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Carbon Storage of Some Rubber Trees (*Hevea brasiliensis*) Clones in HEVECAM's Plantations in South Cameroon

Menoh A. Ngon René, Tsoata Esaïe,

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Abstract

The objective of this work was to estimate the quantity of carbon stored by four main clones of rubber tree cultivated in South Cameroon: GT 1, PB 217, PR 107 and RRIC 100. The forest inventory method was used to measure trees morphological parameters, the latter used to calculate carbon storage using the allometric equation of Wauters et al., (2008). The main morphological parameters measured were: leaf area index (LAI), circumference (C), diameter at breast height (DBH) and total tree height (h). Comparing the morphological parameters of clones two by two using a Dunn test, we observe significant differences in the circumference, the diameter and even very significant in the leaf area index, but not in the height. The clones GT 1, PR 107, PB 217, and RRIC 100 stored on average: 111.05 tC / ha, 150.18 tC / ha, 165.25 tC / ha, and 187.25 tC/ha respectively. A significant difference was established between the means of carbon storage of the clones GT 1 and PB 217 ($p = 0.0488$) on one hand and, that of the clones GT 1 and RRIC 100 ($p = 0.0240$), on the other hand. These results are an estimation of models, further research can be undertaken for exact measurements.

Keywords: carbon storage, rubber tree, clones, HEVECAM, Cameroon

1. Introduction

According to the IPCC (Intergovernmental Panel on Climate Change), since the industrial revolution, the concentrations of greenhouse gases (GHGs) in the atmosphere have only increased and carbon dioxide (CO₂) constitutes 76.7% of this increase [1]. Mitigating global warming is a major concern and inevitably constitutes one of the major challenges of the present century [2]. Negotiations during the conferences of the parties (COP) of the UNFCCC (United Nations Framework Convention on Climate Change), led in 2012 during the COP 18 in Doha, to an objective of reducing GHG emissions by at least 18% during the period 2013–2020, compared to the level of the 1990s [3]. During the COP 21, the President of the Republic of Cameroon (PRC) asserted that Cameroon ratified the UNFCCC in 1994 and pledged to reduce its GHG emissions by 32% by 2035 compared to 2010 [4]. Thus, reliable estimates of the quantities of carbon stored by the various plant formations are necessary in order to be able to count them in the reduction of GHGs. The purpose of quantifying

carbon storage is therefore to evaluate efforts to reduce CO₂ emissions and fight against global warming [5, 6]. Studies for estimating the amounts of carbon stored has long been limited to natural forests neglecting the storage potential of planted forests and agricultural plantations [7]. However a study conducted by Makundi in African forest plantations revealed that, they stored nearly 40 million tonnes of CO₂ per year. Those tonnes of CO₂ could be credited with REDD + (reducing greenhouse gas emissions from deforestation and forest degradation, promoting conservation, forest management) in Africa [8]. In Cameroon, *Hevea brasiliensis* plantations are estimated at more than 52,000 ha planted and in full extension [9]. However, there would be very little research on the carbon storage potential of these plantations [10]. In addition, existing studies on the estimation of carbon storage by *Hevea brasiliensis* have not taken into account the clonal differences [10, 11]. So this study fills the gap in a neglected sector of research on carbon storage in Cameroon. The results of the latter could be used in the implementation of the reduction of GHG emissions due to REDD+ through the village plantations of *Hevea brasiliensis*, and allow Cameroon to meet its commitments to reduce GHG emissions. This research is based on the question of whether the amount of carbon stored by *Hevea brasiliensis* varies between clones. The general objective of this work was to estimate the amount of carbon stored by four cultivated clones of *Hevea brasiliensis*. Specifically, the study aimed to: determinate some morphological parameters of the clones cultivated at HEVECAM; estimate the aboveground biomass (AGB) and estimate the carbon stored by the different clones.

2. Material and methods

2.1 Material

The study was carried out in HEVECAM plantation located in the Southern region of Cameroon, Niété subdivision (2° 40' North, 10° 03' East) (**Figure 1**). Established in 1975, but the examined trees was 24 years. These plantations are the largest plantations of *Hevea brasiliensis* in Cameroon. It is also the government largest cultivation project of *Hevea brasiliensis* and the largest “development society” in South Cameroon [13]. HEVECAM was acquired by several groups, including Corrie Maccoll Limited, the American group to which it currently belongs.

The climate is equatorial of the Guinean type, marked by four seasons: a long dry season (from November to February with a peak in December); a small rainy season (from March to May with the peak in May); a short dry season (from June to mid-August); and a long rainy season (mid-August to November); The average annual rainfall is 3000 mm and the average annual temperature is 27° C. The relief is between the southern plateau and the coastal plain. The altitude varies between 20 and 300 m. The population is cosmopolitan, made up mostly of nationals from the far North, North and South West regions of Cameroon.

The HEVECAM plantation occupies approximately 22,000 ha, subdivided into 17 villages (numbered from V 1 to V 17). Each of these villages has blocks divided into plots. This research took place in V 10 and V 15. The choice of villages was based on the presence in the village and the suitable age of the clones retained in the study. Four clones was chosen for this study, because of their performance in this area: PB 217, GT 1, RRIC 100 and PR 107.

2.2 Methods

The estimation of the storage potential was made using the forest inventory method because it was the most suitable for this study [14]. This method consists in

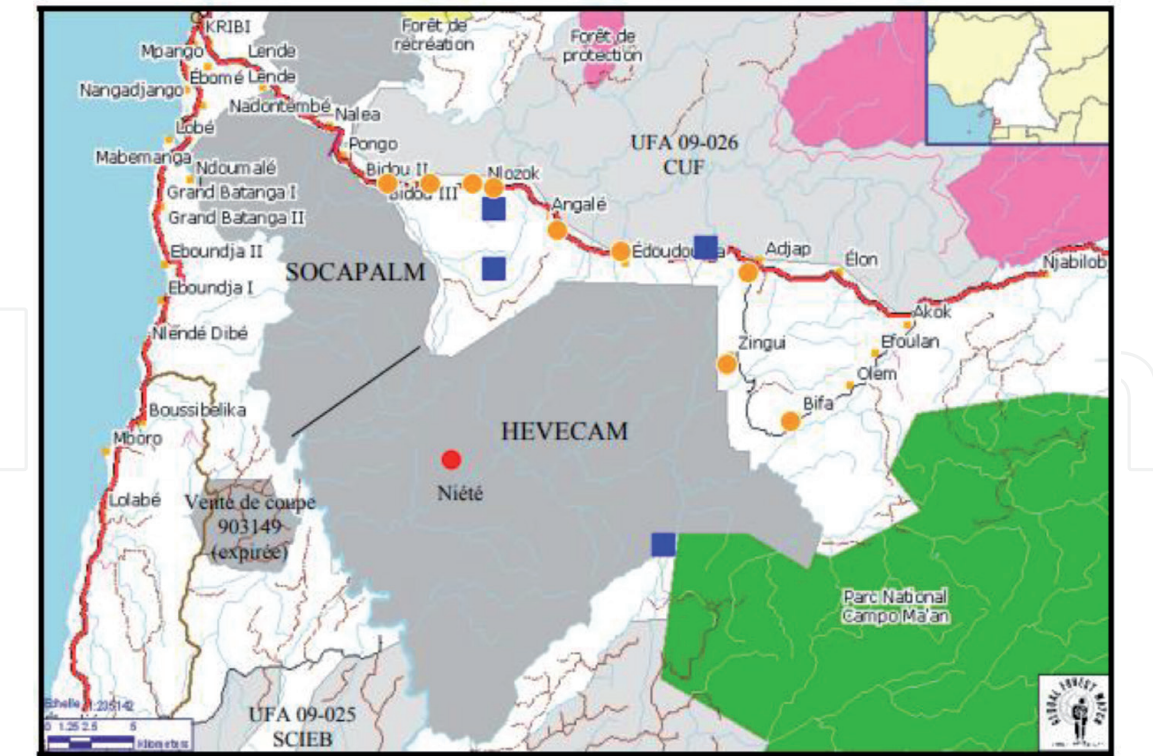


Figure 1.
Location of the HEVECAM plantation. Source [12].

recording the morphological parameters of standing trees and calculating the carbon stored using allometric equations relating the parameters to the carbon stored. Sampling was done according to the method proposed by [15]. Indeed, 4 temporary plots each measuring 25 m x 25 m were installed for the four clones to be studied (ie one plot per clone). Plots of this size are recommended, as they are more effective in a monoculture system such as *Hevea brasiliensis* plantations [15]. In addition, this size is recommended for trees with a diameter between 20 and 50 cm, as is the case in this study [15]. In each of these four plots, measurements were taken on 10 trees, so a total of 40 trees was used for the study. Ten trees were chosen because 8 to 10 trees are sufficient for taking measurements in a plot of this size 25 m x 25 m, and that this is fairly representative of a hectare of plantation [15].

Overall, there were 4 samples plots each with 45 trees planted in a row, 6 m between rows and 3 m between trees in the same row, for a density of 555 trees/ha. In all, 4 plots, data were collected on 40 randomly selected trees. The data collected were: the DHB at 1.5 m height because it had to be above the bled panel; the height h of the tree using a clinometer.

2.2.1 Diameter at breast height measurement

The diameter was obtained from the circumference measured at 1.5 m from the ground using a tape and a 1.5 m pole [16].

2.2.2 Height measurement

This is the total height of the tree from the foot to the terminal bud of the tree. It was measured using a Steren clinometer [17]. The operator stands at a distance (B) as close as possible to the estimated height of the tree. Then, through the dioptric viewfinder of the clinometer, he aims to turn at the top and then at the base of the tree. On each side, he notes the graduation to the right of the dial. This is the tangent of the angle of inclination expressed as a percentage (%). Let α be the angle

of inclination with the foot of the tree, β the angle of inclination with the top of the tree and B the distance between the operator and the tree. The height h of the tree is given by the formula:

$$h = B(\tan \alpha + \tan \beta) \quad (1)$$

h and B in meters, α and β in degrees.

2.2.3 Leaf area index determination

LAI was determined using the logistic regression model proposed by [18], express by the following formula:

$$\ln LAI = 1.225 + \frac{0.474}{1 + \left(\frac{\ln D^2}{6.327} \right)^{-21.48}} \quad (2)$$

D is the DBH in cm; LAI is a dimensionless quantity.

2.2.4 Quantifying living aboveground biomass

The above – ground biomass (AGB) is the mass of the entire upper part of the plant which includes: the trunk, branches and leaves. It was calculated on tree scale using the allometric equation proposed by Dey et al. [19], then converted to the hectare using the planting density of the plantation.

$$AGB = 0,0202 C^{2,249} \quad (3)$$

(C) is the circumference at 1.5 m from the ground in cm.(AGB) the above-ground biomass in Kg/tree.

This model was preferred because it is suitable for our research for three main reasons: It is specific to *Hevea brasiliensis* and not generic to several species like the majority of models; in addition, the use of the circumference instead of the diameter reduces the errors that can occur in the calculation of the diameter; moreover, this model allows that by measuring the circumference at 1.50 m from the ground, one avoids the bleeding panel generally located at 1.30 m from the ground [19].

2.2.5 Calculation of the stored carbon by the different clones

The estimate of stored carbon was carried out according to one of the methods propose by [20]. In fact, we determine the average carbon stock per tree and by multiplying by the density, we get the carbon per hectare. To do this, we used the allometric equation specific to *Hevea brasiliensis* proposed by [20].

$$\ln CS = -5,147 + 2,392 \ln C \quad (4)$$

C represents the circumference measured at 1.5 m the ground and CS the total carbon stored expressed in Kg/tree.

This model was preferred over the others for two main reasons: first, it is specific to the species *Hevea brasiliensis* and the trees used to establish this equation are practically the same age as those in the present study [20].

2.3 Statistical analyzes

The data were processed (ordered, classified and grouped) by the Excel software from which an input mask was obtained and later analyzed using R software. The main tests performed is the Dunn test. It made it possible to identify pairs of clones whose variables are significantly different [21].

3. Results

3.1 Determination of morphological parameters of clones

When comparing the morphological parameters of clones two by two using a Dunn test, we observe significant differences in the circumference, the diameter and even very significant in the leaf area index, but not in the height (Table 1).

		RRIC 100	PB 217	GT 1
DBH	GT 1	0,014*	0,032*	
LAI	GT 1	0,001**	0,010*	
	PR 107			0,467

Meaning of the codes: * = significant; ** = very significant.

Table 1.
Dunn's test of morphological parameters.

3.2 Estimation of aboveground biomass and carbon storage

The diagram shows that the RRIC 100 clone store the most carbon, i.e., 187.11 tC /ha and GT 1 the less carbon (111.04 tC/ha) (Figure 2). By performing a

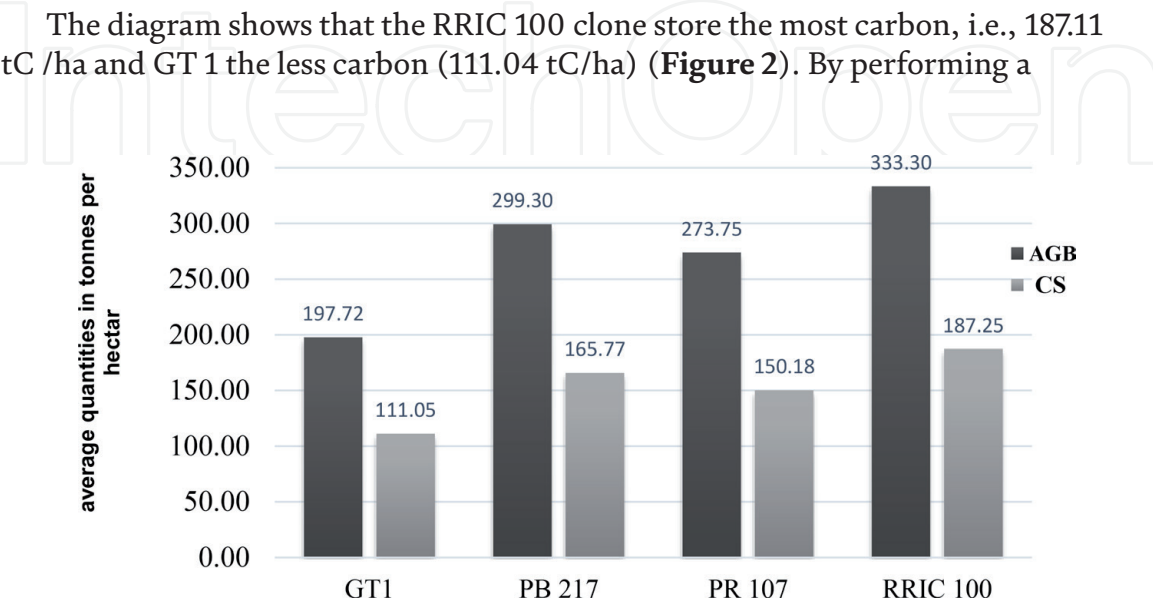


Figure 2.
Average quantities of above-ground biomass and carbon stored as a function of clones.

two-by-two comparison using a Dunn test (**Table 2**), a significant difference is observed ($0.001 < p < 0.05$) between two pairs of clones: PB 217 and PR 107 ($p\text{-value} = 0.0488$); GT 1 and RRIC 100 ($p\text{-value} = 0.0240$). The other comparisons show non-significant differences.

		p-value	p-value Signification
GT 1	PB 217	0,0488	*
GT 1	PR 107	0,0961	Ns
GT 1	RRIC 100	0,0240	*
PB 217	PR 107	0,760	Ns
PB 217	RRIC 100	0,774	Ns
PR 107	RRIC 100	0,553	Ns

Meaning of the codes: **** = significant; Ns = not significant.

Table 2.
Dunn’s test of the carbon stored by the different clones.

4. Discussion and conclusion

4.1 Discussion

4.1.1 Morphological parameters of the studied clones

In this research it was established that there is a very significant difference between the leaf area indices of the studied clones. The RRIC 100 clone has the highest LAI, ie 4.98, a value different from that obtained by [22], who obtained for the same clone, a leaf area index of 3.37. The difference between these values could be explained by the differences in the age between the trees, 20 years for [22] and 24 years for the present study. In addition, [22] used a direct measurement method using a leaf area meter. Concerning circumferences, a study by [23] on the GT 1 clone obtained an average of 100 cm, which is different from the obtained 75 cm for the GT 1 clone in this study. Once again, the age difference between the trees of the two studies could justify the difference in the results, as the circumference increases with the age of the trees. Trees in the study of [23] were slightly older (33 years) than the trees in the present study. On the other hand, [6] obtained an average DBH of 24.9 ± 0.7 for 25-year-old trees. Although the study [6] does not give details on the clones studied, it is noted that this diameter is substantially equal to the mean diameter of the GT 1 clone (24.01 ± 5.07) of the present study.

4.1.2 Quantity of aboveground biomass and stored carbon

AGB is between 197 and 333 tC / ha, and stored carbon between 111.05 and 187.25 tC / ha. The RRIC 100 clone stored more carbon than the other four clones and the difference is significant or even highly significant with the other clones [24]. Obtained 214 tC/ha, a value closer to what we obtained in this work (333 tC/ha). The trees in this study are 24 years old and in the studies of [24] they were 31 years. It is therefore understandable why the results we obtained are closer to those in [24], in view of the approximation of age.

Compared to other ecosystems, rubber plantations can store more carbon than secondary forests of the same age, which the storage capacity varies with the age between 91.75–256.5 tC/ha, according to [25].

4.2 Conclusion

The question behind this work was to know whether the carbon storage potential of the *Hevea brasiliensis* species varies among clones. To answer this question, it was necessary on one hand to determine the morphological parameters related to carbon storage and on the other hand to quantify the biomass and then the storage potential of 4 *Hevea brasiliensis* clones. From the four clones studied, it was established that there is a significant difference in the means of carbon stored between the GT 1 and RRIC 100 clones on the one hand and between GT 1 and PB 217 on the other hand. The clone RRIC 100 exhibits the greatest average carbon stored (187.11 tC/ha) These results are an estimation of models, further research can be undertaken for exact measurements.

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