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THE FLORISTIC DIVERSITY AND THE CARBON STOCK EVALUATIONIN ON SOME PERIPHERIES SITES OF THE DOUALA-EDEA WILDLIFE RESERVE IN CAMEROON

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ABSTRACT

The study carried out in three of the 61 villages of the reserve during the period of December 2014 to April 2015 with the objective of evaluating floristic diversity and carbon stock in these three villages. 60 transects, each of 250 m length and 20 m wide, for total area of 30 ha was used to evaluate the carbon stock. The chosen carbon reserve was the epigeneous carbon and the non-destructive method through the allometric equations based on the dendrometric measurements were used. The amount of atmospheric CO2 absorbed by forest was obtained by multiplying carbon stocks by 3.67. The monetary value was obtained by multiplying the quantities of CO2 absorbed by the price of one ton of carbon dioxide (tCO2eq) which is of the order of $ 5.9. The results show that the periphery of the reserve has a total of 10,205 trees belonging to 38 families, 78 genera and 123 species. Analysis of the diversity showed that the reserve is diversified with equidistribution of species between identical facies. The ANOVA test (P< 0,05) reveals that carbon stocks sequestered do not vary significantly between the various villages. In this villages, the adult secondary forests (FSA) sequester more carbon (362, 36 T C/ha) than all others types of forest, with a high monetary value of carbon stocks estimated at 3 730 047, 31 FCFA (6700 $).

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INTRODUCTION

Ecosystems are diversified in Cameroon with 8,000 species of plants including 300 commercial species Letouzey (1975). The growing of human needs for forests and the economic development of the country, which is mainly focused on the use of natural resources, have given rise to various forms of exploitation without guaranteeing the capacities of the resources to be regenerated Sonke (1998). These pressures lead to a decline of 100,000 to 200,000 ha of forest per year, which an annual rate of deforestation of 0.3 to 1%. The degradation rate of tropical forests and the threats of ecological extinction of the resources they contain, are at the heart of international concerns for sustainable management of the environment. By advocating the integration of rural communities into sustainable management and conservation of forest resources, it is a question of reconciling sustainable exploitation and conservation of forest resources Nguenang et *al*., (2010). The conversion of these forests through deforestation and degradation is a source of approximately 20% of global greenhouse gas (GHG) emissions and is the second leading cause of global warming Ajonina & Usongo 2001).

There are incentives to emit less and capture more greenhouse gases such as:

- Joint implementation (JI);
- The Clean Development Mechanism (CDM) under the Kyoto Protocol (KP) in 1997, which commits the industrialized countries to reduce their greenhouse gas emissions, the main cause of global warming in the order of 5.2% d by 2020 relative to their 1990 emissions;
- The GHG emission reduction mechanism for deforestation, degradation (REDD +), an incentive mitigation measure aimed at reducing deforestation, conserving and increasing forest carbon stocks in developing countries;
- The voluntary carbon market (MVC).

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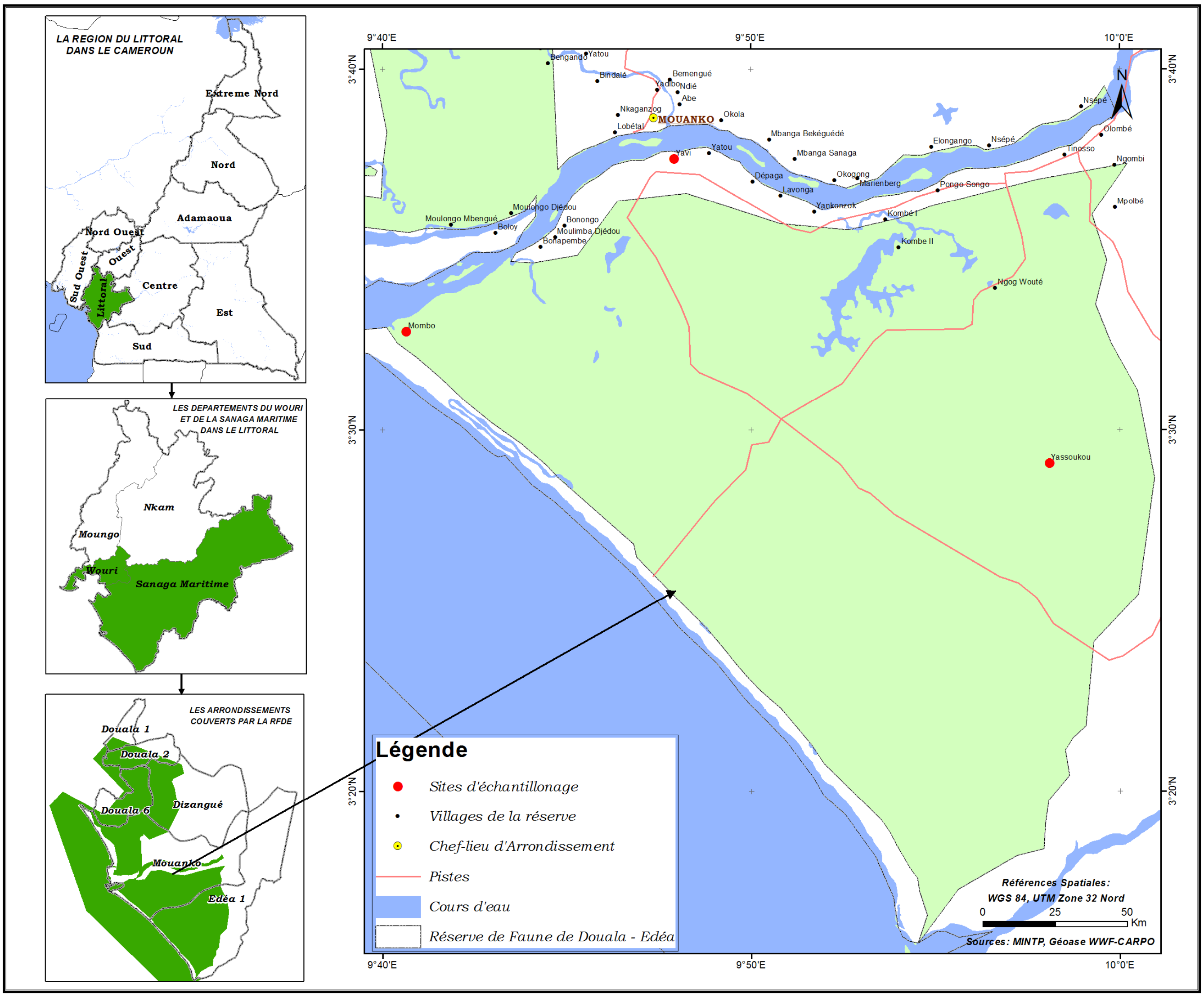

Figure 1. Location of Douala-Edea faunal reserve

All these different mechanisms give rise to payments for environmental services. Under the REDD + mechanism, equitable distribution of effort requires quantification of each country's contribution through scientific expertise. Carbon quantification has become crucial for sub-Saharan Africa to participate and develop actions to mitigate an environmental crisis to which it is most vulnerable (Zekeng (2013).

The main objective of this study is therefore to evaluate the carbon stock in some peripheral localities of the Douala-Edea reserve. Specifically, it asked to:

- Make an inventory of the vegetation;
- Identify biometric measurements of trees;
- Evaluate the carbon stock in the identified sites.

MATERIAL AND METHODS

Study site: The Douala-Edea Wildlife reserve (RFDE) is a large 2960 km^{2}on a category of protected area located in the Littoral region (Figure 1). It includes the Department of Maritime Sanaga (Districts of Edea and Mouanko) and the Wouri Department (District of Manoka). The geographical coordinates are between 3 ° 14- 3 ° 50 N of latitude and 9 ° 34'- 10 ° 03 'E of longitude.

The study area is characterized by an equatorial coastal monsoon climate with a single rainy season. Average annual rainfall is 3000-4000 mm. The reserve is divided into two parts; the largest is located south between the Sanaga and Nyong river with an area of about 100,000 ha and the smallest in the North, along the Atlantic coast to the Souelaba location with an area almost equal to 60,000 ha. The reserve is very rich in terms of biodiversity because of the presence of several habitats Ajonina and Usongo (2001).

MATERIALS AND METHODS

Vegetation inventory Method

Botanical inventories were conducted using the quadrats method (Figure 2). This method has been used by several researchers in the Boumba Beck and Nki reserves in South-East Cameroon by Nkongmeneck (1999), in the UTO coastal site of Campo-Ma'an by Angoni (2005). A total of 60 quadrats of 250 m x 20 m, representing 0.5 ha giving a total forest surface area of 30 ha. This area was used to identify all trees and shrubs of diameter at breast height (DBH) greater than or equal to 10 cm. The species have been determined scientifically and directly in the field by two botanists using differents volumes of Cameroon flora and the guide of the rainforest trees of Central Africa by Vivien and Faure (1985), the dendrology manual Anonyme (1983) and Letouzey (1983) books volumes of forest botany. The identifications were subsequently confirmed at the National Herbarium of Cameroon through the fragments of stems, branches, leaves and fruits harvested in the field.

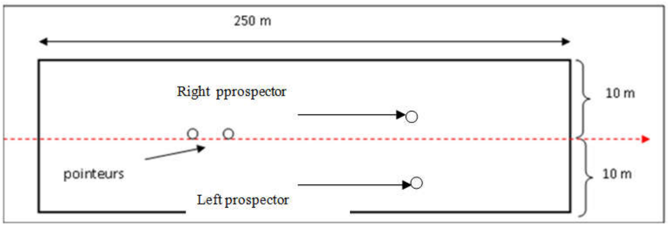

Figure 2. Counting teamdevice

Biometric measurements

In the quadrats of 250 mx 20 m, all trees from a diameter of 10 cm were identified and measured at chest height and with the aid of a tape measure, a value of the circumference of 31.4 cm to the largest trees. The measured trees were slightly wounded with a machete to avoid repeating the measurements on the same trees Vivien and Faure(1985). The diameter is obtained by the following relation:

$D = C / \pi$

D = diameter, C = circumference, Constant (π) = 3.14

Carbon Stock Assessment Method

The choice of the carbon reserves type: Several types of carbon pools exist in forest types in Africa. The present study took into account only the epigeneous carbon (carbon of living trees) and only one method was used for this purpose, namely the non-destructive method through allometric equations based on the dendrometric measurements. The choice of the allometric equation by measurements of woody upland biomass were made from the Brown et *al.* (1989) equation.

As $Y = 38.4908 - 11.7883 \times D + 1.1926 \times D^2$,

With D = diameter

The biomass evaluation for the evaluate the biomass contained in Arecaceae and other families, the following Frangi and Lugo (1985) equation was used:

$Y = 4.5 + 7.7 \times \text{height}$.

The evaluation of epigenetic carbon stocks for each biomass stock obtained by the carbon stock of the latter was obtained by dividing the biomass by two Zapfack and *al*., (2013).

Estimate of the amount of CO2 absorbed and its monetary value

The amount of atmospheric CO2 absorbed by forest ecosystems in Douala-Edea reserve was obtained by multiplying carbon stocks by 3.67 Somarriba *et al.,* (2013). The monetary value was obtained by multiplying the quantities of CO2 absorbed by the price of one ton of carbon dioxide (tCO2eq), which is about \$ 5.9 Anonymous (2013). The value of \$ 5.9 is given in CFA francs; the equivalent of 2805,686 CFA francs.

Data analysis: The floristic structure was analyzed by determining the distribution of individuals in diameter classes and density (or abundance). These ecological variables make it possible to assess the dynamics of the woody stand Kimpouni et *al*., (2008). The floristic diversity was evaluated through the species richness (RS), the Shannon index (1948), the Pielou equitable index (1965) and the Simpson index (1949).

Shannon-Weaver Diversity Index

$$\text{Ish ou } H = -\sum_{i=1}^{s} \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

Where: H = the diversity indexs = the number of taxonomic groups
Ni = the number of individuals in the first taxonomic group;
N = the number of individuals at the station.

This index makes it possible to measure the species composition of an ecosystem, in terms of the number of species and their relative abundances. However, stands with very different physiognomy may have the same diversity

RESULTS

Floristic composition: During the study conducted in the DEFR 60 qudrats, 10,205 trees including 244 dead wood were inventoried, corresponding to a density of 340.8 trees / ha. These trees belong to 123 species, 78 genera and 38 families.

Diversity of forest habitats in the RFDE: A total of 5 habitats types were identified during this study:

- The old secondary forests characterized by a fairly closed canopy with the appearance of climax forests at first glance, but distinguished from primary forests by their thicker undergrowth with a strong presence of Marantaceae and Zingiberaceae ;
- Young secondary forests are generally pre- or post-forest fallow, characterized by their dense undergrowth dominated by Marantaceae, Zingiberaceae and suffrute shrubs such as *Mallotus oppositifolius* and *Alchornea floribunda*. The pioneer species found in this plant formation are: *Musanga cecropioides* and *Trema orientalis*.
- Periodically flooded forests (FPI), which are hydromorphic forests (Figure 3). The degree of hydrometry follows an increasing gradient from dry land forests to the watercourse bank. The remarkable abundance of *Xylopia rubescens* is characteristic of these facies ;
- The swampy forests with raffia are found on hydromorphic soil and dominated by species of the genus *Raphia*, in this case *Raphia monbutorum* and *Raphia hookeri*.

Specific richness and floristic diversity variation indices: A total of 123 species were recorded in this reserve including 97 in Yavi belonging to 37 families, 55 to Mombo belonging to 30 families and 58 to Yassoukou belonging to 26 families.

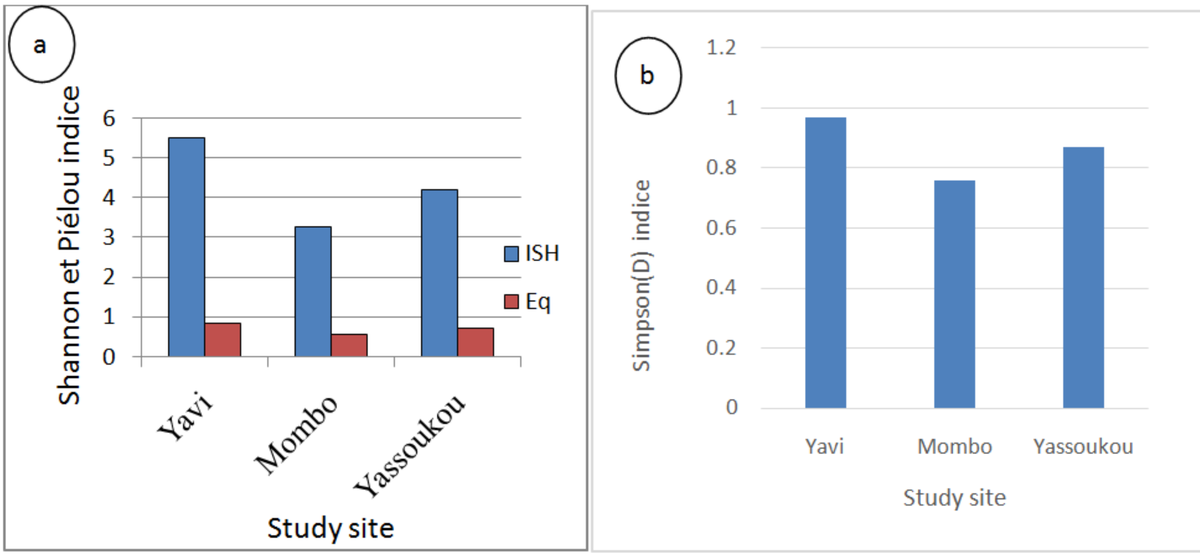

Figure 3. Variation of the indices of Shannon and Pielou (a) and Simpson (b)

Table 1. Coefficient of similarity of Sorensen in some study sites

Villages	Yavi	Mombo	Yassoukou
Yavi		42,11 %	
Mombo			31,85 %
Yassoukou	46,45 %		

The Shanon diversity index and Wiver varies between 3.26 bit (Mombo) and 5.49 bit (Yavi), with an overall value of 5.27 bit for the reserve. The Pielou equitaility variation profile follows a similar evolution and presents an overall value of 0.74 for the reserve Simpson's Yavi, Mombo and Yassoukou values are 0.97, 0.76 and 0.87 respectively (Figure 3). The overall value of this index is 0.94 for the reserve.

Abundance and diversity of families by site

Abundance of families by site: The most represented families in Yavi are: Fabaceae (16.64%), Annonaceae (12.41%), Euphorbiaceae (7.97%), Apocynaceae (7.56%), Ochnaceae (6 , 20%), Olacaceae (6.27%) and Phyllanthaceae (6.14%) (Table II).In Mombo, Ochnaceae (46.24%), Rubiaceae (10.90%), Clusiaceae (10.35%), Fabaceae (6.74%), Humiriaceae (4.41%) and Palmae (4.21%) are the most abundant families.In the Yassoukou site, the Olacaceae family is the most abundant (26.90%), followed by the Humiriaceae family (19.24%), Annonaceae (9.18%), Fabaceae and Euphorbiaceae with 7.70% and 4.26% respectively.

Gender Diversity and Abundance in RFDE: The most diverse genera encountered in this reserve are: *Albizia* (7 species), *Cola* (4 species), *Celtis*, *Combretum*, *Macaranga*, *Afzelia*, *Caloncoba, Anthocleista, Ficus, Mytragyna* and *Zanthozyllum* with 3 species each. The most abundant genera are: *Lophira* (19.49%), *Coula* (10.71%), *Sacoglottis* (7.08%), *Allanblackia* (5.89%), *Albizia* (5.18%), *Xylopia* (4.67%), *Nauclea* (3.94%), *Phyllanthus*(2,59 %) and *Macaranga*(3,25 %).

Species abundance by studied site: The most abundant species found in Yavi are: *Xylopia rubescens* (358 individuals), *Coula edulis* (248 individuals), *Lophira alata* (245 individuals), *Phyllanthus acidus* (174 individuals) and *Albizia gyzia* (173 individuals). In Mombo, *Lophira alata* (1612 individuals) *Nauclea diderrichii* (377 individuals), *Allanblackia floribunda* (236 individuals), and *Sacoglottis gabonensis* (154 individuals) are the most abundant species. *Coula edulis* (799 individuals), *Sacoglottis gabonensis* (532 individuals) and *Macaranga alnifolia* (118 individuals) are the most abundant species in Yassoukou .

Structure in diameter classes: In this study, we have classes of diameter of about 10 cm of amplitude. For all the inventories, the distribution of the numbers of trees between the diameter classes shows a large number of small trees between 20 and 30 cm than the large trees diameter (demographic structure in "inverted J") and almost a constant reduction in the number of trees from one class to another in the three villages (Figure 4). The trees are belonging to the first 5 classes studied (20-30, 30-40, 40-50, 50-60 and 60-70).

Carbon sequestration in the different sites studied

Figure 5 shows that:

- In Yavi site, old secondary forests are the most important component in carbon sequestration at 290.17 t C / ha. Young secondary forests sequestration value is 122.29 t C / ha while forests temporarily flooded sequestration value is 46.52 t C / ha and forests flooded permanently, 59.59 t C / ha. However,
- In Mombo, adult secondary forest is the most important component in carbon sequestration at 388.49 t C / ha, FSJ sequester 114.81 t C / ha and swamp forests at raphial store 63.08 t C / ha and 22.5937141 t / C / ha respectivly.
- In Yassoukou, on the other hand, adult secondary forests store 408.28 t C / ha while young secondary forests store 128.91 t C / ha.

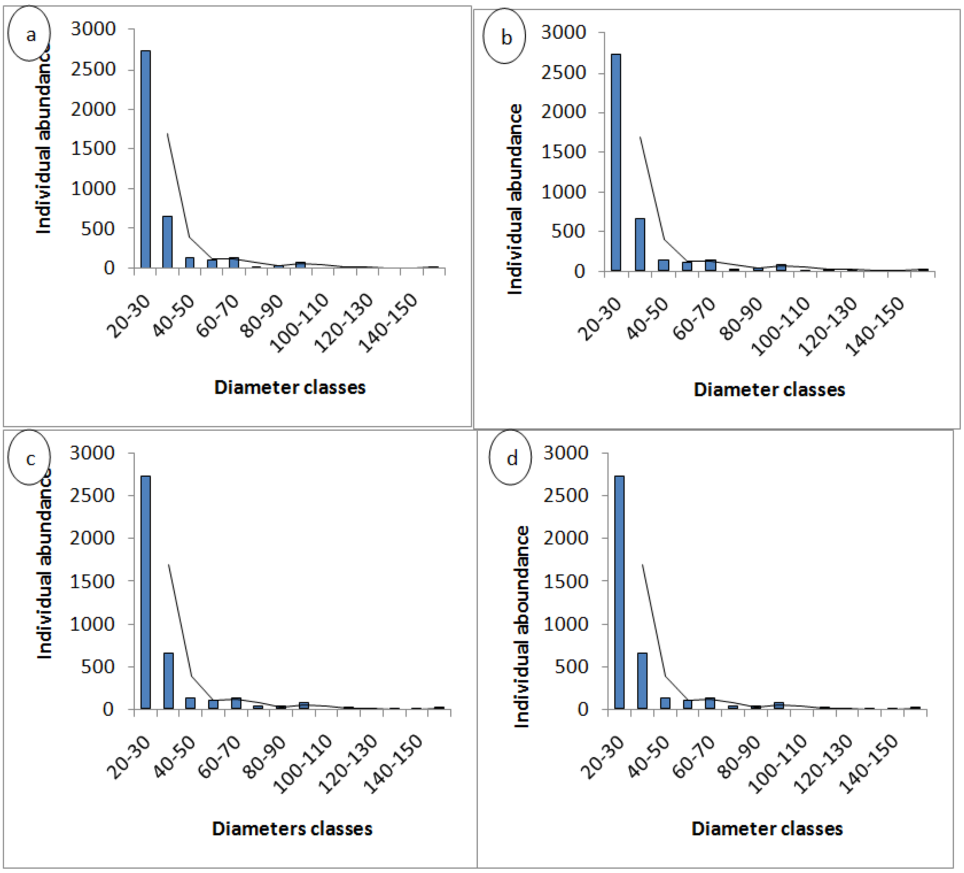

Figure 4. Distribution of species by diameter classes at Yavi (a), Mombo (b), Yassoukou (c) et dans la RFDE (d)

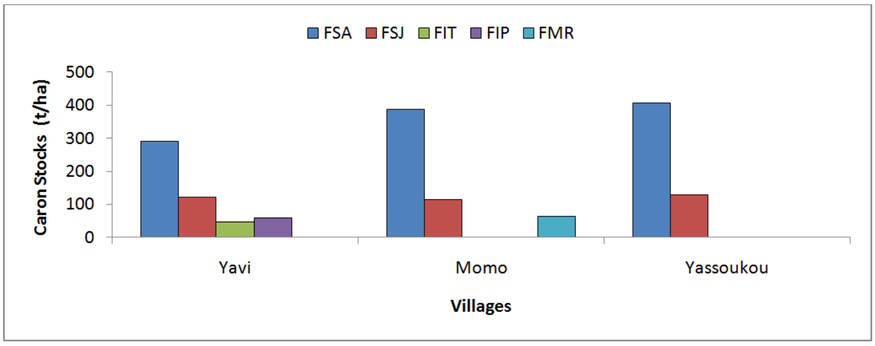

Figure 5. Spatial variation of carbon stocks in FSA, les FSJ, les FIT, les FIP and FMR

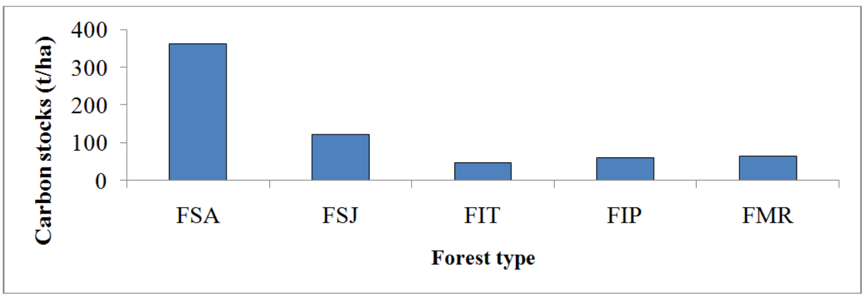

Figure 6. Carbon stocks in different forest type of forest

Table 2. Total amount of CO2 absorbed by RFDE forests and its monetary value

Forest type	Quantity of CO_2 absorb (t/ha)	Monetary value ($)
Secondary adult forest (FSA)	1329,46	7845 $
Secondary young forest (FSJ)	447,74	2642 $
Temporarily flooded forest (FLT)	170,73	1008 $
Permanentlyswamp forest (FIP)	217,56	1284 $
Swampy forest with raphials(FMR)	231,50	1366 $

Quantity of CO2 absorbed by the forest ecosystems of the RFDE and its monetary value: The monetary value depends on the quantity of absorbed CO2 by the forest. Thus the FSAs that absorb 1329.46 t CO2 / ha have the largest monetary value, followed by the FSJ with a monetary value of 1,255,217.85 F CFA (2642 $), as a result of the FMRs, the FIPs and at the end of the FITs with monetary values between 500 000 (1051 $) and 650 000 FCFA (1366 $) Table II).

DISCUSSION

In total, the species richness is 123 species recorded in all three sites visited in the reserve. This number is less than the one obtained by Angoni *et al.*, (2015) who had identified about 500 species by a study conducted in neighboring sites. The difference could be explained by the restriction of the study area around the periphery, unlike the previous one, which extended to all type of vegetation. The same result is also much lower than that obtained by Fongnzossie *et al.*, (2008) in the study of tree stands at the Mengame Gorilla Sanctuary in South Cameroon, which had identified 307 tree species. This difference in the number of species can be explained by the fact that the area surveyed (70.2 ha) by Fongnzossie *et al.*, (Op.cit.) is almost triple than that inventoried in the present study. In addition, from a phytogeographic view, the Mengame Gorilla Sanctuary reserve is located in an area known as mixed forests, characterized by the coexistence of semi-deciduous dense forest species and evergreen dense forest species. Letouzey (1968). This study confirms the importance of Douala Edea faunal reserve in carbon storage. Overall, there is a significant difference between carbon stocks sequestered by different types of forest habitats (ANOVA test ($P < 0.05$)). This difference would be related on the one hand to the low density of the woody in flooded environments and the small circumference of trees encountered in young environment on the other hand. The ANOVA test carried out in similar forests between the three villages revealed that there was no difference between them.

Thus, in the whole reserve, 362,25 t C / ha in the FSA were obtained. This result is similar to that obtained by the IPCC (2003) in the report on dense tropical forests which would store 310 t C / ha. In the FSJ, 122 t C / ha were obtained and this result is similar to those obtained by Zapfack (2013) in the Lobeke National Park in Cameroon (105.70 t C / ha) and those obtained by Romeo *et al.* (2014) in Lesio-Louna forests in the Republic of Congo (130.99 t C / ha). The sequestred carbon stock by the FIP (59.28 t C / ha), is meanwhile similar the one obtained by Romeo and al. in 2014 in the same crop formation in the Republic of Congo (67.34 t C / ha). Ha). On the other hand, the results in the FSA (362,25 t C / ha) are higher than those obtained by Roméo et *al.* (2014) in the Republic of Congo in the forest of Lesio-Louna which had obtained carbon stocks of 204 t C / ha. The carbon stocks obtained in the ITFs (46.52 t C / ha) are different from those obtained by Kono *et al.*, (2015) (109 to 227.90 t C / ha). These differences could be explained by the density of trees per hectare, the density of large diameter trees, the size of circumferences, soil fertility and the choice of carbon reserves.

Conclusion

This study assessed the floristic diversity in the Douala Edea reserve and demonstrated its influence on carbon sequestration potential. At the end of this study, the botanical inventory in the different quadrat and villages made it possible to identify 123 plant species divided into 78 genera and 38 families. It is clear from this inventory that the flora of this reserve is relatively rich, with a rather high specificity (ISH = (5,27).The adult secondary forests (ASF) sequester more carbon (362.36 t C / ha) than young secondary forests (FSJ = 122 t C / ha), followed by temporarily flooded forests (FIT) that store 46, 52 t C / ha, permanently flooded forests FIP sequestering 59.28 t C / ha and swamp forests to raphial (FMR) which store 63.08 t C / ha. The amount of carbon stored in biomass varies with the density of trees per hectare, the density of large diameter tree. The monetary value of the reserve is estimated at CFAF 3,730,047.31 (7845 $) for the FSA, CFAF 1,256,217.85 (2642 $) for the FSJ, CFAF 479,010.28 (1008 $) for the FIT, CFAF 610,398.31 (1284 $) for the FIP and 649,526.41 FCFA (1366 $) for the FMR. These figures clearly demonstrate the ecological importance of the stands of the reserve in the storage of carbon storage consequently in the mitigation of the greenhouse effect phenomenon. Given the current size of the reserve, which is estimated at 160 000 ha and, this monetary value shows that incitative actions that can emanate from the carbon market through the REDD + mechanism are important.

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Appendix I. List of DEFR flora

Family	**species**	family	**species**
Anacardiaceae	*Trichoscypha arborea*	Euphorbiaceae	*Bridelia feruginea*
	Trichoscypha sp.		*Alchornea cordifolia*
Annonaceae	*Allanblackia floribunda*		*Macaranga alnifolia*
	Annickia chlorantha		*Macaranga cordifolia*
	Annonidium mannii		*Macaranga spinosa*
	Polyalthia suaveolens		
	Sirdavidia solannona		
	Xylopia aethiopia		
	Xylopia rubescens		
	Alstonia boonei	Fabaceae	*Microberlinia* sp.
Apocynaceae	*Funtounia africana*		*Acacia* sp.
	Rauvolfia sp.		*Afzelia africana*
	Rauvolfia vomitoria		*Afzelia bella*
	Strophanthus welwitschii		*Afzelia bipindensis*
Asteraceae	*Vernonia conferta*		*Albizia adianthifolia*
Bignoniaceae	*Newbouldia laevis*		*Albizia ferruginea*
Boraginaceae	*Cordia millenii*		*Albizia glaberrima*
Burseraceae	*Canarium schweinfurtii*		*Albizia gummifera*
	Dacryodes buettneri		*Albizia zygia*
	Santiria trimera		*Albizia lebbeck*
Cannabaceae	*Celtis africana*		*Albizia micrantha*
	Celtis mannii		
	Celtis tessmannii		*Anthonotha macrophylla*
Cecropiaceae	*Musanga cecropiodes*		*Distemonanthus benthamianus*
Clusiaceae	*Allanblackia floribunda*		*Erythrophleum africana*
	Allanblackia gabonensis		*Erythrophleum guineensis*
	Garcinia cola		*Pentaclethra macrophylla*
	Garcinia sp.		*Millettia sanagana*
	Harungana madagascariensis		*Piptadeniastrum africanum*
Combretaceae	*Combretum hispidum*		*Tetraberlinia* sp.
		Flacourtiaceae	*Caloncoba glauca*
	Combretum quadrangulara		*Caloncoba* sp.
	Combretum zenkeri		*Caloncoba welwischii*
Conaraceae	*Cnectis ferruginea*	Humiriaceae	*Sacoglottis gabonensis*
	Cnectis palala	Irvingiaceae	*Desbordesia glaucesens*
Dilleniaceae	*Tetracera scandens*		*Irvingia robur*
Ebenaceae	*Diospyros ferrea*		*Irvingia won bulu*
	Diospyros sp.	Loganiaceae	*Anthocleista liebrechtsiana*
			Anthocleista schweinfurtii
			Anthocleista vogelii

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Malvaceae	*Bombax buenopozense*	Passifloraceae	*Barteria fistulosa*
	Ceiba pentandra		
	Cola accuminata	Phyllanthaceae	*Margaritaria discoides*
			Phyllanthus acidus
	Cola grandifolia		*phyllanthus discoides*
	Cola nitida		*Phyllanthus distachus*
	Cola pachycarpa	Polygalaceae	*Carpolobia alba*
	Desplatsia dewevrei		*Carpolobia lutea*
	Sterculia rhinopetala		
	Sterculia setigera	Putranjivaceae	*Drypetes chevalieri*
Melastomacaceae	*Marieta guianensis*		*Drypetes reticulata*
Meliaceae	*Khaya grandifolia*	Rubiaceae	*Mitragyna speciosa*
	Trichildia acuminata		*Mitragyna stipulosa*
Moraceae	*Ficus mucuso*		*Nauclea diderrichii*
	Ficus ombellata		*Psychotria vogeliana*
	Ficus polita		*Rhothmania* sp.
	Milicia excelsa	Rutaceae	*Fagara macrophylla*
Myristicaceae	*Pignantus angolensis*		*Fagara zanthoxyloides*
Ochnaceae	*Lophira alata*		*Zanthoxylum heitzii*
Olacaceae	*Coula edulis*		*Zanthoxylum macrophyllum*
Palmae	*Calamus moli*		*Zanthoxylum* sp.
	Elaeis guineensis	Sapindaceae	*Paullinia pinnata*
	Laccosperma robustum	Sapotaceae	*Baillonella toxisperma*
	Laccosperma secundiflorum	Ulmaceae	*Trema* sp.
	Raphia monbuttorum		*Autranella congolensis*
	Raphia sp.	Verbenaceae	*Vitex doniana*

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