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Feasibility Study For The Redd + Mechanism: The Case Of The Establishment Of Permanent Plots In The Ngoyla Mintom Forest Massif In Ufa 10-032 And 10-035

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Abstract
This study focuses on the contribution to the conservation of biodiversity and evaluation of carbon stocks in the forest of Ngoyla-Mintom. The objectives of the establishment of plots sampling in the area of Ngoyla-Mintom have been achieved. Indeed, field visits were conducted in January to March 2012 in two MFU 10-032 (102,103 ha) and 10-035 (101 793 ha). Trees and some shrubs have been identified, measured and marked according to the methodology proposed by Wildlife Works Carbon, coordinator of the project study (WWC-version of 18 January 2012). Twenty people took part in the establishment of permanent plots of biomass carbon assessment for a preparation for the future REDD+ mechanism. The results obtained during the implementation of plots show 1053 species with 395 species of shrubs located within the three meters radius and 658 trees in the ten meter radius of the floristic survey. The establishment of plots sampling can be used for future experimental studies in the assessment of carbon stocks for the preparation of Cameroon for the future REDD+ mechanism.

Keywords: Ngoyla-Mintom, plots, REDD, carbone.

1. INTRODUCTION

The Congo Basin accounts for 70% of the African continent's forest cover and is home to a large proportion of Africa's biodiversity. The six countries in the Basin - Cameroon, Gabon, Equatorial Guinea, the Central African Republic, the Democratic Republic of Congo and the Republic of Congo - share this ecosystem. Around 57% of the region is covered by forest, making it the second largest tropical forest area in the world after the Amazon (Megevand C. et al., 2013). Cameroon accounts for 11% of the total forest area in the Congo Basin, i.e. 19,639,000 ha out of 184,155,999 ha (Megevand C. et al., 2013).

It has been established that the world's climate is changing every day as a result of natural variability and anthropogenic causes. This leads us to understand changes in atmospheric composition, hydrological cycles, solar inputs and changes in the biogeochemical carbon cycle, given that one hectare of forest can sequester up to 2 to 5 tonnes of carbon per year (Negi et al., 2003).

Global change is affecting the composition of the atmosphere, land use and, more specifically, the climate (Mooney et al., 1999). Environmental degradation in terms of greenhouse gases (GHGs), carbon dioxide (CO2) emissions, ozone depletion, land degradation, water scarcity, deforestation and other calamities are considered a threat to human well-being (Anon 2001, Alamgir et al., 2008).

In today's context, the increase in GHG emissions is one of the main concerns addressed by the Kyoto Protocol (Ravindranath et al., 1997) because it is the main factor responsible for global warming. This protocol recognises that forests should be the best carbon sink for storing CO2 in the atmosphere (Ross, 2000, Alamgir et al., 2008). In addition to this, Jana et al (2009) have pointed out that an increase in the concentration of CO2 in the atmosphere stimulates the rate of photosynthesis in trees and can lead to an increase in growth rates and biomass production.

Following the initial findings on climate change, the Intergovernmental Panel on Climate Change (IPCC) was set up in 1988. It was behind the signing of the United Nations Framework Convention on Climate Change (UNFCCC), ratified in 1992 at the Earth Summit in Rio de Janeiro. The aim of this convention is to stabilise GHG concentrations in the atmosphere (Anonymous, 1992), designating the countries responsible in Annex 1 (35 developed countries). The governments of Papua New Guinea proposed integrating the reduction of emissions from deforestation (RED) in developing countries at the Conference of the Parties (COP) in Montreal in 2005 (Anonymous, 2005).

This study proposes to establish permanent plots to collect biomass data that will be used to estimate the total amount of carbon stored in the 10-032 and 10-035 Forest Management Units

(FMUs), which are 102,103 ha and 101,793 ha respectively allocated to NM in this study.

More specifically, it aims to:

- Set up permanent plots in FMUs 10-032 and 10-035;
- Identify the tree species in the plots;
- Measure and mark the species identified in the plots;
- Assess the biomass in the various plots sampled;
- Estimate the carbon stock sequestered in the sampled plots.

2. MATERIAL AND METHODS

2.1 Inventory: data collection protocol

The protocol sets out the measurement conventions, study variables and data collection conditions. To set up the plots, it is important to ensure that all the necessary equipment has been assembled and is in good condition. The coordinates of the 50 plots to be identified were pre-recorded in the GPS so that the plots could be set up efficiently on a daily basis. The time of departure and return to the camp, as well as the meeting points with the other team, must be included in the daily reports of the different teams. The team leaders must ensure that everyone has returned safely to the camp and that the equipment has been inventoried.

The descent into the field consists of gathering all the necessary equipment is assembled and in good working order with the GPS coordinates pre-recorded and locating the plot closest to the village or camp, i.e. a 2-hour walk from the village or camp. Some plots can be easily accessed with a vehicle, while others require climbing steep cliffs through thick vegetation. There is no guarantee that the plots will be accessible. Pocket GPS and knowledge of the area are the only guarantees of getting down to the land. It is therefore extremely important to understand how to navigate in order to minimise the risk of getting lost.

While it is possible to navigate in a vehicle close to the selected plot using a GPS, it is preferable to follow the road until it is perpendicular to the location of the plot and then take a perpendicular route on foot to the centre of the plot. Each group was made up of one (1) team leader (forestry engineer), one (1) ecoguard, one (1) botanist/biologist, one (1) nurse, one (1) sociologist/anthropologist, one (1) compass-maker, two (2) macheters and two (2) surveyors.

Fig. 1. Land surveyors.

2.2 Setting up plots

Once the installation site has been located, the following steps must be taken to mark out the plot on the ground:

- Give preference as far as possible to flat land to make it easier to lay out the plots, while bearing in mind that some points may be in uneven areas (watercourses, marshes, slopes, stones, etc.)
- Select and mark the centre of the plot permanently by hammering an iron bar (about 30 cm) into the ground with a plastic cap on top (you can come back to these plots 25-30 years later, as carbon projects are long-term);
- Use the compass to identify the magnetic north of the direction of the centre of the standing plot, avoiding the proximity of any metal objects that might interfere with the reading on the compass;
- Measure the plot with a radius of 10 m from the centre of the plot;
- Mark out a 3 m radius to count the shrubs;
- Determine the minimum diameter of the tree, i.e. 10 cm dbh (below this diameter, the tree is considered to be a shrub). This will depend on the average size of trees in the region and the number of trees on a plot);
- As far as possible, select plots with an average number of trees of 20-25;
- Move the centre of the plot if it is on the road or inaccessible, then walk 100 m north. (If you come across another inaccessible spot during this 100 m walk, continue in another (random) direction until you reach an accessible point. This will be the new centre of the revised plot);
- Record the new coordinates of the centre of the revised plot on the field sheet;
- Compile all the data in the appropriate forms.

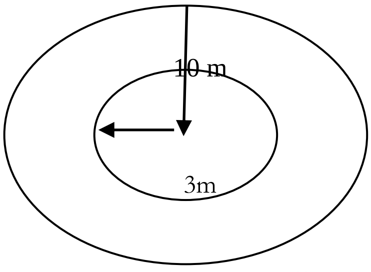

Fig.2. Sample plot of trees in different radii.

2.3 Measuring and marking trees

Our study is based on the design and implementation of a protocol for measuring dbh and tree height with a view to calculating biomass in tropical rainforests. The list of trees identified is given in the appendix.

Estimated variables

In the case of our study, the following parameters were selected:

- Diameter in centimetres (cm) to measure the growth of trees (diameter = 10 cm) in order to determine their long-term land area, volume and biomass;
- Height in metres (m) to estimate the volume of standing trees;

2.4 Measurement conventions

The measurement conventions define the conditions under which individuals are retained and measured within the permanent plots: The diameter is measured on the bark at chest height (1.30 m from the ground) at the foot of trees with a diameter greater than or equal to 10 cm, with the exception of those with obvious defects (buttresses, bumps, knots, bulges, forks, bends, etc.). In these cases, the measurement is taken above or below the defect. Large-diameter trees have been estimated and the word "estimated" is entered in the observation box on the inventory data sheet; The total height is estimated visually using a clinometer or laser telemetry at a certain distance from the trunk so that the operator can see the top of the crown. For the 3 m radius, a string is tied to the iron bar at the centre of the plot and a distance of 3 m is measured with the tape measure. The multicoloured signalling tapes are placed in a circular fashion, starting from the north direction, so that the first tree in the north angle can be measured. So, within the 10 m radius, start by measuring the tree closest to the northern boundary of the centre of the plot, going clockwise until you complete a full circle. Tableau 1. Récapitulatif des angles d'une parcelle.

Table 1 Orientation of land

Land	Orientation	Viewing angle
Portion 1	North-South	0°
Portion 2	East-West	90°
Portion 3	South-North	180°
Portion 4	West-East	270°
Portion 5	South-West	359°

2.5 Measuring shrubs

Although it can be tedious, all shrubs within each plot should be counted and recorded. Depending on the ecosystem and the distribution of shrub species, methods may vary slightly. It is therefore important to become familiar with the growth patterns of the species in the project area and use this information to develop an accurate method for assessing shrub biomass. Measurement of herbaceous vegetation or lianas is not necessary.

For the purposes of this study, all shrubs are counted within a 3 m radius.

- from 0.10 to 1 m in height are in the 'small' class (P);
- from 1 to 3 m in height are in the 'medium' class (M);
- from 3 m in height with less than 10 cm DBH are classified as 'large' (G).

2.6 Measuring trees

Biometric data must be collected in each plot. All trees in the plots should be measured, including live trees, standing and lying dead trees. The following steps are used to measure and collect data on the trees:

- locate the tree closest to north (the smallest angle from north);
- enter the number stamped on the tree's aluminium tag on the field sheet;
- identify and record the tree species. If the species is unknown, record the tree's form class using the form's class identification sheet:
- If the species is unknown from the numerous species in the ecosystem (more than 15), samples of the bark and leaves (and fruit) of the tree should be taken for possible laboratory tests;
- If the tree species is unknown, but represents a dominant species in the field, this information is recorded in the species column of the field sheet (species A, species B, etc. for all trees that reproduce in the ecosystem but are not identified). The aim is to ensure that the fundamental foreign samples are collected.
- If the species is unknown and only a few species are unknown in the ecosystem (less than 15), herbarium samples are taken for subsequent analysis, including, if possible, samples of bark, leaves, fruit and flowers. Also take a photograph of unknown species.
- measure and record the angle of the distance between the centre of the plot and the centre of the tree trunk using metric tape;
- assess the tree trunk to determine whether the tree is single or multi-trunk:
- if it is a single trunk, use the D-tape to measure the diameter at tree breast height (DBH) at 1.3 m from the ground;
- if it is a tree with several trunks and splitting occurs below the height of 1.3 m, each stem is measured just above the first split at the smallest visible diameter;
- if several groups exist below 1.3 m in height, only the diameters of the stems resulting from the first split need be recorded;

- if the split occurs below ground level, the tree should be considered a multiple trunk and each stem should be measured at approximately 10 cm above ground level;
- if the tree splits again below the height of 1.3 m, only the branches directly after the first split should be measured and recorded.
- determine the condition of the tree and record the information in the appropriate column on the field data sheet:
- live tree upright (L)
- live tree leaning (LL)
- dead tree standing (SD)
- dead tree lying (LD)
- determine the start of the canopy closest to the centre of the plot;
- determine the end of the canopy at the point furthest from the centre of the plot;
- determine the height of the trees using a clinometer or other measuring method by aiming at the highest leaf in the crown;
- determine the status of standing dead (SD) trees using the following elements
- trees with branches and twigs that resemble living trees (except for leaves);
- trees showing loss of twigs and branches.
- determine for fallen dead (LD) trees, collect and record the fallen dead condition using the machete according to IPCC (2003), including any of the following: rot, sound, etc....
- nail on an aluminium tag containing the tree number recorded on the data collection sheet;
- repeat all the steps listed, moving clockwise until all the trees in the plot are recorded on the field sheet.

Fig. 3. Measurement of the circumference of a tree.

Since the tree height is obtained by laser telemetry, three trigonometric calculation models were used to obtain it:

Table 2: Trigonometric calculation models for obtaining tree heights.

	Equation Trigonometric rule applied Parameters used
1	$H = \mathit{d\ top} + 2.1\ \mathit{d\ top}$
2	$H = ((\mathit{d\ top} + 0.8) * \mathrm{Sin}\,(+ 0.8)) + 1.3$
3	$H = ((\mathit{d\ top} + 0.8) * \mathrm{Sin}(\mathrm{Acos}(\mathit{d\ top} / \mathit{dhorizontal}) + 0.8))$

Where: *d top*: the distance to the top; *d horizontal*: the horizontal distance to the trunk. The values 0.8 m and 1.3 m represent the length of the observer's arm and the height to the chest, respectively.

All trees with a DBH greater than 10 cm were marked in each plot. Species identification was carried out with the naked eye by local people (Baka and Djem) by observing the leaves, and in some cases it was necessary to take samples of bark, leaves and fruit. For those that could not be identified with certainty, herbarium samples were collected so that identifications could be verified in the laboratory. Small trees with a DBH of less than 10 cm were counted within a 3 m radius, which was also the subject of our inventories.

2.7 Dendrometric data

Once the data has been collected in the field, we enter it into Microsoft Office Word in alphabetical order, in the rows the trees and in the columns the scientific names, botanical families and dendrometric parameters (diameter and height). Then, in the columns, we add the volume and aerial biomass of the two equations chosen, as well as their constants. These tables, drawn up in 'Word', are then entered into Microsoft Office Excel to carry out the various possible treatments using statistical formulas.

The descriptive statistics involved grouping the data contained in the sheets designed on an Excel workbook called "raw data" into a single sheet, in the form of a database. This basic data was used to carry out a number of processing operations as follows:

- checking, correcting and validating the data with the field sheets in Excel using the "automatic filter" option in the "Data" menu and the "Find and replace" option in the "Edit" menu;
- preliminary calculations: variables to be calculated with "Dynamic cross-tabulations" and verification of the consistency and relevance of the results.

3. RESULTS

3.1 Setting up plots

A total of fifty (50) permanent plots were installed and marked out in the field in FMUs 10-032 (102103 ha) and 10-035 (101793 ha), covering a total area of 203 896 ha. These plots are circular in shape, each 20 m in diameter.

3.2 Number of species recorded

In the plots sampled, 687 trees with a dbh greater than or equal to 10 cm were counted, as shown in the table below.

Table 3: Number of trees by height.

Height	**5-10m**	**10-20m**	**20-30m**	**30-45m**	**>45m**	Total
Number of species	32	405	162	81	7	687

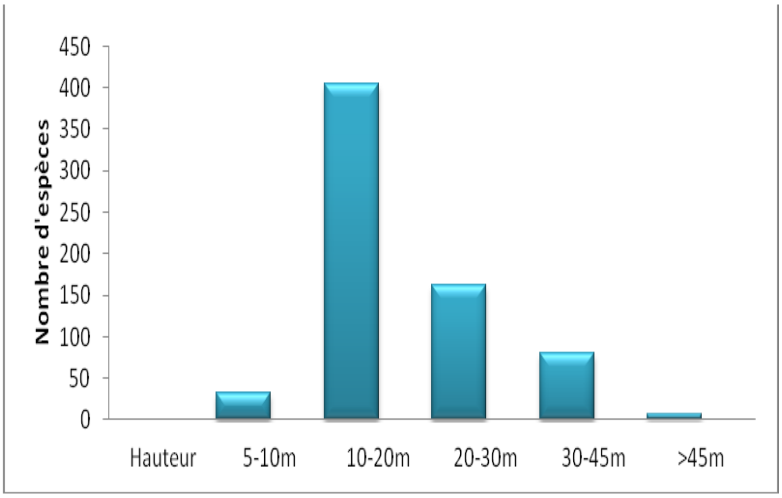

Fig.4. Histogram of the number of trees according to their height.

We note that the 10-20m height class is more representative than the others. The shape of the bars tells us that this structure has a lot of small trees (or young trees). This large number decreases rapidly in the 20-30m class, then more slowly in the over 45m class, where we counted 7 species. A total of 4,675 shrubs were inventoried when the plots were laid out. The following table details the small, medium and large shrubs according to their DBH and height.

Table 4. Number of shrubs by dbh and height.

	Number of small shrubs (P)	Number of medium shrubs (M)	Number of large shrubs (G)	
Diameter	0-1,9	2-4,9	5-9,9	
Height	0,1-1	1-3	3-10	
Total	3453	796	426	4675

Table 5: Diametric structures of trees in plots.

Tree diameter class	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	
Number of trees	394	131	62	28	17	20	7	14	9	5	687
TOTAL											687

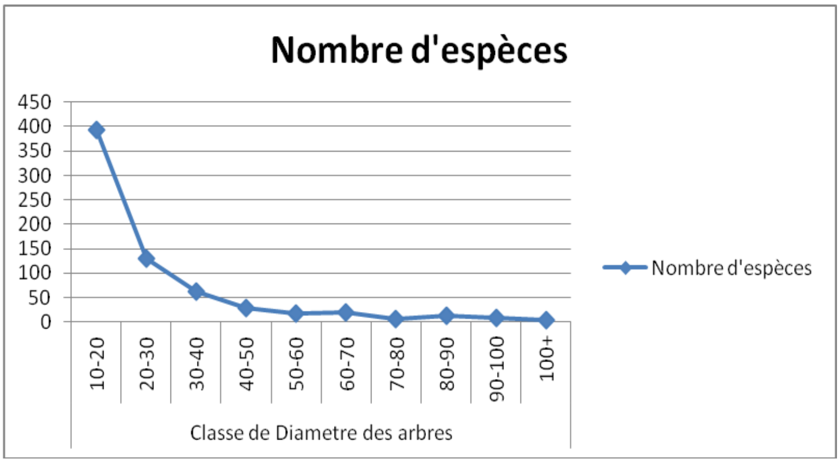

Fig.5. Diametric structures of trees in plots

Calculation and estimation of data

Calculating the carbon stock involves several stages. Field measurements provide the dendrometric data that enable us to calculate the above-ground biomass contained in the trees using allometric equations. This biomass is then converted using a conversion factor (CF).
In addition, these variables from the forest inventory are used to calculate the volume and basal area (G) of all the trees in the plot.

Tree density and distribution

- Density (N) is the number of standing trees per hectare. To calculate it with relative diversity, we applied the formulae below: N = n / S avec N : density (in tree/km^2), n: number of trees in the area under consideration and S: area under consideration (ha);
- Relative Density = (Number of species/Total number of species in the sample) × 100 ;
- Relative diversity = (Number of species within a family/Total number of species) × 100.

The first two indices above show the increase in the number of families or trees as a function of increasing surface area.

Total volume of wood (Vt)

For the total volume of wood (Vt), we used the formula below: Volume autres arbres Vt= G x H x 0,5.
Avec G = Surface du tronc à 1,30 m, H= hauteur totale de l'arbre et 0,5= Facteur de forme (Ponce, 2004). It is expressed in m^3/km^3.

1) Above-ground biomass and allometric equations

This is the mass of dry woody plant matter per unit area. The total above-ground wood biomass is divided into the above-ground biomass of the trunk and the above-ground biomass of the crown (branches). Allometric equations were used to estimate the above-ground biomass of trees, integrating the dendrometric parameters from the forest inventory as shown below:
B.A (kg) = **ñ** × exp (- 1.499 + 2.148ln (dhp) + 0.207(ln (dhp)) ^{2} + 0.0281(ln (dhp)) 3 (Chave et al, 2005) ; Area of validity (cm) de 5 < dhp < 156.
2) AGBtrees (kg) = 0,05378909 × $_{D}$2.828851; Area of validity (cm) of 1 < D < 79.
3) tree biomass (kg) = 42.69 – 12.80 DBH + 1.24 DBH^2 ; Area of validity (cm) of 5 < DBH < 148.

Calculation of forest carbon stock

The forest carbon stock in trees is calculated for all trees by multiplying the dry matter of the above-ground biomass by a conversion factor (CF) of 0.5.

Percentage

Percentage (%) = (Number of individuals in a family or tree / Total families or trees) ×100.

Biomass by diameter class

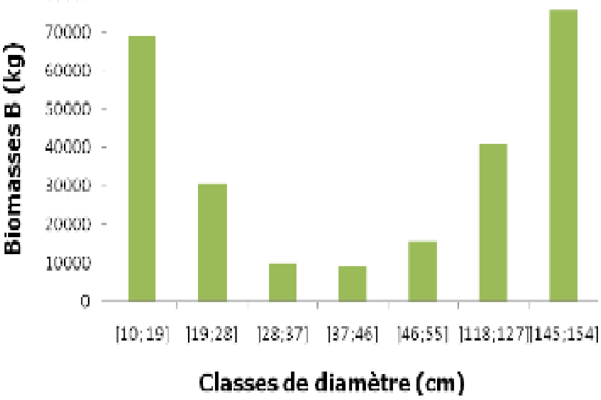

Figure 6. B biomasses as a function of the diameter classes of the trees in the plot.

We observe that the biomasses of the equation of Brown, 1997 of the class of diameter]10 ;19] are more important. Whereas the biomass B of the equation of Ibrahima et al. 2002 of the diameter class]145 ;154] are important. In other words, the Brown equation (1997) overestimates small diameters, whereas the Ibrahima et al. 2002 equation overestimates large diameters.

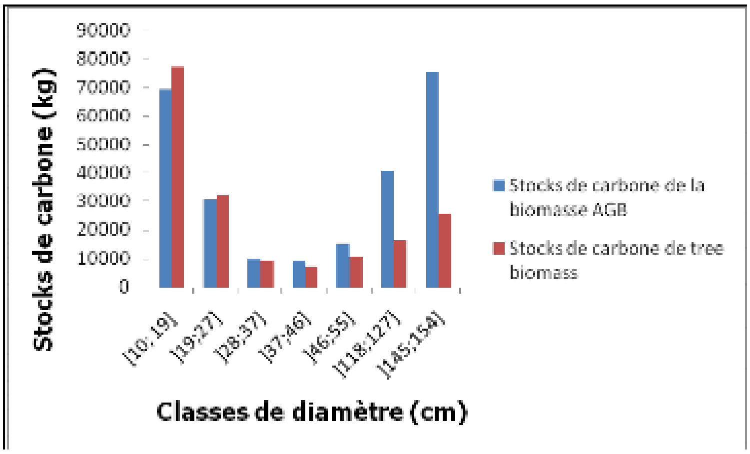

Fig.7. Variations in carbon stocks as a function of tree diameter classes in the plot.

The histogram in Fig. 16 shows the carbon stocks derived from the equations of Ibrahima et al. 2002 and Brown 1997, respectively, as a function of the diameter classes in the plot.

We can see that the carbon stocks derived from the tree biomass in the equation of Brown, 1997 are higher than those in the equation of Ibrahima et al. 2002 for the diameter class [10; 19]. For the diameter class]145 ;154], the carbon stocks of the AGB biomass are higher than those of the tree biomass.

This means that the carbon stock is a function of the most representative diameter class.

Calculation of tree biomass

Table 6. Calculation of tree biomass.

Land	Number of species	Biomass A (CHAVE et al., 2005)	Biomass (tC)	Carbon Stock	Cairns et al 1997 Biomasse Sout.
Total at NM	687	668569,9	668,57	334,285	171,4691
	Mean	13052,74566	13,05245283	6,52622642	3,235266
	Standard deviation	11994,25361	11,99443235	5,99721617	2,619874
	Coefficient of Variance	91,89065595	91,89408691	91,8940869	80,97862
	Variance in Biomass/C	143862119,6	143,8664073	35,9666018	6,86374
Standard deviation verification	Standard Déviation	11994,25361	11,99443235	5,99721617	2,619874
	ET Error ET	457,6093177	0,014669195	0,23194032	0,143292
	Error (%)	3,505847195	0,112386503	3,553973	4,429063

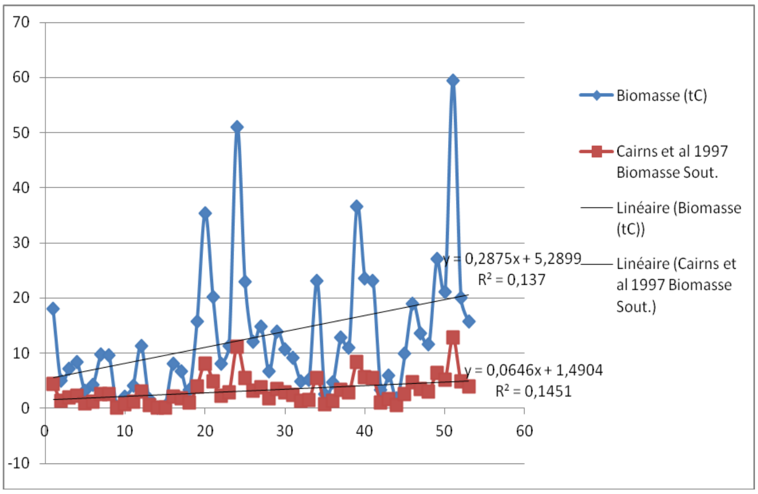

Fig. 8. Calculation of tree biomass in the different plots according to Clains et al 1997.

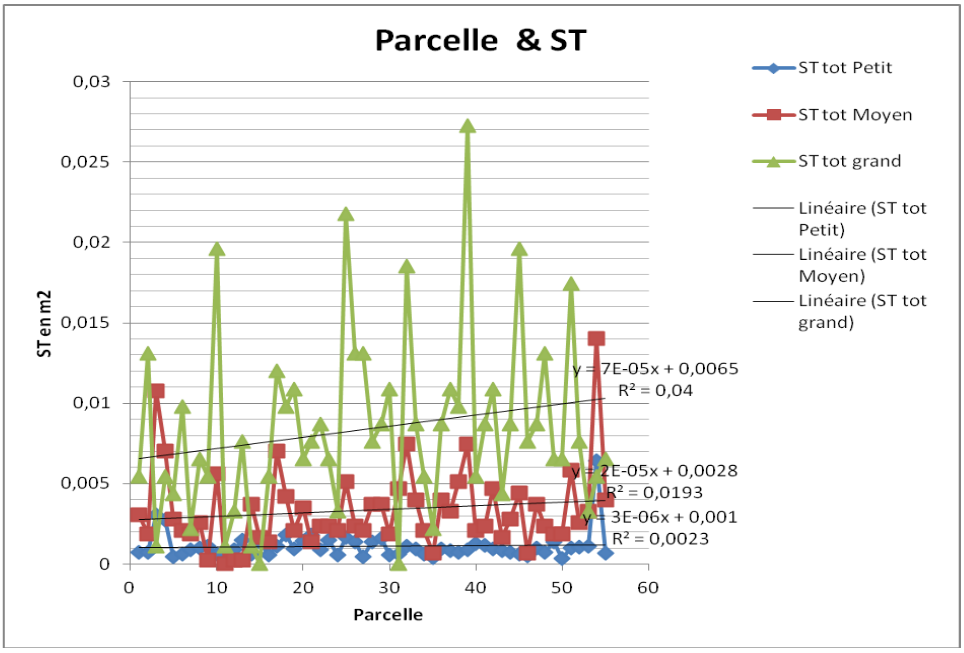

Fig. 9. Carbon stock frequency in different plots.

4. DISCUSSION

Our study involved estimating the quantity of carbon contained in the living above-ground biomass of permanent plots of NM Forest FMUs covering an area of one hectare. We found 118 tonnes of carbon per hectare (118 Tc/ha) with a quantity of above-ground biomass of 250,430.45 kg, derived from the allometric equation of Ibrahima et al. 2002 and cited by Nasi et al. 2008. In other words, to calculate the carbon stock, we chose the two equations cited above because they include only the DHP parameter, and the range of validity of this parameter encompasses the measured data. Whereas the equation of Chave et al. 2005 integrates the specific density of each tree (ñ), which is not complete for all the trees in our tropical rainforests. Analysis of our results shows, firstly, a high density of Musanga cecropioides (Moraceae), with a high biomass. This can be explained by the fact that biomass is calculated as a function of tree density (842) and forest type. In addition, the large number of trees in diameter classes [10; 19] and the shape of the curve indicate that, despite the fact that there are many young trees and seedlings that can grow in the forest, most of them die quickly, leaving a few trees with an average size of 15.2 #177;5 cm.

We then observed that the species Macaranga monandra and Aucoumea klaineana occupy almost the entire plot. We can justify this by the fact that they are found within the plots. In addition, the composition of the site, revealing 28 species, bears witness to the floristic richness of the site. This is due to a succession of vegetation that reflects the reconstitution of the forest following human disturbance. One of the long-term interests of this plot is to be able to monitor the struggle between trees and lianas, insofar as we have a precise inventory of the starting point. Similarly, we will be able to monitor the behaviour of sciaphilous species that are in the process of establishing themselves, and which still face strong competition from the pioneers.

5. CONCLUSION

This study shows that forests can contribute to global climate change by influencing the carbon (C) cycle. They store large quantities of carbon in the vegetation and the soil, by promoting exchange between the earth and the atmosphere through photosynthesis and respiration. They are sources of atmospheric carbon when they are disturbed, become sinks when they are no longer disturbed and regenerate, and can be managed in such a way as to modify their role in the carbon cycle (Brown, 1996).

In our study, we were interested in the above-ground biomass of fifty (50) permanent plots occupying an area of 203896 hectares, and we used the carbon stock of Ibrahima et al. 2002 because it is overestimated, unlike Brown 1997. This gives 118 Tc/ha for a biomass of 250430 kg (Ibrahima et al., 2002 and cited by Nasi et al., 2008). At the same time, during our fieldwork, we were confronted with a number of technical and logistical difficulties.

-the insufficient number of plots, one (1) instead of a minimum of thirty (30), did not allow us to confirm the carbon stock of our plant formation;

-the absence of allometric equations specific to the forests of the Congo Basin
-It was difficult to visually estimate the total height of the trees under close cover (tangled or contiguous crowns);
The identification of certain trees required the use of botanical manuals (De Saint Aubin., 1996; Issembé and Wilks., 2000) after samples had been taken.
This internship provided an opportunity to strengthen basic forest mapping skills, particularly in the production of thematic maps using MapInfo software. It also enabled us to discover and use certain allometric equations for aerial biomass in tropical forests and to become familiar with the LAI light meter for taking leaf indices.
In all, 50 plots were established, delimited and measured. The coordinates of each plot were recorded and the dbh of each tree was measured, indicating the species and height of each tree. This study shows that forests, like those in Gabon, can contribute to global climate change by influencing the carbon (C) cycle.
They store large quantities of carbon in the vegetation and soil, promoting exchange between the earth and the atmosphere through photosynthesis and respiration, are sources of atmospheric carbon when disturbed, become sinks when disturbed and regenerate, and can be managed to modify their role in the carbon cycle (Brown, 1996).
In our study, we were interested in the above-ground biomass over an area of 203896 ha and we used the carbon stock of Chave et al. This gives 118 Tc/ha for a biomass of 250430 kg. These results should be treated with great caution as they are based on an initial study.

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