CARBON STOCK AND BIOMASS OF PINUS CARRIBAEA AND NAUCLEA DIDERRICHII PLANTATIONS IN OMO FOREST RESERVE, OGUN STATE, NIGERIA

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Abstract

This study investigated the carbon stock in above and below ground biomass of three age series of Pinus carribaea (1991, 1992 and 1996)and Nauclea diderrichii (1974, 1975 and 1976) in Omo Forest Reserve,Area J4, Ogun state, Nigeria. Five plots of 20m by 20m dimension were randomly laid making a total of 30plots. 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. Laboratory analysis were carried out to determine the bulk density, soil organic carbon, particle size, soil organic matter and soil carbon stock was estimated. The data were analyzed using the General linear Model of SAS software. Analysis of Variance (ANOVA) and LSD (Least Significant Difference) were used to compare and further separate means respectively. Correlation analysis was carried out to examine if relationship exist between soil depth and the soil properties in the different land use. Above ground was estimated using Browns et al (1987) 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 was obtained for soil moisture, sand, clay, silt, bulk density, organic carbon and organic matter irrespective of depth. Organic carbon stored up in the soil was highest (3.05±0.52g/kg) in Naucleadiderrichii plantation (1975), while Pinuscarribaea plantation (1996) had the least soil organic carbon (0.01±0.3g/kg). Soil organic carbon was significantly high in depth 0-15cm (1.59). Pinuscarribaeaplantation (1996) had a higher total carbon stock than(1166.35ton/ha)Naucleadiderrichii plantation (1976) with (380.41ton/ha). Pinuscarribaea plantation (1996) had the highest above ground biomass, below ground biomass and carbon dioxide concentration(728966.19, 160372.56 and 4198845.28/ha) respectively, while Pinuscarribaea plantation (1992) had the lowest (227644.66, 50081.83 and 1311233.26/ha). Land use practices influence the storage of carbon in soils by forest trees. The carbon stock in all carbon pools plays a significant role in mitigating climate change.Therefore, as the 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.

Key words: *Carbon stock, Plantation, Pinus carribea, Naucleadiderrichii, Biomass*

Introduction

The forests contain the largest store of carbon (IPCC 2001). The major carbon pools in the forests are plant biomass (above and below). Where there is disturbance in forest growth or destruction of the forest, Carbon dioxide (CO_2) and other greenhouse gases (such as methane 'CH_4', nitrous oxide 'N_2O') are released back into the atmosphere via respiration, combustion or decomposition (Richards and Evans 2004). 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. The problem of global warming has led to the investigation of innovative methods that can be used to minimize the atmospheric greenhouse gasses like carbon dioxide effect (IPCC, 2007). Methods for capturing carbon dioxide are one of the primary global focuses (IPCC, 2007). Ocean sequestration, geologic sequestration and terrestrial sequestration are a number of techniques under investigation for sequestering carbon from the atmosphere. (IPCC, 2000).

Carbon is stored in forests predominantly in live biomass and in soils, with smaller amounts in coarse woody debris (Malhiet al., 2009). 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. (Dixon et al., 1994). Furthermore, adapting to changing climate, conserving natural resources and promoting sustainable development are several ways communities can also derive benefits from the forest. (Sohelet al., 2009). Now it is high time to incorporate the existing forest management strategies with the climate change through the sequestration of carbon. The timber portion (and in some cases the bark) of the forest carbon stock are removed by cyclical harvesting of forest plantations while the remaining portions are typically left on the site which continues to sequester carbon through new tree growth. However, in recent years the demand for renewable energy and mechanized harvesting systems have led to removal of additional biomass from plantations such as tree bark, branches and, in some cases foliage. Residue burning, carried out to improve access for silvicultural operations and reduce wildfire risk, also results in loss of biomass and carbon on the site.

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 (Watson, 2008). The terrestrial carbon sequestrations depend on land use practices and different ecosystem conditions that sustain established vegetation over longer periods. Biomass estimation of forest trees has been subject to research for a long time (Fehrmann andKleinn, 2006). An allometric equation is to estimate the aboveground biomass for forest plantation. 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 Kauffman et al. (2009), 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).

This thus justifies need to develop datasets to quantify carbon stocks by assessing the carbon stocks of forests. 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. 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.

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 (Ojo, 2004). 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 (Isichei, 1995). 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 (Karimu, 1999). The study was carried out on three different age series of Pinuscarribaea(PC) and Naucleadiderrichii(ND) plantations. The Pinuscarribaea plantations were established 1991, 1992 and 1996 while the Naucleadiderrichiiplantations were established 1974, 1975 and 1976.

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 moisturewere 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.

Data Analysis

The statistical analysis of the data was conducted using Analysis of Variance (ANOVA) on the General Linear Model of SAS software. Least Significance Difference (LSD) was further used to separate the means that were significantly different. Correlation analysis was carried out to examine the relationship between soil depth and different land use on soil organic carbon content and all other soil properties.

Results

Table 1 shows the result for the distribution of soil moisture among the various land use. The result shows thatNaucleadiderrichii(ND1975) has the highest soil moisture estimate ($30.50^a \pm 2.45$). This is followed by Pinuscarribaea (PC) 1991 with soil moisture estimate of ($21.90^b \pm 2.06$), with Pinuscarribaea (PC) 1996 having the least ($10.31^d \pm 0.73$). The result further shows that there was a significant difference between the soil moisture of Pinuscarribaea (PC) 1976 ($15.65^c \pm 0.69$), Pinuscarribaea (PC) 1991($21.90^b \pm 2.06$) and Pinuscarribaea (PC) 1996 ($10.31^d \pm 0.73$). However, there was no significant difference between NaucleadiderrichiiND1974($18.30^{bc} \pm 1.85$), Naucleadiderrichii (ND)1975($30.50^a \pm 2.45$) and Pinuscarribaea(PC)(1992:$20.33^{bc} \pm 1.19$)

Result obtained from soil particles showed that sand particles was highest in Pinuscarribaea (PC) 1996 ($97.17^a \pm 0.00$) with ND 1975 having the least sand particle (0.00 ± 0.00). There was no significant difference between Naucleadiderrichii (ND) 1974, 1975, 1976 and Pinuscarribaea (PC) 1992. However, there was a significant difference between Pinuscarribaea (PC) 1991 and 1996. Silt particles were highest in Pinuscarribaea (PC) 1991 (5.33^{a}±0.71) with Naucleadiderrichii (ND) 1975 having the least silt particles (0.00^{d}±0.00). The result further showed that there was no significant difference between Pinuscarribaea (PC) 1991 and 1996. However, there was a significant difference between Naucleadiderrichii (ND) 1974, 1975, 1976 and Pinuscarribaea (PC) 1992.

In another dimension, Naucleadiderrichii(ND) 1975 had the highest bulk density estimate (0.31^{a}±0.01) while the least bulk density estimategoes to Pinuscarribaea (PC) 1991 with value (0.17^{d}±0.02). The result further showed that there was a significant difference between the bulk density of Naucleadiderrichii (ND) 1975 and 1976. However, there was no significant difference between Naucleadiderrichii (ND) 1974, Pinuscarribaea (PC) 1991, 1992, and 1996. Result of soil organic carbon concentration shows that Naucleadiderrichii (ND) 1975 had the highest carbon concentration (3.05^{a}±0.52) andPinuscarribaea (PC) 1996 had the least organic carbon concentration of 0.01^{c}±0.30. The result further showed that there is no significant difference among the plantation of each age series except Pinuscarribaea (PC) 1996.

Soil organic matters were highest in Naucleadiderrichii (ND) 1975 (5.31^{a}±0.90) while Pinuscarribaea (PC) 1996 had the least soil organic matter (0.15^{d}±0.05). The result further shows that there is no significant difference in the soil organic matter of Naucleadiderrichii (ND) 1976, Pinuscarribaea (PC) 1991 and 1992. However, there is a significant difference between the soil organic matter of Naucleadiderrichii (ND) 1974, 1975 and Pinuscarribaea (PC) 1996. Although there is no significant difference in the clay particles obtained in Naucleadiderrichii (ND) 1974, 1975, 1976 and Pinuscarribaea (PC) 1996. There was a significant difference between the clay particles of Pinuscarribaea (PC) 1991 and 1992, percentage clay were more in Pinuscarribaea (PC) 1991 (1.67^{a}±0.84) with no clay particles found in the other plantations.

Table 1: Effect of Land Use on Soil Properties

LAND USE	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= Naucleadiderrichhi plantation, PC= Pinuscarribaea 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 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.

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.

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 Naucleadiderrichhi (ND) 1976. The result further shows thatNaucleadiderrichhi(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 Naucleadiderrichhi (ND) 1975 and Naucleadiderrichhi (ND) 1976 at both depth, while there was a significant difference in the sand particle of Naucleadiderrichhi (ND) 1974, Pinuscarribaea (PC) 1991, 1992 and 1996 at both depths. However, Pinuscarribaea (PC) 1996 (0-15cm) had the highest sand particle of 97.67^{a}±0.00 with least sand particle in Naucleadiderrichhi (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 Naucleadiderrichhi (ND) 1974, 1976, Pinuscarribaea (PC) 1991, 1992 and 1996 at both depths, as well as there is no significant difference in percentage silt in Naucleadiderrichhi (ND) 1975 between depths. However, Pinuscarribaea (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 Naucleadiderrichhi (ND) 1974 (0-15cm) and Naucleadiderrichhi (ND) 1975(0-15 and 15-30) respectively. Results for bulk density shows that there is a significant difference in both plantation at each age series between the soil depths. However, the result further shows that Naucleadiderrichhi (ND) 1975(15-30cm) had the highest bulk estimate (0.36^{a}±0.01), followed by Naucleadiderrichhi (ND) 1975 (0-15cm) with value of 0.31^{abc}±0.01.With the least bulk density estimate (0.11^{i}±0.03) in Naucleadiderrichhi (ND) 1974 at depth 15-30cm.

Result for soil organic carbon content shows that there is no significant difference in Pinuscarribaea (PC) 1991, 1992 and 1996 between depths. There is a significant difference in Naucleadiderrichhi (ND) 1974, 1975 and 1976 between depths (P< 0.05). However, Naucleadiderrichhi (ND) 1975 had the highest organic carbon content (3.57^{a}±0.51) at depth 0-15cm and Pinuscarribaea (PC) 1996 had the lowest carbon content (0.08^{c}±0.06) at depth 15-30cm. There is a significant difference in Naucleadiderrichhi (ND) 1974, 1975 and 1976 between depths(P< 0.05). However, Naucleadiderrichhi (ND) 1975 had the highest organic matter content (6.21^{a}±0.90) at depth 0-15cm, followed by Naucleadiderrichhi (ND) 1974 (5.03^{a}±1.18) at depth 0-15cm and Pinuscarribaea (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 Naucleadiderrichhi (ND) 1974, 1975 and 1976 between depths, while there was a significant difference in the percentage clay particles of Pinuscarribaea (PC) 1991, 1992 and 1996 between depths (P< 0.05). However, Pinuscarribaea (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 Pinuscarribaea 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).

Correlation Matrix of Tree Variables in Naucleadiderichii Plantation

Table 5 shows the result of correlation matrix of tree variables in Naucleadiderrichii 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 Pinuscarribaeaand Naucleadiderrichiplantation 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 Naucleadiderrichii 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.(Table 5&7).

Table 3: Interactive Effect of Land Use and Depth on Soil Properties

LU	DEPTH	SM	SAND	SILT	BD	SOC	SOM	CLAY
ND 1974	0 – 15	$19.50^{bcd}\pm2.34$	$0.00^{b}\pm0.00$	$0.00^{d}\pm0.00$	$0.27^{bcd}\pm0.03$	$2.89^{a}\pm0.68$	$5.03^{a}\pm1.18$	$0.00^{b}\pm0.00$
	15 - 30	$17.10^{cde}\pm0.33$	$65.67^{ab}\pm0.00$	$1.00^{cd}\pm0.58$	$0.11^{i}\pm0.03$	$2.57^{ab}\pm0.87$	$4.48^{ab}\pm1.52$	$0.00^{b}\pm0.00$
ND 1975	0 – 15	$32.95^{a}\pm2.45$	$0.00^{b}\pm0.00$	$0.00^{d}\pm0.00$	$0.31^{abc}\pm0.01$	$3.57^{a}\pm0.51$	$6.21^{a}\pm0.90$	$0.00^{b}\pm0.00$
	15 - 30	$16.27^{def}\pm3.61$	$0.00^{b}\pm0.00$	$0.00^{d}\pm0.00$	$0.36^{a}\pm0.01$	$1.39^{bc}\pm0.16$	$2.42^{bc}\pm0.28$	$0.00^{b}\pm0.00$
ND 1976	0 – 15	$16.47^{def}\pm0.80$	$32.67^{ab}\pm0.00$	$0.67^{cd}\pm0.67$	$0.26^{cde}\pm0.01$	$1.32^{bc}\pm0.13$	$2.30^{bc}\pm0.23$	$0.00^{b}\pm0.00$
	15 - 30	$14.83^{def}\pm1.01$	$64.00^{ab}\pm0.00$	$2.67^{bcd}\pm1.45$	$0.23^{def}\pm0.01$	$0.49^{c}\pm0.13$	$0.84^{c}\pm0.23$	$0.00^{b}\pm0.00$
PC 1991	0 – 15	$19.88^{bcd}\pm1.32$	$95.33^{a}\pm0.00$	$4.67^{ab}\pm1.46$	$0.20^{efg}\pm0.02$	$0.82^{c}\pm0.25$	$1.28^{c}\pm0.53$	$0.00^{b}\pm0.00$
	15 - 30	$23.92^{bc}\pm3.92$	$90.67^{a}\pm0.88$	$6.00^{a}\pm0.00$	$0.13^{hi}\pm0.01$	$0.38^{c}\pm0.28$	$0.66^{c}\pm0.48$	$3.33^{a}\pm0.88$
PC 1992	0 – 15	$22.02^{bcd}\pm1.35$	$64.33^{ab}\pm0.00$	$2.33^{bcd}\pm1.20$	$0.24^{def}\pm0.02$	$0.98^{c}\pm0.40$	$1.70^{c}\pm0.69$	$0.00^{b}\pm0.00$
	15 - 30	$18.63^{cd}\pm1.55$	$92.33^{a}\pm1.15$	$5.67^{a}\pm0.33$	$0.17^{gh}\pm0.01$	$0.43^{c}\pm0.17$	$0.75^{c}\pm0.30$	$2.00^{a}\pm1.15$
PC 1996	0 – 15	$10.86^{ef}\pm0.30$	$97.67^{a}\pm0.00$	$2.33^{bcd}\pm0.33$	$0.19^{fg}\pm0.01$	$0.10^{c}\pm0.04$	$0.17^{c}\pm0.07$	$0.00^{b}\pm0.00$
	15 - 30	$9.76^{f}\pm1.51$	$96.67^{a}\pm0.00$	$3.33^{abc}\pm0.67$	$0.22^{defg}\pm0.01$	$0.08^{c}\pm0.06$	$0.14^{c}\pm0.10$	$0.00^{b}\pm0.00$

ND= *Naucleadiderrichhi* plantation, PC= *Pinuscarribaea* 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.

Number of trees per stand ranges from 44 - 252. Pinuscarribaea (PC) 1996 had the highest number per stand (252), least was Naucleadiderrichhi (ND1974 (44). In other vein, aboveground biomass ranges from 227644.7kg – 728966.2kg.Pinuscarribaea(PC) 1996 had the highest above ground biomass (728966.2 kg), least was recorded in Pinuscarribaea (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 Pinuscarribaea(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. Pinuscarribaea(PC) 1996 had the highest carbon dioxide per hectare and the least was Pinuscarribaearecorded in (PC) 1992 (1311233.26).

Table 4: Correlation Matrix of Tree Variables in *Pinuscarribaea*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 *Naucleadiderichii* Plantation

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

Source: Field survey, 2017.
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

Source: Field survey, 2017.
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

Source: Field survey, 2017.
DBH= Diameter at breast height

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

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 (Anikweet al., 2003). 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 Pinuscarribaeaplantation 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 Schefferet al., (2001) 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 Naucleadiderrichhi plantation shows that Naucleadiderrichhihad more concentration of carbon compared to Pinuscarribaea plantation. This is as a result of litter fall and decomposition. This result is in agreement to Zhang et al., (2014) 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 (Gregory et al., 2014), which can be an important component of global carbon cycle. (Baisdenet al., 2002). Although, sand particles were highest in Pinuscarribaea than in Naucleadiderrichii, there is a significant difference in the percentage sand particles of the two plantations. Silt particles were highest in Pinuscarribaea than in Naucleadiderrichii; 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 Muoghalu and Awokunle (1994) in the Nigerian rain forest region and Chima (2007) in Omo biosphere reserve, 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 (Oyedeleet al., 2008).However, soil moisture showed no regular pattern between the two plantations. From the result obtained,Pinuscarribaea 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 Naucleadiderrichhi 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

Kirby and Potvin (2007) who stated that species coverage contributes to the total carbon stock were more in line with their relative abundance. Consequently, land use practices have shown greater capability in influencing the storage of carbon in soils by forest trees. Therefore, as the 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.

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