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Carbon Stock Assessment of *Bambusa vulgaris* stands in a regenerating secondary rainforest, Thirty-four years after Ground fire in Ile-Ife, Nigeria

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ABSTRACT: There are few investigations on the potentials of bamboos in carbon storage and as carbon sink in African tropical rainforests, especially in Nigeria where there are no baseline data on this subject. The study assessed carbon stock of ~ 60 years old *B. vulgaris* stands in a regenerating secondary forest in Ile-Ife, Nigeria. Destructive method was employed to assess aboveground biomass and for its carbon stored. Results showed that mean aboveground biomass was 257.82 t ha^{-1} with culm (210.75 t ha^{-1}) significantly higher than twigs (35.59 t ha^{-1}) and leaves (11.47 t ha^{-1}). The mean carbon stored was 237.94 t C ha^{-1} of which 138.70 t C ha^{-1}were stored in the aboveground biomass; 32.72 t C ha^{-1} in the belowground biomass and 66.52 t C ha^{-1} in the soil. It sequestered ~32.22 t C ha^{-1} yr^{-1} and stored carbon higher than some dominant tree species in the secondary forest, some Agroforestry system in Africa and most bamboo species in tropical and subtropical countries. Bamboo plantation should be considered in coastal regions to check the effect of climate change.

Keywords: Aboveground biomass; Belowground biomass; Carbon stock; Regression equation

INTRODUCTION

Bamboo is often referred to as 'green gold' which introduces itself as a cheap and plentiful resource to meet the vast needs of the human population and frequently known as "poor man's timber" and as emerged as a precious wood substitute in the last 15 – 20 years (Tariyal *et al*., 2013). It is commonly found in African tropical rainforests. Some of the common species of bamboo in Nigeria include the widespread *Bambusa vulgaris* var. vulgaris Schrad. ex Wendel., commonly found in Southern Nigeria, *Bambusa tulda* Robx., *Dendrocalamus giganteus* Munro and *Oxytenanthera abyssinica (A. Rich.)* Munro (Ekebafe *et al*., 2010). Bamboos are a significant structural component of many forest ecosystems and play a major role in ecosystem dynamics through their distinctive cycles of mass flowering and subsequent die-off that may have evolved as an adaptation to forest fires, and can certainly affect fire cycles (Clark, 1995; Keeley and Bond, 1999).

Management of bamboos by controlling their distribution in areas of where density is high can be an important forest restoration method (Larkpern *et al*., 2010). In areas of intense forest disturbance, bamboos can take advantage of their inherent fast-growing and efficient dispersion characteristics and influence the natural regeneration of forests in its early stages (Rother *et al*., 2009; Betina *et al*., 2010). Bamboo is an efficient user of land, and produces more biomass per unit area than most tree species (Kumar *et al*., 2002). The carbon sequestration ability of bamboo is likely to be second to none and if at all, only few (Anonymous, 1997; Zhou *et al*., 2005). Bamboos plantation/ stands in a secondary

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status of woody species and due to their fast growth and high productivity, they can be noteworthy as a sink of atmospheric carbon (Nath *et al*., 2008; Tariyal *et al*., 2013). Bamboo can absorb 12 metric tons of harmful carbon dioxide per hectare from the air, which is twice that of a similar size forest (Scurlock *et al*., 2000; Choudhary, 2008). Studies have demonstrated the potential of bamboos in C storage and as C sinks (Kumar *et al*., 2005; Chen *et al*., 2009; Yen *et al*., 2011; Nath and Das, 2012) in forests/ plantations. Carbon stock, nutrient accumulation and dynamics in bamboo plantations have been studied in a chronosequence (Shanmughavel *et al*., 2001), but natural bamboo forests of Africa (Kigomo, 1988; Lakshmana, 2002) have not been well studied. Previous studies on bamboo from tropical and subtropical countries show that various bamboo species have close or higher carbon than many valuable fast growing timber species or tropical forest ecosystem (Sohel *et al*., 2015). There is paucity of information on the carbon stock and sequestration potentials of bamboo species in tropical Africa, especially in Nigeria, where there are no baseline data on the carbon stock of bamboo stands in the tropical rainforests; where they are continuously deforested at alarming rate to meet the socio-economic and ethno-botanical need of the people.

The bamboo stands in the secondary forest existed before the ground fire that ravaged the secondary rainforest thirty-four years ago and it is believed to have influenced the regeneration status of tree and shrub species in the secondary forest, through its nutrient release from litter production (Borisade, 2015) and carbon storage. This study, addressed the following questions:

1. what are the amounts of bamboo biomass accumulated in the regenerating forest?
2. The role played in sinking carbon in the forest ecosystem to mitigating climate change?
3. How do we predict the carbon sequestration potentials of the bamboo stands in the regenerating secondary forest?

To address this issue we examined the carbon stock of *B. vulgaris* and compared the results with existing data on dominant trees species studied in same secondary forests and bamboo species studied in other continents. We also examined soil carbon pool and developed a regression equation model for predicting the biomass and organic biomass carbon content (Carbon stock) of ~60 years old *B. vulgaris* stands in the regenerating secondary forest.

MATERIALS AND METHODS

Study Area

The study was carried out in the secondary rainforest within the Biological Garden of Obafemi Awolowo University, Ile-Ife, Nigeria. Ile-Ife lies within latitudes 7° 30' N to 7° 35' N and longitudes 4° 30' to 4° 3 5' E. The coordinate of the study areas is: Latitude 7°31.417' to 7°31.430' N, and Longitude 4°31.442' to 4°31.455' E. The elevation of the areas ranges from 302 m to 329 m above sea level. There are two prominent seasons in the Ife area, the rainy season (March - November) and the dry season (November-March). The most recent climatic survey conducted in 2016 by the Atmospheric Physics Research Group, Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife, showed that the annual rainfall averaged 1302 mm per year, with relative humidity of 82.80%, average temperature of 25.5° C, solar radiation of 164.30 Wm^{-2} and average wind speed of 2.06 km per hour.

Onochie (1979) reported that Ile-Ife area lies in a dry deciduous forest zone. White (1983) also describes the vegetation as Guineo-Congolian drier type. The most frequently occurring plant families in the secondary rainforest are Apocynanceae, Eurphorbiaceae, Mimosaceae, Moraceae, Rubiaceae and Sapindaceae (Awokoya, 2003).

The soil has been classified as Lixisols (FAO/UNESCO 1974) and Ultisols (USDA 1975). The soils which are usually acid contain less than 10% clay which is mainly Kaolinite and hence are characterized by low cation exchange capacity and low water holding capacity (Ayodele, 1986).

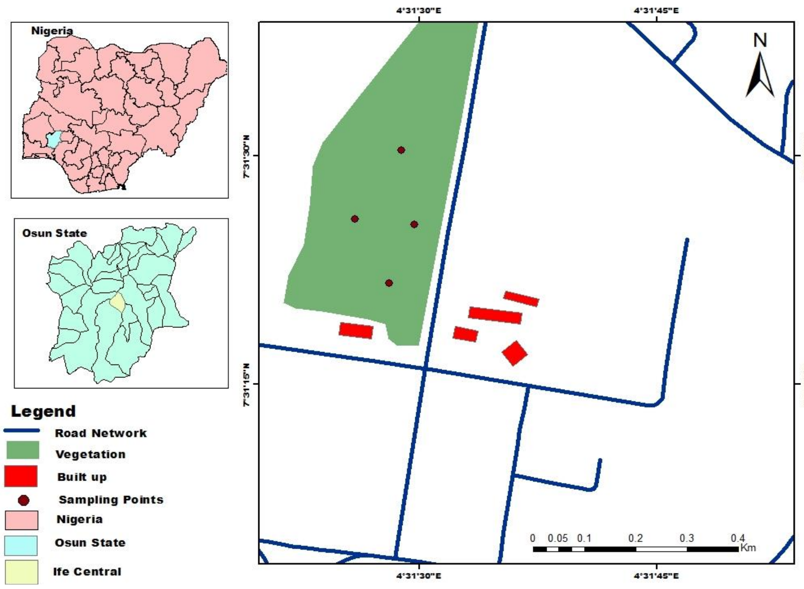

Figure 1: Map of Secondary forest (right) where the bamboo stands are located

Sampling Procedure

Four study plots were established within the Secondary rainforest, each sampling plot of size; 25 m x 25 m with intervals of 50 m were marked out using measuring tape and demarcated with narrow cut-lines.

Above and below ground biomass estimation of *B. vulgaris*

Bamboo biomass was determined by harvesting randomly selected culms from ~ sixty years *B. vulgaris* stands at secondary forest. A total of 80 culms were harvested from established plots (20 culms from each plot). The number of total culms in each plot was counted and diameter at breast height (DBH) and total height were measured by using a diameter tape and haga-ultimeter respectively. After harvesting, the culm samples were divided into leaf, branch and culm components and their respective fresh weights were taken in the field. Several sub-samples of each component were then collected and their fresh weights were measured. All the sub-samples were then oven-dried at 80°C for 72 hours and weighed.

For each sub-sample, a ratio of oven-dried to fresh weight was calculated and an average ratio was obtained. Multiplication of the total fresh weight of each component by the corresponding oven-dried to fresh-weight ratio resulted in an estimate of the dry weight of the component. The sum of the entire components represented oven-dried weight or biomass of the bamboo species. Then total stand biomass for *B. vulgaris* was determined and then computed on a hectare basis. Total aboveground dry weight of the culm is the sum of the dry weight of the components, which is;

$$\text{Component dry weight (kg/culm)} = \frac{\text{Total fresh weight (kg)} \times \text{Subsample dry weight (g)}}{\text{Subsample fresh weight (g)}}$$

$$\text{Aboveground biomass density (t ha}^{-1}\text{)} = \frac{\text{Average dry weight (kg/culm)} \times \text{no.of culms (g)}}{\text{(1000) hectare}}$$

Root biomass was not sampled destructively due to its difficulty and cost; instead, an already established method of below ground biomass estimation for bamboo species was used. Below ground biomass (BGB) of each culm was estimated from the aboveground biomass (AGB) by multiplying it with a factor of 0.27 (root/shoot ratio) described by Darcha and Birhane (2015):

$$\text{BGB per culm} = 0.27 \times \text{AGB culm}^{-1}$$

Determination of Carbon content in the above and belowground biomass of *B. vulgaris*

Oven-dried ground samples were taken (2.00 g) in pre-weighted crucibles. The crucibles were positioned in the furnace at 550°C for one hour and were cooled slowly inside the furnace. After cooling, the crucibles with ash were weighted and the percentage of organic carbon was calculated as Allen *et al*. (1986)

$$\text{Ash (\%)} = \frac{(w3 - w1)}{(w2 - w1)} \times 100$$

C (%) = (100−Ash %) × 0.58 (considering 0.58% carbon in ash free stem, branch and foliage materials). where C is the organic carbon, W1 the weight of crucibles, W2 the weight of oven dried grind samples + Crucibles, W3 is the weight of ash + Crucibles. Therefore,

$$\text{C stored (t C ha}^{-1}) = \text{Total dry weight} \times \text{C content}$$

The total carbon storage in the above ground standing biomass was obtained by summing the carbon concentration values of leaf, twig and culm components.
Belowground carbon was calculated, where conversion to carbon was based on coefficient of IPCC (2006) which is;

$$\text{C(BGB)} = \text{Biomass} \times 0.47$$

Soil Sampling and Analysis

In each of the 625m^2 sampling plot, soil samples were obtained within a 0.5m x 0.5m subplot at 0-30 cm depth from the soil surface. Three subplots were randomly selected. Soil samples taken from 3 subplots quadrat were mixed to have a composite sample; 500 g soil sample were taken for carbon content analysis. The soil samples were air-dried and oven dried at 105°C for 72 hours. The soils were sieved through a 5mm mesh screen to separate other components and mixed to get a uniform color and consistency. Soil samples were brought to International Institute of Tropical Agriculture (IITA), Ibadan for soil organic carbon (SOC) determination using Walkley-Black method (Mac Dicken, 1997) and for bulk density by oven drying method.

Bulk density was determined by collecting undisturbed soil from the site using soil corer with a known volume of 224.24 cm^3. The weight of Soil Organic Carbon (SOC) per hectare was obtained using Patricio and Tulod, 2010 formula;

$$\text{Carbon density (t C ha}^{-1}) = \text{weight of soil} \times \text{SOC (\%)}$$

Where: Weight of soil (Mg) = BD (bulk density) x volume of 1 hectare

Therefore, BD (g/cm^3) = Oven - dried weight of soil/Volume of soil core

V (volume of soil core) = 224.24 cm^3

Volume of 1 ha = 100m ×100m × 0.30m

Statistical Analysis

The descriptive statistics were used such as mean, percentage in comparing biomass density, biomass carbon stored and soil organic carbon stored. Analysis of variance (ANOVA) and Fisher's Least Significant Difference (LSD) post-hoc test were used to determine significant differences in the means of the different carbon pools in this study. Simple linear regression method was used to develop the equation for the estimation of biomass and biomass organic carbon content of the bamboo stands in the secondary forest. All tests were performed using R version 3.4.1 package of the R Foundation for Statistical computing.

RESULTS

Stand structure of *Bambusa vulgaris* in the Secondary forest

The average number of clumps, encountered per plots where the *Bambusa vulgaris* stands are located in the secondary forest was three. The number of culms per plot ranged from 31-58 with mean value of 46 culms per clump of the stands in the secondary forest (Table 1). The height of sampled culms of *Bambusa vulgaris* stands ranged from 19.50±0.17m-21.50±0.34m with mean values of 20.29±0.24m (Table 1). Diameter at breast height ranged from 0.08±0.01 m - 0.11±0.01 m with mean values of 0.1±0.01m in the Secondary forest (Table 1). There were no significant differences (P>0.01) in the height and diameter at breast height (1.3m) of the sampled culms.

Aboveground and belowground biomass density of *Bambusa vulgaris* stands in the Secondary forest

The total Aboveground biomass density (t ha^{-1}) of bamboo stands ranged from 229.22-285.32, with mean value of 257.81 (Table 2). Of the bamboo component; the order of aboveground biomass content was culm>twigs>leaves in which culms contributed 81.74%, twigs contributed 13.80% and leaves 4.46% to the aboveground biomass of the stands in the secondary forest. The total belowground biomass density in this study was; 278.44 t ha-^{1} (Table 4). The belowground biomass of the stands in the secondary forest ranged from 61.89 -77.04 t ha^{-1} with mean value of 69.01 t ha^{-1}.

Table 1. Measurement data of *Bambusa vulgaris* stands in the Secondary forest (Mean±Standard error n=10)

Plots	Number of clumps per plot	Number of culms per plot	Height of sampled culms per plot (m)	Diameter at breast height (m) of sampled culm per plot
1	3	46	19.50±0.25^{a}	0.09±0.01 ^{a}
2	2	31	21.50±0.34 ^{a}	0.08±0.01 ^{a}
3	3	58	20.09±0.17 ^{a}	0.11±0.01 ^{a}
4	3	44	20.05±0.19 ^{a}	0.10±0.01 ^{a}
Mean	3	46	20.29±0.24 ^{a}	0.1±0.01 ^{a}

*Value of the same alphabet along a column are not significantly (P > 0.01) different using Fisher's LSD.

Table 2. Aboveground biomass density of *Bambusa vulgaris* stands in the Secondary forest.

Aboveground bamboo component	**Average dry weight of 10 culms sampled in each component (kg) per plot**				**Stand density**	**Aboveground biomass density ($t\ ha^{-1}$)**			
	Plot 1	2	3	4		Plot 1	2	3	4
Culm	53.5	50.80	52.35	53.4	17,900	186.62	197.86	224.15	234.36
Twigs	9.87	8.89	9.80	9.82	17,900	31.10	33.25	38.50	39.54
Leaves	3.48	3.42	3.54	3.33	17,900	11.5	10.85	12.11	11.42
Total	66.85	63.11	65.69	66.55	17,900	229.22	241.96	274.76	285.32
Mean	65.55					257.82			

Table 3. Mean carbon stored in the aboveground biomass density of *Bambusa vulgaris* stands in the Secondary forest

Aboveground bamboo component	**Aboveground Carbon density ($t\ C\ ha^{-1}$)**			
	Plot 1	2	3	4
Culm	111.26	110.02	125.75	125.27
Twigs	13.82	14.01	15.40	18.20
Leaves	5.2	5.51	4.85	5.50
Total	130.29	129.54	146.00	148.97
Mean	138.70			

Mean carbon stored in the soil, aboveground and belowground biomass density of *Bambusa vulgaris* stands in the secondary forest

The carbon stored ($t\ C\ ha^{-1}$) in the aboveground biomass density of bamboo stands ranged from 129.54-148.97 with mean values of 138.70 (Table 3). The carbon stored ($t\ C\ ha^{-1}$) in the belowground biomass density ranged from 29.09-36.21 with mean values of 32.72 (Table 4). Among the bamboo components studied, carbon was stored most in the culm (85.13%) than the other fractions; twigs (11.07%) and leaves (3.8%). The carbon stored ($t\ C\ ha^{-1}$) in the soil of bamboo stands ranged from 54.39-89.28 with mean values of 66.52 (Table 5). The bulk density was relatively close to each other per plot, ranged from 0.69-0.93gcm^{-3}(Table 5). The mean value of organic carbon in the soil was 2.90% (Table 5). While comparing soil bulk density and organic carbon percent a significant correlation ($p=0.01$) was found of that soil in the study site. We obtain a positive correlation ($r=0.79$) between bulk density and organic matter of soil samples. Our study indicated a direct relationship between soil bulk density and organic carbon content.

Table 4. Mean carbon stored in the belowground biomass density (t C ha $^{-1}$) of *Bambusa vulgaris* stands in the Secondary forest.

Plots	Mean below biomass density (t ha^{-1}) (AGBD*0.27)	Mean Annual belowground Carbon density (t C ha^{-1}) (BGBD*0.27)
1	61.89	29.09
2	65.32	30.70
3	74.19	34.87
4	77.04	36.21
Total	278.44	130.87
Mean	69.61	32.72

Table 5: Carbon stored in the soil of *Bambusa vulgaris* stands in the Secondary forest.

Plots	Bulk density (gcm^{-3})	Weight of soil (t)	Carbon content (%)	Soil carbon stored (t C ha^{-1})
1	0.93	2790	3.20	89.28
2	0.70	2100	2.59	54.39
3	0.72	2160	2.84	61.34
4	0.69	2070	2.95	61.07
Mean	0.76	2280	2.90	66.52

Total Carbon stock of *B. vulgaris* stands in the Secondary forest

The total carbon stored was 237.94 t C ha^{-1} with 138.70 t C ha^{-1} stored in the aboveground biomass; 32.72 t C ha^{-1} in the belowground biomass and 66.52 t C ha^{-1} in the soil (fig. 2). There were significance differences ($p>0.01$) in the total carbon stored with the aboveground carbon significantly higher than the others (belowground and soil carbon stored). It was in the order: Aboveground C > Soil C > belowground C in which the aboveground, soil and belowground contributed 58.29%, 27.96% and 13.75%, respectively, to the total carbon stock of *B. vulgaris* stands in the secondary forest.

Regression equations for the estimation of biomass and organic biomass carbon content of ~60 years old *B. vulgaris* stands

By regressing, the total biomass organic carbon (Y) against the corresponding green biomass of bamboo(X), a regression model was obtained on which predictions of the biomass organic carbon can be made. Hence, the simple linear regression equation for biomass organic carbon estimation on the basis of DBH and height would be,

$$Y= 245.389 + 131.714 (D^2H) \text{ where } r^2= 0.84$$

Here, Y= biomass (kg), D=DBH (m), H=Height (m).

From the equation r^2 value of 0.84, is an indication that the performance of the model is statistically valid for biomass organic carbon estimation.

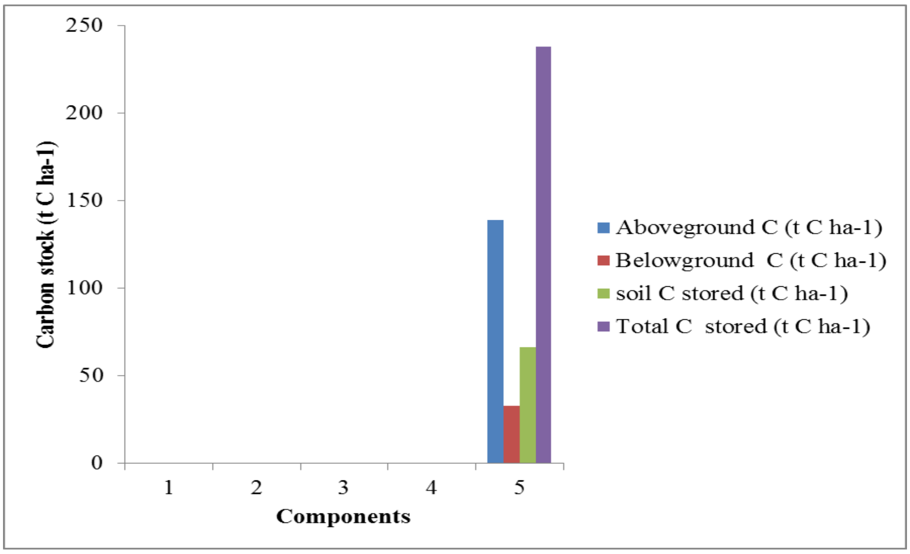

Figure 2: Total Carbon stock of *Bambusa vulgaris* stands in the Secondary forest

DISCUSSION

The height range in this study is consistent with the findings of Ohrnbeger 1999; Rao *et al.*, (1998) and Sohel *et al.*, (2015) who outlined that the height range of *Bambusa vulgaris* lies within 10-20m. Diameter at breast height range is consistent with the findings of Rao *et al*., (1998). Zhou (1983) asserted that there is no increase in size with age once the growth in height of bamboo species has attained full maturity.

The mean aboveground biomass density of *B. vulgaris* stands in the secondary forest compares favorably within the range of 122-287 t ha^{-1} reported by Shanmughavel and Francis (1996) for *Bambusa bamboos* in India and Pongon *et al*., (2015) for *Dendrocalamus asper* plantations in Northern Mindanao, Philippines. However, this was greater than; 110 t ha^{-1} reported by Embaye *et al*., (2005) for bamboo species in Masha forest, Ethiopia; 97.6 t ha^{-1} for 5 years old *B. vulgaris* stands by Sohel *et al*., (2015) in degraded tropical forests of Bangladesh; 10.4-16.2 t ha^{-1} reported by Agarwal and Purwar (2012) for *B. vulgaris* stands in mid Himalayan region, India and 106 t ha^{-1} reported by Uchimura (1978) for *B. vulgaris* stands in tropical bamboo forests in Philippines and 61.05 t ha^{-1} reported by Nath *et al*., (2008) for 4 years old bamboo plantation (*B. cacharensis*, *B. vulgaris* and *B. balcooa*) in India.

The percentage contribution of culm to the aboveground biomass content falls within the percentage recorded by Sohel *et al*., (2015) and Pongon *et al*., *(*2016) for *Bambusa vulgaris* and *Dendrocalamus asper* respectively. The order of aboveground biomass content culm > twigs > leaves is consistent with the findings of several authors (Pongon *et al*., 2016; Patrico and Dumago 2014; Reyes and Luderese 2015; Shanmughavel *et al*., 2015; Sohel *et al*., 2015). The total belowground biomass density in this study compares favorably with 71.33 t ha^{-1} reported by Pongon *et al*., (2016) for *D. asper*, however higher than values reported by Isagi (1994), Bijaya (2008) and Sohel *et al*., (2015) for belowground biomass of *Phyllostachys bambusoides*, *D. strictus* and *B. vulgaris* respectively in tropical and subtropical regions. The higher stand density per hectares of bamboo stands (17900), age of the bamboo stands, differences in seasonality of the locations could have accounted for the high values of biomass content observed in this study compared to most other studies.

The mean carbon stored in the aboveground component of the bamboo stands in the secondary forest compares favorably with the findings of Pongon *et al.* (2016) and Zaragoza *et al*., (2016) for *D. asper* and *Swietenia macrophylla* in Philippines. While, same study of Uchimura (1978), Agarwal and Purwar (2012) and Sohel *et al*., (2015) of *B. vulgaris* expressed lower carbon density as compared with the present study with mean values of (t C ha^{-1}) 53.00, 5.20 and 50.44 respectively.

The carbon stored (t C ha^{-1}) in the belowground biomass density compares favorably with the belowground carbon stored reported by Patrico and Dumago (2014) and Pongon *et al*., (2016) for *B. vulgaris* and *D. asper* respectively in Philippines. However, values obtained from the present study were higher than those reported by Isagi (1994); Bijaya (2008) and Sohel *et al*., (2015) for *P. bambusoides, D. strictus* and *B. vulgaris* stands respectively in tropical and subtropical regions. The age, species type and obviously the high biomass content must have accounted for the larger carbon stored compared to most studies and this conforms with the assertion made by Tulod (2015) and Pongon *et al*., (2016) that the amount of carbon stock is usually dependent on the biomass content of the bamboo stands.

Among the bamboo components studied, carbon was stored most in the culm (85.13%) than the other fractions; twigs (11.07%) and leaves (3.8%). This conforms with the findings of Uchimura (1978) and Sohel *et al*. (2015) for *B. vulgaris* and reports from several authors for different species of bamboo (Kumar *et al.*, 2005; Nath *et al*., 2008; Singh and Singh, 1999; Patrico and Dumago 2014; Pongon *et al*., 2016; Quiroga *et al.*, 2013, Shanmughavel *et al*., 2015) in tropical and subtropical regions. The study of Isagi (1994); Isagi *et al.*, (1997); Bijaya (2008) and Ly *et al.*, (2012) on bamboo species (*P. bambusoides, P. pubescens, D. strictus* and *D. barbatus*) respectively, showed higher soil organic carbon compared to the present study. This may be attributed mainly to environment factors (soil type and climates). It was observed that these different species had higher soil carbon but lower aboveground carbon compared to *B. vulgaris* stands in this study.

However, the soil carbon storage of the stands in the secondary forest falls within the range reported by Tariyal *et al*., (2013) for *B. vulgaris* in North India and different species of bamboo (Fu *et al.*, 2013; Pongon *et al*., 2016). The soil of *B. vulgaris* stands in the secondary forests had higher carbon storage than 24.71 t ha^{-1} and 53.3 t ha^{-1} reported by Sohel *et al*., (2016), Tripathi and Singh (1996) for *B. vulgaris* (5 years old) and *D. barbatus* in Bangladesh and Vietnam respectively. The age obviously had accounted for this higher value, as it tends to influence high litter production (Borisade, 2015), increasing the organic carbon content of the soil, invariably, reflecting higher soil organic carbon of *B. vulgaris* stands observed and this is in conformity with the assertion made by Pongon *et al*., (2016) and Hosur and Dasog (1995). Divergence of soil organic carbon could be influenced by differences in soil type, soil organic matter, bamboo species, climate disturbance and land use practices (Pongon *et al*., (2016) as well as soil weight, age and litter production. The mechanisms and process of carbon sink in soil has not been fully comprehended (Bajracharya *et al*., 1998; Lal *et al*., 1995).

The positive correlation between bulk density and organic carbon/matter is consistent with the findings of Leifeld *et al*., (2005) and Catherine and Ouimet (2008) However, Curtis and Post (1964); Sohel *et al*., (2015) reported reverse correlation between bulk density and organic carbon/matter. The high amount of litter falls, moisture content, clay content and slightly acidic content of soil of the bamboo stands in the regenerating secondary forest might have resulted in the positive correlation observed between bulk density and organic carbon/matter (Borisade and Odiwe, 2018). It is noteworthy that negative correlation between bulk density and organic carbon/matter was observed in other area where the stands are not situated in same secondary forest (Borisade, 2015).

The total carbon stock was higher than the 77.67 t C ha^{-1} reported by Sohel *et al.*, (2015) for *B. vulgaris* in Bangladesh and other bamboo species reported by several authors (Isagi 1994, INBAR, 2009; Khan, 2009; Zhou and Jiang, 2004). This compares favorably with the values of total carbon stock for *D. strictus* reported by Bijaya (2008) in Nepal and 60 years *P. pubescens* plantation reported by Lou *et al*. (2010) in china. The order: Aboveground C > Soil C > belowground C of bamboo species is consistent with the findings of Sohel *et al.*, (2015) but contradicts the findings of several authors (Bijaya, 2008; Isagi, 1994; Pongon *et al*., 2015; Tripathi and Singh, 1996; Zhuang *et al*., 2015) for different bamboo species in which soil yielded the highest C stored in tropical and subtropical regions. The nature of the bamboo species might have accounted for this observation. The age, biomass and environmental factors (climate and soil) are some potent factors responsible for the observed variations.

The total carbon stock of *B. vulgaris* when compared with those of five dominant tree species, was found to have lower carbon stock (t C ha^{-1}) than that of *Celtis zenkeri* (391.10±35.32), but higher than values of 160.98±16.56, 108.98±9.36, 92.45±9.51 and 47.15±4.01 for *Holarrhena floribunda, Funtumia elastica, Newbouldia laevis* and *Sterculia tragacantha* respectively as reported by Alimi (2015) in same secondary forest, Ile-Ife. It was also higher than 20.08 ± 0.20 and 8.10 ± 0.05 in a ten year *Tectona grandis* plantation and degraded secondary forests respectively reported by Odiwe *et al.*, (2012) in Ile-Ife. It was greater than values of 157 t C ha^{-1} and 66-88 t C ha^{-1} reported for agroforestry system by Duguma *et al.*, (2001) and Egbe *et al.*, (2012) respectively in Cameroon.

CONCLUSIONS

The carbon stock of bamboo stands in the secondary rainforest was estimated for the first time, thirty-four years after the ground fire that ravaged in 1983. Results from this study indicated that the total carbon stored in the aboveground component was significantly higher than soil and belowground components. It sequestered ~32.22 t C ha^{-1} yr^{-1} which was more when compared with the result of five dominant tree species earlier reported in same area and other studies from agroforestry systems in tropical Africa and most bamboo species in some tropical and subtropical countries.

This study has served as baseline for future studies on carbon stock and sequestration potentials of bamboo species in tropical Africa especially Nigeria, where there is paucity of information on this subject. We therefore, recommend that the stands should be properly managed to prevent indiscriminate harvesting as it is found to play an important role in the functioning of the forest ecosystem. The result from the study had shown that it could play a prominent role in sinking carbon than most dominant tree species to mitigating adverse effect of climate change in same secondary forest and this is indicative in the high amount of biomass and carbon stored in the aboveground component.

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