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Research Article

Evaluation of Aerial Carbon Sequestration in Cocoa Plantations of Different Ages in Baradères, Haiti

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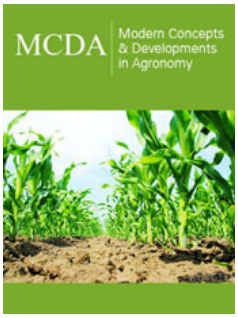

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Abstract

During the work, localities such as: Calbacier, Maton, Font-Tortue, Vincent-dron and Boino were identified by their reputation in cacao culture to collect data that were collected through the five (5) localities, of which 30 cacaoyers per locality were randomly selected within a radius of two-thirds of a hectare (10000m^2), making a total of two hundred and forty (240) cacaoyers measured by the method described by Purata [1]. To estimate biomass, dendrometry parameters such as (H and D) were selected and then the allometric equation of Chave et al. [2] was used. Therefore, sequestered airborne carbon was projected by biomass, the result of which is multiplied by the IPCC constant [3]. After calculation, the results found for the space-sequestered carbon were respectively: Calbacier 4,665tC/ha, Maton 2,463tC/ha and Font-Tortue 4,101tC/ha for the class of 1-year; for the class of 2-years: Calbacier 8,796tC/ha and Maton 6,823tC/ha and for the class of 3-years: a Font-Tortue 7,073tC/ha, Vincent-dron 81,137tC/ha and Boino 2,463tC/ha. In addition to space, the air carbon sequestered over time was estimated and the following results were obtained: Calbacier 1 and 2 years 4,665tC/ha, 8,796tC/ha; Maton 1 and 2 years 2,463tC/ha, 6,823tC/ha and Font-Tortue 1 and 3 years 4,101tC/ha, 7,073tC/ha. Following the different results found in the different localities of different ages, it has been shown that carbons can vary from one locality to another in time and space. In space the equation found is y=-1.013x3 + 14.01x2 - 50.95x + 50.75. R^2=0.273 and y=0.254x3 - 2.516x2 + 7.047x + 0.454, R^2=0.192 in time.

Keywords: Cacao culture; Airborne carbon; Allometric equation

Introduction

Many countries invest in the cocoa sector such as: Côte d'Ivoire, Ghana, Indonesia, Ecuador, Nigeria, Cameroon, Brazil, Rep. Dominican Republic, Colombia, and others [4]. Since the end of the 16th century, the cacaoyer has been cultivated in most tropical regions of Central and South America as well as in the West Indies. The introduction of cocoa (*Theobroma cacao* L) in Haiti dates back to the sixteenth and seventeenth centuries and remains rather difficult to trace in a relevant way [5]. In Haiti, cocoa farming accounts for a relatively large share of the farm income of the families that farm it. Cocoa is grown mainly in the country's three departments: Nord, Nord-Est and Grand' Anse [1]. Today we find the three largest varieties of cocoa grown (Forestaro, Trinitario, Criollo), the first two remain much higher, than that of Criollo, the name given to Creole cocoa.

However, the Haitian cocoa sector has been experiencing a chronic crisis since the early 1970s with the total lack of public and private investment; other factors such as systematic tree felling, soil erosion led to the downfall of this crop [6]. In the early 2000s, the cocoa sector reached a critical level of dysfunction. The share of cocoa in total Haitian exports, which stood at around 3% in recent years, fell, during the period 2000-2001, below 1% [7]. The vulnerability of the population pushes more and more families to cut down their cocoa trees to produce charcoal, the main fuel used for cooking. Due to a lack of economic resources for farmers, cocoa plantations gradually disappeared, and producers favored the planting of short-cycle food crops such as beans or maize in order to limit food insecurity, which is still far too prevalent in rural areas, [6]. The municipality of Baradères, located in the department of Nippes, is not spared from this scourge. Cocoa farming is practiced in small pockets by peasants. Several factors, such as the lack of supervision for farmers, the vulnerability of road infrastructure, cyclones, phytosanitary diseases, insects, etc., take over the crop. After Hurricane Mattthew, 80% of cocoa production is devastated. The discrepancy that exists as it is described and observed by some, leads us to do this research work. This study is specifically to assess the carbon sequestered in the air with a view to proposing alternative solutions. This study takes place in this context.

Material and Method

The purpose of the study

It is to evaluate the airborne carbon sequestered in the cocoa plantation of different ages in the municipality of Baradères.

Research direction

The study was conducted during the vegetative phase of the crop and is based on a period of 1 to 3 years. The selection of cocoa plantations was done in collaboration with the Community Organizations of Bases (OCB) which work in cocoa farming, and which allowed us to find information related to this culture to better guide the work. Compared to the above-mentioned collaboration, eight plantings of different ages (1-3 years) were identified in locations such as Calbacier, Maton, Font-Tortue, Vincent-dron and Boino. The indirect method is used to determine biomass and calculate carbon.

To adjust the model, height and diameter were selected as dendrometric parameters. The calculation of these parameters was carried out by this method: the height was measured from the collar to the apical part and the diameter was taken from the soil of 0.30m. The type of sampling used is a simple, stratified random sample for which they were selected according to the area from the age distribution of the cacaoyer, the dendrometric parameters and the vital distance of the feet of the cacaoyer at the (3m 3m). From a radius of two-thirds of 1 hectare (ha) (10000m^2), thirty trees were measured per plantation, for a total of two hundred and forty (240), [1].

The volume of cacaoyers was calculated using the formula V=Π/4 (D^{2}m L) or (0.785 D^{2}m L) proposed by Huber using the dendrometric parameters (H and D) of cacaoyers, [10]. To estimate the airborne carbon sequestered in the cacao culture, the indirect method was selected using dendrometric parameters (H and D). After the biomass was calculated, it was multiplied by the constant of 0.45 according to [5] cited by [8]. to find the airborne carbon sequestered in the cocoa tree. C=B* 0.45; C: Carbon in kilograms (kg); B: Biomass in kilograms (kg) and the comparison of the averages for the different variables studied was obtained by a one-way ANOVA.

Result

Experimental result

After treatment, the following localities were obtained average heights for the age of one 1-year: Calbacier, 1.11m, Maton, 0.85m and 0.91m Font-Tortue and for two (2) years, the values were of the order: 1.59m and 1.37m, Calbacier and Maton, finally for those of three (3 years): Font-Tortue 1.49m, Vincent- dron 2.71m and Boino 1.58m. These values found for the height of the cacaoyers showed that there is a statistically significant difference between them (Figure 1).

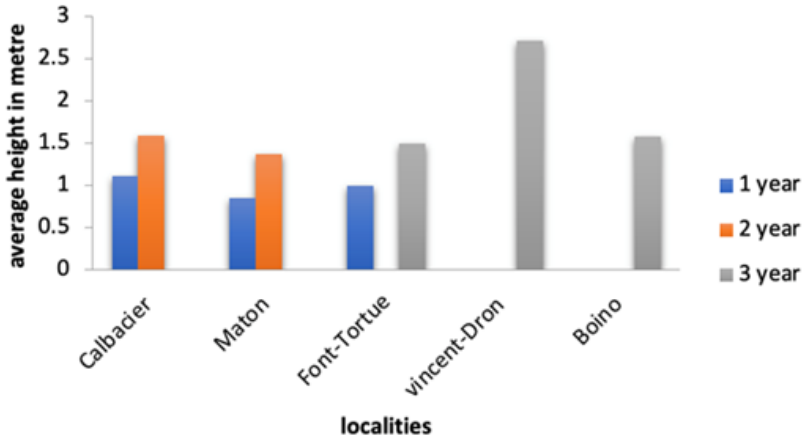

Figure 1: Average height of cocoa trees at different locations.

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Average diameters in cm of cocoa trees

Compared to their heights, it has been noted that their diameters have been extremely high for the localities of Calbacier, Maton and Font-Tortue, of one year: ; 6.16cm, 4.9cm, 6cm and for Calbacier and Maton of 2-years: 7.26cm, 6.82cm in end Font-Three-year-old turtle, Vincent-dron and Boino: 6.8cm, 17cm, 11cm, because these values only concern the diameter of the cacaoyers (Figure 2).

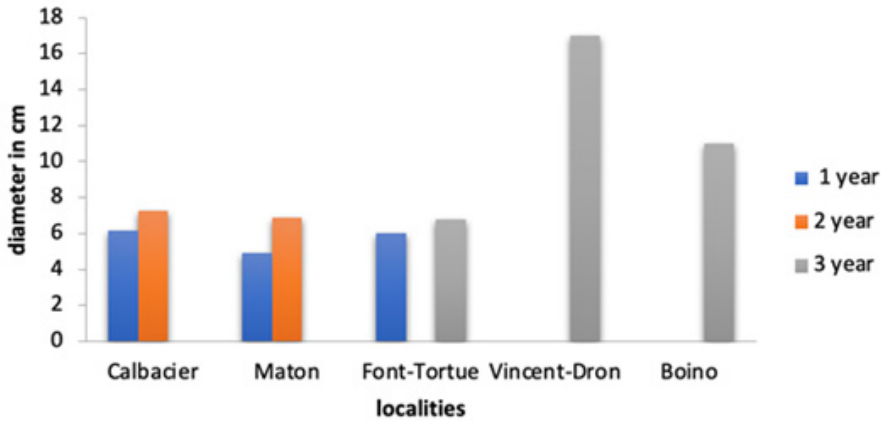

Figure 2: Average diameter of cocoa trees at different locations.

Average volume of cocoa trees in different localities

With Huber equation Π/D2L or 0.785D2L, for 1-year localities such as Calbacier, Maton and Font-Tortue, a mean volume of 0.00330639m^3, 0.00160207m^3 and 0.00279774m^3, respectively, was obtained (Figure 3). With a p-value of 0.0000004227, these values showed no statistically significant difference in volume of cocoa trees between them. Calbacier and Maton, who are 2-years, were respectively estimated at 0.0065787m^3; 0.00506102m^3. The test showed a p-value of 0.007249. The locality of Calbacier gave a volume of cocoa trees more or less significant compared to Maton. For the 3-years as Font-Tortue, Vincent-dron and Boino spread out a respective volume of 0.00540846m^3; 0.0006148m^3; 0.00015008m^3 and a p-value of 2.2e-16 showed that Font-dronTurtle is the locality that has a high significant difference, yet the others do not have a significant difference.

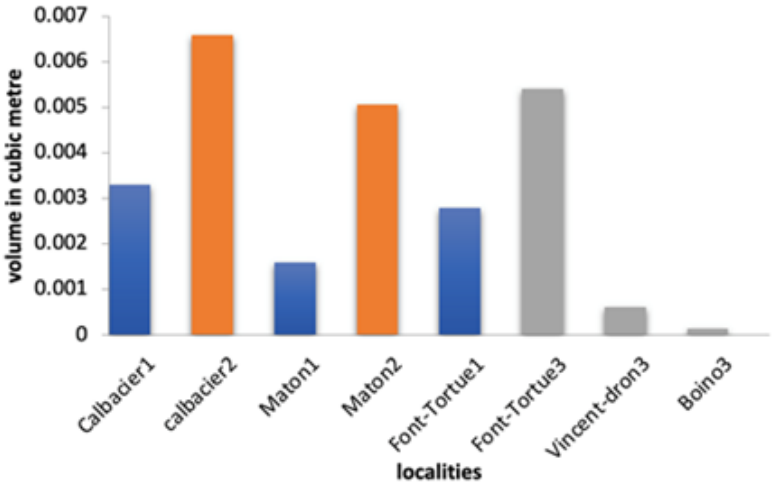

Figure 3: volume of cocoa in different locations.

Average overhead biomass of cocoa trees

Following the formula proposed by Huber AGB = 0.0509 (Wi (DBHi2) Hi), [8]. the corresponding biomass was calculated for 1, 2, 3 years in the following localities: Calbacier, Maton and Font-Tortue: 1.036kg, 0.547kg, 0.410kg respectively. Calbacier had a more or less significant difference from the other two localities that did not have a significant difference with a p- value of 0.0000004227 (Figure 4). However, with p-value of 0.007249 for the class of 2 years, Calbacier and Maton had each a mass of 1,954kg; 1,516kg and they do not show any significant difference and 3 years as Font-Tortue, Vincent-dron and Boino had 1,571kg; 18,030 kg; 4,548kg. Compared to the two classes, Vincent-dron reached an exponential level in terms of biomass with a p-value of 2.2e-16. However, Vincent-dron and Boino showed no significant difference.

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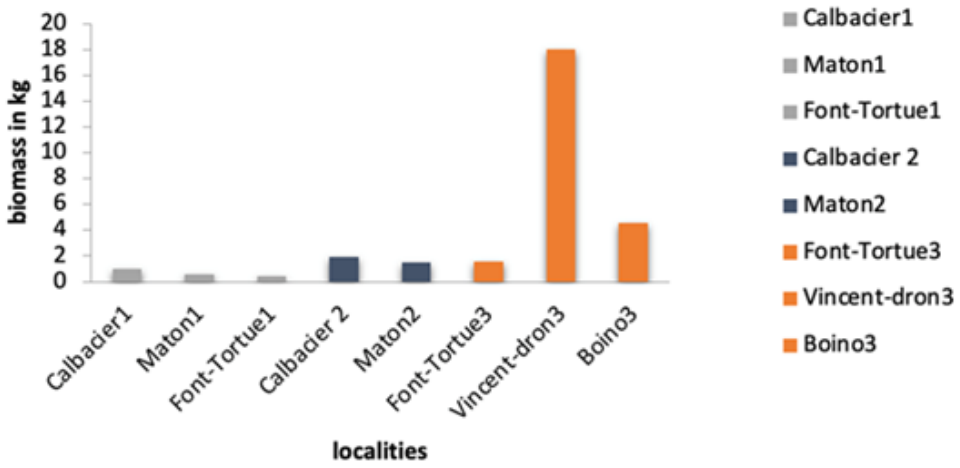

Figure 4: Aerial biomass of cocoa trees from different locations.

Medium airborne carbon sequestered in kg/ha in space

Compared with the p-value obtained of 0.000000003603, the respective carbon values for the following zones were obtained on average: Calbacier of 1 year sequestered a carbon quantity of 4665.10kgC/ha; followed by Maton, 2463.57kgC/ha and then Font-Turtle 4101.24kgC/ha (Figure 5). However, the 2-years as Calbacier and Maton had a value of 8796.39kgC/ha and 6823.85kgC/ha with a p-value of 0.00003892. Other localities such as Font-Tortue, Vincent-dron and Boino, 3-years-old, had a p-value of 7.036e-10 and after calculation, 7073.75kgC/ha for Font-Tortue; Vincent-dron 81137.0457kgC/ha and 2046.75kgC/ha for Boino.

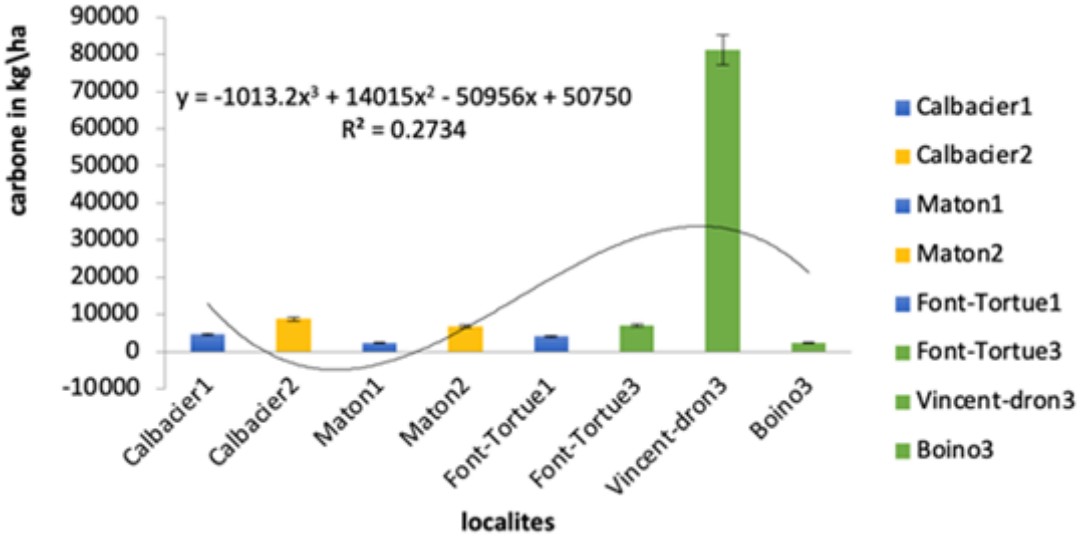

Figure 5: Carbon sequestration in space.

Medium airborne carbon sequestered in kg ha over time

After calculating the airborne carbon sequestered in the different zones, it was projected over time. A p-value of 0.000005522 justifying the correlation between the data whose IPCC formula was applied: C=0.45*B in the dwelling of Calbacier of different ages, (Appendix, 3). The 1-year-old cocoa trees at Calbaciers stored a quantity of carbon equivalent to 4665.10kgC/ha and those at two years had 8796.39kgC/ha (Figure 6). However, at Maton for the ages of 1 and 2 years they stored respectively a carbon quantity of 2463.57kgC/ha; 6823.85kgC/ha with a p-value=0.000006279 and at Font-Tortue, the carbons stored were 4101.24kgC/ha; 7073.75kgC/ha with a p-value of 0.0000004468.

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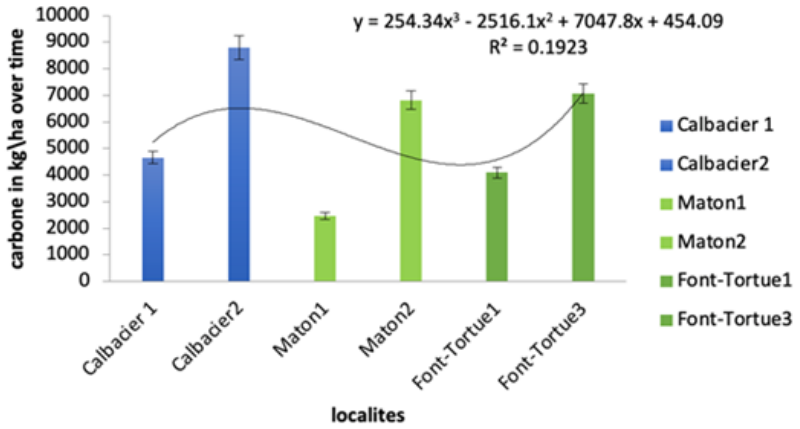

Figure 6: Carbon sequestration in kg/ha over time.

Sequestered airborne carbon in t ha in space

Localities such as Calbacier, Maton and Font-Tortue for the 1-year class had a quantity of carbon per hectare respectively: 4,665tC/ha; 2,463tC/ha; 4,101tC/ha (Figure 7). These results were found by dividing the stored carbon into kilograms per hectare per 1000. With this same calculation, for the 2-year class for the localities of Calbacier and Maton a quantity of carbon per hectare of 8,796tC/ha; 6,823tC/ha (Figure 7). The 3-year class for the following localities Font-Tortue, Vincent-dron and Boino sequestered at 7,073tC/ha, 81,137tC/ha, 2,463t/ha (Figure 7).

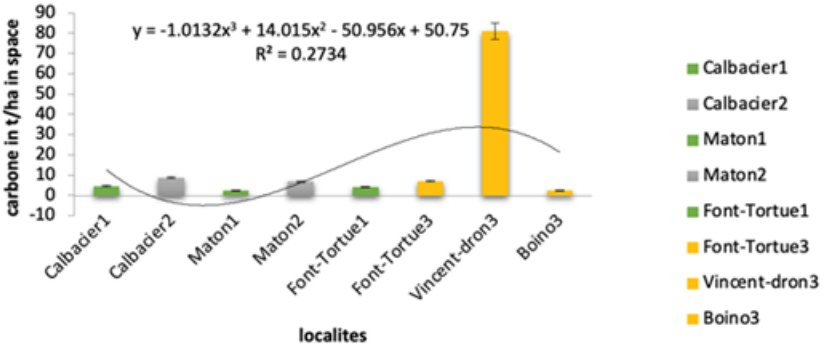

Figure 7: Airborne carbon sequestered in t/ha in space.

Carbon sequestered over time in t ha

To get a clear idea of the amount of carbon stored, the results were converted into t ha. Calbacier stored for 1 and 2 years: 4,665tC/ha and 8,796tC/ha, Maton 1 and 2 years: 2,463tC/ha, 6,823tC/ha and Font-Tortue 1 and 3 years: 4,101tC/ha and 7,073tC/ha. This graph below gave information about the different localities (Figure 8).

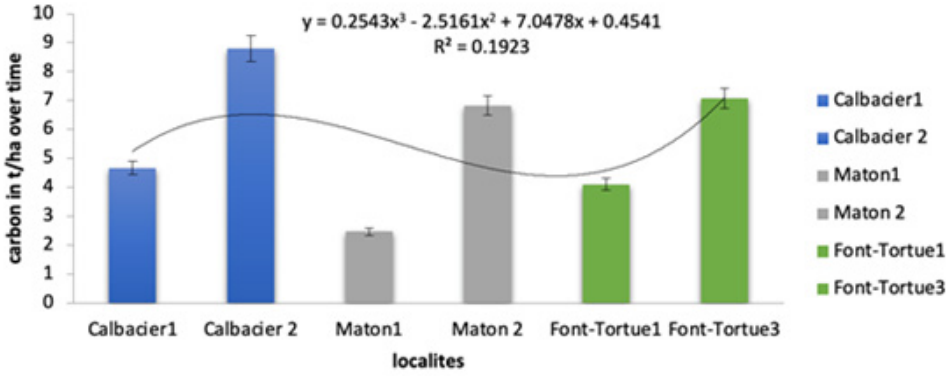

Figure 8: Sequestered carbon in t/ha over time.

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Carbon dioxide (CO_2) in tonnes per hectare in space

The results found for the different locations of 1-year were respectively: Calbacier 17.120tCO_2/ha; Maton, 9.041tCO_2/ha and Font-Tortue 15.051tCO_2/ha (Figure 9). For the 2-year localities; Calbacier 32,282tCO_2/ha, Maton 25,043tCO_2/ha and the 3-year localities had: Font-Tortue 25,960tCO_2/ha, Vincent-dron 297,772tCO_2/ha and Boino 9,041tCO_2/ha.

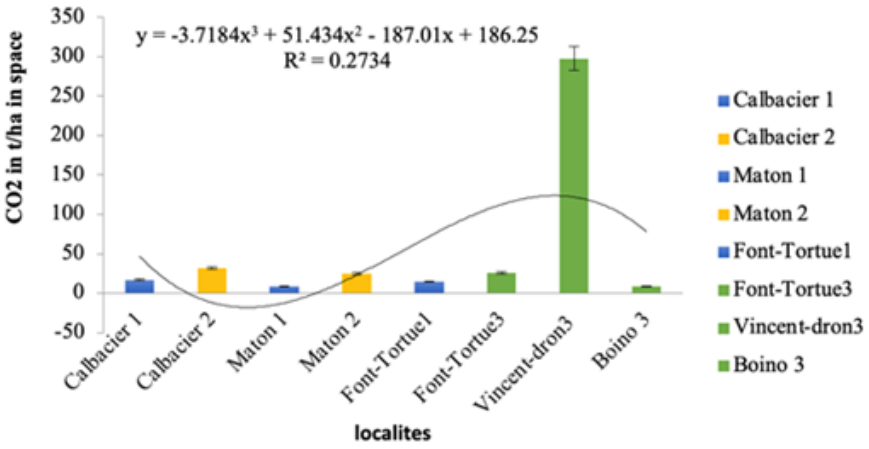

Figure 9: Sequestered carbon in t/ha over time.

Carbon dioxide (CO_2) in tonnes per hectare over time

The carbon dioxide ratio was presented as follows: Calbacier 1 and 2 years 17,120tCO_2/ha and 32,282tCO_2 ha, Maton 1 and 2 years 9,041tCO_2/ha; 25,043tCO_2/ha and Font-Tortue had 1 and 3 years 15,051tCO_2/ha; 25,960tCO_2/ha (Figure 10).

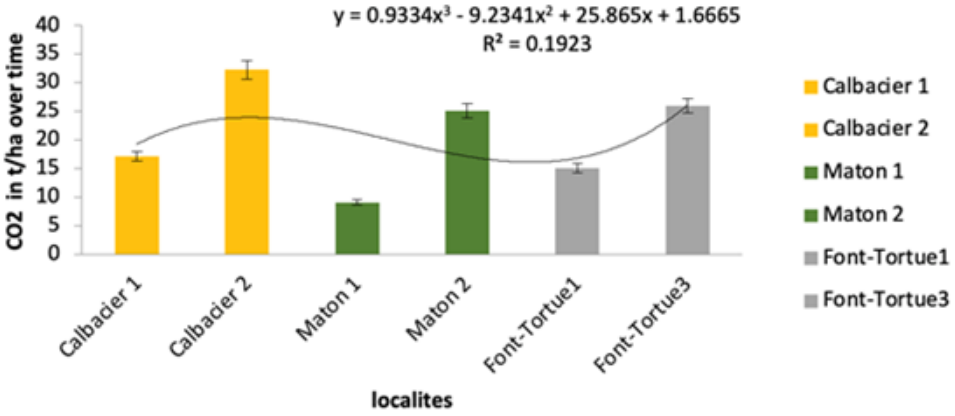

Figure 10: Ratio of carbon and carbon dioxide in t/ha over time.

The estimation of airborne carbon via the airborne biomass of the cacaoyers by the allometric equation provided an idea of the amount of carbon in localities such as Calbacier, Maton, Font-Tortue, Vincent- dron and Boino from 1 to 3 years. The results found by statistical tests were, respectively, for the 1-year class: 4,665tC/ha; 2,463tC/ha; 4,101tC/ha (Calbacier, Maton and Font-Tortue) for the 2-year class: 8,796tC/ha; 6,823tC/ha (Calbacier and Maton) and for the class of 3-years: 7,073tC/ha; 81,137tC/ha, 2,463tC/ha. Through the Analysis of Variance (ANOVA), we have observed in the class of 1-year, there is a significant difference between Calbacier and Maton with a p-value of 0.000000003603. However, Font-Tortue is not significantly different. Statistical tests, or normality tests, bartlett homogeneity tests have shown that no correlation between the two-year data has been linked. For this, the Analysis of Variance (ANOVA) did not present a significant difference for the 2-years class; its p-value was 0.00003892. However, with the same processes for the 3-year class, there is a significant difference at an exponential rate justified by its p- value of 7.036e-10. Compared to the first two classes, Font-Tortue and Boino show no significant difference. However, for localities such as Vincent-dron and Font-Tortue there is a very significant difference (Figure 6).

Discussion

On the one hand, a study on the dynamics of woody biodiversity and carbon stocks in agroforestry systems based on cocoa trees in

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central Cameroon, [9]. presented in cocoa SAFs from 0 to 10 years old, 78tC/ha were kidnapped; the same goes for cocoas from 11 to 20 years old 109.3tC/ha. Compared to that of [9] it was found that for the classes of 1, 2 and 3-years, making a proportional report compared to the SAFs from 0 to 10 years of [9], there is a big difference in terms of sequestered carbon.

On the other hand, estimated that the carbon stocks of associated trees in shady cocoa trees in Cameroon were respectively 88.7tC/ha; 107tC/ha; 135.5tC/ha and [9,10], presented the importance of these systems in carbon sequestration of (660tC/ha).

However, our study is based on the vegetative phase where the cocoa trees considered are totally young, in addition to space, we must put the emphasis on the carbon sequestered over time and we have seen that the edaphological and climatic factors, agro-ecological, planting distance, cultivation operations have strongly influenced cocoa farming in terms of the quantity of carbon sequestered. After analysis of variance (ANOVA), the Calbacier-plantation had a significant difference between these values 4665.10kg/ha and 8796.395kg/ha. This difference showed that two-year-old cocoa trees stored more carbon than one-year-old cocoa trees [11-13]. For the two strata of the Maton dwelling, the following results were found: 2463.57kg/ha; 6823.85kg/ha, by comparing the carbons stored in the two zones (Calbacier, Maton); it was noticed that the results found are proportional and present the same agroecological configurations. In addition, the estimates of carbon stocks at Font-Tortue are presented as follows: 4101.241kg/ha; 7073.75kg/ha (Figure 6).

Conclusion

The objective of this study was to assess the aerial carbon sequestered in cocoa plantations of different ages, by developing allometric equations for cocoa plants. From the dendrometric parameters, it was possible to determine the biomass from which the aerial carbon of cocoa trees was calculated. The allometric equation of [2] AGB=0.0509 (Wi (DBHi2) Hi was the equation chosen to determine the above-ground biomass in cocoa plantations of different ages.

The different results obtained were respectively: for the 1-year class: 4,665tC/ha; 2,463tC/ha; 4,101t/ha (Calbacier, Maton and Font-Tortue), for the 2-year classes: 8,796tC/ha; 6,823tC/ha (Calbacier and Maton) and for the 3-year classes: 7,073tC/ha; 81,137tC/ha, 2,463tC/ha. The balance between the age of the cocoa trees, the cultivation area has a similarity with respect to the quantity of carbon sequestered. Dendrometric parameters such as the diameter and height of the cocoa trees as well as the density of the wood were to breed to calculate the biomass and were used for calculating carbon in space, the equation found is: $y= -1.013x3 + 14.01x2 - 50.95x + 50.75$; $R^2=0.273$ and $y=0.254x3 - 2.516x2 + 7.047x + 0.454$; $R^2=0.192$ in the temps.

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Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

Authors Vincent, Ruiz-Blandon, Gallegos-Rodríguez and Hernández-Álvarez, designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors Mateyer, Martin, Rochel and Michel, managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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