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Carbon stock estimation of Sawn wood in Iloabuchi Sawmill, Port Harcourt, Rivers State, Nigeria

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Abstract

The study measured carbon stock of sawn wood in Iloabuchi Sawmill Port Harcourt. This was achieved through: composition and characterization of various species, estimation and comparison of carbon stock density, estimation of volumetric yield coefficient (VYC) and carbon yield coefficient (CYC) in logs. 528 logs ≥ 50cm diameter and length were randomly selected.Measured using smalian method. Descriptive and inferential statistics used for analysis. However, result showed dealers selection of wood depend only on quality and knowledge of their uses. Fabaceae (22.0%) had the highest while Guttiferae (2.3%) least from eleven families. Wood basic density average (0.7 g cm^{-3}) extended from 0.4g cm^{-3} to 0.8 g cm^{-3}, Khaya ivorensis (0.8g cm^{-3}) had the highest while Ceiba pentandra and Funtumi aelastica (0.4 g cm^{-3}) were least. The most abundant species obtained were Pterocapu serinaceus, Ceiba pentandra and Nucleadiderrichii. Volumetric and Carbon yield coefficient average (46.20%) were converted to sawn wood, Berlinia grandiflora having highest percentage while Milicia excel sahab the least and53.80 % of sawmill waste realized.It is concluded, carbon can still be retained in final sawn wood products hence, sawn wood product provide a key information for undertaking climate change impact challenges. Therefore, it is recommended that a support structure be set up to encourage wood species enriched with large amount of carbon for carbon enhancement.

Keywords: Carbon stock, sawn wood, logs, volumetric yield coefficient, carbon yield coefficient.

Introduction

Climate change widespread is now an emergent concern leading to all-embracing discussions and negotiations internationally[1,2]. Reactions to this alarming situation have concentrated on reducing emission of greenhouse gas (GHG) especially Carbon dioxide (CO_2). Carbon dioxide is the most greenhouse gas influencing global warming resulting to possibly climate change. Forest, soils and water help to reduce CO_2 in our atmosphere therefore, measuring the carbon stock absorbed has become a primary goal of international efforts[3]. Majorly, forests play a vital role in carbon cycle because they constitute a greater part of carbon exchange in the atmosphere more than any other ecosystem[4]. Wood is a part of the trees from the forest, in its nature capture and store carbon in the atmosphere through photosynthesis after a biological, chemical or physical processes during tree growth. Product from wood continue to store carbon after its use life in building[5]. It may be emitted by burning or decay[6,7]. Some products may end up in landfills or `reprocessed into new products[8,9]. Wood remains one of the most important raw materials available to mankind for that reason steadily required throughout the world. According to Petersen and Solberg[10], with Gustavss on and Sathre[11] stated that the comparison between the flowed of harvested wood product and use of wood for energy increase competitiveness of wood over other materials, making it prominent over many economic and eco-friendly advantages to other alternatives due to climate change impact for instance, steel and alloy replace by wood alternatives releases less carbon dioxide, other pollutants and less waste during the whole product life cycle compared with non-wood materials.

Wood products are considered to contribute to the mitigation of carbon dioxide emissions. One options for decelerating the rise of greenhouse gases absorption in the atmosphere thus possible reduce the CO_2 emission requires maintaining the sustainability of the natural forest and increase in volume of carbon removed from the forest[12]. Also, information from wood product carbon stock can assist forest managers and public of the trade-offs between carbon storage, objectives and significances to forest management[13,14]. Consistent and appropriate information on the carbon stock of harvested wood is essential for policy formation and development for decreasing productions of carbon dioxide from deforestation and forest degradation (REDD). Hence, the wood product is the complement of carbon restoration. There is need for updated information relating to carbon stored in sawn wood. Based on this, the study seek to assess carbon stock of sawn wood in Iloabuchi sawmill, Port Harcourt, Rivers State.

Methodology

Study Area: The work were carried out in Ilaobuchi Timber Sawmill Port Harcourt the capital city of Rivers State. Location at latitude 4.51ºN, and longitude 7.01ºE total area of about

109km^2 with an elevation of 468m in the Niger Delta region lying along the Bonny River, 66km upstream from the Gulf of Guinea[15].

Sampling and Data Collection: Total enumeration of logs inventory provided by the company size range ≥ 50cm in diameter were measured in total 528 logs were evaluated. Philip[16] method were used for the calculation of sample size using the formula;

$$n = t^2 CV^2 (E\%)^2 \quad (1)$$

Where: n = optimal number of logs; t^2 = tabulated value of the Student's t-test (α = 0.05); cv^2 = coefficient variance; E^2 = allowable error limit (10%) considering the equation.

Laboratory Procedures: Wood disc sampled about 4cm thick were cut at every intervalsof0 m to 4 m until the full length of the each sixteen species of logs was reached[17]. The collected wood discs were cut into segment from each disk representing the volume proportional to the volume of each portion of the full disc. The segments were submerged in water for 21 days, and the saturated volume were measured using immersion method[17]. After, these sampled segments were dried in a forced-air oven until weight stabilization was reached[18]. Then, wood basic density was calculated as the ratio of dry weight (g) to saturated volume (cm^3). A density value for each individual tree was obtained as the arithmetic mean of the densities of the wood segments from that individual, and a species mean was calculated as the average of the means for the individual trees[19]. The species were categorized for dbc<0.5g/cm^3 as "low density" and species with dbc > 0.5-0.8g/cm^3 as "high density" ,heavy (between 0.8-1.0 g/cm^3) and > 1.0g/cm^3 very heavy[20].

Volume Estimation: Volume estimation measuring the diameter along the stem above the stump cut using Smalian method[17].

$$Vlog = \frac{A1 + A2}{2} \times L \quad (2)$$

Where: V_{log} = log volume in m^3, A_1 = cross sectional area of the top end of log in m^2, A_2= cross sectional area of the base of the log in m^2; L = log length in m.

Sawn Wood Product Estimation: The logs with bark were sawn into planks of different widths, rafters, battens, boards, beams of wood produce. The measurement was calculated using a standardized field form where the quantities of the produces assign base on categorized dimension: thickness (T; cm), width (W: cm), and length (L; m) of each lumber produce (V_{Lum}) using the formula;[21]

$$Vlum = \sum(W \times T \times L) \quad (3)$$

After they were added together to obtain the volume of sawn wood for each processed log.

Biomass Estimation

$$B = V_{log} \times dbc \quad (4)$$

Where: B = biomass of the sampled log with bark (Mg), V_{log}, = log with bark (m^3) volume and dbc= arithmetic means of the wood basic densities of the log's segments from that individual log with bark (g cm^{-3}) using Romero[22] and Soares et al.[23] process. Also, complete method of samples by sections to determine the basic density of wood in products using Nogueira et al.[24] method. Therefore, the biomasses of the commercial logs (with bark) and the sawn-wood products were obtained by multiplying the basic wood density by the volume of the log and of the products using the formula;

$$Biomass = dbc \times Vlum \quad (5)$$

Where; dbc= the wood basic density and Volume = the volume of the lumber of sawn produce.

Carbon Stock Estimation: The carbon stock in the log and in the wood, produce was calculated using the method of Romero et al.[18] where carbon content determination of log was based on a random sample of segments of each species by multiplying the biomass values and carbon content of 0.49 with standard deviation 0.05 to get the carbon stock for each log.

$$CS_{log} \text{ and } CS_{sawn} = Biomass \times 0.49 \quad (6)$$

The carbon yield coefficient (CYC; %) and volumetric yield estimation (VYC; %) of log obtain with the formula[24,25];

$$CYC = \frac{CSsawn}{CSlog} \times 100 \quad (7)$$

$$VYC = \frac{Vsawn}{Vlog} \times 100 \quad (8)$$

$$FC = \frac{CSsawn}{Vlog} \times 100 \quad (9)$$

Where: CS_{sawn} = carbon stock in wood produce (MgC), CS_{log} = carbon stock in log (MgC), CS_{sawn}= Carbon Stock in Sawn Wood (MgC), V_{log}= log volume with bark (V_{log}; m^3) and V_{sawn}= volume of pieces of wood produce (V_{sawn}; m^3) and FC = factor (in %) that transforms data on log volume into carbon stored in wood produce.

Statistical Analysis: All evaluation was accomplished using version 19 of IBM SPSS software and Microsoft Excel 2010. The descriptive statistics were used to summarize the estimate growth parameters and carbon stock densities among logs. Inferential statistics using ANOVA were adopted for comparing the yield between the species and turkey test to discriminate their averages when a significant effect was recognized.

Results and Discussion

Descriptive statistics: Trees maintain carbon dioxide from the atmosphere by storing and capturing thereby reduces climate change[7]. Carbon stock (CS) of logs average were 2.18MgC with average 0.07±0.03standard error presented in Table-1.

Characteristics of Wood Species: The study sampled total of five hundred and twenty-eight (528) commercially valuable trees. The hardwoods had 23.13%, Semi hard wood (43.37%) and Soft wood 30.49% proportion in Table-2. Categorically of tree species were from eleven (11) families following the descending of Fabaceae, Rubiaceae, Meliceae, Malvaceae, Apocynaceae, Boraginaceae and Sterculiaceae, Combretaceae and Ochnaceae, Moraceae and Guttiferae. The four most diverse families were Fabaceae (116 stems), Rubiaceae (99 stems), Meliceae (76 stems) and Malvaceae (50 stems) which partly endorse with total of 119 plants species belonging of 51 families and 100 genera were identified in the forest reserved whereby wood species represented the most diverse life form[26].

Edet, Ijeomah and Ogogo[27] stated that *Afzelia bipidensis* and *Ceiba pentandra* were the abundant species. Also, total of 214 individual trees of 20 tree species from 12 families were encountered, the dominant families are Moraceae, Fabaceae, Myrtacaeae, Combretaceae and Eupobaceae[28]. Despite the forest contribution to economic progress of logging the outcome has been complicated because only a few abundant tree species are cut, while others are neglected or destroyed during harvesting[29]. These lesser tree species faces approval in intercontinental marketplaces leading to high damage and depletion of genetic stock of the commonly commercial used species. The knowledge of species composition in the forest area will go a long way in identifying important elements of plants diversity, protecting and preserving threatened plant species, monitoring and providing effective management of the reserve[26].

Therefore sustainable conservation effort should be geared towards ensuring their continuous existence in order to main environmental integrity[28].

Species basic density Characteristics: Wood density of tree species is widely expressed as a value on wood basic density influence by the strength and other growth characteristics parameter in carbon cycle research[30]. The result revealed wood basic density of the species extended from $0.4_{g/cm}{}^{3}$ to $0.8_{g/cm}{}^{3}$, with average of $0.7_{g/cm}{}^{3}$ contradicts the findings of Romero et al.[31] report of $0.3_{g/cm}{}^{3}$ to $0.8_{g/cm}{}^{3}$ with an average of $0.6_{g/cm}{}^{3}$. Wood basic density recorded highest for *Khaya ivorensis* (mahogany) and *Ceiba pentandra* (silkcotton/floater) and *Funtumia elastica* (bush rubber) the least. The study showed that *Ceiba pentandra* and *Funtumia elastica* (bush rubber) wood basic density $0.4_{g/cm}{}^{3}$ with mean diameter of greater than 50 cm till store low wood basic density.

The findings align with Romero et al.[31] result of *Ceiba pentandra* with a mean diameter >100 cm having low *d̲bc* (0.3g cm^{-3}). High-density" species (> $0.5_{g/cm}{}^{3}$) store the greatest amounts of carbon in their logs in Table-4. Wood density and DBH were the determinant variables for estimating biomass[31]. The study revealed variation in wood density among the sixteen species examined may be as a result of strength, stiffness and stability of wood[32,33]. Some species are dominant in the rainforest due to vast features of species richness[34].

Carbon stock valuation of wood: Carbon stock and biomass in logs were recorded highest in Khaya ivorensis (mahogany) with 8.24Mg (4.12MgC) and the lowest in *Ceiba pentandra (silkcotton/floater)* with 2.84Mg (1.42MgC) average in Figure-2. Among the growth variables compared in Figure-2, biomass influences carbon storage in the logs showing consistently increased with increasing carbon stock. Biomass values remain one of the key factor compare to other growth variables attribute such as diameter and height[35,36].

This study found significant relationship between biomass, carbon stock and wood basic density, interaction revealed species with high biomass have highest in carbon stock implies supply of durable wood produce and carbon storing by capturing or releases carbon dioxide for a long time.

Table-1: Summary statistics of Wood in the Study Area.

Variables	Mean	Min	Max	Std. Dev.	Std.Error
Diameter(cm)	0.85	0.71	1.10	0.07	0.00
Length(m)	3.68	3.51	4.27	0.18	0.01
Volume (m^3)	7.99	5.58	12.66	1.46	0.06
Wood Biomass(Mg)	4.37	2.26	9.46	1.39	0.61
Wood basic density(g/cm^3)	0.55	0.39	0.76	0.10	0.00
Carbon Stock (MgC)	2.18	1.13	4.73	0.70	0.03

Table-2: Classification Wood Species in Ilaobuchi Sawmill Area.

Type	Families	Scientific Names	Local Names	No of species	Proportion (%)
Hard wood	Boraginaceae	*Xylopia aethiopica*	Uder	39	7.39
	Fabaceae	*Brachystegia eurycoma*	Achi	14	2.65
		Petadethra macrophylla	Ugba	26	4.92
	Meliaceae	*Khaya ivorensis*	Mahogany	29	5.49
	Moraceae	*Milicia excelsa*	Iroko	14	2.65
	Ochnaceae	*Lophira alata*	Ekki	16	3.03
					26.13
Semi-hard wood	Combretaceae	*Terminalia ivorensis*	Black afar	18	3.41
	Fabaceae	*Pterocarpus osun*	*boko*	26	4.92
	Meliaceae	*Berlinia grandiflora*	ububa red	47	8.90
	Rubiaceae	*Mitragyna cilitate*	Abura	49	9.28
		Nuclear diderrichii	Opepe	50	9.47
	Sterculiaceae	*Mansonia altissima*	Mansonia	39	7.39
					43.37
Soft wood	Apocynaceae	*Funtumia elastic*	Bush rubber	49	9.28
	Fabaceae	*Pterocapuserinaceus*	Kosso	50	9.47
	Malvaceae	*Ceiba pentandra*	Silkcotton/ Floater	50	9.47
	Guttiferae	*Symphonia globulifera*	Okololo	12	2.27
					30.49
			Total	528	100

Table-3: Wood Species basic density in the Study.

Scientific name	Local name	Volume	Density	
		Sawn Products (m^3)	d_{bc} ($_{g/cm}{}^3$)	d_{bc} category
Berlinia grandiflora	Ububa red	2 by 4 by 8	0.6	High
Brachystegia eurycoma	Achi	2 by 4 by 8	0.7	High
Ceiba pentandra	Silk cotton/Floater	2 by 4 by 8	0.4	Low
Funtumia elastic	Bush rubber	2 by 4 by 8	0.4	Low
Khaya ivorensis	Mahogany	2 by 4 by 8	0.8	High
Lophira alata	Ekki	2 by 4 by 8	0.7	High
Mansonia altissima	Mansonia	2 by 4 by 8	0.6	High
Milicia excels	Iroko	2 by 4 by 8	0.5	High
Mitragyna cilitate	Abura	2 by 4 by 8	0.6	High
Nucleadiderrichii	Opepe	2 by 4 by 8	0.6	High
Petadethra macrophylla	Ugba	2 by 4 by 8	0.6	High
Pterocapus erinaceus	Kosso	2 by 4 by 8	0.6	High
Pterocarpus osun	boko	2 by 4 by 8	0.5	High
Symphonia globulifera	Okololo	2 by 4 by 8	0.5	High
Terminalia ivorensis	Black afar	2 by 4 by 8	0.5	High
Xylopia aethiopica	Uder	2 by 4 by 8	0.5	High
Total			0.7	

Wood basic density (d_{bc} = g/cm^3) using[19,20].

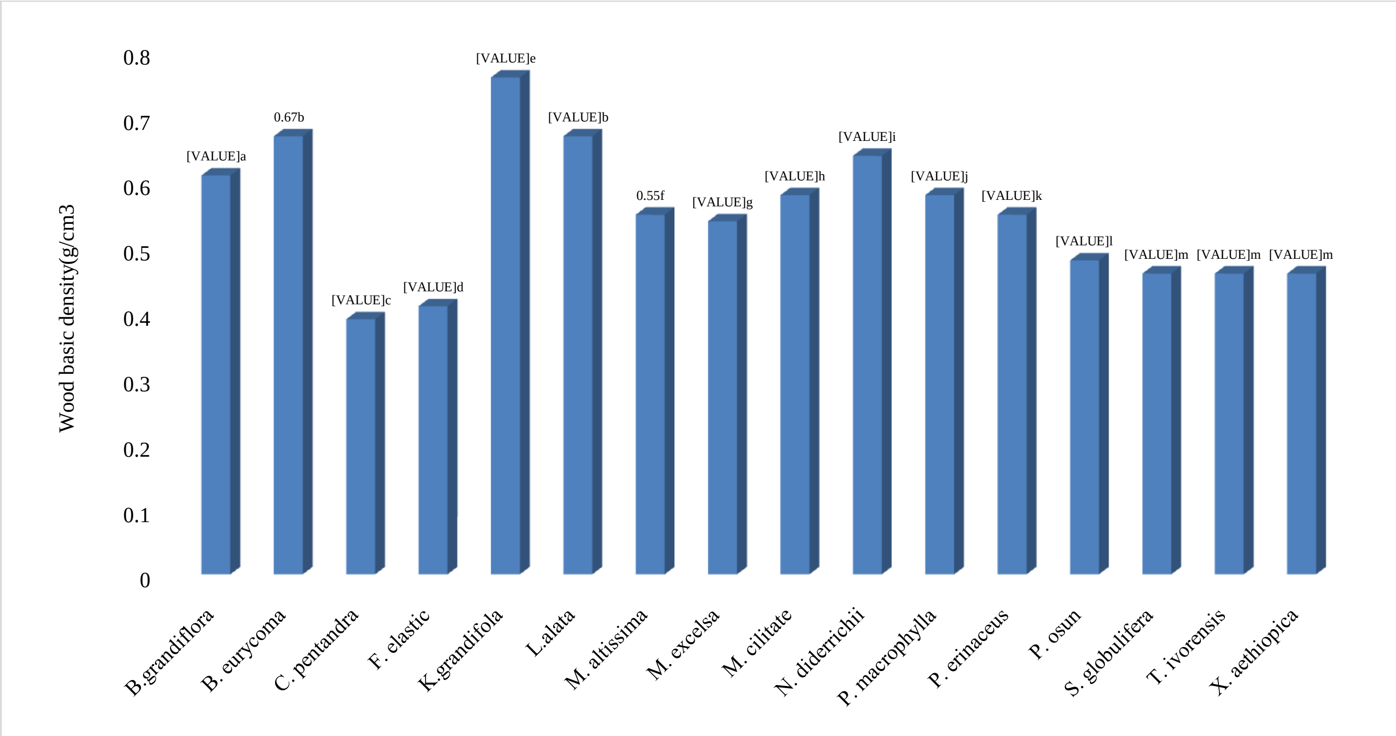

Figure-1: Comparison of mean wood basic density among the sixteen species investigated. Means tracked by the same letters did not vary meaningfully by Turkey test ($p < 0.05$).

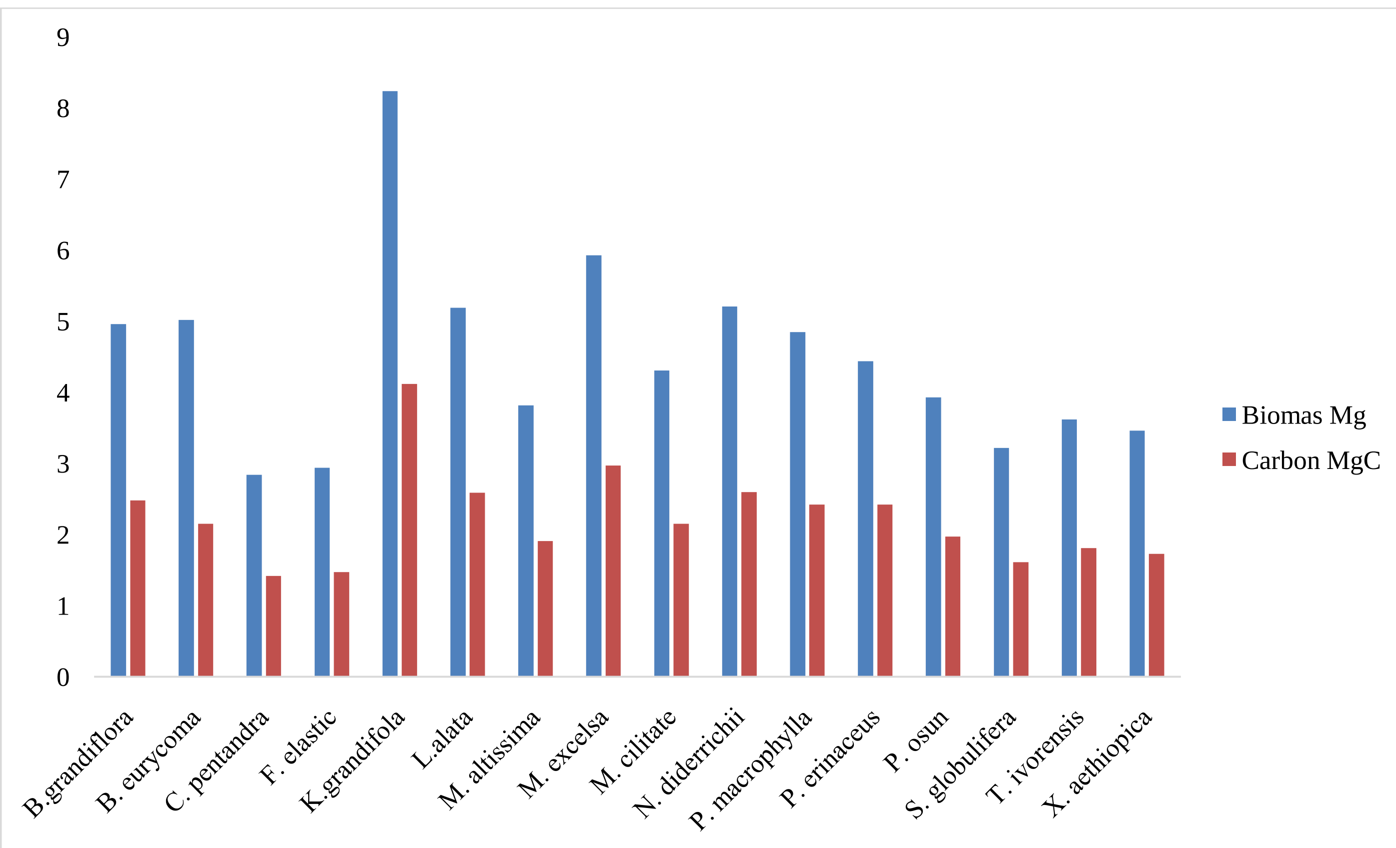

Figure-2: Associating the biomass influence on carbon store in the logs.

Table-4: Volumetric and Carbon yield obtained Products in logs.

Scientific name	Volume				Carbon			
	Log (m^3)	S V (m^3)	SP (m^3)	VYC%	Carbon in logs (MgC)	Carbon in S V (MgC)	CYC%	FC %
Berlinia grandiflora	381.4	181.3	3940	47.53	116.47	55.35	47.52	14.51
Brachystegia eurycoma	108.4	50.06	1479	46.18	35.17	16.25	46.20	15.0
Ceiba pentandra	368.3	173.9	2990	47.22	71.03	33.53	47.21	9.10
Funtumia elastic	356.4	167.7	2789	47.05	72.07	33.92	47.07	9.52
Khaya ivorensis	314.7	127.1	2943	40.39	119.40	48.22	40.39	15.34
Lophira alata	123.9	58.53	2359	47.24	41.50	19.61	47.25	15.83
Mansonia altissima	270.1	126.8	2320	46.95	74.46	34.97	46.96	12.95
Milicia excelsa	154.7	62.39	2266	40.33	41.53	16.75	40.33	10.83
Mitragyna cilitata	362.3	170.0	3143	46.92	105.46	49.47	46.91	13.65
Naucleadide rrichii	408.2	191.2	3816	46.84	130.11	60.94	46.84	14.93
Petadethra macrophylla	219.1	103.1	3458	47.06	63.00	29.63	47.03	13.52
Pterocapus erinaceus	405.7	190.3	3399	46.91	111.03	52.07	46.90	12.84
Pterocarpus osun	212.4	100.6	3382	47.36	51.10	24.20	47.36	11.39
Symphonia globulifera	85.37	40.46	3820	47.39	19.30	9.15	47.41	10.72
Terminalia ivorensis	214.8	100.5	1998	46.79	47.02	22.00	46.79	10.24
Xylopia aethiopica	291.5	135.6	3716	46.52	67.41	31.36	46.52	10.76
Total	4219.2	1952.3	47818		1166.1	537.4		
Average				46.20			46.20	12.60
Unused(waste)				53.80			53.80	

SV; Sawn volume in cubic meters, S P; Sawn Product in cubic meters; VYC%; volumetric yield coefficient, Carbon in Logs in Megagram, Carbon in Sawn volume in Megagram Carbon, CYC%; Carbon yield coefficient, F C%; Carbon store in wood produce in percent.

Trees carbon storage maintains the atmosphere by lessens carbon dioxide making product from wood a key source of information for undertaking climate impact challenges. The reference data given represent the most updated and complete (above ground) estimated carbon stock density used in this study. In the table, average carbon stock in logs revealed highest in *Khaya ivorensis* (mahogany) with 8.24Mg (4.12MgC) and the least in *Ceiba pentandra (silkcotton/floater)* with 2.84Mg (1.42MgC). The findings revealed volumetric yield coefficient 46.20% for logs converted to sawn wood lies within value range of 40.42 % to 47.53% depending on their species differences. The findings revealed carbon yield coefficient (CYC) of the log, the VYC, and the basic wood density were key factors in determining the low carbon storage in the low wood-density species, as was also observed by Romero et al.[31], Nogueira et al.,[24], Chave et al.[37], Goodman et al.[38]. This is derived from measuring tree magnitude from growing stock. The volumetric yield recorded by Pacelli et al.[39], with De Lima et al[40] and Biasi and Rocha[41], align with the findings of 46.20% for logs converted to sawn wood in this study. Within the general average 46.20% some species demonstrate good performance and utilization capacity even though some were low example *Milicia excelsa* (iroko) and *Khaya ivorensis* (mahogany) in Table-4. These two species seemingly below the general range of (46.20%) because about 53.80% due to hollow or cracks of the wood species does not contain in the main wood produce therefore the volumetric cracks, knots and other substances disturb causes variations in cutting result to yield waste in sawmill. Volume of wood unused (100 - 46.20 = 53.80%) and carbon (100 - 46.20 = 53.80) signifies that the yield coefficient of 53.80 % of CO_2 returned to the atmosphere. These may be projected or minimize to avoid sawdust and other remains[42]. One way of meeting the supply demands of the wood industry is through the reduction of waste in timber processing. Also, experimental results further indicates that the sawing techniques used had no significant influence on lumber yield[43]. The conversion factor for transforming log volume into carbon stored in sawn-wood products was 12.60% as observed with Romero et al.[31], were on the average of 16.2%. This entails that for each cubic meter extracted from the forest 0.126 MgC is store in wood produce. Also[44], results showed the store in harvested wood products will contribute to reduction market condition. Carbon storage in wood produce over years release carbon at the end of their useful life result to breakdown of the wood useful life[6,7].

Conclusion

The study revealed dealers demand only recognized available selected timber species and knowledge of utilization depending on their quality. Sawn wood product can bond carbon for longer period since carbon stock can still be retained in the final sawn products and high or low density is due to allocating of biomass or carbon to stem development. Carbon stock in species often increase with increasing biomass value. The findings shows that greater amount of sawmill waste return to the atmosphere as CO_2 and do not consist in the main sawmill product because large amount of waste was realized. The influence of low yield is due to the defects in the wood. Finally, the study provided a baseline and accounting support of sawn wood prediction in the study.

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