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Floristic Diversity and Structure of Cocoa Agro-Ecosystems in Southeastern Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Author VNN helped designing the study, wrote and proposed the manuscript to the journal. Author LZ proposed the subject as a master research and supervised the work. Authors JRN, VAD, JDN, RMH, BN, NW and RBTM read the manuscript and performed the literature. All authors read and approved the final manuscript.

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ABSTRACT

The study was carried out in two localities surrounding the national park of Lobeke in Cameroon. It aims to evaluate floristic diversity and carbon stock in Cocoa agro-ecosystems. 44 plots (25 x 25 m) were established in 15 agro-ecosystems of different ages to identify all timbers of at least 10 cm of Diameter of Breast Height (DBH). 2,676 individuals of timbers and 42 bananas belonging to 32 families, 68 genera and 74 species were recorded. The most abundant families were Malvaceae (80.1%), Mimosaceae (4.6%), Euphorbiaceae (2.5%), Cecropiaceae (2.3%), Moraceae (1.3%) and Apocynaceae (1.1%). *Theobroma* was the most abundant genus (79.2%), followed *Albizia* (4.33%),

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Myrianthus (1.57%), *Macaranga* (1.12%) and *Antiaris* (1.08%). Biomass was estimated at 140 Mg C.ha^{-1}. In timbers, carbon stock was estimated at 128.7 Mg C/ha. That of litters was estimated at 7.7 Mg C/ha; herbs at 2.53 Mg C/ha; roots at 1.43 Mg C/ha and bananas at 0.5 Mg C/ha. Carbon stocks from this agro-ecosystem were compared to data recorded in Costa Rica and India. Several species used as non-timber forest products during dry season were recorded. Cocoa agro-ecosystems could be assimilated to a carbon well; and consequently as an attenuation and adaptation measure in mitigating climate change.

Keywords: Adaptation; agro-ecosystem; attenuation; biodiversity; carbon stocks; climate change.

1. INTRODUCTION

Climate change is a global phenomenon that increases the average temperature (from -18°C to 15°C), due to excessive emissions of greenhouse gases (GHG) [1-2]. The area of rainforest in southeastern Cameroon has a great diversity of flora and fauna [3]. Forests are a lung which absorbs these GHG and stores carbon dioxide. Some human activities (deforestation, degradation) were identified as causes of climate change. In recent years there has been a growing concern in understanding the economic value of agricultural land for community livelihood. Increasing global population within environmental limits has been identified to be the major reason for such concern. In Africa for example, 80% of the population depend on agriculture for their livelihoods [4].

Slash and burn agriculture have many ecological consequences, ranging from the reduction of carbon stock to desertification, through declining soil fertility [5]. According to several authors Slash and burn agriculture accounts for about 30% of total carbon dioxide emissions and greenhouse gases and land-clearing for agricultural use, including croplands and shifting cultivation as well as deforestation are the most important sources of these emissions [6]. Throughout Africa as a whole, nearly 60% of new agricultural land was derived from intact forests, and another 35% came from disturbed forests. The remaining 5% of new agricultural land was taken from shrub lands [7]. Climate change is placing additional stress on agricultural productive areas exacerbated by recent pressure for biofuels production. As a result, land conversion and land degradation are currently taking place at an alarming rate resulting to low agricultural productivity and substantial release of greenhouse gases when forests are cut. The main causes of forest destruction are slash and burn agriculture and logging, at a rate of 700,000 ha per year [8]. Deforestation has negative environmental consequences, including biodiversity losing, land degradation and climate degradation. It is responsible for about a third of the increase of the rate of atmospheric carbon [9]. International concern about GHG and their impact on global warming and consequently climate change were used to study the potential of plants in the carbon sequestration process. Human, being conscious of their negative action on climate has developed many measures of adaptation against the phenomenon; in Africa, the surrounding peoples of forests used to collecting Non-Timber Forest Products for feeding and commercialization during dry seasons. Several measures are known as individual responses of populations in connection with climate change. These measures were assigned as an autonomous adaptation. In that way, if people of forestry regions could develop adaptation measures against climate change, they could also fight against the phenomenon by developing attenuation measures such as reforestation and conservation. One of a best attenuation measure known in Africa is agro-ecosystems that can be identified as carbon wells. In consequence, cocoa plantations are the most common agro-ecosystems known in Africa, particularly in Cameroon. Cocoa, the main cash crop, is practiced in association with fruit, medicinal herbs, and various species. These species are deliberately protected or planted in cocoa for feeding or for their economic value, and then to provide shade when necessary [10-13].

The present study aims to evaluate the sequestration potential of such agro-ecosystems at a time when natural ecosystems are under severe degradation.

2. MATERIALS AND METHODS

2.1 Study Site

The work was carried out in two localities (Mambele and Yenga) located in the Eastern

Region, sub-division of Boumba and Ngoko. Mambele is located geographically at 2°26' N and 15° 25' E with an elevation of 562 m [14,15]. The geographical coordinates of Yenga are 2° 16' N and 15° 20' E and 606 m of elevation. The two localities are separated by a distance of 20 km (Fig. 1).

2.2 Floristic Inventory

Plots method was used to assess the floristic diversity in the area. Sampling was carried out in plots of 25 x 25 m (625 m²) according to the methodology developed by Hall and Swaine. The sampling was done in each band of 125 m² to reduce counting errors (Fig. 2). A plot is assigned to a survey; 44 surveys were conducted in 15 cocoa agro-ecosystems. Cocoa is classified into age group: young cocoa (JCA, 0-15 years), medium-sized cocoa (MCA, 15-20 years) and old cocoa (VCA, 20-30 years).

2.3 Above Ground Biomass (AGB)

AGB concerns trees of Diameter of Breast Height (DBH, at 1.3 m) of at least 12.5 cm, litter and herbs of understory. Trees were collected in the plots of 25 x 25 m²; herbs in sub-plots of 1 x 1 m² and litter in sub-plots of 0.5 x 0.5 m² subdivided in the 25 x 25 m² plots (Fig. 2).

2.4 Below Ground Biomass (BGB)

Small roots and rootlets of soil were concerned. These roots were extracted from soil in sub-plots of 0.2 x 0.2 m² at 0.2 m of depth (Fig. 2). In each survey of 625 m², 4 sub-plots of 0.2 x 0.2 m² were demarcated.

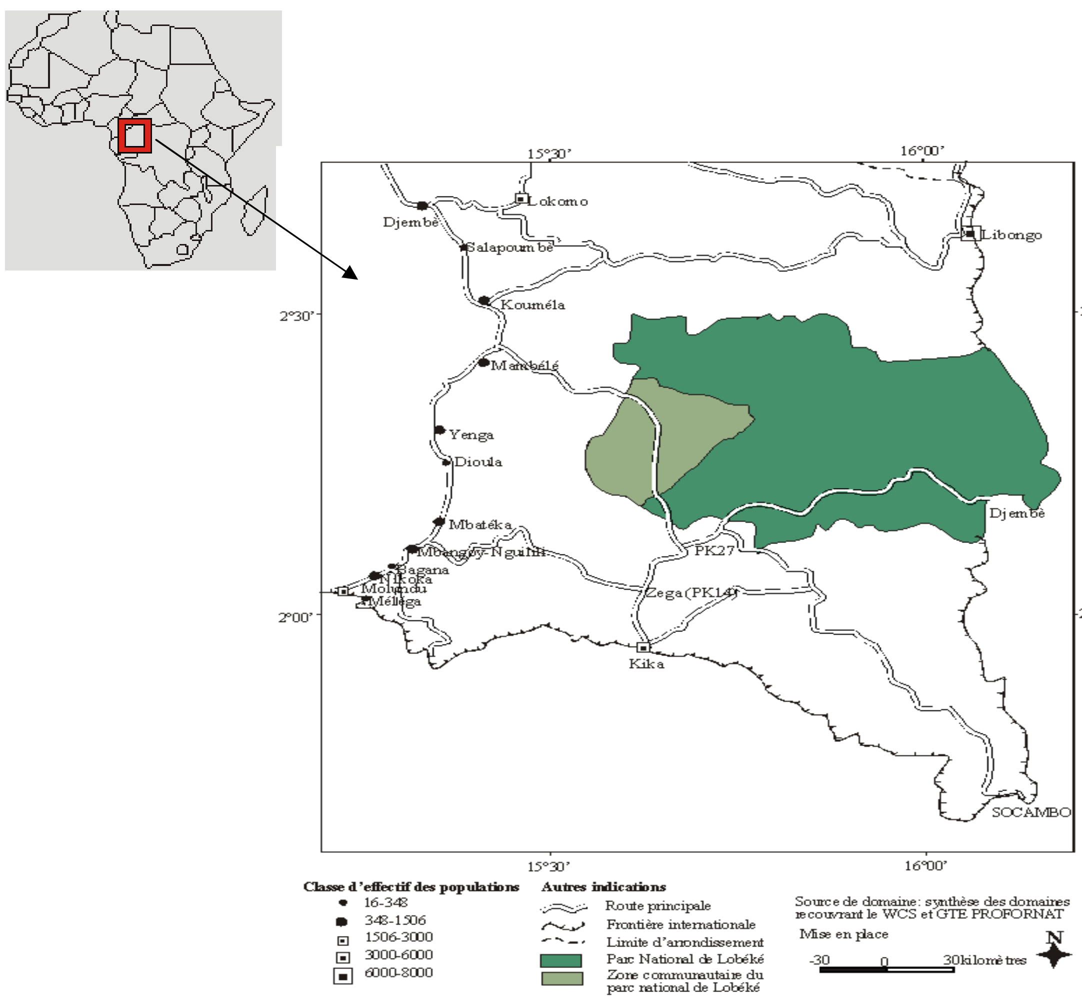

Fig. 1. Localization of site

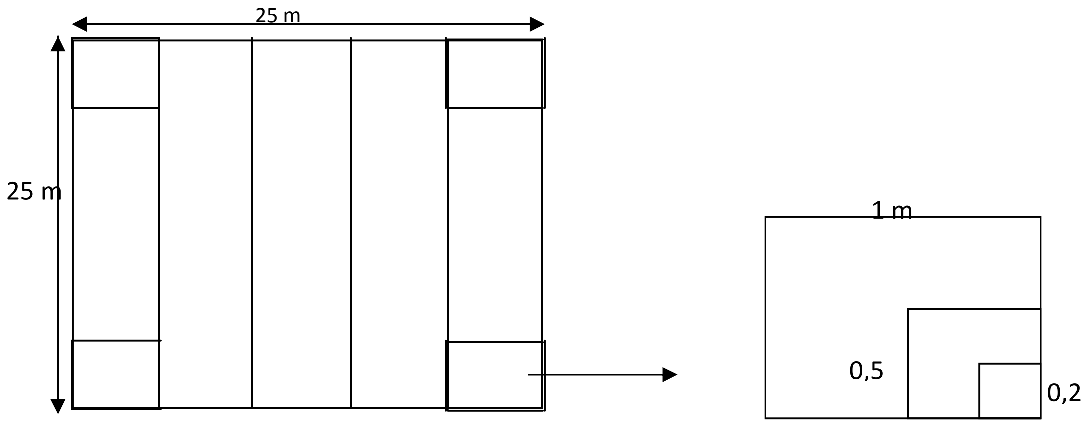

Fig. 2. Sampling plots (at right 625 m2; at left detail of carbon sampling method for herbs, litter and small roots

2.5 Data Analysis

2.5.1 Floristic diversity

The indexes for their importance have been used in this work:

- Shannon diversity index (ISH) [16]

  ISH=-Σ (Ni/N)$\log_2$(Ni/N), with Ni =size of species i, N = size of all species; ISH in bits.

- Pielou evenness (EQ): EQ=ISH/Log_2N [17].
- Simpson diversity index (D)

  (D) =1/D', where D' = Σ$(Ni/N)^2$ [18-19].

- Sorensen's similarity between two communities

  K= (2c/a+b) x 100, with a = number of species of survey 1; b = number of species of survey 2; c = number of the same species in surveys.

2.5.2 Above ground biomass (AGB)

The following allometric equations were used [20-22]:

- [20]: Y_1 = 38.4908 - 11.7883*D + 1.1926 D^2. .
- [22] :(2005) : Y_2 = αExp[-1.499 + 2.148*ln(DBH) + 0.207*$(\ln(DBH)^2$ - 0.0281*$(\ln(DBH))^3$] .
- [21] : Y_3 = (α / 0.6)Exp[-3.742 + 3.450*ln(DBH) - 0.148*$(\ln(DBH))^2$].

Y_1, Y_2 and Y_3 are biomass (kg), D (DBH) is the diameter (cm) at 1.30 m above the ground, α is the specific density of the wood. Otherwise α = 0.58 g/cm^3, and the coefficient of determination R^2 = 0.78. From this biomass, the amount of carbon (kg/ha) is obtained by multiplying the biomass by 0.47, then it will be converted into tons of carbon per ha.

- In Musaceae, the following formula was used: Y = 0.0303*$D^{2.1345}$, where Y is biomass, and D the diameter (cm).
- In Palmae, the following formula was used: Y = 10.0 + 6.4*H, where Y = biomass, H = total height (m).

2.5.3 Below ground biomass (BGB)

Small roots and rootlets were dried at constant temperature and their biomass was obtained by weighing until getting constant weight.

Total carbon was obtained by summing the carbon in timbers, bananas, undergrowth (grass), litters, and roots.

2.5.4 Analysis of variance (ANOVA)

The analysis of variance was conducted through ANOVA tests, and multiple comparisons (MCP) using Fisher's test.

3. RESULTS

3.1 Floristic Inventory

We recorded and identified 2,676 timbers and 42 bananas belonging to 32 families, 68 genera and

74 species. The most important families were Malvaceae (80.1%), Mimosaceae (4.6%), Euphorbiaceae (2.5%), Cecropiaceae (2.3%), Moraceae (1.3%) and Apocynaceae with 1.1% (Fig. 3). The genus *Theobroma* was the most abundant (79.2%), followed *Albizia* (4.33%), *Myrianthus* (1.57%), *Macaranga* (1.12%) and *Antiaris* (1.08%).

Beside *Theobroma cacao* which is the main species of the agro-ecosystem, *Albizia zygia* (21.17%), *Macaranga hurifolia* (7.66%), *Celtis zenkeri* (5.47%), *Oncoba gilgiana* (5.29%), *Bridelia micrantha* (4.19%), *Markhamia lutea* (4.01%) were the most abundant species; while *Ricinodendron heudelotii* (one of species used as spice), *Petersianthus macrocarpus*, *Omphalocarpum*, *Rauvolphia macrophylla*, *Zanthoxylum heitzii* were rare.

3.2 Indexes of Diversity

Only timbers were concerned in this analysis. The different indexes are recorded in Table 1. The Shannon index has almost the same value in all three habitats: young cocoa (1.91), medium cocoa (1.75) and old cocoa (1.53).

The index shows a large number of rare species namely *Pycnanthus angolensis*, *Piptadeniastrum africanum*, *Nesogordonia papaverifera* (red data listed, IUCN criteria; see [23], *Markhamia tomentosa*, *Lannea welwitschii*). The Pielou evenness is very low in all type of cocoa. This low value explains that a few dominant species namely *Theobroma cacao*, *Albizia zygia*, *Macaranga hurifolia*, *Celtis zenkeri*, *Oncoba gilgiana* and *Musanga cecropioides* were very important in the flora. The value of the Simpson index was the same in all type of cocoa groups.

3.3 Specific Richness and Relative Diversity

The greatest species richness was in old cocoa for a relative diversity of 75.67%. Medium Cocoa represents 63.51% of relative diversity. Young cocoa had low diversity with 45% relative diversity compared to others. The number of species per hectare gave a more accurate view of species richness.

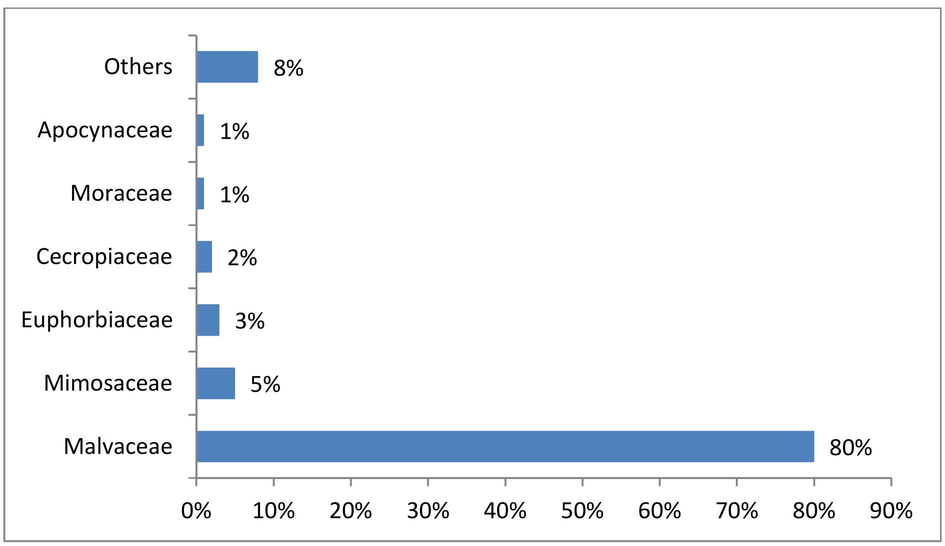

Fig. 3. Proportion of families

Table 1. Indices of diversity

Indices	Shannon (H')		Pielou		Simpson		Number of species	Number of individual	Number of family	S. (ha)
Type of cocoa	with Theo.	without Theo.	with Theo.	without Theo.	with Theo	without Theo.				
JCA	1.91	4.54	0.22	0.68	1.74	18.31	33	413	22	0.375
MCA	1.75	4.40	0.177	0.57	1.64	9.41	47	949	24	1.0625
VCA	1.53	4.75	0.147	0.60	1.48	14.98	54	1214	28	1.3125

JCA: Yong cocoa; MCA: Middle cocoa; VCA: Old cocoa; Theo: Theobroma

The same indices were calculated without taking into account *Theobroma cacao*. Values are much higher than those previously computed with *Theobroma cacao* (Table 1). Values justify that there was floristic diversity in these habitats in spite of the strong dominance of *Theobroma cacao*.

3.4 Sorenson's Similarity

Similarity coefficient of Sorensen assessed the floristic affinity between the two surveys. The three studied habitats form a single plant community. Young, medium, old cocoa farm shave between them over 50% similarities (Table 2).

Table 2. Indexes of similarity

	JCA	MCA	VCA
JCA	100		
MCA	55	100	
VCA	55.17	63.37	100

JCA: Yong cocoa; MCA: Middle cocoa; VCA: Old cocoa

3.5 Carbon Stocks

The carbon stock of timbers was estimated at 11.7 Mg $C.ha^{-1}.yr^{-1}$. That of litters was estimated at 0.7 Mg $C.ha^{-1}.yr^{-1}$, herbs represented 0.23 Mg $C.ha^{-1}.yr^{-1}$, roots 0.13 Mg $C.ha^{-1}.yr^{-1}$ and bananas 0.046 Mg $C.ha^{-1}.yr^{-1}$ (Table 3).

3.6 Analysis of Variance

The P value was 0.0065; $p < 0.05$. Therefore, the test was considered highly significant between Brown [20] and Chave [21] formula and the average variation between the columns is significant. The average variation between the equation of Brown et al. [20] and that of Shave et al. [21] was not significant. The two equations gave the same result. The variation of the average and that of Shave et al. [22] was highly significant.

The curves of the three linear regressions of the allometric formulas are represented by Fig. 4. The equations of Brown et al. [20] and Shave et al. [21] are similar; there is no significant different between the two models. They are applicable in tropical forests.

4. DISCUSSION

4.1 Abundance and Diversity

The flora is less diverse in cocoa agro-ecosystem which constitutes a homogeneous densely stand of Theobroma cacao. The most important families were Malvaceae (80.15%), Mimosaceae (4.63%), Euphorbiaceae (2.57%), Cecropiaceae (2.39%), and Moraceae (1.34%). Herbaceous speciesrichness is less important because the undergrowth is regularly

Table 3. Comparison of biomass following the allometric formulae

	Timbers	Herbs	Litter	Roots	Musa	Total
Brown et al. (1989)	11.7	0.7	0.23	0.13	0.046	12.85
Shave et al. (2004)	13.08	0.7	0.23	0.13	0.046	14.2
Shave et al. (2005)	8.38	0.7	0.23	0.13	0.046	9.5

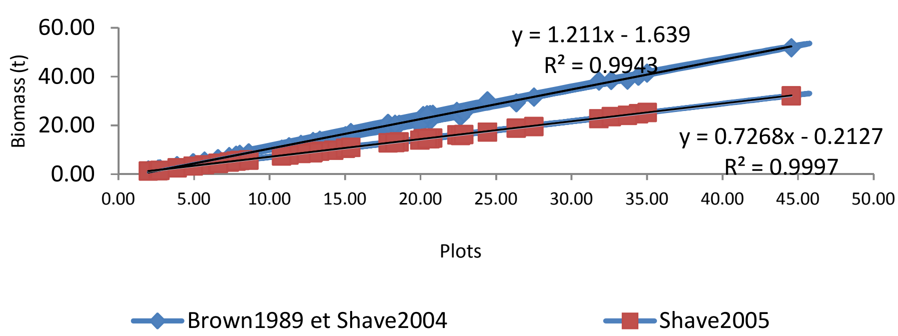

Fig. 4. Curves of regression showing similarity between Brown et al. [20] and Shave et al. [21] allometric equation

cleaned by the farmers. The physiognomy of the agro-ecosystem is dominated by secondary forest species. The Shannon (ISH) index (1.74 %) presents a strong homogeneity of cocoa with a high density of *Theobroma cacao*. It has almost the same value in all types of cocoa. A high value of ISH indicates a large number of rare species (*Pycnanthus angolensis, Piptadeniastrum africanum, Nesogordonia papaverifera, Markhamia tomentosa, Lannea welwitschii*).

A high ISH (6.3 bits) corresponds to favourable conditions of environment that lead to the installation of many species represented by a small number of indexes [17,24]. Pielou's evenness tends to 0 in all habitats. According to the Simpson index and Pielou evenness, each type of cocoa has a similar level of diversity. The results of floristic inventories in the studied agro-ecosystem show that the floristic richness of the community is low but not negligible. In addition to the intensification of cocoa by farmers, there are also species of primary forest (*Entandrophragma cylindricum, E. utile, Pericopsis elata, Klainedoxa gabonensis, Khaya ivorensis*), secondary forests (*Alstonia boonei, Terminalia superba, Eribroma oblongum, Antiaris africana, Ceiba pentandra*), fruity species (*Persea americana, Mangifera indica*) and useful non-timber forest products (NTFPs). Indices of Shannon and Simpson also show that the community is dominated by a few species; the most representative is *Theobroma cacao*.

4.2 Coefficients of Similarity

The similarity coefficients are greater than 50%; indicating that all types of cocoa studied belongs to the same plant community. Cocoa forms a group because, after disturbance, these habitats are awaiting regeneration or degradation by farmers. Degradation will be exacerbated by the cutting of shade trees that permits to fight against brown rot of cocoa trees, and possible conversions of cocoa into food crops. Distribution of trees/shrubs using class of diameter shows that the cocoa stands are comparable to a secondary forest in different stages of development. In addition to the intensification of cocoa-cultivation by farmers, cocoa are rich in primary and secondary forests.

4.3 Biomass

For the entire work, the stock was estimated at 140.20 Mg C/ha. This value represented half of the resulting stock in heterogeneous terra firme forests and was almost the same value in *Gilbertiodendron dewevrei* forests and periodically flooded forests in the Dja biosphere reserve in Cameroon [25]. This stock of carbon was also approximately half of the resulting stock in 50 ha in the eastern part of the Dja biosphere reserve [26]. This data was approximately comparable with many anterior results in tropics [22,27-31]. These data were as important as the work carried out in Tanzania in some agroforestry practices such as parklands, homegardens and woodlot [32]. Carbon stocks were significant and much higher than those obtained in agro-ecosystems in the centre of the Himalayas in India, in tropical moist lowland forests in Costa Rica and in young stands of *Annona reticulata* and *Annona squamosa* in the Campus of Aurangabad University [33-35]. Although this work is not taken into account the carbon stock of soil as considered in Costa Rica, the importance of the stock is dependent to the age of agro-ecosystems; in Costa Rica, carbon stocks were evaluated in plantations of 0-16 years and those in India in the plantations of 0-8 years. This study shows that the age of the ecosystem is an important feature in carbon sequestration. As the natural forests are under degradation, such ecosystems could be used as a measure of attenuation of climate changes. Analysis of variance using ANOVA of the three allometric formulas shows that there is a highly significant difference (5.24; 44; $p<0.0065$), while two formula have no significant difference [20-22]. This analysis leads to another problem which is the need of establishing a standard formula for the TNS and the Congo Basin.

5. CONCLUSION

The physiognomy of the cocoa agro-ecosystem is close to that of secondary forests; in fact, most species were those usually found in secondary forests namely *Terminalia superba, Albizia zygia, Musanga cecropioides, Antiaris africana, Funtumia elastica, Cola lateritia*.

Even though, the values of diversity indices were low, several species of the previous ecosystem were recorded (secondary and primary forest species); agro-ecosystems could offer necessary conditions to endogenic species to regenerate after deforestation. It is also a refuge for some endangered species such as *Nesogordonia papaverifera*, a red data listed of IUCN. Carbon stocks were compared to those harvested in Costa Rica and India and represented more approximately ½ of data recorded in selected natural stand in the Dja biosphere reserve. Several species used as non-timber forest products during dry season were also recorded. Cocoa agro-ecosystems could be assimilated to a carbon well; and consequently as an attenuation and adaptation measure in mitigating climate changes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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