure of the minerals in the soil. In some parts of the samples, the values were higher than the maximum set limit. These may be due to high organic carbon content and large amounts of heavy minerals such as magnetite, limonite, and hematite, while the low record is attributed to an increase in organic matter in the soil.

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