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Aboveground Carbon Stock in Natural and Planted Forests, Congo

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Abstract

Quantify global carbon stock in tropical forests to climate change mitigation requires availability of data and tools such as allometric models. The study aimed to estimate aboveground biomass (AGB) and carbon stock in natural and artificial lowland forests. The study retained two study sites. The first site is located in the planted forest in urban commune of Kintélé, on the northern outskirts of Brazzaville, in the Pool Department, Republic of Congo. The second site is located at the Lisanga natural forest in Mbamou Island, which is in the sub-prefecture of Brazzaville Department, Republic of Congo. A total of six plots were recorded, with 50 m × 50 m, *i.e.* 2500 m^2 each for this study. DBH ≥ 10 cm at 1.30 m above ground level for each tree was measured. The results show that for planted forest, Plot 2 has a high biomass (582.8 $t \cdot ha^{-1}$) and carbon stock (273.9 $t \cdot ha^{-1}$) compared to plots 1 and 3, which have 242.3 $t \cdot ha^{-1}$ of biomass and 113.9 $t \cdot ha^{-1}$ of carbon, and 206 t ha^{-1} of biomass and 96.8 $t \cdot ha^{-1}$ of carbon. About natural forest, there was an increase in the amount of biomass in the lower height classes (with 47.4 $t \cdot ha^{-1}$ of biomass and 22.2 $t \cdot ha^{-1}$ of carbon stocks for the 10 m to 19.9 m class) towards the middle class, reaching its peak in class II, from 20 to 29.9 m with 582.8 $t \cdot ha^{-1}$ of AGB and 273.9 $t \cdot ha^{-1}$ of carbon. The variations in biomass by diameter class and height class in the two forest types studied are remarkable. The planted forest has a higher biomass and carbon stock than the natural forest.

Keywords

Aboveground Biomass, Carbon, Forest, Kintélé, Mbamou Island

1. Introduction

Since the beginning of the industrial era, the average global temperature has risen by around +1.1˚C [1]. Extreme events (storms, droughts, etc.) are occurring with increasing frequency. This climate disruption is linked to an increase in the atmospheric concentration of man-made greenhouse gases (GHGs). One of the main contributors is carbon dioxide [2]. Carbon dioxide is the most important greenhouse gas produced by human activity (fossil fuel combustion, agriculture, etc.). Its emissions account for 55% of total GHG emissions in carbon equivalent, and its concentration has increased by 2.0 ppm per year. Since 2001, bringing it to an atmospheric concentration of 390.5 ± 0.2 ppm in 2011 [3]. The same is true of other greenhouse gases, whose presence in the atmosphere is contributing to the phenomenon of climate change.

Forests play an important role in mitigating of climate change phenomenon through photosynthesis, in this case of tropical forests. In addition to their role as reservoirs of biodiversity, they are now considered as carbon sinks in the context of climate change. This is why, in international agreements on limiting greenhouse gas (GHG) emissions and temperature rise, forests are seen as important carbon reserves on which it is easy to act [4]. In the process of implementing the United Nations Framework Convention on Climate Change (UNFCCC), [5] states that: Africa is counted among the zones where natural vegetation can contribute to the reduction of greenhouse gas emissions through carbon sequestration if activities are carried out in terms of reforestation and the reconstitution of degraded land. This consideration has led to a particular focus on the carbon sequestration capacities of Africa's tropical forests and savannahs. However, we note the loss of biodiversity and the increase in greenhouse gas (GHG) emissions [4]. According to [6], annual carbon emissions from tropical deforestation and degradation during the 2000s accounted for around 10% - 20% of total anthropogenic GHG emissions.

This is why the REDD+ mechanism (Reducing emissions from deforestation and forest degradation in developing countries, plus conservation and sustainable management of forests and enhancement of forest carbon stocks) encourages developing countries to limit GHG emissions from deforestation and forest degradation. This limitation generates a "carbon-credit" which is a bonus for efforts to protect forests. To access this "carbon-credit", quantification of carbon stocks and flows between different vegetation types is essential [7] pointed out that "insufficient data on the carbon stocks of different forest pools, as well as the lack of monitoring of their variations, are delaying the installation of the REDD+ mechanism that will enable countries to access the carbon-credit". Significant efforts have been made at regional level to improve carbon stock databases by integrating both indirect and direct methods [5] [8]. However, these data still remain poorly representative in relation to the high variability of forest biomass in the tropics [7].

The flora of Mbamou Island has been the subject of several studies, notably those carried out by [9]-[11], but these studies are not sufficient to provide relevant information on the flora and carbon stock of the settlement. Nevertheless, the flora of Mbamou Island is disappearing without the necessary information on carbon stocks, particularly aerial carbon stocks, being known in greater detail or with greater precision, and the lack of data on the Kintélé forest, which is also experiencing a decline in biomass as a result of unplanned felling, is a source of concern.

It is therefore urgently necessary to assess the amount of aboveground forest biomass contained in these two forests, in order to provide a more reliable database for sustainable management and effective combating of climate change. With this in mind, our study focuses on assessing the above-ground biomass of the planted forest of Kintélé and the natural forest of Mbamou Island. The objectives of this study were to: 1) estimate carbon stock by forest type; 2) estimate carbon stock as a function of structural parameters; 3) assess the influence of structural parameters on carbon stock.

2. Materials and Methods

2.1. Study Area

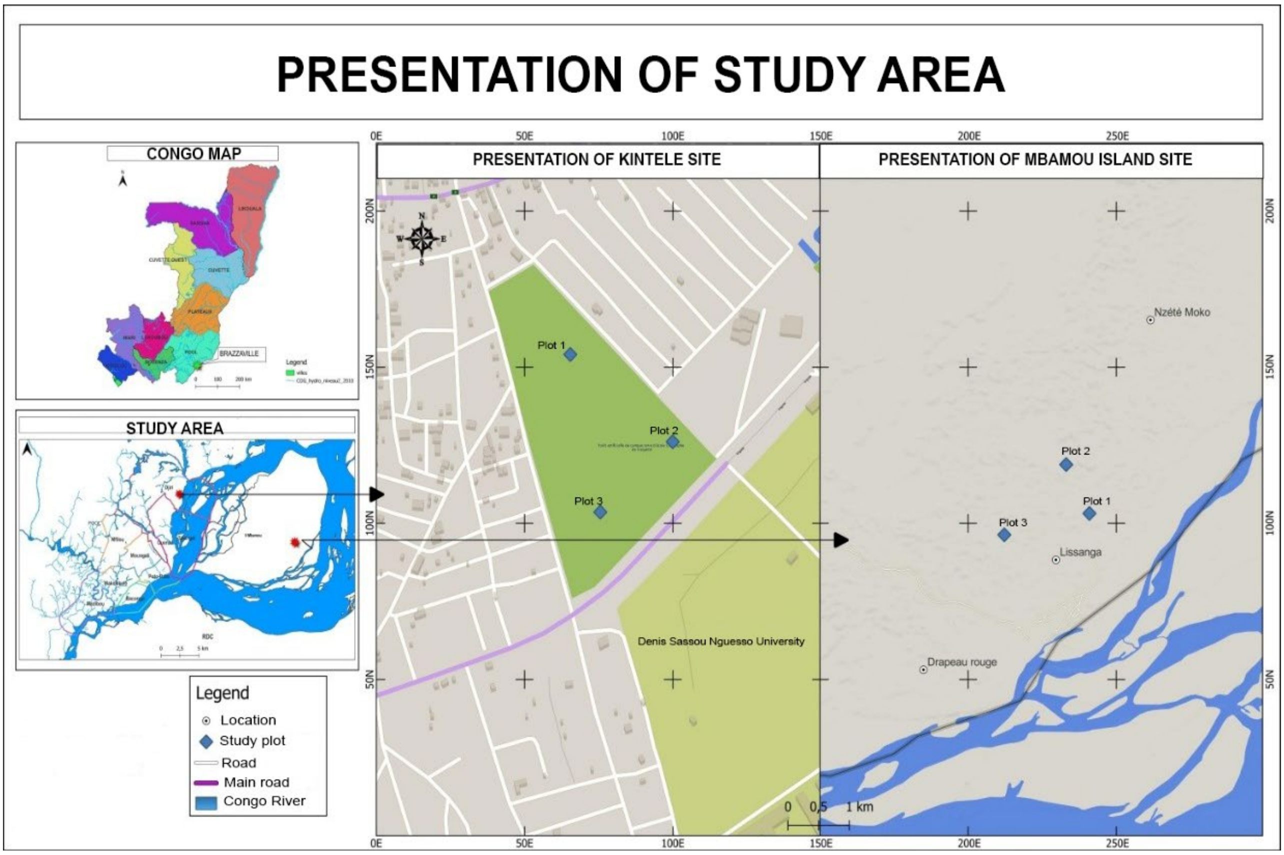


Figure 1. Study area location.

Study was carried out in two plant formations, namely: a planted forest located opposite the Dénis Sassou N'GUESSO University, more precisely in the urban commune of Kintélé, on the northern outskirts of Brazzaville, in the Pool Department, Republic of Congo (**Figure 1**). It is linked to Talangaï by the Talangaï-Kintélé viaduct, bordered to the west by the Djiri river and to the south by the Congo river; a natural forest, the Lisanga forest, located at the very heart of Mbamou Island, which is a sub-prefecture of the Brazzaville Prefecture. It is closer to Brazzaville than to Kinshasa, and a little upstream from both cities [9]. Almost 30 km long and 13 km wide, it occupies a large part of the Stanley Pool, where, after flowing for over 200 km through the narrow valley of the corridor, the Congo River spreads out in a sheet 25 km wide and over 35 km long, bounded to the west by the Kintambo rapids [10].

2.2. Climate

The forests of Mbamou island and Kintélé are the tropical type, with two seasons: a dry season (June to August) and a rainy season (September to May), with a slowdown in rainfall from December to February. Irregular rainfall during the transitional months of May and September contributes, depending on the year, to extending the duration of the dry or rainy seasons. Average annual rainfall is around 1400 mm, and average annual temperature is 25˚C (**Figure 2**).

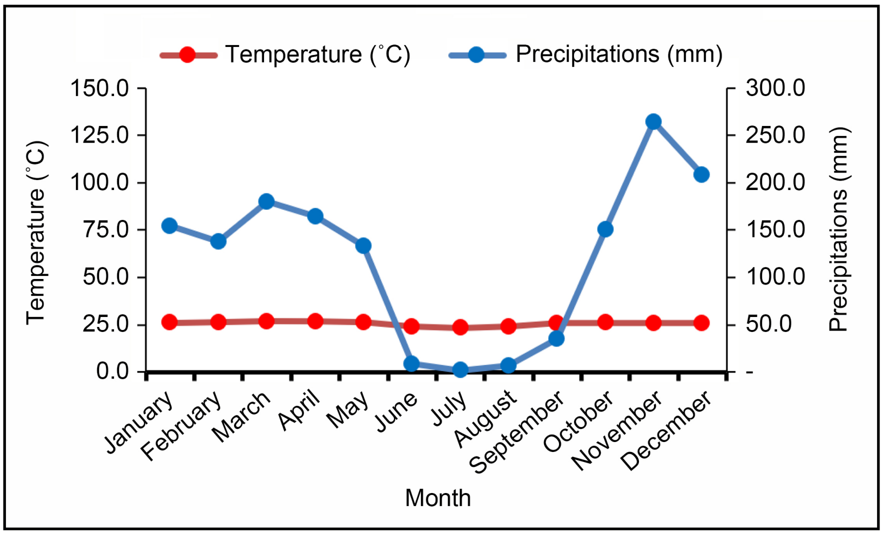


Figure 2. Climograph of the main meteorological station around the study area (average from 2013-2023).

Annual rainfall varies between 1200 and 1500 mm, with rains starting lightly in late September, establishing themselves in October and ending in May. The wettest months are generally April and November, with an average of 200 mm. June to August and part of September are dry [12]. Humidity is always high and the annual hygrometric amplitude is low. The wettest months are December (95.3%) and January (94.4%), while the driest are August (87%) and September (86.6%). Evaporation varies inversely with atmospheric humidity. It has a relative maximum in March and an absolute maximum in September [12].

2.3. Data Collection

Study plots were set up in each forest ecosystem. In the planted forest, as in the natural forest, three square plots measuring 50 m × 50 m, *i.e.* 2500 m^2, were set up using a double decameter, following the compass directions (North-South and East-West). We then marked out our plots with stakes. Tree species were then marked by number, using chalk sticks in planted forest and a machete to make notches in natural forest to avoid double counting in the study plots. A total of six plots (15,000 m^2) were recorded for this study. Diameter at breast height was measured using a forest compass at 1.30 m above ground level for each tree. The scale was to count all trees contained in the study plots with a DBH ≥ 10 cm. The Haglof Vertex Laser GEO 2 was used to measure tree height in both forest ecosystems. All trees have been identified, checked and confirmed by The Missouri botanical garden's herbarium database, which is the one of world's outstanding research resources for specimens and information on plants (see http://www.missouribotanicalgarden.org), and The Xycol database (The list of scientific and vernacular woods names: Accessed December 12, 2024 at http://www.xycol.net/index.php?categorie=0&sess_langue=430).

2.4. Data Analysis

The use of allometric models is a crucial step in the estimation of aboveground biomass [13]. Aboveground biomass was estimated using the standard allometric equation of [14]. This equation was chosen for three reasons: This model takes into account three structural parameters (Diameter, Total Tree Height and Wood Density); trees with DBH ≥ 10 cm are identified and measured for the tropical area; this equation has been recommended by the REDD+ process, used successfully and repeated in several works [15]-[17]. The allometric Equation (1) developed by [14] is presented as follows:

$$\text{AGB}_{\text{est}} = 0.0673 \times \left(\rho D^2 H\right)^{0.976} \tag{1}$$

ρ = wood density ($\text{g}\cdot\text{cm}^{-3}$);

D = diameter at breast height (cm);

H = height of tree (m);

AGB = aboveground biomass ($\text{t}\cdot\text{ha}^{-1}$).

However, the specific wood density for each tree [18] was provided by DRYAD's Global wood density database (accessed on September 16, 2024, at https://doi.org/10.5061/dryad.234). Regarding the species for which specific densities could not be found, the default value for specific wood density of 0.5 $\text{g}\cdot\text{cm}^{-3}$ was used [18].

Basal Area and Expansion Factor

The basal area of a tree is the cross-sectional area of a tree at 1.30 m (2). Basal area gives an indication of the degree to which the forest has been filled [19]. It is expressed in square meter per hectare (m^2/ha). Basal area of a tree were calculated as follow:

$$G = \frac{\left(\sum n \times \pi \times \left(\frac{D_i}{2}\right)^2\right)}{ha} \tag{2}$$

where G is basal area (in $m^2 \cdot ha^{-1}$), D_i is diameter at breast height of individual i at 1.3 m above the ground (in cm), π is 3.14, ha is hectare and n is the number of stems per plot.

Basal area is the area of a given section of land that is occupied by the cross-section of tree trunk and stem at the base. However, the diametric structure was assessed to understand the level of degradation of Kintélé forest ecosystem. To extrapolate the values from the study plots to values per hectare, an expansion factor is required. These expansion factors indicate the area represented by each study plot or sample (3). This standardization is necessary in order to easily interpret the results and also to make comparisons with other studies.

$$\text{Expansion factor} = \frac{10000\ \text{m}^2}{\text{Plot size}\left(\text{m}^2\right)} \tag{3}$$

However, the PAST program used includes standard statistical tests. The data of this study were compiled with SigmaPlot v. 10.0 and PAST ver 3.05 statistical softwares. Study area's location map has been performed using the QGIS ver 2.0 software.

3. Results

The survey conducted in the two forests enabled us to record 158 and 272 trees in the Kintélé and Mbamou Island forests, respectively, with a DBH ≥ 10 cm in three plots, each 50 m × 50 m (*i.e.* 2500 m^2).

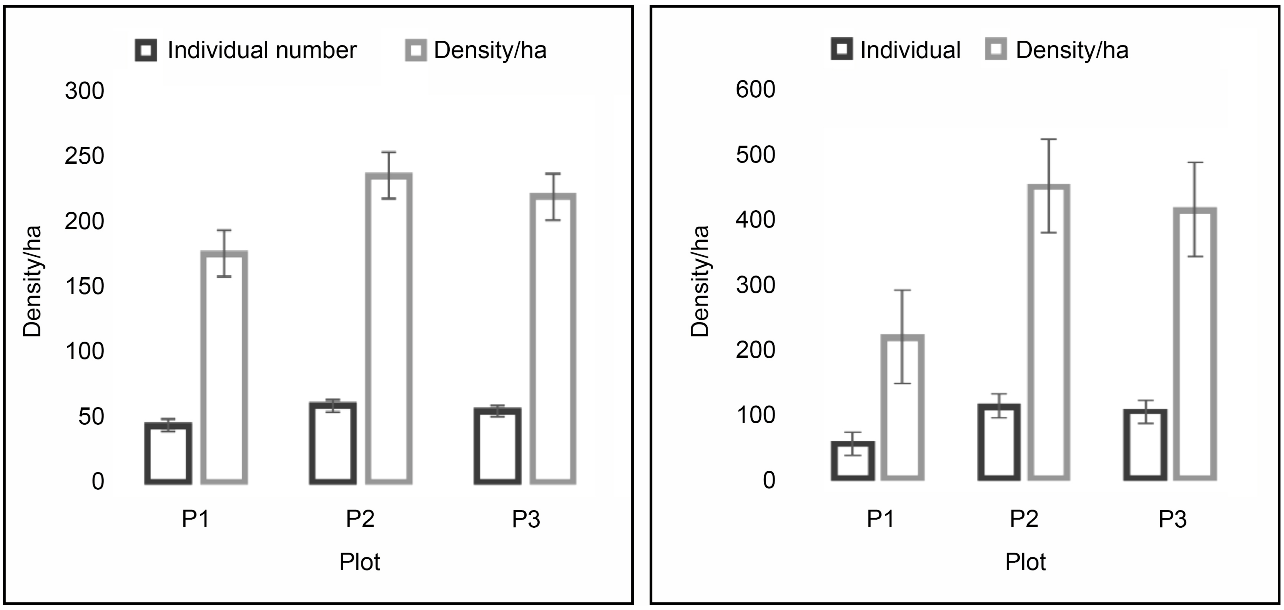


Figure 3. Tree density at both sites. (a) Variation in tree density in planted forests by plot. (b) Variation in tree density in natural forests by plot.

Figure 3 shows the different variations in the two forests according to density. **Figure 3** shows that density varies depending on the plot. The larger the population, the higher the density. It varies from 176 to 236 ha^{-1}, which is the peak, then decreases to 220 ha^{-1}, with an average density of 210.6 ha^{-1}. After processing the data, we found that plot 2 has the highest density and plot 1 has the lowest density. However, **Figure 3** shows that as the number of individuals increases, so does the density. Plot 1 has a low number of trees, resulting in a low density (220 ha^{-1}). In contrast, plots 2 and 3 have a high density (452 ha^{-1} and 416 ha^{-1}) due to the large number of trees found, with an average density of 362.6 ha^{-1}. In fact, **Figure 3(b)**, which is the natural forest, has an average density (362.6 ha^{-1}) higher than **Figure 3(a)** (with an average density of 210.6 ha^{-1}), which shows that the natural forest has greater floristic diversity than the planted forest.

3.1. Basal Area

The basal area values for a stand shown in **Table 1** indicate that the sum of the parameters encountered in plot 2 appears to be much greater than that of the other two plots (1 and 2). The values in **Table 1** show the basal area of the stand in each plot (1, 2, and 3), and plot 2 appears to be larger than plots 1 and 3. The values in **Table 1** show that the natural forest has a large basal area. This increase in basal area may be due to the high floristic diversity found in the forest ecosystem of Mbamou Island.

Table 1. Distribution of Basal area of planted forest (Kintele forest) and natural forest (Mbamou Island forest). G is basal area (in $m^2 \cdot ha^{-1}$) calculated for each plot according to ForestPlots (http://www.forestplots.net) and AfriTRON (http://www.afritron.org) protocols; *n* is the number of sampled trees by plot.

Plot	Planted forest		Natural forest	
	n	G	*n*	G
1	44	22.7	55	24.9
2	59	23.9	113	51.2
3	55	20.4	104	47.1

3.2. Aboveground Biomass and Carbon Stock by Forest Type

Table 2 shows that the greater variation in biomass among individuals encountered in each plot, the greater carbon stock despite the biomass. Plot 2 has a high biomass (221.7 $t \cdot ha^{-1}$) and carbon stock (104.2 $t \cdot ha^{-1}$) compared to plots 1 and 3, which have 242.3 $t \cdot ha^{-1}$ of biomass and 113.9 $t \cdot ha^{-1}$ of carbon, and 206 $t \cdot ha^{-1}$ of biomass and 96.8 $t \cdot ha^{-1}$ of carbon. These results are certainly due to the reasonable functioning of this ecosystem, which leads to variations in aboveground biomass. **Table 2** also shows the amount of aboveground biomass (AGB) and carbon for each study plot. Plot 2 has a significant amount of AGB and carbon, with 311.8 t·ha^{-1} and 146.5 t·ha^{-1}, respectively, compared to plots 1 and 3 with 190.6 t·ha^{-1} of AGB; 89.6 t·ha^{-1} of carbon and 160.7 t·ha^{-1} of AGB; 75.5 t·ha^{-1} of carbon.

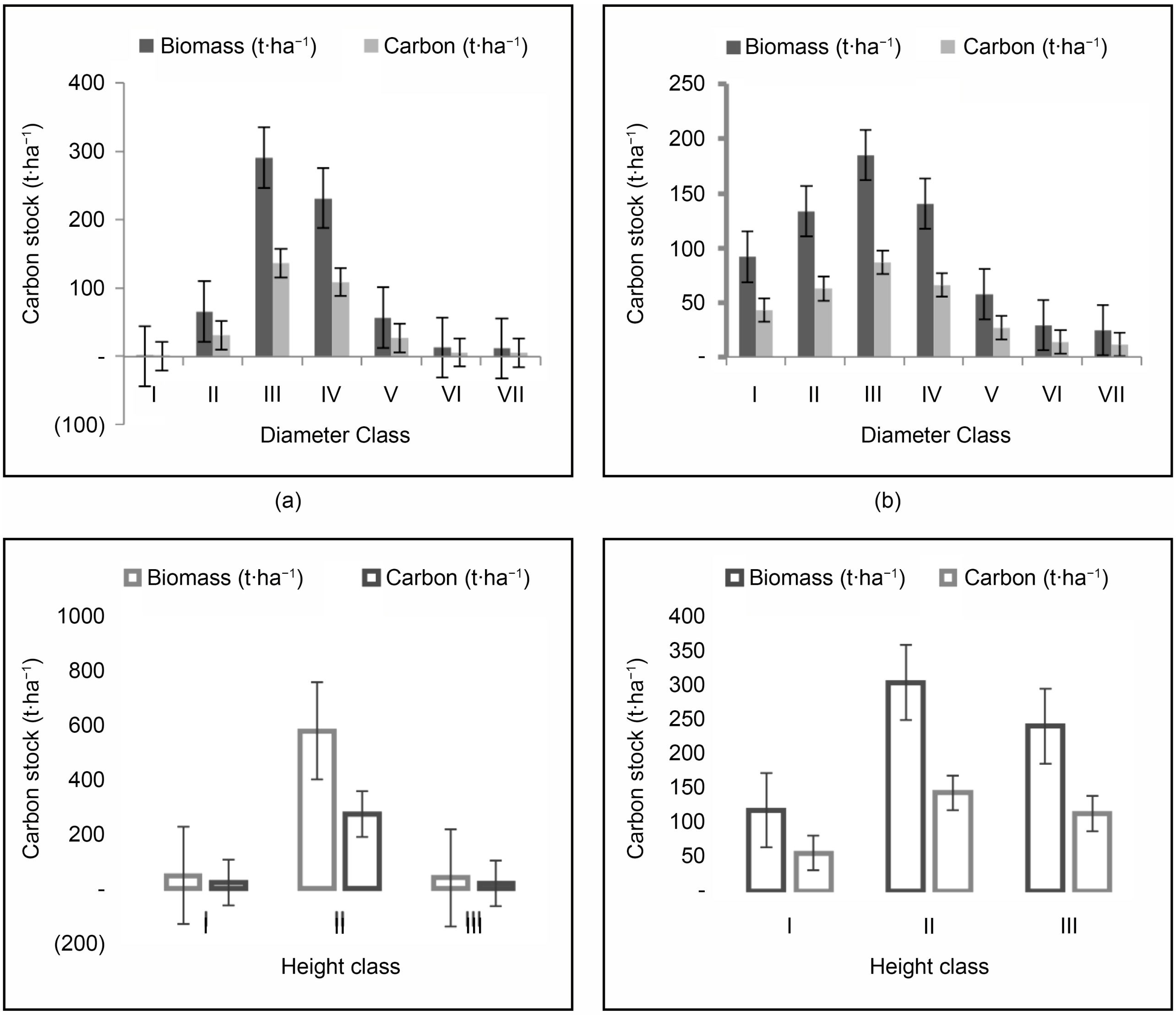
However, statistical tests show that: the probability of these two forests is greater than P-value; *i.e.*, *P*-values of 0.96. As *P*-value is greater than 0.05, there is difference between the two forests in terms of carbon stock. However, it should be noted that from a technical point of view, there is a small but significant difference between the variables. The planted forest has a higher biomass and carbon stock than the natural forest.

Table 2. Evaluation of aboveground biomass in two forest types. AGB is aboveground biomass (in t·ha^{-1}); AGBC is the carbon stock of aboveground biomass (in t·ha^{-1}); *n* is the number of individual tree by plot.

Plot	Planted forest			Natural forest		
	n	AGB	AGBC	*n*	AGB	AGBC
1	44	242.3	113.9	55	190.6	89.6
2	59	221.7	104.2	113	311.8	146.5
3	55	206	96.8	104	160.7	75.5
Average	52.6	223.4 ± 18.1	105 ± 8.5	90.6	221.1 ± 80	103.9 ± 37.6

3.3. Variation of AGB and Carbon Stock by Diameter and Height Classes

The study shows that aboveground biomass and carbon stock has influenced by trees heigh and dimater. Figure 4(a) shows two phases of change: aboveground biomass and carbon stocks. An increase in biomass quantity and carbon stocks in the small diameter classes (with 0.62 t·ha^{-1} of biomass and 0.29 t·ha^{-1} of carbon stocks for the 10 cm to 19.9 cm class, *i.e.*, class I) towards the medium classes reaching its peak in the 30 cm to 39.9 cm class, class III, with 290.9 t·ha^{-1} of AGB and 136.7 t·ha^{-1} of carbon, followed by a decrease towards the upper diameter classes, ranging from class IV with 231.6 t·ha^{-1} of AGB and 108.8 t·ha^{-1} of carbon stock to class VII with 11.7 t·ha^{-1} of AGB and 5.5 t·ha^{-1} of carbon stocks. This is linked to a small number of standing trees. Figure 4(b) also shows two phases of evolution: the aboveground biomass and carbon stock of each class. There is an increase in biomass and carbon stock from the small classes (91.9 t·ha^{-1} of AGB and 43.1 t·ha^{-1} of carbon for class I) to the medium classes, reaching a peak in class III (185 t·ha^{-1} of AGB and 86.9 t·ha^{-1} of carbon). There is then a decrease towards the higher diameter classes, ranging from class IV (140.7 t·ha^{-1} of AGB and 66.1 t·ha^{-1} of carbon) to class VII (24.8 t·ha^{-1} of AGB and 11.6 t·ha^{-1} of carbon). In general, it should be noted that diameter is a key factor. This study shows that diameter has a significant influence on biomass and carbon stock in the two studied forests.



(a) (b)

(c) (d)

Figure 4. Distribution of aboveground carbon (AGB) and carbon stock by diameter and height class: (a) Variation in AGB and carbon stock by diameter class in the planted forest; (b) Variation in AGB and carbon stock by diameter class in the natural forest; (c) Variation in AGB and carbon stock by height class in the planted forest; (d) Variation in AGB and carbon stock by height class in the natural forest.

Figure 4(c) shows that height class II is the most represented, with 582.8 t·ha^{-1} of AGB and 273.9 of carbon stock, followed by height class I with 47.48 of AGB and 22.3 of carbon stock. Height class III is poorly represented in the planted forest. However, Figure 4(d) shows that height class II still contains the most biomass (304.4 t·ha^{-1}) and carbon stock (143 t·ha^{-1}), followed by height class III with 241 t ha^{-1} of AGB and 113.2 t·ha^{-1} of carbon stocks, and height class I is less represented (117.8 t·ha^{-1} for AGB and 55.3 t·ha^{-1} for carbon) in the natural forest. Figure 4(d) shows two phases of change in biomass and carbon stocks. There was an increase in the amount of biomass in the lower height classes (with 47.4 t·ha^{-1} of biomass and 22.2 t·ha^{-1} of carbon stocks for the 10 m to 19.9 m class) towards the middle class, reaching its peak in class II, from 20 to 29.9 m with 582.8 t·ha^{-1} of AGB and 273.9 t·ha^{-1} of carbon. The decrease in the amount of AGB and carbon in class III, with 39.8 t·ha^{-1} of AGB and 18.7 t·ha^{-1} of carbon is remarkable. **Figure 4(d)** also shows the same phases of change. An increase in the amount of AGB and carbon in the small diameter classes (with 117.8 t·ha^{-1} of AGB and 55.3 t·ha^{-1} of carbon corresponding to the 10 to 19.9 m class, *i.e.*, class I), in class II, 20 to 29.9 m it reaches its peak (with 304.4 t·ha^{-1} of AGB and 143.07 t·ha^{-1} of carbon), in class III, 30 to 39.9 m, there is a decrease in the amount of AGB and carbon (with 241 t·ha^{-1} of AGB and 113.2 t·ha^{-1} of carbon). These results show that the height parameter has a strong influence on biomass and carbon stocks in these two forest ecosystems. This study leads us to understand that the height parameter also influences carbon stocks. The variations in biomass by diameter class and height class in the two forest types studied are remarkable.

4. Discussion

The study evaluating the aboveground biomass of the planted forest in Kintélé and the natural forest on Mbamou Island, identified 430 individuals, including 158 in the planted forest and 272 in the natural forest, divided into 22 families, and determined the density per hectare of each forest type.

4.1. Trees Density

This study shows an average density of 210.6 ha^{-1}, ranging from 176 to 236 trees per ha in planted forests, and an average density of 362.6 ha^{-1}, ranging from 220 to 452 trees per hectare in natural forests. The high density of natural forests shows that they have significant floristic diversity. Despite its higher density than the planted forest, the results for the natural forest do not corroborate to [20], which states that in dense tropical forests, densities vary from 450 to 750 trees per hectare. This low density can be explained by the DBH scale, which states that only trees with a DBH ≥ 10 cm should be inventoried. The forest on Mbamou Island is undergoing regeneration following various forms of environmental degradation. In contrast, the planted forest in Kintélé has a low density due to the absence of trees in the plots following uncontrolled logging.

These densities enabled us to determine the population structure of each forest (planted and natural). **Figure 4** shows that the number of individuals in the planted forest varies from class I to class III, then decreases to class VII. In contrast, the number of trees decreases from the smallest class (class I) to the largest class (class VII) in natural forests. In fact, there are more small-diameter trees than large-diameter trees in the natural forest, which shows that it is a young forest in full regeneration, unlike the planted forest, which has more large-diameter trees (medium and large).

4.2. Basal Area of Trees

This study shows that the basal area of the stand varies from 22.7 to 20.4 m^2·ha^{-1}, with an average of 22.3 $m^2 \cdot ha^{-1}$ for planted forest, and from 24.9 to 51.2 $m^2 \cdot ha^{-1}$, with an average of 41.1 $m^2 \cdot ha^{-1}$ for natural forest, which corroborates to [21], which states that the higher the basal area values, the larger the diameters of the trees in the stand, and the smaller the diameters of the trees in the stand, the lower the basal area.

4.3. Assessment of Aboveground Biomass and Carbon Stocks by Forest Type

In order to preserve these forest ecosystems, the indirect method was used, employing an allometric equation that highlights three important parameters: density, height, and diameter. The equation developed by [14] enabled us to estimate the biomass and carbon stock contained in these two forests (planted and natural), with 223.41 ± 18.19 $t \cdot ha^{-1}$ of AGB and 105.00 ± 8.55 $t \cdot ha^{-1}$ of carbon stock in the planted forest. 221.10 ± 80.02 $t \cdot ha^{-1}$ of AGB and 103.92 ± 37.61 $t \cdot ha^{-1}$ of carbon stock in the natural forest. The probability obtained is 0.96 according to statistical texts, where $P\text{-Value} > 0.05$ means there is a significant difference and $P\text{-Value} < 0.05$ means there is no significant difference. In our case, as $P\text{-Value} = 0.96 > 0.05$, there is a significant difference in the carbon stock contained in these two forests (planted and natural). Furthermore, from a technical point of view, it should be noted that there is a small difference, although the natural forest has greater floristic diversity. However, it should be noted that the carbon stock (103.9 $t \cdot ha^{-1}$) of the natural forest is lower than the carbon stock (105 $t \cdot ha^{-1}$) of the planted forest due to its biomass. Our results are low compared to the results from [22] in the secondary forest of Pool Department, which obtained 167 $t \cdot ha^{-1}$ of stock, and [7] in the Likouala forest, with 190.7 $t \cdot ha^{-1}$ of carbon stock.

4.4. Assessment of Aboveground Biomass Based on Diameter Classes

The different diameter classes observed in the planted forest show that the more biomass increases in relation to diameter, the greater the carbon stock becomes. In contrast, in the natural forest, it can be seen that it is not only the diameter parameter but also the number of individuals that influence the carbon stock. The more the population increases, the greater the stock becomes, while also taking diameter into account. This is why [23] state that biomass increase according to tree diameter.

4.5. Assessment of Aboveground Biomass According to Height Classes

The height classes observed in planted forests show that height is a parameter that influences biomass. In class II, there is a peak in biomass (582.8 $t \cdot ha^{-1}$ for aboveground biomass and 273.9 $t \cdot ha^{-1}$ for carbon stock), resulting in a significant variation in carbon stock. However, the drop in the peak towards class III leads us to understand that this amount of carbon stock is due to a low variation in biomass (with 39.8 t·ha^{-1}), which is necessarily due to a low number of individuals. The height classes of the natural forest show a good variation in biomass and carbon stocks, which shows a perfect balance between the number of individuals and the height parameter. The taller the trees and the greater their number, the greater the carbon stock. The results of the present study therefore corroborate to [24], which states that trees of average height improve the prediction of wood biomass and total tree biomass.

However, uncertainties in forest carbon studies are remarkable by stem from measurement errors in field data (like tree dimensions), sampling errors in plot selection, model uncertainties in biomass estimation, and land-cover mapping discrepancies from remote sensing [25]-[27]. Future changes in forest carbon stocks are further complicated by uncertainty in biomass turnover rates, the persistence of carbon in forests, and the variability of ecological processes. Regarding sampling uncertainty, the inaccurate or unrepresentative field plots can lead to significant uncertainty in estimates of carbon stocks and changes, especially in large-scale assessments. About model uncertainty, the models used to estimate forest biomass and carbon fluxes can be inaccurate due to flawed assumptions, improper model forms, or parameter errors.

5. Conclusion

The full value of the tree can only be realized through accurate estimation of its biomass, which has undeniable overall positive environmental effects that should be maximized. The use of the pantropical allometric model to estimate aboveground biomass in the planted forest of Kintélé and the natural forest of Mbamou Island has highlighted the variability of biomass across plant formations and its relationship to diameter, height, and number of trees at the forest scale. The carbon stocks obtained show that these two forests are genuine carbon sinks. In line with the national REDD+ strategy (Reducing Emissions from Deforestation and Forest Degradation, including conservation of natural resources, sustainable forest management, and carbon stock enhancement), the forests of Mbamou Island and Kintélé can generate real carbon credits and enable the Republic of Congo to occupy a main place in voluntary carbon markets. It would be preferable to focus on preserving these two forest ecosystems, which are still exposed to abusive human activity, in order to ensure better atmospheric purification through these forest ecosystems.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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