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Carbon Stock in above and below Ground Biomass of Three Age Series of *Pinus carribaea* and *Nauclea diderrichii* Plantations; Omo Forest, Area J4 Ogun State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Forest carbon is identified in three major pools that is, above and below ground living vegetation, dead organic matter and soil organic carbon whose quantities have been identified for few forest types. The study investigated the carbon stock in above and below ground biomass in three age series of *Pinus* (1991, 1992 and 1996) and *Nauclea* (1974, 1975 and 1976) plantations at area J4, Ogun state Nigeria. Five plots of 20m x 20m dimension were randomly laid making a total of 30 plots. Diameter at breast height and height were measured using diameter tape and Spiegel Relaskop respectively. Soil samples were collected in each plantation at 0–15cm and 15–30cm depth with the aid of soil auger and laboratory analysis carried out. Data were analyzed using the General Linear Model of SAS software. Analysis of Variance (ANOVA) and Duncan Multiple Range Test was used to separate means and correlation analysis was carried out. Above ground was estimated using Brown *et al*. (1989) equation {$Y= 34.4703- 8.0671 (DBH) + 0.6589(DBH^2)$} and below ground biomass was also estimated as 20% of above ground biomass. Result showed that

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Organic carbon stored up in the soil was highest (3.05±0.52g/kg) in *Nauclea* plantation (1975). *Pinus* plantation (1996) had a higher total carbon stock (1166.35ton/ha) than *Nauclea* plantation (1976) with (380.41ton/ha). *Pinus* plantation (1996) had the highest above ground biomass, below ground biomass and carbon dioxide concentration (728966.19, 160372.56 and 4198845.28/ha) lowest (227644.66, 50081.83 and 1311233.26/ha), *Pinus* plantation (1992) respectively. Variation in the above ground carbon stock among these plantations could be result of tree stand density, hence, higher number of trees in a plantation will eventually result to high above ground carbon stock of that plantation.

Keywords: Above ground; below ground; carbon stock; plantation; pinus carribea; Nauclea diderrichii; biomass; Omo forest; area J4.

1. INTRODUCTION

The forests contain the largest store of carbon [1]. The major carbon pools in the forests are plant biomass (above and below ground). Forests play an extremely important role in stabilizing CO_2 concentration for it acts as significant source of global CO_2 and also provides opportunities to act as sink through soil, vegetation and wood products. Carbon is stored in forests predominantly in live biomass and in soils, with smaller amounts in coarse woody debris [2]. About 50% of the total carbon is stored in aboveground biomass and 50% is stored in the top 1m of the soil in tropical forests worldwide [3,4].

Major terrestrial carbon pools are components of the ecosystem that can either accumulate or release carbon and have classically been divided into five main categories: living Aboveground Biomass (AGB), living Below-Ground Biomass (BGB), Dead Organic Matter (DOM) in wood, DOM in litter and soil Organic Matter (SOM). Classification of carbon pools is not strict and it is not the number of categories that is important but their completeness; pools must not be double-counted and significant pools should not be excluded [5]. The terrestrial carbon sequestrations depend on land use practices and different ecosystem conditions that sustain established vegetation over longer periods. Land management practices such as monoculture plantations, which sequester carbon or reduce the emissions of CO_{2},, are being considered in the mitigation strategies of climate change [6]. Biomass estimation of forest trees has been subject to research for a long time [7]. However, there is still a lack of studies including precise estimates of the amount of carbon in the various forest compartments, such as the roots, leaves and branches. According to [8], the understanding of the dynamic development of carbon sinks and sources is important in establishing strategies related to the Clean Development Mechanism (CDM) and in planning future actions related to the Reducing Emissions from Deforestation and Forest Degradation (REDD). Being able to accurately estimate biomass both above and below ground is therefore important to assess the role of forests in the global carbon (C) cycle, particularly when defining its contribution toward sequestering carbon [9] This thus justifies need to develop datasets to quantify carbon stocks in *Pinus carribaea* and *Nauclea diderrichii* Plantations; Omo Forest, Area J4 Ogun State, Nigeria**.** At a long run the evaluation of carbon stock will enable us to know that forest plantations have been playing the role of carbon sequestration. Thus the objectives of this study are to evaluate the above ground biomass and below ground biomass in three age series of each plantation, estimate the carbon stock under different soil depths of each plantation and estimate the total carbon stock of the study area.

2. MATERIALS AND METHODS

The study was carried out in Area J4, Ijebu-Ode which is located within Omo Forest Reserve, Ogun State. The 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 about 130,500 hectares [10]. The mean annual rainfall ranges from about 1600 to 2000 mm with two annual peaks in June and September, with November and February being the driest months [11]. The reserve shares a common boundary in its northern part with two other forests- Ago Owu and Sasha in Osun State. It also shares a common boundary with Oluwa Forest Reserve in Ondo State [12]. The study was carried out on three different age series of *Pinus carribaea* (PC) and *Nauclea diderrichii* (ND) plantations. The *Pinus carribaea* plantations were established 1991, 1992 and 1996 while the *Nauclea diderrichii* plantations were established 1974, 1975 and 1976 (Fig. 1).

2.1 Tree Variable Measurements

Five plots of 20m x 20m dimension were randomly laid in each age series of *Pinus carribaea* and *Nauclea diderrichii* stands. Diameter at breast height (DBH at 1.3m) was measured for each standing tree having DBH ≥5cm using diameter tape and Tree Height was measured using spigel relascope.

2.2 Estimation of Carbon in above Ground Biomass

From the different available allometric equations to estimate the above ground biomass, the model that was developed by [13] was selected for the study site since the general criteria described by the authors are similar to that of the study area. The general equation that was used to calculate the above ground biomass is given below:

$$Y = 34.4703 - 8.0671(DBH) + 0.6589(DBH^2) \quad (1)$$

Where; Y is above ground biomass, DBH is diameter at breast height.

2.3 Estimation of Carbon in below Ground Biomass

According to [14], Standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root-to-shoot ratio value of 1:5 is used. Similarly, [15] described this method as it is more efficient and effective to apply a regression model to determine belowground biomass from the knowledge of biomass in aboveground. Thus, the equation developed by [14] to estimate below ground biomass was used. The equation is given below:

$$BGB = AGB \times 0.22 \quad (2)$$

Where;

BGB is below ground biomass and AGB; is above ground biomass

0.2 is conversion factor (or 20% of AGB).

Then the tree biomass was converted into carbon by multiplying the above ground tree biomass by 0.5 [14,9]

$$\text{Biomass carbon stock} = \text{Biomass} \times 0.5 \quad (3)$$

Biomass carbon stock was then converted to CO_2 equivalent as follows:

$$CO_2 = \text{Biomass C} \times 3.6$$

2.4 Soil Sample Collection and Analysis

Soil samples were collected at two different soil depths namely 0-15cm and 15-30cm. Sampling was done in triplicate from each soil depth and bulked together by the two plantations at three age series. Soil organic carbon, soil organic matter, particle size, bulk density and moisture were estimated from soil. Soil analysis was done separately for each sample at each soil depth. The carbon stock in each soil depth was calculated.

$$SOC = BD \times D \times \%C$$

Where; SOC = Soil Organic Carbon stock per unit area (t/ha),

BD = soil bulk density (g/cm^3),
D = the total depth at which the sample was taken (30 cm) and
%C = Carbon concentration (%) determined in the laboratory.

2.5 Data Analysis

The effect of plantations with age on soil properties were subject to ANOVA in a Completely Randomized Design (CRD). The two-way analysis of variance (ANOVA) was used to examine the significant differences of carbon stock in above and below ground biomass in relation to the age series of *Pinus carribaea and Nauclea diderrichii* plantations. The statistical analysis of the data was conducted using Analysis of Variance (ANOVA) on the General Linear Model of SAS software. Duncan Multiple Range Test was further used to separate the means. Correlation analysis was carried out to examine the relationship between tree growth variable, biomass and carbon stock.

3. RESULTS

Table 1 shows the result for the distribution of soil moisture among the various land use. The result shows that *Nauclea diderrichii* (ND 1975) has the highest soil moisture estimate ($30.50^{a}\pm2.45$) followed by *Pinus carribaea* (PC) 1991 with soil moisture estimate of ($21.90^{b}\pm2.06$), with *Pinus carribaea* (PC) 1996 having the least ($10.31^{d}\pm0.73$). The result further shows that there was a significant difference between the soil moisture of *Pinus carribaea* (PC) 1976 ($15.65^{c}\pm0.69$), *Pinus carribaea* (PC) 1991($21.90^{b}\pm2.06$) and *Pinus carribaea* (PC) 1996 ($10.31^{d}\pm0.73$). However, there was no significant difference between *Nauclea diderrichii* ND 1974($18.30^{bc}\pm1.85$), *Nauclea diderrichii* (ND) 1975($30.50^{a}\pm2.45$) and *Pinus carribaea* (PC) (1992:$20.33^{bc}\pm1.19$).

Result obtained from soil particles showed that sand particles was highest in *Pinus carribaea* (PC) 1996 ($97.17^{a}\pm0.00$) with ND 1975 having the least sand particle (0.00 ± 0.00). There was no significant difference between *Nauclea diderrichii* (ND) 1974, 1975, 1976 and *Pinus carribaea* (PC) 1992. However, there was a significant difference between *Pinus carribaea* (PC) 1991 and 1996. Silt particles were highest in *Pinus carribaea* (PC) 1991 ($5.33^{a}\pm0.71$) with *Nauclea diderrichii* (ND) 1975 having the least silt particles ($0.00^{d}\pm0.00$). The result further showed that there was no significant difference between *Pinus carribaea* (PC) 1991 and 1996. However, there was a significant difference between *Nauclea diderrichii* (ND) 1974, 1975, 1976 and *Pinus carribaea* (PC) 1992.

In another dimension, *Nauclea diderrichii* (ND) 1975 had the highest bulk density estimate ($0.31^{a}\pm0.01$) while the least bulk density estimate was recorded in *Pinus carribaea* (PC) 1991 with value ($0.17^{d}\pm0.02$). The result further showed that there was a significant difference between the bulk density of *Nauclea diderrichii* (ND) 1975 and 1976. However, there was no significant difference between *Nauclea diderrichii* (ND) 1974, *Pinus carribaea* (PC) 1991, 1992, and 1996. Result of soil organic carbon concentration shows that *Nauclea diderrichii* (ND) 1975 had the highest carbon concentration ($3.05^{a}\pm0.52$) and *Pinus carribaea* (PC) 1996 had the least organic carbon concentration of $0.01^{c}\pm0.30$. The result further showed that there is no significant difference among the plantation of each age series except *Pinus carribaea* (PC) 1996.

Soil organic matters were highest in *Nauclea diderrichii* (ND) 1975 ($5.31^{a}\pm0.90$) while *Pinus carribaea* (PC) 1996 had the least soil organic matter ($0.15^{d}\pm0.05$). The result further shows that there is no significant difference in the soil organic matter of *Nauclea diderrichii* (ND) 1976, *Pinus carribaea* (PC) 1991 and 1992. However, there is a significant difference between the soil organic matter of *Nauclea diderrichii* (ND) 1974, 1975 and *Pinus carribaea* (PC) 1996. Although there is no significant difference in the clay particles obtained in *Nauclea diderrichii* (ND) 1974, 1975, 1976 and *Pinus carribaea* (PC) 1996. There was a significant difference between the clay particles of *Pinus carribaea* (PC) 1991 and 1992, percentage clay was more in *Pinus carribaea* (PC) 1991 ($1.67^{a}\pm0.84$) with no clay particles found in the other plantations.

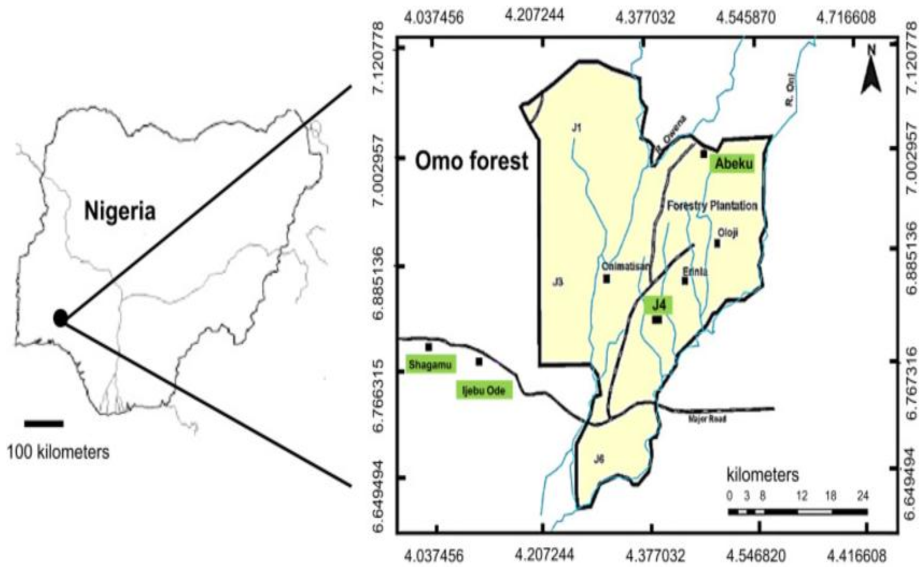

Fig. 1. Map showing Omo biosphere reserve, the study sites and surrounding reserves

Table 1. Effect of plantations with age on soil properties

Plantation	SM	Sand	Silt	BD	SOC	SOM	Clay
ND 1974	18.30^{bc}±1.85	32.83^{bc}±0.00	0.50^{d}±0.34	0.19^{d}±0.04	2.73^{a}±0.49	4.76^{ab}±0.89	0.00^{b}±0.00
ND 1975	30.50^{a}±2.50	0.00^{c}±0.00	0.00^{d}±0.00	0.36^{a}±0.01	3.05^{a}±0.52	5.31^{a}±0.90	0.00^{b}±0.00
ND 1976	15.65^{c}±0.69	48.33^{abc}±0.00	1.67^{dc}±0.84	0.25^{c}±0.01	0.90^{bc}±0.21	1.57^{dc}±0.36	0.00^{b}±0.00
PC 1991	21.90^{b}±2.06	93.00^{a}±0.84	5.33^{a}±0.71	0.17^{d}±0.02	0.64^{bc}±0.20	1.03^{dc}±0.36	1.67^{a}±0.84
PC 1992	20.33^{bc}±1.19	78.33^{ab}±0.68	4.00^{ab}±0.93	0.21^{d}±0.02	0.70^{bc}±0.23	1.22^{dc}±0.40	1.00^{ab}±0.68
PC 1996	10.31^{d}±0.73	97.17^{a}±0.00	2.83^{bc}±0.40	0.21^{d}±0.01	0.01^{c}±0.30	0.15^{d}±0.05	0.00^{b}±0.00

ND= Nauclea diderrichhi plantation, PC= Pinus carribaea plantation, SM= Soil moisture, SOC= Soil organic carbon, SOM= Soil organic matter and BD=Bulk density, P<0.05; Means with the same letter are not significantly different

Table 2. Effect of depth on soil properties

Depth	SM	Sand	SILT	BD	SOC	SOM	Clay
0 -15	19.52^{a}±1.41	48.33^{a}±0.00	1.66^{b}±0.49	0.25^{a}±0.01	1.59^{a}±0.29	2.74^{a}±0.51	0.00^{b}±0.00
15 -30	16.75^{b}±1.31	68.22^{a}±0.94	3.11^{a}±0.58	0.20^{b}±0.02	0.97^{b}±0.27	1.69^{b}±0.47	0.94^{a}±0.39

SM= Soil moisture, SOC= Soil organic carbon, SOM= Soil organic matter, BD=Bulk density. P<0.05; Means with the same letter are not significantly different

Table 2 shows the result for soil moisture irrespective of plantation in respect to depth 0-15cm and 15 -30cm shows there is significant difference with soil moisture significantly high in depth 0-15cm with the value (19.52^{a}±1.41). Soil organic carbon was significantly high in depth 0-15cm (1.59a±0.29). Sand particles were higher at depth 15-30cm (68.22^{a}±0.94) compared to depth 0-15cm (48.33^{a}±0.00), though, not significantly different (P< 0.05). Clay particles were higher at depth 15-30cm (0.94^{a}±0.39), while no clay particles exist in depth 0-15cm. Although there is no significant difference in clay particles across the soil since the amount that existed at depth 15-30cm is highly negligible. Hence there was significant difference (P< 0.05) between the silt particles at depth 15-30cm (3.11^{a}±0.58) compared to those at depth 0-15cm (1.67^{b}±0.49). Soil organic matter was significantly high at depth 0-15cm (2.74a±0.01). Soil bulk density were higher at depth 0-15cm (0.25^{a}±0.01) compared to depth 15- 30cm (1.69^{b}±0.49). The result showed a significant difference between each depth.

A comparison of the soil elements across the soil depth, among the three age series of each plantation (Table 3) shows that there was a significant difference in soil moisture at depth 0-15cm and 15-30cm of all the plantations at each age series except *Nauclea diderrichhi* (ND) 1976. The result further shows that *Nauclea diderrichhi* (ND) 1975 (0-15cm) had the highest soil moisture (32.95^{a}±2.45) across all soil depth in each age series of the plantation with the value of 23.92^{bc}±3.92. PC 1996 at depth 15-30cm had the lowest value of 9.76^{f}±1.51 in the plantations at each age series. Result for soil particle shows that there was no significant difference in the sand particle of *Nauclea diderrichhi* (ND) 1975 and *Nauclea diderrichhi* (ND) 1976 at both depth, while there was a significant difference in the sand particle of *Nauclea diderrichhi* (ND) 1974, *Pinus carribaea* (PC) 1991, 1992 and 1996 at both depths. However, *Pinus carribaea* (PC) 1996 (0-15cm) had the highest sand particle of 97.67^{a}±0.00 with least sand particle in *Nauclea diderrichhi* (ND) 1975 at both depths (0.00^{b}±0.00).

Result for percentage silt (Table 3) shows that there was significant difference in the silt particles of *Nauclea diderrichhi* (ND) 1974, 1976, *Pinus carribaea* (PC) 1991, 1992 and 1996 at both depths, as well as there is no significant difference in percentage silt in *Nauclea diderrichhi* (ND) 1975 between depths. However, *Pinus carribaea* (PC) 1991 (15-30cm) had the highest silt particle of 6.00^{a}±0.00, followed by with least silt particle of 0.00^{d}±0.00 in *Nauclea diderrichhi* (ND) 1974 (0-15cm) and *Nauclea diderrichhi* (ND) 1975 (0-15 and 15-30) respectively. Results for bulk density shows that there is a significant difference in both plantations at each age series between the soil depths. However, the result further shows that *Nauclea diderrichhi* (ND) 1975 (15-30cm) had the highest bulk estimate (0.36^{a}±0.01), followed by *Nauclea diderrichhi* (ND) 1975 (0-15cm) with value of 0.31^{abc}±0.01. With the least bulk density estimate (0.11^{i}±0.03) in *Nauclea diderrichhi* (ND) 1974 at depth 15-30 cm.

Result for soil organic carbon content shows that there is no significant difference in *Pinus carribaea* (PC) 1991, 1992 and 1996 between depths. There is a significant difference in *Nauclea diderrichhi* (ND) 1974, 1975 and 1976 between depths (P< 0.05). However, *Nauclea diderrichhi* (ND) 1975 had the highest organic carbon content (3.57^{a}±0.51) at depth 0-15cm and *Pinus carribaea* (PC) 1996 had the lowest carbon content (0.08^{c}±0.06) at depth 15-30cm. There is a significant difference in *Nauclea diderrichhi* (ND) 1974, 1975 and 1976 between depths (P< 0.05). However, *Nauclea diderrichhi* (ND) 1975 had the highest organic matter content (6.21^{a}±0.90) at depth 0-15cm, followed by *Nauclea diderrichhi* (ND) 1974 (5.03^{a}±1.18) at depth 0-15cm and *Pinus carribaea* (PC) 1996 had the lowest organic matter content (0.14^{c}±0.10) at depth 15-30cm. Result for clay particles (Table 3) shows, there was no significant difference in percentage clay particles of *Nauclea diderrichhi* (ND) 1974, 1975 and 1976 between depths, while there was a significant difference in the percentage clay particles of *Pinus carribaea* (PC) 1991, 1992 and 1996 between depths (P< 0.05). However, *Pinus carribaea* (PC) 1991 had the highest clay particle (3.33^{a}±0.88) at depth 15-30cm and the other plantation at each age series had the lowest clay particles (0.00±0.00) at both depths.

Table 4 shows the result of correlation matrix of tree variables in *Pinus carribaea* plantation. The result shows that there is a significant relationship between dbh and biomass and between dbh and carbon stock respectively (0.984). Also biomass shows a positive relationship (1.00).

Table 3. Interactive effect of plantations and depth on soil properties

LU	DEPTH	SM	SAND	SILT	BD	SOC	SOM	CLAY
ND 1974	0 – 15	19.50^{bcd}±2.34	0.00^{b}±0.00	0.00^{d}±0.00	0.27^{bcd}±0.03	2.89^{a}±0.68	5.03^{a}±1.18	0.00^{b}±0.00
	15 - 30	17.10^{cde}±0.33	65.67^{ab}±0.00	1.00^{cd}±0.58	0.11^{i}±0.03	2.57^{ab}±0.87	4.48^{ab}±1.52	0.00^{b}±0.00
ND 1975	0 – 15	32.95^{a}±2.45	0.00^{b}±0.00	0.00^{d}±0.00	0.31^{abc}±0.01	3.57^{a}±0.51	6.21^{a}±0.90	0.00^{b}±0.00
	15 - 30	16.27^{def}±3.61	0.00^{b}±0.00	0.00^{d}±0.00	0.36^{a}±0.01	1.39^{bc}±0.16	2.42^{bc}±0.28	0.00^{b}±0.00
ND 1976	0 – 15	16.47^{def}±0.80	32.67^{ab}±0.00	0.67^{cd}±0.67	0.26^{cde}±0.01	1.32^{bc}±0.13	2.30^{bc}±0.23	0.00^{b}±0.00
	15 - 30	14.83^{def}±1.01	64.00^{ab}±0.00	2.67^{bcd}±1.45	0.23^{def}±0.01	0.49^{c}±0.13	0.84^{c}±0.23	0.00^{b}±0.00
PC 1991	0 – 15	19.88^{bcd}±1.32	95.33^{a}±0.00	4.67^{ab}±1.46	0.20^{efg}±0.02	0.82^{c}±0.25	1.28^{c}±0.53	0.00^{b}±0.00
	15 - 30	23.92^{bc}±3.92	90.67^{a}±0.88	6.00^{a}±0.00	0.13^{hi}±0.01	0.38^{c}±0.28	0.66^{c}±0.48	3.33^{a}±0.88
PC 1992	0 – 15	22.02^{bcd}±1.35	64.33^{ab}±0.00	2.33^{bcd}±1.20	0.24^{def}±0.02	0.98^{c}±0.40	1.70^{c}±0.69	0.00^{b}±0.00
	15 - 30	18.63^{cd}±1.55	92.33^{a}±1.15	5.67^{a}±0.33	0.17^{gh}±0.01	0.43^{c}±0.17	0.75^{c}±0.30	2.00^{a}±1.15
PC 1996	0 – 15	10.86^{ef}±0.30	97.67^{a}±0.00	2.33^{bcd}±0.33	0.19^{fg}±0.01	0.10^{c}±0.04	0.17^{c}±0.07	0.00^{b}±0.00
	15 - 30	9.76^{f}±1.51	96.67^{a}±0.00	3.33^{abc}±0.67	0.22^{defg}±0.01	0.08^{c}±0.06	0.14^{c}±0.10	0.00^{b}±0.00

ND= Nauclea diderrichhi plantation, PC= Pinus carribaea plantation, SM= Soil moisture, SOC= Soil organic carbon, SOM= Soil organic matter and BD=Bulk density, $P<0.05$; Means with the same letter are not significantly different.

Table 5 shows the result of correlation matrix of tree variables in *Nauclea diderrichii* plantation. The result shows that there is a positive correlation between dbh and biomass (0.970) and between dbh and carbon stock (0.971). Growth characteristics of *Pinus carribaea* and *Nauclea diderrichii* plantation results was shown respectively. Total mean of DBH (74.61cm and 99.55cm); DBH of individual trees ranges from (32-138cm and 18cm-204cm), standard deviation of (21.87 and 41.05) for both *Pinus carribea* and *Nauclea diderrichii* respectively. Furthermore, individual tree biomass ranges from (451.04 - 11469.3 and 102.75kg– 25809.56kg) with a mean biomass of (3415.04 and 6864.75kg) and a standard deviation 2134.99 and 5280.95). Carbon stock of individual trees ranges from 225.52C – 5734.65C, with mean carbon stock of 1707.52C and standard deviation of 1067.49. Carbon stock of individual trees ranges from 51.37C – 12904.78C with mean carbon stock of 3432.37C and standard deviation of 2640.47 (Tables 6 & 7). Number of trees per stand ranges from 44 - 252. *Pinus carribaea* (PC) 1996 had the highest number per stand (252), least was *Nauclea diderrichii* (ND 1974 (44). In other vein, aboveground biomass ranges from 227644.7kg – 728966.2kg. *Pinus carribaea* (PC) 1996 had the highest above ground biomass (728966.2 kg), least was recorded in *Pinus carribaea* (PC) 1992 (227644.7kg). Carbon stock per hectare ranges from 364231.46 - 1166345.91, while highest and lowest carbon stock per hectare was recorded for PC 1996 (1166345.91) and 1992 (364231.46) respectively. Below ground biomass ranges from 50081.83kg - 160372.56kg. Both *Pinus carribaea* (PC) 1996 and 1992 recorded the highest and lowest below ground biomass (160372.56kg) and (50081.83kg) respectively. Carbon dioxide per hectare ranges from 1311233.26 - 4198845.28. *Pinus carribaea* (PC) 1996 had the highest carbon dioxide per hectare and the least was *Pinus carribaea* recorded in (PC) 1992 (1311233.26).

Table 4. Correlation matrix of tree variables in *Pinus carribaea* plantation

	DBH	**Biomass**	**Carbon**
DBH	**1**		
Biomass	0.984	1	
Carbon	0.984	1.00	1

DBH= Diameter at breast height
P<0.05; Means with the same letter are not significantly different.

Table 5. Correlation Matrix of Tree Variables in *Nauclea diderichii* Plantation

	DBH	**Biomass**	**Carbon**
DBH	**1**		
Biomass	0.9701	1	
Carbon	0.971	1.00	

DBH=Diameter at breast height
P<0.05; Means with the same letter are not significantly different

Table 6. Summary for *Pinus carribaea*

Variables	**Mean**	**Std.E**	**Std.D**	**Minimum**	**Maximum**
DBH	74.61	1.08	21.87	32	138
Biomass	3415.04	105.7	2134.99	451.04	11469.3
Carbon	1707.52	52.85	1067.49	225.52	5734.65

DBH= Diameter at breast height, Std. E= Standard error, Std. D= Standard deviation.
P<0.05; Means with the same letter are not significantly different

Table 7. Summary for *Nauclea diderrichii*

	Mean	**Standard Error**	**Standard Deviation**	**Minimum**	**Maximum**
DBH	99.55	3.22	41.05	18	204
Biomass	6864.75	413.64	5280.95	102.75	25809.56
Carbon	3432.37	206.82	2640.47	51.37	12904.78

DBH= Diameter at breast height

Table 8. Total above ground biomass, below ground biomass, carbon stock and carbon dioxide concentration in *Pinus carribaea* and *Nauclea diderrichii* plantations

Year	Biomass	NO/STAND	C/STOCK	C/Ha	CS (ton/ha)	Below ground	CO2/Ha
PC1991	436725.41	109	218362.71	698760.66	698.76	96079.59	2515538.37
PC1992	227644.66	47	113822.33	364231.46	364.23	50081.83	1311233.26
PC1996	728966.19	252	364483.10	1166345.91	1166.35	160372.56	4198845.28
ND1974	453116.12	44	226558.06	724985.79	724.99	99685.55	2609948.83
ND1975	428084.25	61	214042.12	684934.80	684.93	94178.53	2465765.27
ND1976	237753.56	58	118876.78	380405.69	380.41	52305.78	1369460.49

PC= Pinus carribaea, ND= Nauclea diderriichi, CS= Carbon stock, CS/Ha= Carbon stock per hectare, CS (ton/ha) = Carbon stock in ton/ hectare, CO_2/Ha= Carbon dioxide per hectare

4. DISCUSSION

Soil bulk density values varied among each of the plantations, which could be due to compaction resulting from a combination of factors such as human and animal trafficking, rain drop impacts and wetting and drying cycles in soil [16]. Bulk density is routinely assessed to characterize the state of soil compactness in response to land use and soil management practices [17,18] Bulk density values are important for calculating the total quantities of carbon stored at a particular time and soil depth. The evaluation of soil organic carbon in both plantations indicates that, there is less carbon concentration in the soil of *Pinus carribaea* plantation in the three age series. This is highly attributed to low litter decomposition of the plantation, hence, low soil organic carbon. This result is in agreement with those of [19] who stated that decomposition of leaf litter is a vital ecological process in carbon balance and nutrient cycling in terrestrial ecosystem. Soil organic carbon in *Nauclea diderrichhi* plantation shows that *Nauclea diderrichhi* had more concentration of carbon compared to *Pinus carribaea* plantation. This is as a result of litter fall and decomposition. This result is in agreement to [20] who stated soil carbon concentration may largely depend on belowground and underground biomass production and input through litter fall, root exudation and the addition of plant residue.

Soil organic carbon had higher concentration in the soil at 0-15cm depth compared to 15-30cm depth. This result is in agreement with the statement that considerable concentration of soil organic carbon occur in the top soil, although there can be equal; or greater total amounts in the sub soil [21] which can be an important component of global carbon cycle [22]. Although, sand particles were highest in *Pinus carribaea* than in *Nauclea diderrichii*, there is a significant difference in the percentage sand particles of the two plantations. Silt particles were highest in *Pinus carribaea* than in *Nauclea diderrichii*; however, there is a significant difference in the percentage silt particles of both plantations. Percentage clay particles contents were the least of the soil particles under study as compared to percentage sand and silt particles. However, there is no significant difference in the clay particles of the two plantations studied.

Sand, silt and clay did not follow a regular pattern; this explains the significant difference between the two depths. Similar trends in the particle size distribution have been reported by [23] in the Nigerian rain forest region, [24] in Omo biosphere reserve, Nigeria and [25] in Tropical forest of International Institute of Tropical Agriculture, Nigeria The percentage soil organic matter in both plantations was highest in the 0-15cm depth. The significant difference is probably due to leaf litter and root accumulation or decay on the forest floor. The decrease of soil organic matter with depth may be due to the decrease in the abundance of the fine roots with depth, a greater depth, larger diameter root predominance [26]. However, soil moisture showed no regular pattern between the two plantations. From the result obtained, *Pinus carribaea* had the highest total carbon stock, having a total of 408 sampled trees in the plantation and the dbh ranges from 32cm-108cm, as compared to *Nauclea diderrichhi* plantation that has a lesser concentration, with a total of 108 sampled trees and dbh range from 18cm-204cm. This agrees to the finding of [27] who stated that species coverage contributes to the total carbon stock were more in line with their relative abundance [28]. From the result obtained, it is observed that Carbon sequestration capacity varies from species, age, tree sizes in terms of DBH and height, as well as the stand growth of each of the plantations under study. This is evident with the result obtained from this study, as the total carbon concentration of *Naulea diderichii* and *Pinus caribaea* in the same forest reserve, varies from each other. This is similar to the findings of [29] in their study, proposed that Diameter at breast height (DBH), tree height and age were linearly related to the amount of carbon sequestered by a forest tree. This also corresponds to the findings of [30] who mentioned that carbon sequestration potential in the different forest types tends to be correlated to DBH and tree height.

Consequently, land use practices have shown greater capability in influencing the storage of carbon in soils by forest trees. This study has evaluated the effectiveness of estimating the above ground biomass and below ground biomass in *Nauclea diderrichii* and *Pinus carribaea* plantations The adoption of this method was solely aimed at estimating carbon stock without destructive approach because conservation of biological diversity is a driving force to sustain the environment. Variation in the above ground biomass and below ground biomass carbon stock among these plantations is as a result of tree stand density, hence, higher number of trees in a plantation will eventually result to high above ground carbon stock of that plantation. The result of correlation in all the plantation shows that increase in DBH will lead to increase in above ground biomass, and an increase in the total carbon stock as a whole. This agrees with the findings of [31] Carbon dioxide per hectare ranges from 1311233.26 - 4198845.28. *Pinus carribaea* (PC) 1996 had the highest carbon dioxide per hectare and the least was *Pinus carribaea* recorded in (PC) 1992 (1311233.26). Variation in the amount of CO2 sequestered and stored in the trees within a forest stand is affected greatly by the stand density of trees this may implies that Carbon stock of a land-use system is influenced by vegetation and stand density. A land use system consisting of tree species with high wood density will have a higher biomass carbon compared to that with a low wood density and similar tree diameter.

5. CONCLUSION

It is evident that carbon stock in all carbon pools in the forest tree plays a significant role in mitigating climate change, it is recommended that, plantation establishment, silvicultural treatment, regeneration and reforestation is a panacea for sustainable forest trees in removing carbon dioxide from atmosphere. Biomass and carbon stock are key information criteria to understanding the role of forest in regulating global climate [32]. A small fraction of carbon remaining in forest continuously accumulates in vegetation, detritus and soil [33]. Hence, undisturbed forest ecosystem or a well-managed forest plantation is important global carbon sink [34]. The study on the assessment of carbon stock in soil and above ground biomass of *Pinus caribaea,* and *Nauclea didrerrichii* plantation indicates that carbon stock in Area J4, Omo Forest Reserve varies from one site to another, and from one plantation to another. Conclusively, Carbon storage in soils can be influenced by land use practices as evident in the monoculture of forest plantations used for this study. Land use had influence on the soil properties measured in Carbon stock estimate under different plantations with different age across the depths. In addition, Tree variables like diameter at breast height has a great influence on the above ground biomass and carbon stock of the plantation, however age of the plantations play very little role unlike stand density as evident in the result of correlation matrix of the tree variable, biomass and carbon stock which subsequently reflect of below ground biomass.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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