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TREE-BASED CARBON SEQUESTRATION AND STORAGE ABILITIES VARY IN NATURAL AND PLANTATION FOREST ECOSYSTEMS

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ABSTRACT
Little is known about the relevance of natural forests and plantations in the wake of global warming and climate change. Understanding the impacts of land use conversion from natural forests to plantations on carbon sequestration and storage is critical for sustainable land and forest management. In this study, tree-based carbon sequestration and storage abilities were assessed in natural and plantation forest ecosystems. Four plots within a natural forest and cashew orchard were randomly chosen and four belt transects were established. In each plot, tree species were identified and their density, height, Diameter at Breast Height (DBH) enumerated and measured, respectively. In each plot, litter boxes were placed to collect litter weekly. Soils (at 0 -15 cm and 15 – 30 cm) within each plot were obtained with soil auger. AGB (aboveground biomass), BGB (belowground biomass), AGC (aboveground carbon) and BGC (belowground carbon) were calculated using allometric equations for pan moist and dry tropical forest. Twenty-three and eleven tree species were found in the forest and orchard, respectively. The forest had the largest total biomass allocation (188.61 Mg ha^{-1}) and carbon stock (146.89 Mg $C.ha^{-1}$) while the orchard had the least total biomass apportionment (37.20 Mg ha^{-1}) and carbon stock (45.60 Mg ha^{-1}). The forest ecosystem had the largest sequestration ability (593.04 Mg CO_2ha^{-1}) which followed this trend: aboveground (295.18 Mg CO_2ha^{-1}) > belowground (60.51 Mg CO_2ha^{-1}) > soils (133.73 Mg CO_2ha^{-1}) > litter (49.62 Mg CO_2ha^{-1}) while cashew orchard had the least sequestration ability (167.37 Mg CO_2ha^{-1}) which followed this order: soil (99.09 Mg CO_2ha^{-1}) > litter (35.75 Mg CO_2ha^{-1}) > aboveground (27.00 Mg CO_2ha^{-1}) > belowground (5.53 Mg CO_2ha^{-1}). From these results, land use change affects carbon budgets of ecosystems, hence, this study argues for protection of natural forest while practicing afforestation towards global warming mitigation.

Keywords: Global warming, Climate change, Land use change, Afforestation, Deforestation, Biomass, Carbon pools

INTRODUCTION
Forests are fundamental to the well-being and sustainability of humanity. They provide the basis for life ecologically furnishing humans with a wide range of essential goods and services (Carandang, 2005). Forest trees play essential role in reducing carbon in the atmosphere. They are storehouses for carbon dioxide (CO_2) by capturing and storing carbon to form biomass (Qiu *et al*., 2020). Forests are recognized as a major terrestrial carbon reserve which covers nearly 4.1 billion global hectares and sequesters large quantity of carbon both in above and belowground biomasses (Dixon and Wisniewski, 1995). The storage of carbon in forest ecosystems is strongly affected by stand age, climate, disturbance regimes, edaphic factors and forest type (Pregitzer and Euskirchen, 2004). Furthermore, various components of the ecosystem like soil, vegetation and detritus, vegetation respond differently to variations in these regulatory factors (Law *et al.*, 2003; Martin *et al.*, 2005; Pregitzer and Euskirchen, 2004).

Due to climate change and increased anthropogenic activities and perturbations, the patterns and processes of several ecosystems at various scales are driving concerns about the carbon sequestration potential of these ecosystems (Rodríguez-Echeverry *et al*., 2018; Li *et al*., 2020). Explicitly, the forest ecosystem is an important source of carbon sequestration, as it accumulates almost 40 percent of the terrestrial biomass carbon (Dixon *et al*., 1994; Qiu *et al*., 2020). Nonetheless, in recent epochs, forest decimation and land use changes are recurring incidences evidenced most especially in natural ecosystems causing severe loss of global carbon reserves (Carandang, 2005). Plantation forests, however, are being recognized by global change researchers as an important resource, to balance the global carbon cycle and regulate climate change (Nery *et al*., 2019). These conversions of natural forests to plantations stem from increasing human population which trigger the need to meet increasing food demands. Deforestation and conversion of natural forests to plantation ecosystems affect carbon stock. Although anthropogenic woody plantations may have a lower biodiversity than natural forests, they will sequester CO_2 from the atmosphere into plant biomass and the soil (IPCC, 2001). According to the IPCC (2001), approximately 700 Mha of forestland and 345 Mha of plantations and agroforestry exist worldwide. Projections have it that land has the potential to sequester up to 319 Gt C by 2050 in global forests, while the mitigation potential of plantations could reach a maximum rate of 2.2 Gt C yr^{-1} (IPCC, 2001; Metz *et al*., 2007). In as much as plantation forests offer a potential store of carbon, uncertainties still remain regarding its carbon storage capacity when compared to natural forests (Liao *et al*., 2010). Information and data on carbon storage and sequestration in diverse plantation and natural forests are lacking. Hence, assessing the dynamics of various plantation and natural forests' distribution and their contribution to carbon storage is increasingly vital for developing future land-use policies, to minimize the tradeoffs between climate change mitigation and food security, especially in low-income developing countries.

MATERIALS AND METHODS

Study Area

This study was conducted in natural (a forest) and plantation (a cashew orchard) ecosystems in Akwa Ibom State, Nigeria. Their specific coordinates are shown in Table 1. The forest ecosystem is located in Ikot Efre Itak in Ikono Local Government Area of Akwa Ibom State between latitudes 4° 30` and 5° 30' N and longitudes 7° 31` and 8° 20' E. It is an evergreen forest fragment with an area of 3.2 ha managed by the Ikot Efre Itak community as a sacred grove. The average yearly rainfall of the state is between 2400 mm and 3000 mm. The average minimum and maximum temperature are 26 ºC and 30.5 ºC, respectively, while the mean relative humidity of the area is about 83%. The forest is only accessed through the consent of the village council who gives such permission. The forest is diverse in terms of plant species. At the moment, several human perturbations such as infrastructural encroachments, logging and unregulated species exploitation are dominant in and around the forest.

The cashew orchard is located along Uyo village road in Uyo Local Government Area of Akwa Ibom State within latitude 5º 17' N – 5º 25'N and longitude 7º 3' E – 7º 58' E. Uyo is geographically bounded on the East by Uruan Local Government Area, Abak Local Government Area in the West, Ibiono Ibom Local Government Area in the North and Ibesikpo Asutan Local Government Area by the South. The area is characterized by a tropical climate with minimum and maximum temperatures of 20.56 °C and 30.56 °C. The yearly rainfall averages 2509 mm. This orchard is proximal to the main road. The area has sparse human settlements with an undulating topography.

Vegetation Sampling and Carbon Analysis in Litter and Soils

Four plots within the forest and orchard were randomly chosen for this study. In each of the plot, four belt transect were established. The soil and vegetation (tree species) were sampled systematically with a 10 m x 10 m quadrat at a spacing of 10 m along the established belt transect. Tree species were identified and their parameters such as densities, height and Diameter at Breast Height (DBH) were enumerated and measured, respectively. For the density, each tree species density was determined by enumeration in the respective plots using the procedures of Cochran (1963). The number of individuals of each tree species was expressed as a proportion of the transect number to give the mean of each species. This mean value was then expressed in relation to the quadrat area to give rise to density (in m^2) which was further multiplied by 10, 000 to yield density in stems per hectare (st/ha). The heights of tree species were measured with a haga altimeter. For trees that had odd shapes or were bent, an estimation of the height was done. The DBH of tree species (in cm) was measured using a girthing tape at 1.3 m above ground level.

Collection, Analysis and Carbon Stock in Litter Samples

In each chosen plot, litter boxes were placed at every distance of 20 m to collect litter weekly. The collected litter samples were sorted into various components, leaves, twigs and fine roots while other parts like fruits and trash were discarded. The litter were pooled for each plot based on the sorted parts, stored in ziplock bags and taken for carbon content analysis in the laboratory. In the laboratory, the litter (leaves, twigs and fine roots) were placed in an oven to dry at 80°C to achieve a constant weight. The samples were pulverized and analyzed for organic carbon using the Loss on Ignition (Dean 1974). The biomass of the litter was obtained through the multiplication of the carbon amount with the dry weight. The carbon stock in the litter was obtained by multiplying the estimates of organic carbon with 0.47 (a conversion factor) (IPCC 2006).

Carbon Stock in the soil

Soil samples were collected at two distinct depths (0 to 15 and 15 to 30 cm) from each established transect using a soil auger. Soil samples from the same plots were bulked into composite samples, stored in labeled ziplock bags and transported to the laboratory for analysis. In the laboratory, the soil samples were air-dried before analysis. Using Walkley Black method (Black *et al.*, 1965), the organic carbon in the soil was determined. The bulk density of the soil was derived as the ratio of the mass of oven-dried sample to its volume. The stock of carbon in the soil was calculated from the formula of Ehrenbergerová *et al*. (2016) as shown below :

$$\text{Soil Carbon} = C_{ox} \times BD \times SD$$

Where, C_{ox} = oxidative carbon amount or content (%), SD = Soil depth (cm) and BD = Bulk density of soil ($g.cm^{-3}$)

Biomass and Carbon Stock Estimation in Vegetation

Since this study did not adopt a destructive sampling technique for the vegetation, allometric equations for pan moist and dry tropical forest by Brown *et al*. (1989) was used in calculating the AGB of each woody species as shown in the formula below:

$$\text{Above ground biomass (mg)} = \exp(-3.11+0.97 \ln(dbh^2 H)$$

Where dbh = diameter at breast height (cm) and H = Tree height (m)

The BGB of woody species was determined using the ratios of root to shoot formulae of Mokany *et al*. (2006) below:

If $AGB \leq 125$ Mg ha^{-1} then, $BGB = 0.205 \times AGB$

If $AGB > 125$ Mg ha^{-1} then, $BGB = 0.235 \times AGB$

Where AGB = Aboveground biomass and BGB = Belowground biomass

The amount of carbon in the individual trees was expressed as 50 % of the aggregate of above and below ground biomasses (IPCC 2006).

The stock of carbon in the belowground of tree species was calculated using the formulae of Liu *et al*. (2014) below:

If $AGC \leq 62.5$ Mg ha^{-1}, then $BGC = 0.205 \times AGC$

If $AGC > 62.5$ Mg ha^{-1}, then $BGC = 0.235 \times AGC$

Where;

BGC = Belowground carbon and AGC = Aboveground carbon

Carbon Sequestration Ability of the Ecosystems

In assessing the ecosystems' ability to sequestrate carbon, the sum total of the carbon stock across the various pools was converted to carbon dioxide (CO_2) by multiplying with the atomic mass quotient of CO_2 to C ($^{44}/_{12}$) (Justine *et al.*, 2015).

Statistical Analysis

The means and standard errors of replicates were computed with Graphpad Prism 9.0.

RESULTS

Tree Species Composition of the Ecosystems

The tree species composition of the forest is presented in Table 1. Twenty tree species were found in this forest. *Afzelia africana* had the highest density (190.00 ± 15.30 st/ha) while *Erythrophleum ivorensis* (10.00 ± 0.80 st/ha), *Guara cedrata* (10.00 ± 1.10 st/ha) *Coula argentea* (10.00 ± 1.03 st/ha), *Alstonia boonei* (10.00 ± 1.00 st/ha), *Coula edulis* (10.00 ± 1.00 st/ha), *Piptadeniastrum africanum* (10.00 ± 1.02 st/ha), *Pycnanthus angolensis* (10.00 ± 1.68 st/ha) and *Khaya senegalensis* (10.00 ± 3.00 st/ha) had the least density values. In terms of height, the tallest and shortest species were *Berlinia confusa* (19.03 ± 3.05 m) and *Anthonatha macrophylla* (2.61 ± 0.30 m), respectively. For the DBH, *Khaya ivorensis* had the largest value of 8.84±1.11 cm while *Maesoboytra dusenii* had the least value of 0.35±0.07 cm.

In the cashew orchard (Table 2), eleven tree species were encountered. *Anacardium occidentale* had the highest density of 166.67±6.32 st/ha while *Acacia auriculiformis* (33.33±2.21 st/ha) *Anthocleista vogelli* (33.33±1.97 st/ha), *Anthonatha macrophylla* (33.33±1.90 st/ha), *Barteria nigritiana* (33.33±2.00 st/ha), *Entandrophragma utile* (33.33±2.10 st/ha), *Harungana madagascariensis* (33.33±1.90 st/ha) and *Rauvolfia vomitoria* (33.33±1.98 st/ha) had the least density values. The tallest and shortest species were *Pentaclethra macrophylla* (9.00±2.36 m) and *Anthocleista vogelli* (1.20±0.03 m), respectively. *Anacardium occidentale* had the largest DBH (6.01±1.24 cm) while *Rauvolfia vomitoria* (0.25±0.05 cm) had the least DBH value.

Table 1: Tree species composition of the forest ecosystem

Species	Family	Density (stems/ha)	Height (m)	DBH (cm)
Afzelia africana Sm. ex Pers.	Fabaceae	190.00 ± 15.30	5.62 ± 0.63	3.65±0.82
Alstonia boonei De Wild	Apocynaceae	10.00 ± 1.00	4.57 ± 0.05	1.42±0.04
Anthonatha macrophylla P. Beauv.	Fabaceae	30.00 ± 1.54	2.61 ± 0.30	0.50±0.01
Bambusa vulgaris Schrad. Ex Wend	Poaceae	90.00 ± 10.82	5.59 ± 0.29	1.59±0.21
Barteria nigritiana Hook. f	Passifloraceae	30.00 ± 2.81	6.97 ±0.29	2.10±0.43
Berlinia confusa Hoyle	Leguminosae	20.00 ± 1.11	19.03 ± 3.05	6.34±1.02
Calamus deeratus Mann and Wendl	Arecaceae	175.00 ± 16.00	6.31 ± 0.63	0.97±0.03
Cannarium schweinfurthii Engl.	Burseraceae	40.00 ± 6.01	4.30 ± 2.00	2.27±0.24
Coelocaryon preusii Warb.	Myristicaceae	30.00 ± 3.17	14.36 ± 3.83	2.01±0.36
Cola argentea Mast.	Sterculiaceae	10.00 ± 1.03	5.87 ± 0.28	6.34±0.99
Coula edulis Baill.	Olacaceae	10.00 ± 1.00	15.50 ± 5.12	7.15±1.08
Elaeis guineensis Jacq.	Arecaceae	35.00 ± 4.51	7.20 ± 0.39	5.25±0.74
Erythrophleum ivorense A. Chev.	Fabaceae	10.00 ± 0.80	6.23 ± 2.10	2.97±0.14
Guarea cedrata (A. Chev.) Pellegrin	Meliaceae	10.00 ± 1.10	5.21 ± 1.00	5.48±0.69
Khaya ivorensis A. Chev.	Meliaceae	20.00 ± 3.01	8.50 ± 2.50	8.84±1.11
Khaya senegalensis (Desr.) A.Juss.	Meliaceae	10.00 ± 3.00	4.15 ± 0.73	7.44±1.06
Maesoboytra dusenii (Pax) Hutch.	Euphorbiaceae	52.00 ± 7.80	3.14 ± 0.08	0.35±0.07
Mansonia altissima (A.Chev.) A.Chev.	Malvaceae	50.00 ± 7.50	10.57 ± 1.80	2.99±0.52
Musanga cecropioides R. Br	Papilionaceae	30.00 ± 3.20	11.69 ± 5.54	2.63±0.60
Pentaclethra macrophylla Benth	Fabaceae	80.00 ± 7.50	9.88 ± 3.50	6.79±1.01
Piptadeniastrum africanum Hook.f	Leguminosae	10.00 ± 1.02	14.20 ± 3.21	2.10±0.41
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	10.00 ± 1.68	8.58 ± 0.05	5.03±0.65
Synsepalum dulcificum (Schum and Thonn.) Daniell	Sapotaceae	20.00 ± 2.01	12.68 ± 4.01	2.53±0.12
Total		**972**		**86.74**

Table 2: Tree species composition of the cashew orchard

Species	Family	Density (st/ha)	Height (m)	DBH (cm)
Acacia auriculiformis A.Cunn. ex Benth.	Fabaceae	33.33±2.21	7.50±0.15	0.50±0.03
Anacardium occidentale L.	Anacardiaceae	166.67±6.32	7.00±0.13	6.01±1.24
Anthocleista vogelli Afzel. Ex R.Br.	Gentianaceae	33.33±1.97	1.20±0.03	0.21±0.01
Anthonatha macrophylla P Beauv.	Fabaceae	33.33±1.90	3.00±0.23	0.42±0.05
Barteria nigritiana Hook. f.	Passifloraceae	33.33±2.00	3.60±0.02	0.94±0.06
Dracaena arborea (Willd.) Link	Dracaenaceae	66.67±4.00	4.00±0.00	0.30±0.01
Elaeis guineensis Jacq.	Arecaceae	66.67±4.30	6.10±0.12	4.30±0.99
Entandrophragma utile Dawe & Sprague	Meliaceae	33.33±2.10	5.00±0.41	0.20±0.81
Harungana madagascariensis Lam. Ex Poir.	Hypericaceae	33.33±1.90	3.00±0.20	4.10±0.97
Pentaclethra macrophylla Benth.	Fabaceae	66.67±3.00	9.00±2.36	1.30±0.06
Rauvolfia vomitoria Afzel.	Apocynaceae	33.33±1.98	4.50±1.20	0.25±0.05
Total		**599.99**		**18.53**

Carbon Pool Distribution in Natural and Plantation Forest Ecosystems

The distribution of carbon in various pools of the natural and plantation forest ecosystems is presented in Table 3. For the vegetation pool, the forest ecosystem had the largest AGB (160.86 Mg ha^{-1}), AGC (80.43 Mg $C.ha^{-1}$), BGB (32.97 Mg ha^{-1}) and BGC (16.488 Mg $C.ha^{-1}$) while the orchard had the least AGB (14.713 Mg ha^{-1}), AGC (7.3565 Mg $C.ha^{-1}$), BGB (3.0226 Mg ha^{-1}) and BGC (1.508083 Mg $C.ha^{-1}$). For the litter pool, the forest ecosystem also had the largest biomass in leaf (15.52±2.30 Mg ha^{-1}), twig (9.15±0.35 Mg ha^{-1}) and fine root (3.08±0.15 Mg ha^{-1}) while the cashew orchard had the least biomass values in leaf (10.23±1.52 Mg ha^{-1}), twigs (6.24±1.10 Mg ha^{-1}) and fine root (2.99±0.08 Mg ha^{-1}). The forest ecosystem also had the largest carbon stored in the leaf (7.52±0.14 Mg ha^{-1}), twigs (4.46±0.20 Mg ha^{-1}) and fine root (1.54±0.04 Mg ha^{-1}) while the orchard had the least carbon stored in the leaf (5.12±0.47 Mg C.ha^{-1}), twig (3.12±0.06 Mg C.ha^{-1}) and fine root (1.50±0.01 Mg C.ha^{-1}). For the soil pool, the forest also had the largest carbon stored in soil depth for 0 – 15 cm (25.19±5.20 Mg C.ha^{-1}) and 15 – 30 cm (11.25±2.50 Mg C.ha^{-1}) while the orchard had the least carbon stored in soil depth for 0 – 15 cm (19.32±4.65 Mg C.ha^{-1}) and 15 – 30 cm (7.68±1.15 Mg C.ha^{-1}).

Carbon Sequestration Ability of the Ecosystems

The carbon sequestration ability of the ecosystems is presented in Figure 1. The forest ecosystem had the largest carbon sequestration ability for the aboveground (295.18 Mg CO_2ha^{-1}), belowground (60.51 Mg CO_2ha^{-1}), litter (49.62 Mg CO_2ha^{-1}) and soils (133.73 Mg CO_2ha^{-1}) while the orchard had the least carbon sequestration ability for aboveground (27.00 Mg CO_2ha^{-1}), belowground (5.53 Mg CO_2ha^{-1}), litter (35.75 Mg CO_2ha^{-1}) and soils (99.09 Mg CO_2ha^{-1}). Generally, the total carbon sequestered by the forest ecosystem is 593.04 Mg CO_2ha^{-1} while that of the cashew orchard is 167.37 Mg CO_2ha^{-1}.

Table 3: Carbon pools distribution in natural and plantation forest ecosystems

S/N	Component	Vegetation Type			
		Forest		Cashew Orchard	
		Biomass (Mg ha^{-1})	Carbon stock (Mg C.ha^{-1})	Biomass (Mg ha^{-1})	Carbon stock (Mg C.ha^{-1})
1	**Vegetation (Trees)**				
	Aboveground	160.86	80.43	14.713	7.3565
	Belowground	32.97	16.488	3.0226	1.508083
2	**Litter**				
	Leaf	15.52±2.30	7.52±0.14	10.23±1.52	5.12±0.47
	Twig	9.15±0.35	4.46±0.2	6.24±1.10	3.12±0.06
	Fine root	3.08±0.15	1.54±0.04	2.99±0.08	1.50±0.01
3	**Soil**				
	0 – 15 cm	-	25.19±5.20	-	19.32±4.65
	15 – 30 cm		11.25±2.50		7.68±1.15
	Total	**188.61**	**146.89**	**37.20**	**45.60**

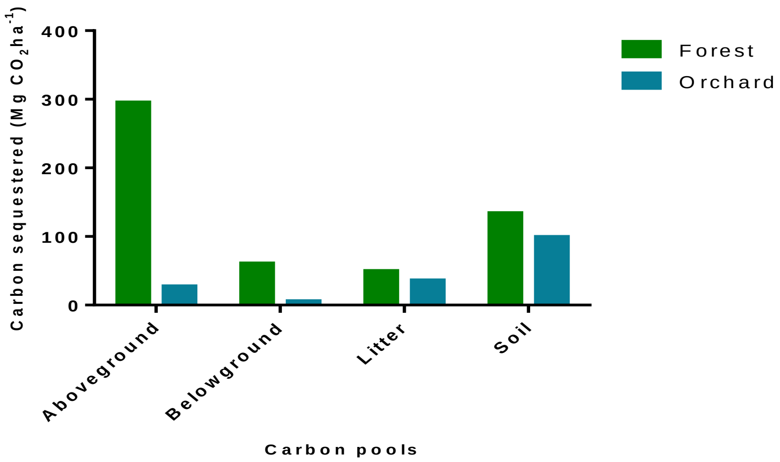

Figure 1: Carbon sequestration in various pools of the ecosystems

DISCUSSION

The floristic survey of the ecosystems showed a rich diversity of tree species, with more trees in the forest ecosystem than in the cashew orchard. This variation in tree species abundance may be linked to their adaptation abilities to fluctuations in habitats, pedological conditions, topography and human disturbances. Tree species with the highest density values in the forest and orchard may point to the suitability of the soil and environmental conditions which favored their establishment and proliferations in the ecosystem (Ogbemudia and Ita, 2016; Ita *et al*., 2019). It is germane to note that, since the forest is a community forest where human activities in and around it are monitored and regulated, the low anthropogenic disturbances such as unregulated logging of timber species might have contributed to its tree richness. Conversely, the low tree species in the cashew orchard may be allied to the size of the orchard, species preference, soil conditions, anthropogenic disturbances and management techniques. Variations in DBH and height of tree species were discernible in both ecosystems. These may be attributed to genetic variations, growth forms, site quality and differences in age of trees (Ceulemans *et al*., 1992; Swamy *et al*., 2003). Tree species with the largest and least DBH reflect their age, size and maturity stages (Krinard and Johnson, 1987). All tree species in the forest and orchard had DBH < 10 cm highlighting that these ecosystems comprise of younger trees.

Biomass allocation also differed in the ecosystems with the forest having higher values for these variables over the orchard. This result contrasts with the findings of Chen *et al*. (2016) who reported a significantly greater biomass in planted pine forest over natural pine forests. Nonetheless, this result is consistent with the findings of Pato *et al*. (2017) who reported a higher total biomass in forest (12.85 Mg ha^{-1}) than in orchard (5.38 Mg ha^{-1}). The variation in tree biomass in this study may be linked to differences in site conditions, tree density, altitude, stand age, tree size class, rainfall pattern and soil conditions (Peichl *et al*., 2006; Terakunpisut *et al*., 2007; Gairola *et al*., 2011; Justine *et al*., 2015; Arubasa and Odiwe, 2019). The high values for AGB and BGB in the forest ecosystem are connected to the high density of trees with large girths while the low values for these variables in the orchard result from low density of trees having small DBH (Gibbs *et al*., 2007; Singh, 2014; Gautam and Mandal, 2016). The above ground biomass estimated in the forest ecosystem (160.86 Mg ha^{-1}) was consistent with the range of 146 – 275 Mg ha^{-1} reported by Nasi *et al*. (2009) in a tropical forest in the Congo Basin.

The carbon stocks (AGC and BGC) in forest and orchard differed considerably due to differences in vegetation, tree density, biomass allotment, stand age (Dar and Sundarapandian, 2015; Thapa-Magar and Shrestha, 2015; Komolafe *et al*., 2020). It is worthy to note that carbon stocks in these ecosystems increased with increasing biomass. This highlights a direct relationship between biomass and carbon storage (Chanan, 2012). The large carbon storage in the forest when compared to the orchard may be ascribed to the high tree density, large DBH and height of tree species. This aligns with the report of Huston and Marland (2003) that carbon sequestration does not depend on productivity rates alone but also on the size of tree and stem proportion biomass for long term locking. Pandya *et al*. (2013) in supporting this view asserted that as the number and diameter of tree species increase, their biomass allocation, carbon sequestration rate and storage rates increase as well. The height of trees is also advantageous as it aids the removal of carbon from the atmosphere during photosynthesis. In the forest, the carbon storage followed this sequence; vegetation > soil > litter while that of the orchard followed this sequence: soil > litter > vegetation. These sequences show that carbon stock contributions vary in pools of various ecosystems (Gautam and Mandal, 2016). The high carbon stock in the vegetation pool of the forest ecosystem is related to high density of tree species with large girths and wide canopy (Gautam and Mandal, 2016). This also emphasizes trees as being the main reservoirs for carbon in the forest. The high carbon storage in the vegetation pool also points to high photosynthetic rates among trees where large amounts of carbon in the form of CO_2 are captured by plants from the atmosphere for storage and food manufacture. The low carbon stock in the litter pool of the forest agrees with the reports of Domke *et al*. (2016) and Sun and Liu (2020) that litter makes a relatively small percentage contribution regarding carbon budgets in forest ecosystems. However, the least carbon storage in the vegetation pool of the orchard is not far-fetched from the fact that this ecosystem had relatively small number of trees with small to average-sized diameters or girths. The high carbon storage in the soil pool of the orchard is in unison with the findings of Gibbon *et al*. (2010) and may be attributed to high amount of organic matter arising from litter decomposition. The low carbon in the vegetation pool of the orchard is due to low tree density having small girth sizes.

Carbon sequestration ability of the ecosystems varied greatly with the forest sequestering 593.04 Mg CO_2ha^{-1} while the orchard sequestered 167.37 Mg CO_2ha^{-1}. This gap may be attributed to the high density of young tree species with large girth sizes in the forest than in the orchard which sequester large volumes of carbon (Binyam, 2012; Nowak *et al*., 2013).

CONCLUSION

The study indicates that carbon sequestration and storage are affected when forests are converted to plantations. It also shows that important vegetation variables such as density, height, DBH differ greatly upon conversion of natural forests to plantations. The carbon sequestration and storage abilities in natural (forest) and plantation (cashew orchard) forests differ in different pools (vegetation, soil, litter) of the ecosystem. The forest ecosystem had higher tree species composition, biomasses, carbon sequestration and storage abilities than the cashew orchard. With greater potentials to sequestrate and store carbon, natural forests are vital ecosystem components towards global warming and climate change mitigation. Despite, the low carbon storage in the cashew orchard, plantation forests also have great potentials in sequestrating and storing carbon. Hence, proper forest management and afforestation practices are essential to protecting and reducing carbon emission. Appropriate sensitization programs should be organized for the public especially those in the rural areas, educating them on the need for forest protection and afforestation in this era of climate change.

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