

Floristic diversity and structure of Cocoa Agro-ecosystems in Southeastern Cameroon

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 %), *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.

Key words: 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) (Kandel, 1998; 2004). The area of rainforest in southeastern Cameroon has a great diversity of flora and fauna (Ghogue, 2007). 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 (ADB, 2010).

33 Slash and burn agriculture have many ecological consequences, ranging from the
34 reduction of carbon stock to desertification, through declining soil fertility (Duchaufour,
35 1983). According to several authors Slash and burn agriculture accounts for about 30% of
36 total carbon dioxide emissions and greenhouse gases and land-clearing for agricultural use,
37 including croplands and shifting cultivation as well as deforestation are the most important
38 sources of these emissions (Thomas, 1998; Pagiola and Holden, 1999; Pagiola and Holden,
39 1999; Coxhead and Southgate, 2000). Throughout Africa as a whole, nearly 60% of new
40 agricultural land was derived from intact forests, and another 35% came from disturbed
41 forests. The remaining 5% of new agricultural land was taken from shrub lands (Gibbs *et al.*,
42 2009). Climate change is placing additional stress on agricultural productive areas
43 exacerbated by recent pressure for biofuels production. As a result, land conversion and land
44 degradation are currently taking place at an alarming rate resulting to low agricultural
45 productivity and substantial release of greenhouse gases when forests are cut. The main
46 causes of forest destruction are slash and burn agriculture and logging, at a rate of 700,000 ha
47 per year (Anonymous, 2006). Deforestation has negative environmental consequences,
48 including biodiversity losing, land degradation and climate degradation. It is responsible for
49 about a third of the increase of the rate of atmospheric carbon (Locatelli, 1993). International
50 concern about GHG and their impact on global warming and consequently climate change
51 were used to study the potential of plants in the carbon sequestration process. Human, being
52 conscious of their negative action on climate has developed many measures of adaptation
53 against the phenomenon; in Africa, the surrounding peoples of forests used to collecting Non-
54 Timber Forest Products for feeding and commercialization during dry seasons (Michael,
55 2006; Chidumayo *et al.*, 2011). Several measures are known as individual responses of
56 populations in connection with climate change. These measures were assigned as an
57 autonomous adaptation (IPCC, 2001). In that way, if people of forestry regions could develop
58 adaptation measures against climate change, they could also fight against the phenomenon by
59 developing attenuation measures such as reforestation and conservation. One of a best
60 attenuation measure known in Africa is agro-ecosystems that can be identified as carbon
61 wells. In consequence, cocoa plantations are the most common agro-ecosystems known in
62 Africa, particularly in Cameroon. Cocoa, the main cash crop, is practiced in association with
63 fruit, medicinal herbs, and various species. These species are deliberately protected or planted
64 in cocoa for feeding or for their economic value, and then to provide shade when necessary
65 (Losch *et al.*, 1995; Gockowski *et al.*, 2004a, b; Zapfack, 2005).

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

2. MATERIAL 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 (Letouzey, 1982; 1985). 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).

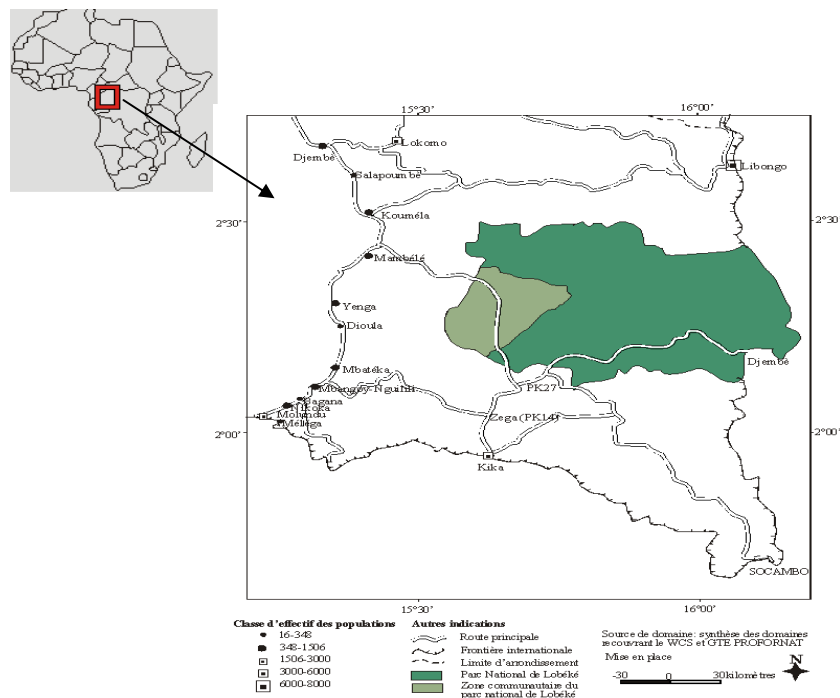


Figure 1. Localization of site

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 (1976 in Zapfack, 2005). 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).

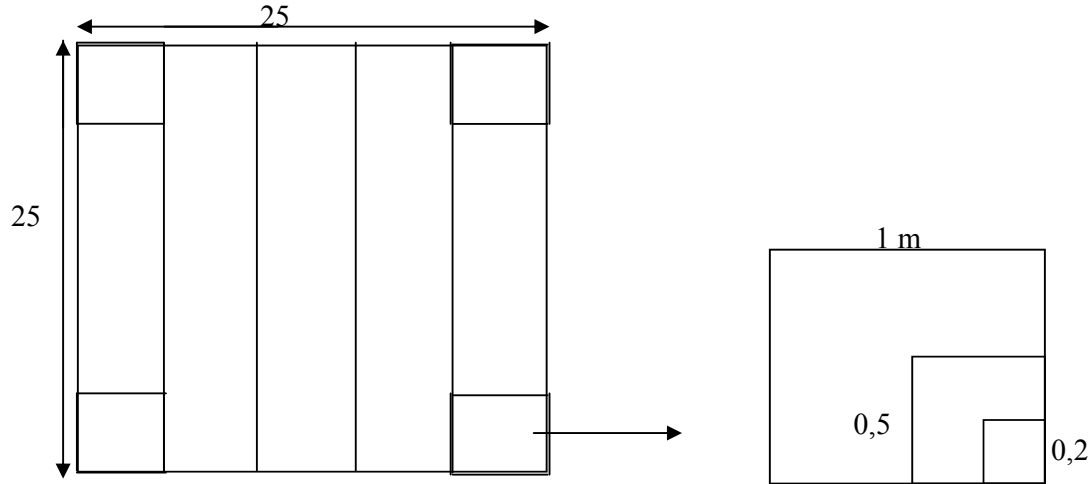


Figure 2. Sampling plots (at right 625 m²; at left detail of carbon sampling method for herbs, litter and small roots.

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.

2.5. Data analysis

2.5.1. Floristic diversity

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

- Shannon diversity index (ISH) (Frontier and Pichod-Viale, 1992)

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

- Pielou evenness (EQ): $EQ = ISH / \log_2 N$ (Dajoz, 1982).

- Simpson diversity index (D)

$(D) = 1/D'$ (Begon *et al.*, 1998), where $D' = \sum (N_i/N)^2$ (Colinvaux, 1986 in Sonke, 1998).

- Sorensen's similarity between two communities

$K = (2c/a+b) \times 100$, 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 (Brown *et al.*, 1989; Shave *et al.*, 2004; Shave *et al.*, 2005):

- Brown *et al.* (1989) : $Y_1 = 38.4908 - 11.7883 \cdot D + 1.1926 D^2$.

- Shave *et al.* (2005) : $Y_2 = \alpha \text{Exp}[-1.499 + 2.148 \cdot \ln(\text{DBH}) + 0.207 \cdot (\ln(\text{DBH}))^2 - 0.0281 \cdot (\ln(\text{DBH}))^3]$.

- Shave *et al.* (2004) : $Y_3 = (\alpha / 0.6) \text{Exp}[-3.742 + 3.450 \cdot \ln(\text{DBH}) - 0.148 \cdot (\ln(\text{DBH}))^2]$.

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 $\alpha = 0.58 \text{ g/cm}^3$, 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: $Y = 0.0303 \cdot D^{2.1345}$, where Y is biomass, and D the diameter (cm).

- In Palmae, the following formula was used: $Y = 10.0 + 6.4 \cdot H$, 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 %).

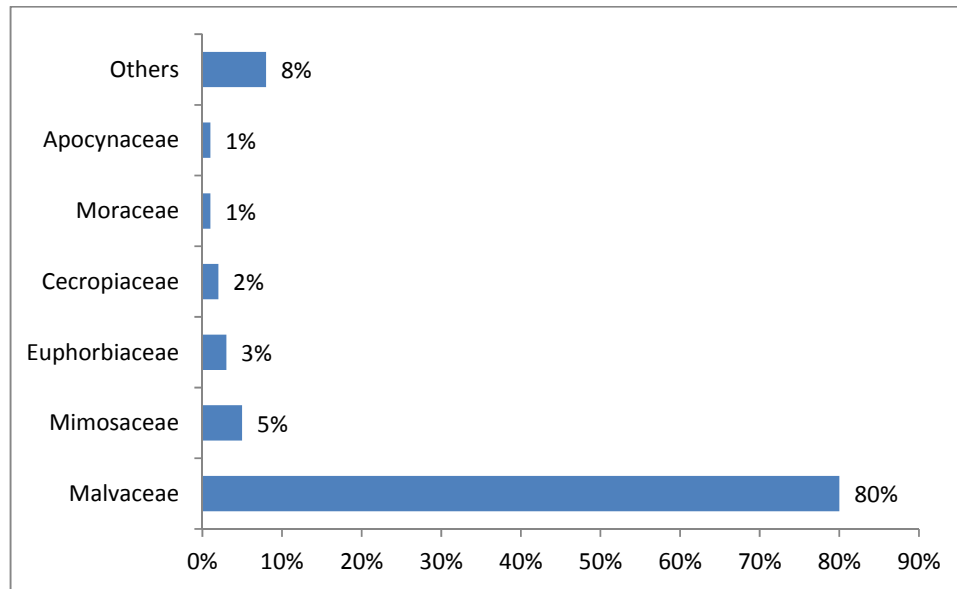


Figure 3. Proportion of families

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*, *Rauvolfia macrophylla*, *Zanthoxylum heitzii* were rare.

3.2. Indexes of diversity

Only timbers were concerned in this analysis. The different indexes are recorded in table I. 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).

Table 1. Indices of diversity

Indices Type of cocoa	Shannon (H')		Pielou		Simpson		Number of species	Number of individual	Number of family	S. (ha)
	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 index shows a large number of rare species namely *Pycnanthus angolensis*, *Piptadeniastrum africanum*, *Nesogordonia papaverifera* (red data listed, IUCN criteria; see Noiha *et al.*, 2015a), *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.

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 share 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).

Table 3. Comparison of biomass following the allometric formulae

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

3.6. Analysis of variance

The P value was 0.0065; $p < 0.05$. Therefore, the test was considered highly significant between Brown and Chave (2004) formula and the average variation between the columns is significant. The average variation between the equation of Brown *et al.*, (1989) and that of Shave *et al.* (2004) was not significant. The two equations (Brown *et al.*, 1989; Shave *et al.*, 2004) gave the same result. The variation of the average and that of Shave *et al.* (2005) was highly significant.

The curves of the three linear regressions of the allometric formulas are represented by Figure 4. The equations of Brown *et al.* (1989) and Shave *et al.* (2004) are similar; there is no significant different between the two models. They are applicable in tropical forests.

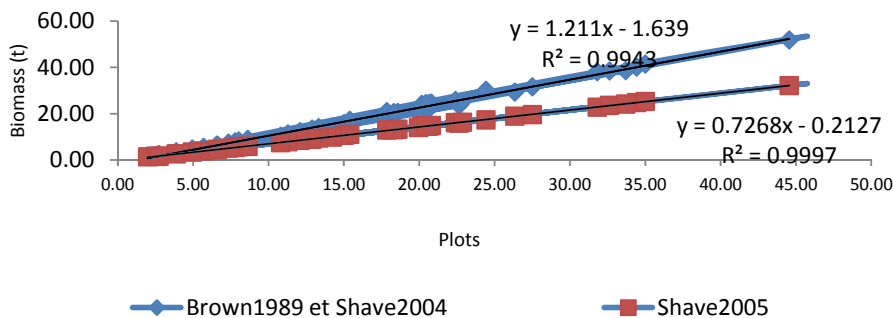


Figure 4. Curves of regression showing similarity between Brown *et al.* (1989) and Shave *et al.* (2004) allometric equation.

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 species richness is less important because the undergrowth is regularly 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 (Dajoz, 1982; Nguenguim *et al.*, 2015). 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 (Djuikouo *et al.*, 2010). This stock of carbon was also approximately half of the resulting stock in 50 ha in the eastern part of the Dja biosphere reserve (Tabue *et al.*, 2016). This data was approximately comparable with many anterior results in tropics

(Clark and Clark, 2000; Dewalt and Chave, 2004; Chave *et al.*, 2005; Lewis *et al.*, 2009a; Noiha *et al.*, 2015b; Zapfack *et al.*, 2016;). These data were as important as the work carried out in Tanzania in some agroforestry practices such as parklands, homegardens and woodlot (Richard *et al.* 2014). 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 (Prakash & Lodhiyal, 2009, William *et al.*, 2011; Chavan and Rasal, 2012). 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 (Brown *et al.*, 1989 and Shave *et al.*, 2004); these formulas are appropriate in tropical African forests. Therefore, formula of Shave *et al.* (2005) is not applicable in tropical Africa; this allometric model underestimates the results. 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 $\frac{1}{2}$ 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.

287 **References**

- 288 Anonymous (2006). Les forêts du Bassin du Congo. Rapport PFBC (Partenaire pour les
289 Forêts du Bassin du Congo), COMIFAC. 256 p.
- 290 Begon, M., Harper, J.L. & Townsend, C.R. (1987). Ecology: Individuals, populations and
291 communities. Oxford, London, Edinburgh, Boston, Palo Alto, Melbourne; Blackwells
292 scientific publications. 876 p.
- 293 Brown, S., Gillespie, A.J.R. & Lugo, A.E. (1989). Biomass estimation methods for tropical
294 forests with application to forest inventory data. *Forest sciences*, 15(4): 881-902.
- 295 Chavan, B.L. & Rasal, G.B. (2012). Carbon sequestration potential of young *A reticulata* and
296 *Annona squamosa* from University campus of Aurangabad, *International Journal of*
297 *Physical and Social Sciences*, 2(3):193-198.
- 298 Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Foilster, H.,
299 Fromard, F., Higuchi, N., Kira, T., Lescure, J.-P., Nelson, B.W., Ogawa, H., Puig, H.,
300 Riera, B. & Yamakura, T. (2005). Tree allometry and improved estimation of carbon
301 stocks and balance in tropical forests. *Oecologia*, 145, 87-99.
- 302 Chave, J., Condit, R., Aguilar, S., Hernandez, A., Lao, S., Perez R. (2004). Error propagation
303 and scaling for tropical forest biomass estimates. *Philosophical Transactions of the*
304 *Royal Society B* 359:409–420.
- 305 Clark, D.B. & Clark, D.A. (2000). Landscape-scale variation in forest structure and biomass
306 in tropical rain forest. *Forest Ecology & Management*, 137:185–198.
- 307 Dajoz, R. (1982). Précis d'écologie. 4^e édition. Bordas, Paris. 503 p.
- 308 Dewalt, J.S. & Chave, J. (2004) Structure and biomass of four Lowland Neotropical Forests.
309 *Biotropica*, 36(1):7–19.
- 310 Djuikouo, M.N., Doucet, J.L., Nguembou, C.K., Lewis, S.L. & Sonke, B. (2010). Diversity
311 and aboveground biomass in three tropical forest types in the Dja Biosphere Reserve,
312 Cameroon. *African Journal of Ecology*, 48:1053–1063.
- 313 Duchaufour, P. (1983). Pédologie: Pédogenèse et classification. Doc. 2^e éd., Masson, Paris.
314 491 p.
- 315 Frontier & Pichod-Viale, D. (1992). Ecosystème: Structure, fonctionnement, évolution.
316 Masson, Collection d'écologie 21, Paris. 392 p.
- 317 Ghogue, R., N. & Dongmo, Z.L. (2007). Les grands et moyens mammifères dans la
318 ZICGC2 : Abondance et pressions. Rapport technique WWF et GTZ, 59p.

319 Gockowski, J., Tonye, J., Baker, D., Legg, C., Weise, S., Ndoumbé, M., Tiki-Manga, T.
 320 & Fouaguégué A. (2004a). Characterization and diagnosis of farming systems in the
 321 forest margins benchmark of Southern Cameroon. IITA. Social Sciences Working
 322 Paper No 1. Ibadan, Nigeria. 69 p.

323 Gockowski, J., Weise, S.F., Sonwa, D.J., Tchata, M. & Ngobo M. (2004b). Conservation
 324 because it pays: shaded cocoa agroforests in West Africa. IITA-HFC Yaoundé,
 325 Cameroon, 29 p.

326 Kandel, R. (1998). Les eaux du ciel. Hachette, Paris. 182 p.

327 Kandel, R. (2004). Le réchauffement climatique, coll. Que sais-je ?, n°3650, 2^e éd., P.U.F.,
 328 Paris, 2004. 254 p.

329 Letouzey, R. (1982). Manuel de botanique tropicale. Afrique tropicale. Nogent sur Marne,
 330 Centre Technique Forestier Tropical, tomes 1, 2A, 2B. 461 p.

331 Letouzey, R. (1985). Notice de la carte phytogéographique du Cameroun au 1 :500000^e.
 332 Institut de la cartographie internationale de la végétation, Toulouse, France. 70p.

333 Lewis, L.S., Lopez-Gonzalez, G., Sonke, B., Affum-Baffoe, K., Baker, T.R., Ojo, L.O.,
 334 Phillips, O.L., Reitsma, J., White, L., Comiskey, J., Ewango, C., Feldpausch, T.R.,
 335 Hamilton, A.C., Gloor, M., Hart, T., Hladik, A., Djuikouo Kamdem, M.N., Jon, L.,
 336 Lovett, J., Makana, J.-R., Malhi, Y., Mbago, F.M., Ndangalasi, H.J., Peacock, J., Peh,
 337 K.S.-H., Sheil, D., Sunderland, T., Swaine, M.D., Taplin, J., Taylor, D., Sean, C.T.,
 338 Votere, R. & Hannsjörg, W. (2009a) Increasing Carbon Storage in Intact African
 339 Tropical Forests. *Nature*, 457:1003–1006.

340 Locatelli, B. (1993). Le stockage et la libération de carbone par les milieux naturels: le cas
 341 des écosystèmes forestiers tropicaux. Rapport d'un stage de fin d'études à l'école
 342 polytechnique. Centre de coopération internationale en recherches agronomiques. 74
 343 p.

344 Losch, B., Fusillier, J.L., Dupraz, P.O. & Ndjoya, J. (1991). Stratégies des producteurs en
 345 zone caféière et cacaoyère du Cameroun: quelles adaptations à la crise? Collection
 346 DSA No 12. DSA-CIRAD, Montpellier, 252 p.

347 Nguen J.R., Zapack L., Noiha Noumi V., Onana D., Betti J.L. et Riera B. (2015).
 348 expériences sylvicoles au Cameroun : Croissance, mortalité et adaptabilité des
 349 espèces de bois l'œuvre dans la station forestière de Mangombé (1964 – 2010).
 350 *International Journal of Biological and Chemical Sciences*, 9(6): 2789-2807.

351 Noiha Noumi, V., Zapfack, L. & Mbade, L.F. (2015a). Biodiversity Management and Plant
 352 Dynamic in A Cocoa Agroforest (Cameroon). *International Journal of Plant & Soil*
 353 *Science*, 6 (2): 101-108.

354 Noiha Noumi, V., ZAPFACK L., Ngueguim J.R., Tabue Mbobda R.B., Ibrahima a. and
 355 Mapongmetsem P.M. (2015b). Sequestered standing carbon stock in selective
 356 exploited timbers grown in tropical forest: a case study from the national park of
 357 Lobeke (Cameroon). *Journal of Botanical Sciences*, 4(2):19-24.

358 Prakash, S. & Lodhiyal, L.S. (2009). Biomass and Carbon Allocation in 8-year-old Poplar
 359 (Populus deltoides Marsh) Plantation in Tar Agroforestry Systems of Central
 360 Himalaya, India, *New York Science Journal*, 2(6) : 49-53.

361 Richard, L. Charles, Emmanuel. F. Nzunda & P.K.T. Munishi (2014). Agroforestry As A
 362 Resilient Strategy In Mitigating Climate Change In Mwanga District, Kilimanjaro,
 363 Tanzania. *Global Journal of Biology, Agricultural and Health Sciences*, 3 (2): 11-17.

364 Sonké, B. (1998). *Etude floristique et structurale des forêts de la réserve de faune du Dja*
 365 *(Cameroun)*. Thèse de doctorat, Université libre de Bruxelles. 267 p.

366 Sonwa, D.J. (2004). *La gestion de la biomasse et la diversification agroforestières de cacao*
 367 *dans la zone de forêt humide du sud Cameroun*. Thèse de docteur. Faculté de
 368 l'Agriculture. Université de Bonn. Allemagne. Verlag Cuvillier. Goettingen. 112p.

369 Tabue Mbobda Roger Bruno, Zapfack Louis, Noiha Noumi Valery, Nyeck Boris, Meyan-Ya
 370 Daghela Raissa Glawdys, Ngoma Louis Roger, Kabelong Banoho Louis-Paul, Chimi
 371 Djomo Cédric (2016). Plant Diversity and Carbon Storage Assessment in an African
 372 Protected Forest: A Case of the Eastern Part of the Dja Wildlife Reserve in Cameroon.
 373 *Journal of Plant Sciences*, 4(5):95-101.

374 William, F., Federico, E.A. & Rey-Benayas, J. (2011). Carbon accumulation in aboveground
 375 and belowground biomass and soil of different age native forest plantations in the
 376 humid tropical lowlands of Costa Rica, *New Forest*, author's copy, 17p.

377 Zapfack, L. (2005). *Impact de l'agriculture itinérante sur brûlis sur la biodiversité végétale*
 378 *et la séquestration du carbone*. Thèse de doctorat d'Etat. Université de Yaoundé I.
 379 225p.

380 Zapfack L., Chimi Djomo C., Noiha Noumi V., Zekeng J. C., Meyan-ya Daghela G. R.
 381 & Tabue Mbobda R. B. (2016). Correlation between Associated Trees, Cocoa Trees

382 and Carbon Stocks Potential in Cocoa Agroforests of Southern Cameroon.
383 *Sustainability in Environment*, 1 (2): 71-84.