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(RESEARCH ARTICLE)

Estimation of the carbon stock of a settlement of three dominant tree species in the forest island of the Concession of the Center Eucharist Father Eymard in Kinshasa

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Abstract

In view of the fight against climate change and the contribution to the mechanism for reducing emissions from deforestation and forest degradation (REDD), a study on the estimation of the carbon stock was carried out within a settlement of Millettia drastica, Millettia laurentii and Markhamia tomentosa in the forest island of the Concession of the Father Eymard Eucharistic Center in Kinshasa. A one-hectare plot, subdivided into four sub-plots, was our study system.

We used the observation method, followed by the inventory of trees concerned supported by geographic coordinates of these trees.

The dendrometric data collected were subjected to an allometric application and while the geographic coordinates were the subject of the development of the spatial distribution map of the trees studied with the ARC software.GIS version 10.0.

A total of 38 individuals of trees with diameters at 1.30 m (breast height) 10 cm were inventoried over the entire study plot. The estimated aerial biomass and carbon stock were 22,670.46 and 11,335.23 kg / ha, respectively. Millettia drastica is the predominant species with 24 individuals. It had the highest aerial biomass and carbon stock estimated at 10,342.506 and 5,171.2,528 kg / ha, respectively.

The forest island studied constitutes a real carbon well of the City of Kinshasa and therefore deserves sustainable management.

Keywords: Climate change; Greenhouse gas; Sequestration; Forest; Kinshasa

1 Introduction

Climate change is one of the most important environmental issues of our time. It is caused by the increased concentration of greenhouse gases (GES) in the atmosphere. Carbon dioxide (CO_2) is the most important anthropogenic

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GHG of this change and represents 52% of the total of these gases [1, 2]. In addition, plants absorb and sequester CO_2 through the photosynthesis process, generally behaving like wells capable of constituting a reservoir and a stock of carbon. The forest thus helps to mitigate the greenhouse effect and the threat of global warming. This function is recognized within the framework of the Framework Convention on Climate Change [3, 4, 5].

However, around the world, forest ecosystems are increasingly victims of deforestation and degradation. In the Democratic Republic of Congo (DRC), if a widely held opinion is to continue to believe that the country remains this reservoir of vast areas of more or less virgin forests than it has been in the past, trends indicate rather that there has been a degradation or even an increasing disappearance of forest massifs for more than a decade, especially around large cities [6].

The city of Kinshasa, capital of the DRC, is also not immune to the anarchic destruction of its forest ecosystems. Indeed, through this City and its surroundings, several forest islands have disappeared; others are currently in a very degraded state [7]. This is the case of the forest island of the Center Eucharist Father Eymard which faces a degradation due to anthropogenic activities associating the felling of trees, in particular agriculture and the use of firewood. Several authors point out that when trees are cut and used as firewood or left to decompose, the sequestered carbon is again released into the atmosphere [8, 9].

In view of the above, it is necessary to set up tools which can guide the managers of the forest island of the Center Eucharist Father Eymard in order to make this ecosystem a reservoir (well) carbon rather than a source of emissions of this greenhouse gas.

Improving and making knowledge available are essential elements that avoid obstacles to the implementation of an integrated approach to sustainable forest conservation and management [10]. To do this, knowledge of the biomass and carbon stock of trees is an important tool for sustainable forest management. Knowledge of biomass makes it possible to deduce the carbon stock, an indicator of the quantity of CO_2 that could be released into the atmosphere if the trees were lost. This makes it possible to estimate the compensation to be set up during the felling of trees in this forest [8, 11, 12].

Thus, this study aims to estimate the carbon stock of a settlement of three dominant tree species in the forest island of the Concession of the Center Eucharist father Eymard in Kinshasa; in addition, it is part of a perspective of combating climate change and contributing to the mechanism for reducing emissions from deforestation and forest degradation (REDD).

2 Equipment and methods

2.1 Study medium

This study concerned the forest island located in the Concession of the Center Eucharistifs Père Eymard, itself located geographically between 04°27'36.3'' and 04°27'44.0'' South latitude and between 015°14'31.2'' and 015°14'39.3'' East longitude, either southwest of the Municipality of Mont-Ngafula, in the City of Kinshasa in the Democratic Republic of Congo. The forest island studied covers an area of 4.31 hectares out of 7.29 which constitute the spatial occupation of the Concession. Figure 1 gives the location of the Concession of the Father Eymard Eucharistic Center in the City of Kinshasa; while Figure 2 presents the spatial occupation of the aforementioned Concession [13].

From the climatic point of view, the forest island of the Pere Eymard Eucharistic Center Concession enjoys the climate of the Kinshasa region, which belongs to the humid and hot tropical climate of the AW4 type, according to the Köppen classification: with a dry season of four months without rain (mid-May to mid-September), a rainy season (November to April) during which the average annual rainfall from 1997 to 2006 was 1811,5 mm, with May and October constituting transition months; however, climate change is manifested by an increase in rainfall in terms of its height and intensity. The average annual temperature is 25°C [14, 15, 16].

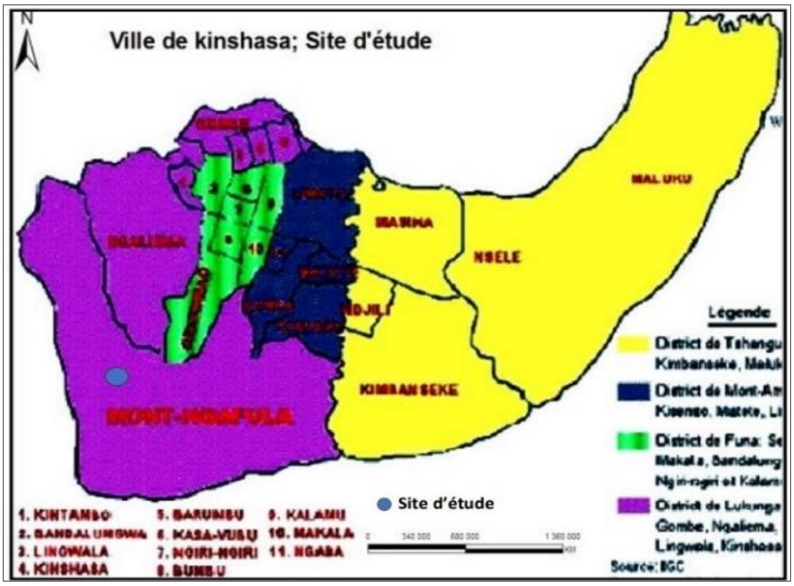

Figure 1 Location of the Concession of the Father Eymard Eucharistic Center in the City of Kinshasa [13]

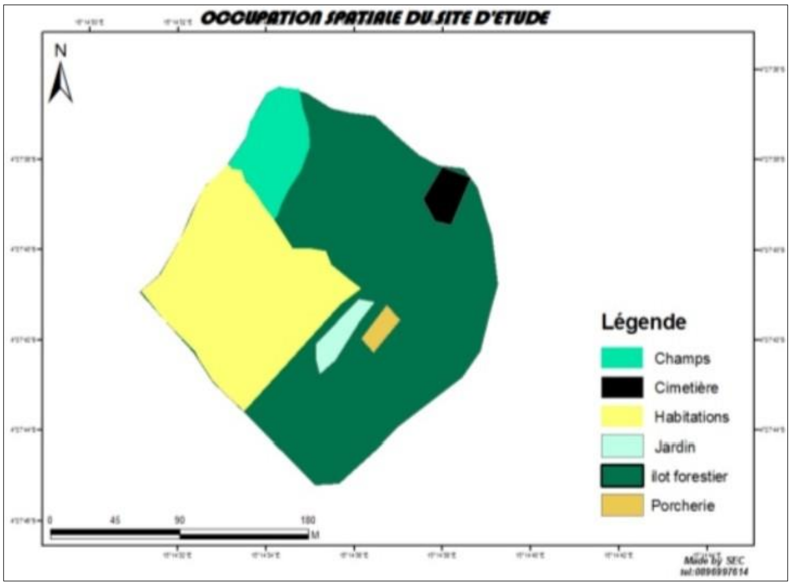

Figure 2 Spatial occupation of the Concession of the Father Eymard Eucharistic Center [13]

2.2 Materials

The material used in this study consisted of a set of botanical samples collected during our field observations of the three most dominant tree species in terms of density in the study environment. In addition, to properly conduct our field investigations, we used the following tools:

- A 25 m nylon line to measure and mark out a study plot;
- A machete to open the lines;
- Secateurs, newspapers and a wooden press to harvest and preserve the botanical samples;
- A GARMIN-branded GPS receiver to pick up the geographic coordinates of points on the ground;
- A 150 cm measuring tape to measure at 1.30 m above the ground (chest height) the circumferences of trees of three species studied;
- Aluminum nails and numbered tags to mark trees;
- An inventory sheet to record the data collected in the field.

2.3 Study methods

To carry out this study, we resorted to the method of observation, followed by the inventory of the population of three arborescent species being the object of study, supported by a statistical analysis and the elaboration of the map of the spatial distribution of this stand. To do this, we have opted for the following methodological approaches:

- Random delimitation, in the forest island, of a study plot of one hectare (100 m x 100 m) divided into four sub-plots (SP) of 2500 m2 (50mx50m) serving as observation and inventory.

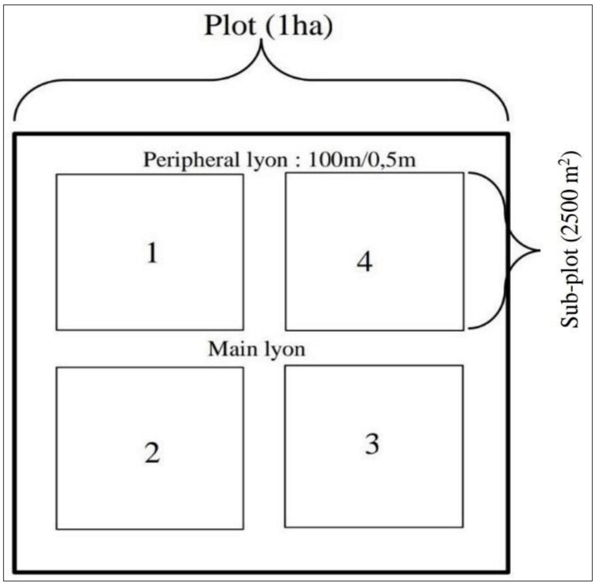

Figure 3 Presentation of the study plot divided into four sub-plots

- Determination of the density of three flagship tree species: it was carried out by counting the number of trees of the flagship species over the entire plot delimited [17].
- Harvests botanical samples of the three dominant tree species in the plot.
- Identification of the three dominant tree species: it was made with the herbarium of Unikin-INERA from our botanical samples collected in the field.
- Tree inventory: it consisted first of all in measuring under plot by sub-plot, using a tape measure, the circumference noted at 1.30m above the ground (at breast height) for each individual of three species concerned by the study [18]. These circumferences allowed us to calculate the diameter of each tree studied. Only individuals whose circumference was greater than or equal to 30 cm were selected for this inventory; this circumference corresponds to a diameter greater than or equal to 9.55 cm ≈ 10 cm. Then we took the geographic coordinates at the base of each foot of individuals retained from the main trees, using a GPS receiver. The circumferences and geographic coordinates of the trees selected were noted in our inventory sheet.
- Calculation of diameters: it required the use of the relationship between the circumference and the diameter: $C = \pi \times D$, or $D = C / \pi$ with, D : diameter of the tree at breast height (DHP or 1,30 m above ground); C: circumference of the tree (measured 1,30 m above the ground) ; π (pie) = 3,14 [18].
- Distribution of diameter classes: it required a priori defining the number of classes (J) and the amplitude or class interval (I). On this, we used the Sturge rule for which, $J = 1 + (3.3\log(n))$. The class interval (I) was then obtained as follows: $I=\frac{Xmax-Xmin}{J}$, with Xmax and Xmin designating respectively the largest and the smallest of the observed values of diameters. From the smallest value observed, the class limits are obtained by successively adding the class interval (I) [19].
- Calculation (estimate) of the aerial biomass of trees: several allometric equations integrating the dendrometric parameters from the forest inventory can be used. In this study, we used the following equation which incorporates only one parameter, namely the DHP of each tree : Biomass (kg) = exp (-2,289 + 2,649*lnDHP – 0,021*lnDHP2). This is an equation applicable for all species in tropical humid climate zones with precipitation varying between 1500 and 4000 mm. In addition, it is used with reliability for any tree whose maximum DHP = 148 cm. It was proposed by Brown S. [8] and updated by Pearson T. et al. [11].

- Calculation of the carbon stock: it consisted in deducting the quantity of the biomass, dividing it by 2 or multiplying it by a conversion factor equal to 0.5 [8, 11]. Indeed, it is generally and widely acquired, according to the average molecular formula of plant material (CH1.44O0.66), that the mass of carbon atoms is half (50%) biomass [20, 21, 22].Other studies show that this relationship varies slightly depending on the species of wood. This is a relationship that should be further studied in order to improve the quality of biomass conversions into carbon masses [23, 24, 25].
- Treatment of field circumferences obtained and calculated diameters was done by the Excell 10 software; while the geographic coordinates obtained in the field have been processed in ARC-GIS software version 10.0, available at the GIS for All digital mapping laboratory at the Faculty of Science at the University of Kinshasa. This treatment consisted in the development of a spatial distribution map of the trees studied.

3 Results

Table 1 Floristic composition of three species in the plot studied (1ha)

Family	Genus and species
Fabaceae / Faboideae	Millettia drastica Welw ex. K. Schum
Fabaceae / Faboideae	Millettia laurentii De Wild
Bignoniaceae	Markhamia tomentosa (Benth) K. Schum Exeng.

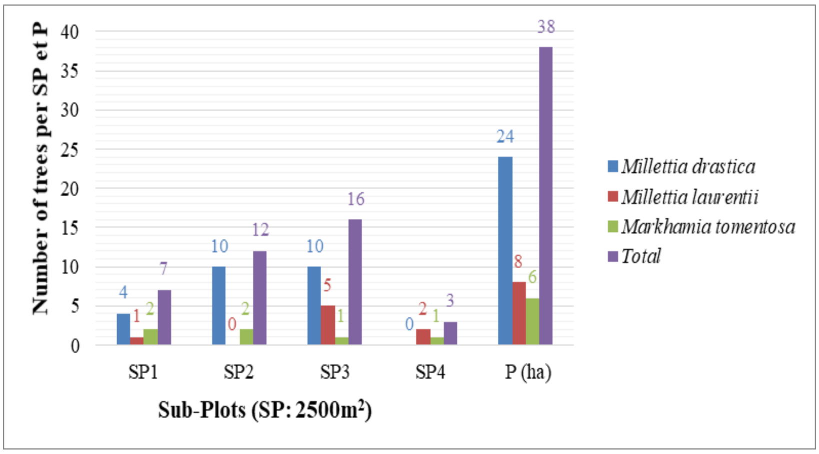

Figure 4 Population density of three tree species studied by sub-plot (SP) of 2500 m^2 and by plot (P) of one ha

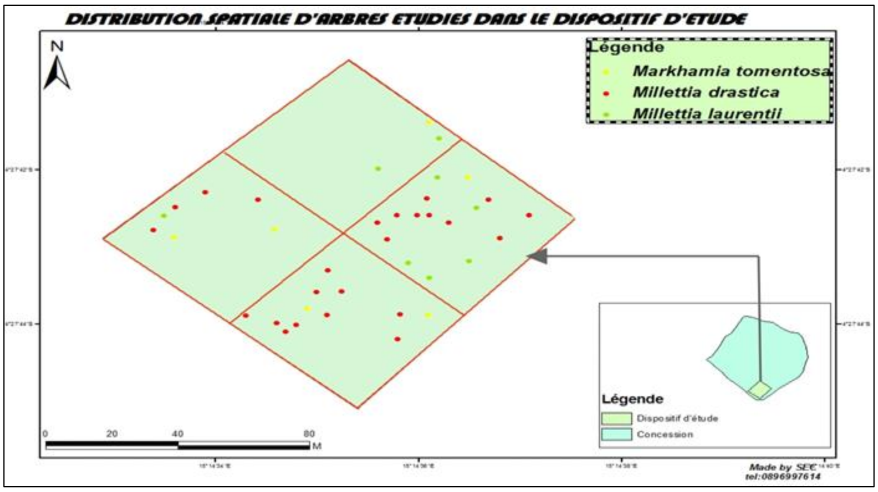

Figure 5 Spatial distribution of the settlement of three tree species studied

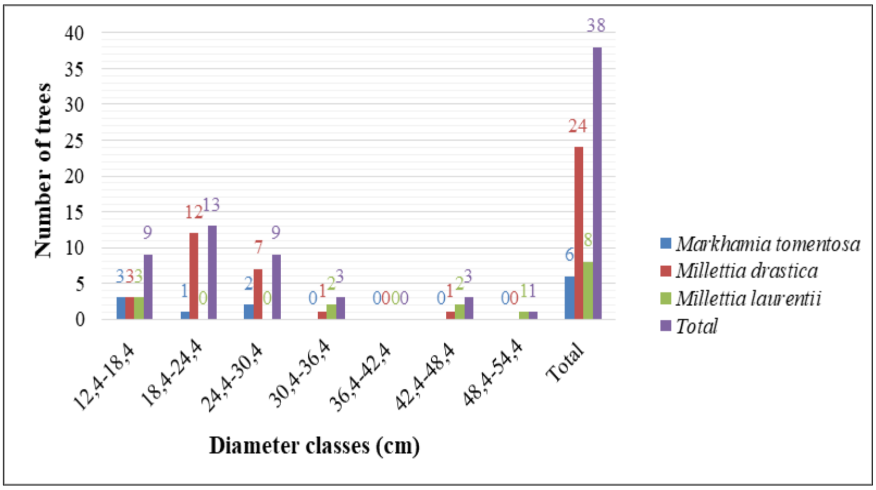

Figure 6 Distribution of trees studied by diameter classes in the plot (1ha)

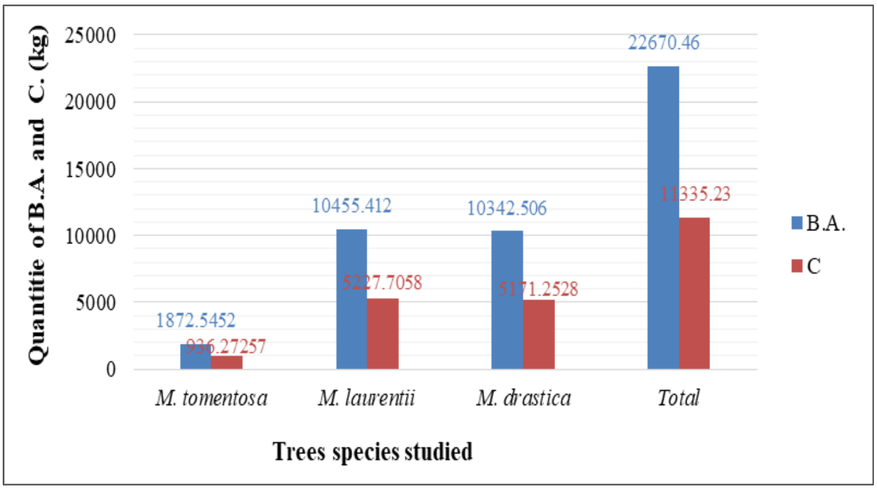

Figure 7 Quantities of aerial biomass (B.A.) and carbon stock (C) estimated by species studied

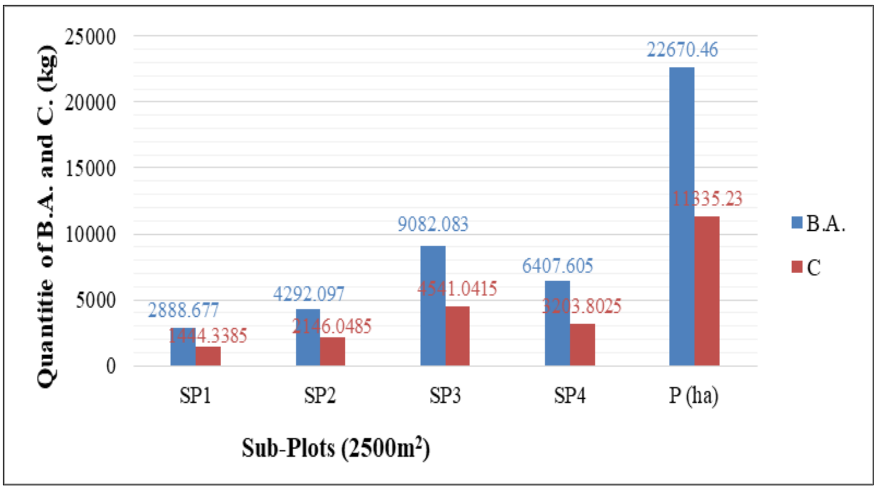

Figure 8 Quantities of aerial biomass (B.A.) and carbon stock (C) estimated by Sub-plot (SP) and by Plot (P)

4 Discussion

Observations made in our study indicate that the forest island of the Concession of the Center Eucharist Father Eymard in Kinshasa is characterized by *Millettia drastica, Millettia laurentii* and *Markhamia tomentosa* as dominant species in the tree layer. In addition, in the forest island of the Monastery Our Lady of Assumption in Kinshasa, Lubini A. and al. [7] identified four of the main species, namely *Anthocleista schweinfurthii, Dracaena mannii, Millettia laurentii* and *Pentaclethra eetveldeana.* While the results of Kiaka N. [26] indicate that our three species studied are among the dominant with 33 individuals from *Millettia drastica*, 28 individuals from *Millettia laurentii* and 3 individuals from *Markhamia tomentosa* on the density of tree and shrub stands evaluated per hectare of the forest islet in the horse racing circle of Kinshasa. *Millettia laurentii* is present in all these forest islands. Regarding the diameter (DHP), the majority of the trees measured for this study have diameters included in the classes of 18,4-24,4; 12,4-18,4 and 24,4-30,4 cm. The other diameter classes are only very little represented, even zero. The scarcity of trees with large diameters in our study plot can testify to the strong degradation of this population following anthropogenic activities, particularly the cutting of trees for carbonization.

In general, the biomass and carbon estimates are 22.670,46 and 11.335,23 kg/ha respectively.

However, these estimates vary according to the species identified. *Millettia drastica* presented a larger aerial biomass of around 10.342,506 kg/ha compared to the other species studied in the plot, which means that it has contained the most carbon (5.171,2528 kg/ha). These observations can be justified by the higher density of this species compared to the others in the plot studied. Comparatively, Kidikwadi [27] estimated the carbon sequestered by the plant stand at *Dialium englerianum* at the bateke plateau; he certified the B.A. and C for this species respectively at 32 ± 6 and 15 ± 2 t/ha, knowing that the density for this species was 164 individuals/ha; while our results on *Millettia drastica* are only for 24 individuals. From this comparison, we can say that for the same number of individuals, *Millettia drastica* has higher results. This can be explained by much larger diameters for *Millettia drastica*. The map of the spatial distribution of the species studied reveals a contagious type distribution with an aggregate trend for *Millettia drastica*. We can therefore characterize this forest island by this species. Compared to the results obtained by Lubini A. et al. [7] on the spatial distribution of the main trees of the forest island of the monastery our lady of assumption in Kinshasa, there is similarity in the type of distribution; however, the Lubini A. et al. [7] shows an aggregate trend for *Pentaclethra eetveldeana*.

5 Conclusion

In this study, we estimated the aerial biomass and the carbon stock of a settlement of three dominant tree species in the forest island of the Concession of the Center Eucharist Father Eymard in Kinshasa, namely *Millettia drastica, Millettia laurentii* and *Markhamia tomentosa*.

The results obtained show that this forest island constitutes a real carbon well of the City of Kinshasa. It is therefore in every interest to establish sustainable management of this forest ecosystem. This study therefore serves as a guide for this management.

Compliance with ethical standards

Acknowledgments

We would like to thank the Head of the Unikin-INERA herbarium for helping us identify the botanical samples collected in the field. We would also like to thank the head of the GIS digital mapping laboratory for all of the Faculty of Sciences of the University of Kinshasa, who allowed us access to this laboratory for the development of the spatial distribution map of the trees studied.

Disclosure of conflict of interest

We declare that no competing interests exist.

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