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Evaluation of soil nutrient status in *Nauclea diderrichii* and *Pinus caribaea* plantations of Omo Forest Reserve, Ogun State

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ABSTRACT

This study assessed the soil nutrient status in *Nauclea diderrichii* and *Pinus caribaea* plantations of Omo Forest Reserve, Ogun State, Nigeria. Soil samples were systematically collected from three sample points at 50-meter intervals and two soil depths (0-15 cm and 15-30 cm). Soil samples from each site were bulked for each soil depth, and analyzed for Particle size distribution, pH, Moisture content, Nitrogen (N), Available phosphorus (P), Organic carbon (OC), Organic matter (OM), Calcium (Ca), Magnesium (Mg), Potassium (P), Sodium (Na) and Copper (Cu). Data collected were analyzed using one-way Analysis of Variance and T-test. Results showed that sand (97.33±0.42%) and silt (2.67±0.42%) particles were not significantly different ($P<0.05$) in both plantations. Calcium (1.66±0.12cmol/Kg), Mg (2.56±0.28cmol/Kg), K (25.64±0.00cmol/Kg) and Na (5.80±0.00cmol/Kg) were higher in *Nauclea diderrichii* plantation than in *Pinus carbaea* plantation, while C.E.C. (35.65±0.25%), P (8.80±3.25Mg/kg) and N (4.89±0.55%) were not significantly different ($p<0.05$) in the two plantations; OC (2.63±0.30%), OM (4.57±0.52%) and Cu (26.67±6.67Mg/kg) varied significantly ($P<0.05$) between the two plantations. Accumulation of soil nutrients in the plantations was higher in the *Nauclea diderrichii* than in *Pinus caribaea*.

Keywords: Nutrient status, soil properties, plantations, soil depth

INTRODUCTION

Soil nutrient dynamics are influenced dominantly by tree crops and its ecological characteristics, canopy closure of the trees and the management practices, as the amount of standing forest on the soil which integrate litter fall and decomposition could be the most relevant parameter for soil organic matter build up (Emadi *et al*., (2008). Nutrient cycling, according to Berg and McClaugherty (2008), is clearly related to decomposition, and the availability of nutrients in any given soil is majorly due to the decay dynamics of the organic matter in the soil. Forest leaves absorb and retain nutrient through photosynthesis, and the nutrient is returned to the ecosystem when the leaves fall and decompose. This is a process through which nutrient is released into the environment. The organic matter present in the soil of a terrestrial ecosystem is majorly from the production and accumulation of fine litter which must decompose to release nutrient (Leon and Osorio, 2014).

Through litter fall and the process of vegetation decomposition, plants add humus and nutrients to the soil which influences soil structure and fertility (NRCS, 2007). The need for soil nutrient improvement and sustainability has generated interest among plantation managers on the proper tree species mixture and its value as a factor in the successful management of plantations (Ojo, 2005). On the other hand, some researchers have proposed that soil physical and chemical properties be used as indicators for assessing the effect of land use management (Alvarez and Alvarez, 2000).

Many soil properties, soil pH, soil bulk density and soil Carbon and Nitrogen concentrations, may have prominent impacts on tree growth, are key indicators of soil fertility. Soil biological, chemical and physical properties are modified by plants, by means of root exudation, uptake of nutrients, contaminants and root growth (Marcet *et al*., 2006) Carbon exchange capacity can be greatly influenced by the accumulation of organic matter in the soil, which also has the positive impacts on the nutrient holding capacity of the soil (Berg and McClaugherty, 2008)

The sustainable management of soil and plantations will to a large extent depend on a thorough understanding of the trends and dynamics of soil properties, therefore, a systematic understanding and knowledge of soil nutrient dynamics due to land use and land cover changes are paramount in predicting the ecological consequences of disturbing natural ecosystems, and the soil impact of current utilization and management practices (Chima *et al.*, 2009).

There is need for more information on the soil nutrient status of plantations within the Omo Forest Reserve as the available data on soil changes in the plantations (Chima *et al*., 2014) require regular monitoring as possible changes could undermine the relevance of these critical soil nutrients resulting in poor plantations management. Thus, this study assessed and compared the soil nutrient status of *Nauclea diderrichii* and *Pinus caribaea* plantations of Omo Forest Reserve.

MATERIALS AND METHODS

Description of the study site

Omo Forest Reserve lies within a typical tropical high forest of the lowland rainforest zone. It falls within the tropical wet- and-dry climate belts characterized by two rainfall peaks separated by a relatively less humid period usually in the month of August. The temperature ranges between 25^0C to 31^0C (Birdlife International, 2020). The forest reserve is located between latitudes 6°35' to 7°05'N and longitudes 4°19' to 4°40'E in the South-west of Nigeria, and covers an area of approximately 130,500 hectares (Ojo, 2004). The mean annual rainfall, is over 2000 mm and Omo Forest Reserve is contagious with five other highly degraded forest reserves, the largest of which is Oluwo forest reserve to the east (Birdlife international, 2020).

The two sites selected for study are monoculture plantations of *Nauclea diderrichii* and *Pinus caribaea* located in the Area J4, Ijebu-Ode, within Omo Forest Reserve. The 10 ha *Nauclea diderrichii* plantation is located at 6^o50'16.11''N and 4^o22'05.56''E while *Pinus caribaea* plantation with an estimated area of 2.4 ha is located at 6^o50'03.54''N and 4^o22'00.65''E.

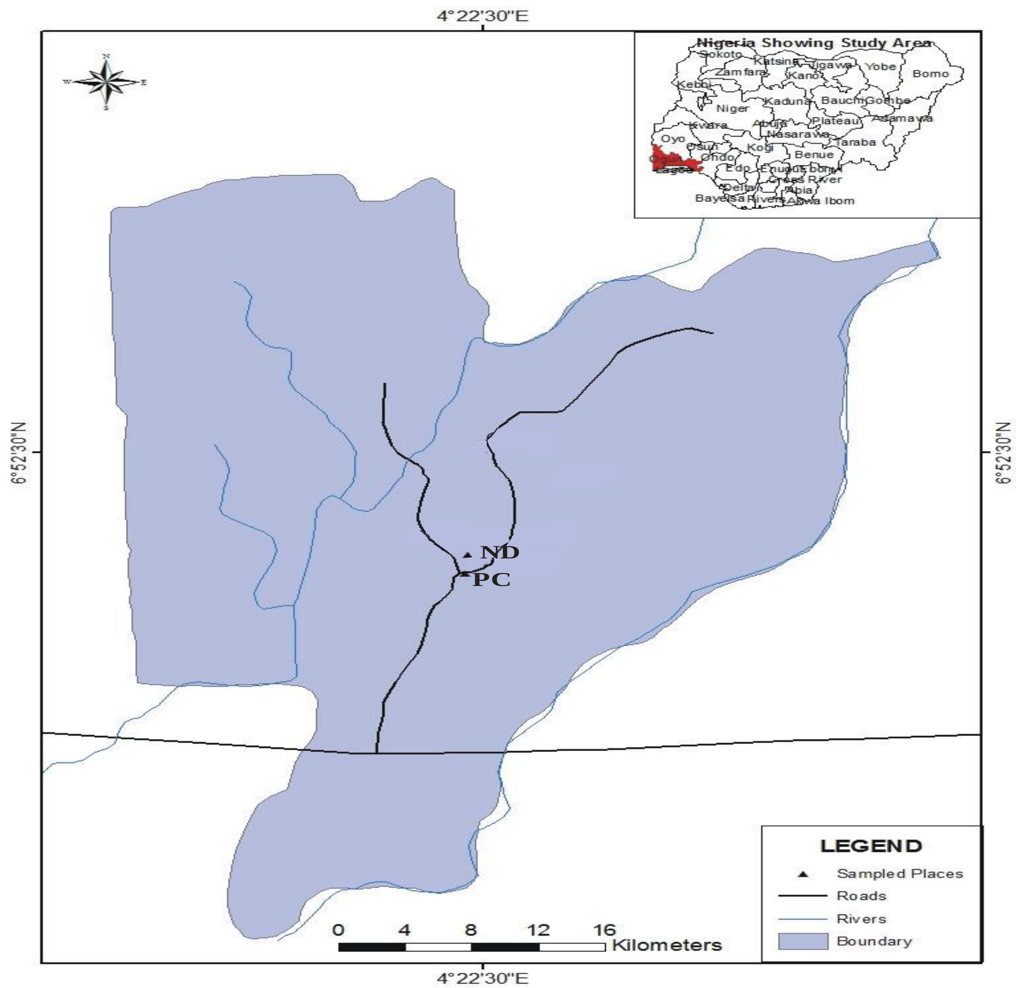

Figure 1: Map of Omo Forest Reserve showing the study sites (Inset: Map of Nigeria).
Source: Adapted from Chima *et al.* (2014).

Soil sampling

In *Nauclea diderrichii* plantation which has an area of 310m by 310m, soil samples were systematically collected from nine sampling points at two soil depths (0-15cm and 15-30cm). On four directions - North-South, East-West, diagonally from North-West to South-East and diagonally from North-East to South-West, the soil samples were collected at three points along each of the four directions at 50-metre intervals. This method was also used to collect soil samples from *Pinus caribaea* plantation, which has an area of 150m by 150m. The soil samples from the same depth were bulked for each plantation, enclosed in polythene bags and taken to the laboratory for the analysis of Particle size distribution, pH, Moisture, Organic Matter (OM), Phosphorus (P), Total nitrogen (N), Organic carbon (C), Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na) and Copper (Cu).

Methods of Soil Nutrient Analysis

The parameters were analyzed using the following methods: Hydrometer method was used for the analysis of particle size (Bouyoucous, 1951); Bray No 1 method to determine Available Phosphorus (Bray and Kurtz, 1945); Kjedahl method to determine Total Nitrogen (Brenmar, 1965); Exchangeable bases were determined by summation method (IITA, 1979); Walkley Black wet oxidation method to determine Organic Carbon (Allison, 1965) and the value was multiplied by 1.72 to derive Organic Matter (Agbenin, 1995), and soil pH was determined in 1:1 soil:water ratio.

The one way analysis of variance (ANOVA) was used to compare the soil nutrients at the two soil depths within each plantation. T-test was used to compare the soil nutrient status of *Nauclea diderrichii* and *Pinus caribaea* plantations.

RESULTS

Soil particle size distribution: The particle size distribution showed that percentage sand decreased from 98% to 96.67% and 97% to 96.33% in the *Nauclea diderrichii* and *Pinus caribaea* plantations respectively with increase in soil depth from 0-15cm to 15-30cm (Table 1). The percentage silt was the same (3%) under *Pinus caribaea* plantation, but increased from 2% to 3.33% under *Nauclea diderrichii* plantation with increased soil depth. There was no clay particle in both plantations at 0-15cm depth, but there was 0.67% at 15-30cm depth in *Pinus caribaea* plantation.

Soil exchangeable bases: The result for exchangeable bases under *Nauclea diderrichii* and *Pinus caribaea* plantations is shown in Table 1. The Ca ranged between 1.48cmol/kg at (15-30cm depth) and1.83cmol/kg at (0-15cm depth) under *Nauclea diderrichii* plantation, and between 1.30cmol/kg at 15-30cm and 2.00cmol/kg at 0-15cm depth under *Pinus caribaea* plantation. There was no significant variation of Magnesium (Mg) under the two plantations at both soil depths ($P<0.05$). However, K remained constant (25.64 cmol/kg) at both depths in *Nauclea diderrichii* plantation but was observed to decrease from 25.64 cmol/kg at 0-15cm depth to 12.14cmol/kg at 15-30cm depth under *Pinus caribaea* plantation. Na showed significant variation between 0-15cm (5.51cmol/kg) and 15-30cm depths (5.22cmol/kg) under *Pinus caribaea* plantation, and also between 0-15 cm (5.94cmol/kg) and 15-30cm depths (5.65cmol/kg) under *Nauclea diderrichii* plantations at 0.05 probability level.

Soil pH, Moisture, Electrical conductivity and Cation exchange capacity: Soil pH varied significantly under the two plantations at both soil depths ($P<0.05$) as shown in Table 1. It reduced with the soil depth, from 7.77 to 7.33 under *Nauclea diderrichii* plantation and from 7.10 to 5.97 under *Pinus caribaea* plantation. The moisture content reduced from 4.92% to 4.82% under *Nauclea diderrichii* plantation and 5.78% to 5.53% under *Pinus caribaea* plantation down the soil depth. There was however no significant difference between the moisture content at 0-15cm and 15-30cm depths under *Nauclea diderrichii* plantation, and also between the moisture contents at 0-15cm and 15-30cm depths under *Pinus caribaea* plantation ($P<0.05$). Electrical Conductivity (E.C) was highest (90.60%) at 0-15cm depth under *Nauclea diderrichii* plantation and lowest (34.27%) at 15-30cm depth under *Pinus caribaea* plantation. E.C varied significantly down the soil depth at 0.05 probability level. There was no significant difference in Cation Exchange Capacity (C.E.C) between 0-15cm and 15-30cm soil depths under *Nauclea diderrichii* plantation, but it varied significantly at these depths under *Pinus caribaea* plantation. The pH, E.C, moisture content and C.E.C decreased with increase in soil depth for both plantations, (Table 1).

Organic carbon, Copper and Available Phosphorus: The organic carbon contents ranged from 0.80% (15-30cm) to 1.07% (0-15cm) under *Pinus caribaea* plantation and from 2.39% (0-15cm) to 2.86% (15-30cm) under *Nauclea diderrichii* plantation. There was no significant difference between organic carbon at 0-15cm and 15-30cm depths under *Pinus caribaea* plantation at 0.05 probability level. The mean copper content decreased from 33.33mg/kg (0-15cm) to 20.00mg/kg (15-30cm) under *Nauclea diderrichii* plantation and also decreased from 66.67mg/kg to 46.67mg/kg at 0-15cm and 15-30cm depth respectively under *Pinus caribaea* plantation. However, there was no significant difference between copper at 0-15cm depth under *Nauclea diderrichii* plantation (33.33mg/kg) and 15-30cm depth under *Pinus caribaea* plantation (46.67mg/kg). While Phosphorus increased down the soil depth from 2.22mg/kg to 3.32mg/kg under *Pinus caribaea* plantation, it decreased from 12.23mg/kg to 5.46mg/kg down the soil depth under *Nauclea diderrichii* plantation (Table 1).

Table 1: Soil parameters under *Naucleadiderrichii* and *Pinus caribaea* Plantations at 0-15cm and 15-30cm soil depths

	***Nauclea diderrichii* plantation**		***Pinus caribaea* plantation**	
Parameters	**0-15cm**	**15-30cm**	**0-15cm**	**15-30cm**
Sand (%)	98.00±0.58a	96.67±0.33b	97.00±0.00ab	96.33±0.33b
Silt (%)	2.00±0.58b	3.33±0.33a	3.00±0.00ab	3.00±0.00ab
Clay(%)	0.00±0.00b	0.00±0.00b	0.00±0.00b	0.670.33a
pH (H_2O)	7.77±0.03a	7.33±0.03ab	7.10±0.10b	5.97±0.28c
E.C (%)	90.60±1.03a	59.37±1.43b	45.67±1.13c	34.27±2.22d
Moisture (%)	4.92±0.31a	4.82±0.07a	5.78±0.20a	5.53±0.46a
Ca (cmol/kg)	1.83±0.17ab	1.48±0.07ab	2.00±0.20a	1.30±0.25b
Mg (cmol/kg)	2.06±0.22a	3.06±0.32a	1.36±1.12a	1.83±0.57a
K (cmol/kg)	25.64±0.00a	25.64±0.00a	25.64±0.00a	12.14±6.75b
Na (cmol/kg)	5.94±0.14a	5.65±0.00ab	5.51±0.14ab	5.22±0.25b
C.E.C (%)	35.47±0.42a	35.83±0.13a	34.51±1.36a	20.49±7.29b
O.C (%)	2.39±0.42ab	2.86±0.47a	1.07±0.54b	0.80±0.50b
Cu (Mg/kg)	33.33±13.33ab	20.00±0.00b	66.67±17.64a	46.67±6.67ab
P (Mg/kg)	12.13±6.14a	5.46±0.74a	2.22±0.18a	3.32±1.16a

- Values are triplicate samples
- Means with the same alphabet on the same row for each soil depth/plantation are not significantly different at 0.05 probability level.

Organic Matter: At 0-15cm, organic matter under *Nauclea diderrichii* plantation (4.17%) varied significantly with that under *Pinus caribaea* plantation (1.86%) at 0.05 probability level. At 15-30cm, organic matter under *Naucleadiderrichii* plantation (4.98%) varied significantly with that under *Pinus caribaea* plantation (1.38%). There was however no significant difference between organic matter at 0-15cm (1.86%) and 15-30cm depths (1.38%) at 0.05 probability level under *Pinus caribaea* plantation (Fig 2).

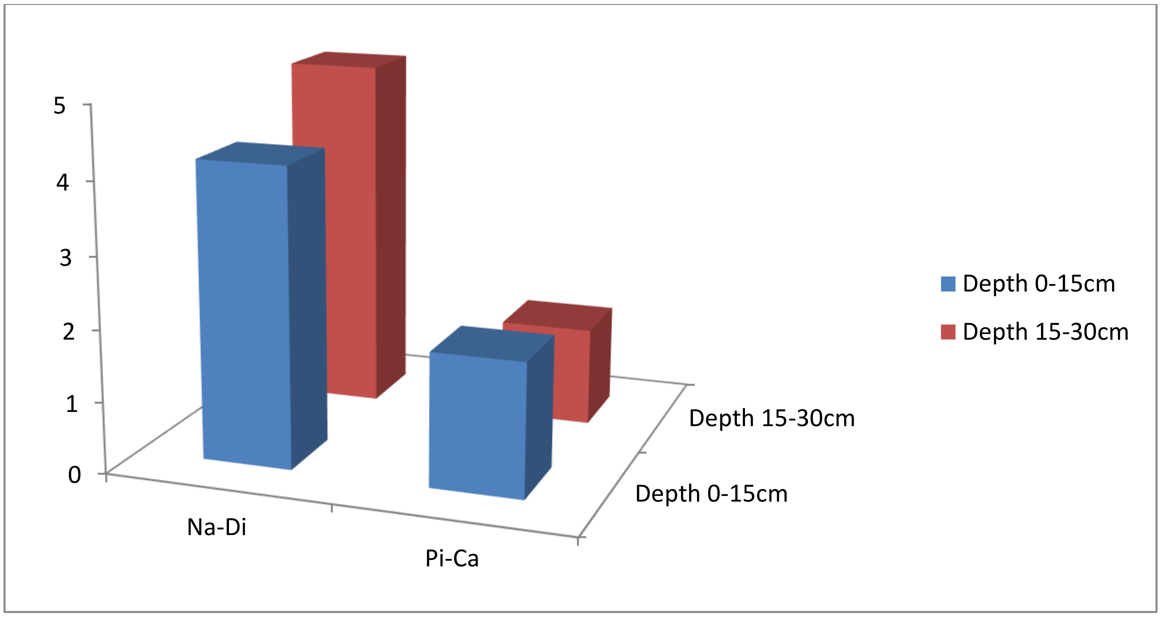

Figure 2: Organic Matter under *Naucleadiderrichii* and *Pinus caribaea* Plantations

Total Nitrogen: There was no significant difference between nitrogen contents at 0-15cm (3.41%) and 15-30cm depths (3.86%) under *Pinus caribaea* plantation at 0.05 probability level. There was also no significant difference between N content at 0-15cm (5.41%) and 15-30cm depths (4.38%) under *Nauclea diderrichii* plantation. However, there was generally high accumulation of Nitrogen in soils under *Nauclea diderrichii* plantation, and low accumulation in soil under *Pinus caribaea* plantation (Fig 3).

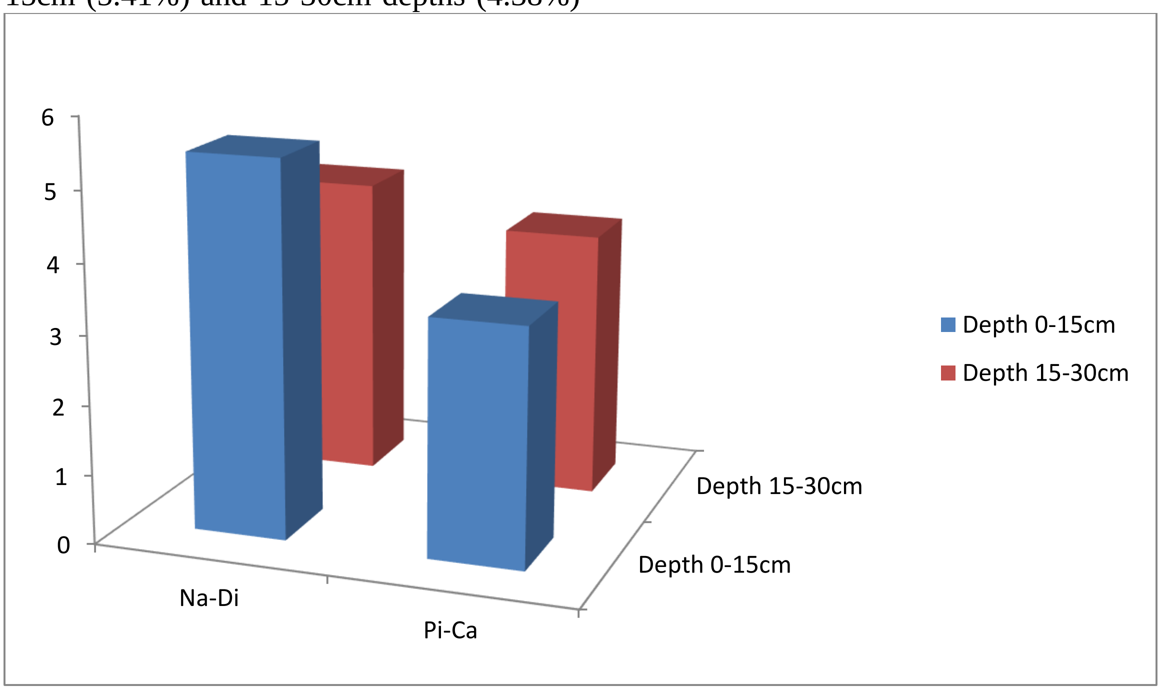

Figure 3: Nitrogen under *Nauclea diderrichii* and *Pinus caribaea* Plantation

Interaction of the soil parameters at the top soil (0-30cm depth)

The mean percentage sand, silt and clay, in *Nauclea diderrichii* plantation was 97.33%, 2.67% and 0.00% respectively, compared with 96.67%, 3.00% and 0.33% percentage sand, silt and clay respectively in *Pinus caribaea* plantation (Table 2). There was no significant difference in the mean percentage sand, silt and clay in the two plantations at 0.05 probability level. E.C and pH were higher in *Nauclea diderrichii* plantation than in *Pinus caribaea* plantation.

Exchangeable bases were generally higher in *Nauclea diderrichi* (Ca = 1.66, Mg = 2.56, K = 25.64 and Na = 5.80) than in *Pinus caribea* (Ca = 1.65, Mg = 1.60, K = 18.89 and Na = 5.36) plantations (Table 2). While there was no significant variation in C.E.C., P and N between the two plantations, the O.C, O.M and Cu varied significantly at 0.05 probability level.

Table 2: Interaction of the soil parameters at the topsoil

Parameters	*Naucleadiderrichii* plantation	*Pinus caribaea* plantation
Sand (%)	97.33±0.42a	96.67±0.21a
Silt (%)	2.67±0.42a	3.00±0.00a
Clay (%)	0.00±0.00a	0.33±0.21a
pH(H_2O)	7.55±0.10a	6.53±0.29b
E.C (%)	74.98±7.03a	39.97±2.78b
Moisture (%)	4.87±0.14b	5.66±0.23a
Ca (cmol/kg)	1.66±0.12a	1.65±0.21a
Mg (cmol/kg)	2.56±0.28a	1.60±0.57a
K (cmol/kg)	25.64±0.00a	18.89±4.27a
Na (cmol/kg)	5.80±0.09a	5.36±0.14b
C.E.C (%)	35.65±0.25a	27.50±4.57a
O.C (%)	2.63±0.30a	0.93±0.34b
O.M (%)	4.57±0.52a	1.62±0.58b
N (%)	4.89±0.55a	3.64±0.46a
Cu (Mg/kg)	26.67±6.67b	56.67±9.55a
P (Mg/kg)	8.80±7.95a	2.77±1.66a

- Values are triplicate samples
- Means with the same alphabet on the same row for each soil depth/plantation are not significantly different at 0.05 probability level.

DISCUSSION

This study showed that sand particle distribution decreased with increase in soil depth while clay particles increased with an increase in soil depth under the *Pinus caribaea* plantation but constant in *Nauclea diderrichii* plantation. The silt particles did not show any change in *Pinus caribaea* plantation with respect to soil depth. The parent materials of soils under the plantations may have influenced the observed soil textural differences in both plantations. Obi and Udoh (2011) reported that, apart from the farmer and tree induced soil property variability, edaphic factors such as the parent material and the soil position on the catena also affect soil variability.

The organic carbon was higher in *Nauclea diderrichii* plantation than in the *Pinus caribaea* plantation. According to Sabina *et al.*, (2020), Organic matter content has significant impact on total organic carbon and also has influence on mean organic carbon in soils of all land use. This could possibly explain the higher organic matter in *Nauclea diderrichii* plantation than in the *Pinus caribaea* plantation. Nitrogen and Phosphorus were also found to be generally higher in *Nauclea diderrichii* plantation than in *Pinus caribaea* plantation. This higher P-concentration in *Nauclea diderrichii* plantation could be due to the higher concentration of organic matter in *Nauclea diderrichii* plantation than in *Pinus caribaea* plantation. Awotoye *et al.* (2011) attributed the increase of nitrate-nitrogen and available phosphorus to improved organic matter content through litter decomposition and mineralization.

While the organic matter increased with increase in soil depth under *Nauclea diderrichii* plantation, the reverse was the case under *Pinus caribaea* plantation as it decreased with soil depth. The decrease in organic matter with depth, may be due to decrease in the abundance of fine roots. According to Shahbaz *et al*., (2017), there is higher accumulation and density of plant materials at the soil surface which provides higher organic matter content within the soil surface layer.

There was generally high available Phosphorus in *Nauclea diderrichii* plantation compared to *Pinus caribaea* plantation, while there was lower concentration at 0-15cm depth than 15-30cm depth under *Pinus caribaea* plantation. Low available phosphorus in top-soils may be due to either reduced mineralization or increased nutrient loss from top-soil through leaching and runoff (Mishra and Laloo, 2006).

Soil pH decreased (i.e increased in acidity) with depth, from 7.77 at 0-15cm depth to 7.33 at 15-30cm depth in *Nauclea diderrichii* plantation and from 7.10 at 0-15cm depth to 5.97 at 15-30cm depth in *Pinus caribaea* plantation. This finding is similar to that of Chima *et al.* (2014) who reported that soil pH decreased with increase in soil depth in both *Nauclea diderrichii* and *Pinus caribaea* plantations of Omo Forest Reserve, due to the significant influence of exchangeable bases especially Ca and Na. This study also revealed that Exchangeable bases generally decreased with increase in soil depth, except Mg which increased from 2.06 cmol/kg (0-15cm) to 3.06cmol/kg (15-30cm) in *Nauclea diderrichii* plantation and from 1.36cmol/kg (0-15cm) to 1.83cmol/kg (15-30cm) in *Pinus caribaea* plantation.

Although there was no difference in the concentration of K (25.64cmol/kg) at 0-15cm depth and 15-30cm depth under *Nauclea diderrichii* plantation, the concentration of K (25.64 cmol/kg) and Na (5.80 cmol/kg) in *Nauclea diderrichii* plantation were found to be higher than the concentration of K (18.89 cmol/kg) and Na (5.36 cmol/kg) in *Pinus caribaea* plantation. This high concentration of K and Na in *Nauclea diderrichii* plantation suggests that *Pinus caribaea* absorbs K and Na more than *Nauclea diderrichii*, in line with the findings of Chima *et al.* (2014), that the lower concentration of K and Na in *Pinus caribaea* plantation suggests that exotic tree species absorb more K and Na from the soil than the indigenous tree species. Cation Exchange Capacity (CEC) decreased with soil depth in *Pinus caribaea* plantation, which could be attributed to the decrease in organic matter content (Oyedele *et al*.2008).

CONCLUSION

The accumulation of essential soil nutrients such as Ca, Mg, K, Na, N as well as organic matter was higher in the *Nauclea diderrichii* plantation than in *Pinus caribaea* of Omo forest reserve, Ogun State. Thus, soil organic matter can be said to influence the accumulation of soil exchangeable bases to an extent.

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