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^{-1}. That of litters was estimated at 7.7 Mg C.ha^{-1}; herbs at 2.53 Mg C.ha^{-1}; roots at 1.43 Mg C.ha^{-1} and bananas at 0.5 Mg C.ha^{-1}. 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 (ADBG, 2010).

Slash and burn agriculture have many ecological consequences, ranging from the reduction of carbon stock to desertification, through declining soil fertility (Duchaufour, 1983). According to several authors Slash and burnagriculture 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 arethe most important sources of these emissions (Thomas, 1998; Pagiolaand Holden, 1999;PagiolaandHolden, 1999; Coxheadand Southgate, 2000). 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 (Gibbs *et al*., 2009). 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 (Anonymous, 2006). 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 (Locatelli, 1993). 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 (Michael, 2006; Chidumayo*et al*., 2011). Several measures are known as individual responses of populations in connection with climate change. These measures were assigned as an autonomous adaptation (IPCC, 2001). 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 (Losch*et al*., 1995; Gockowski*et al*., 2004a, b;Zapfack, 2005).

The present studyaimsto 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

Thework was carried outin two localities(Mambele andYenga)located in theEastern Region, sub-division of Boumba and Ngoko. Mambeleis locatedgeographically at 2°26' N and 15° 25' E withan elevation of562m (Letouzey, 1982;1985).The geographical coordinatesof Yengaare2° 16' N and 15° 20' E and606m of elevation.Thetwolocalitiesare separatedby a distanceof20 km(Fig. 1).

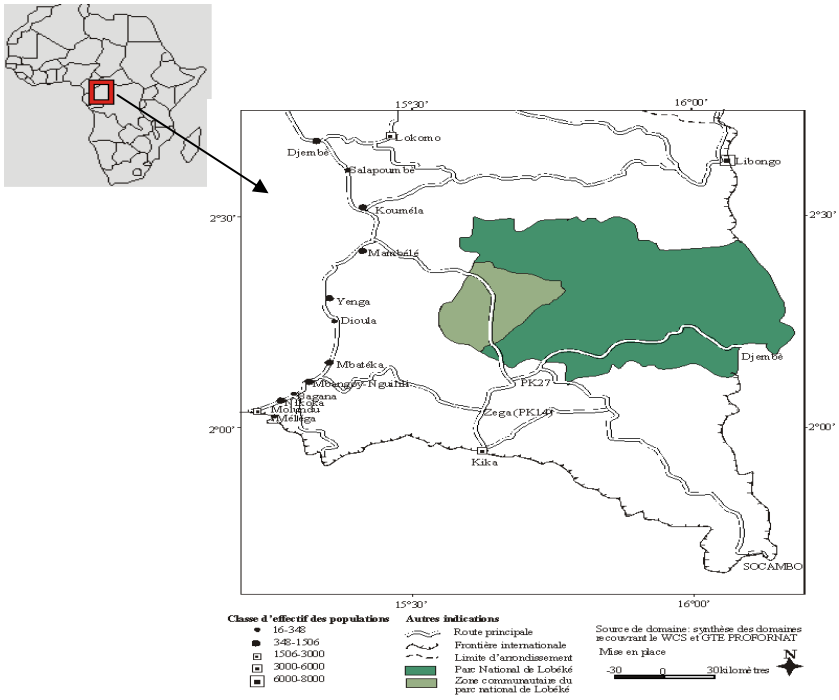

Figure 1. Localization of site

2.2. Floristic inventory

Plotsmethodwas used toassess thefloristic diversityin the area.Sampling was carried out inplots of25 x 25m (625 m²)according to the methodologydeveloped by Halland Swaine(1976 in Zapfack,2005).The sampling wasdone ineach bandof125 m²to reducecounting errors(Fig. 2). A plot is assigned to asurvey; 44 surveys were conductedin 15cocoa agro-ecosystems. Cocoais classified intoage group: young cocoa(JCA, 0-15years), medium-sized cocoa(MCA,15-20years) andoldcocoa(VCA, 20-30years).

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).

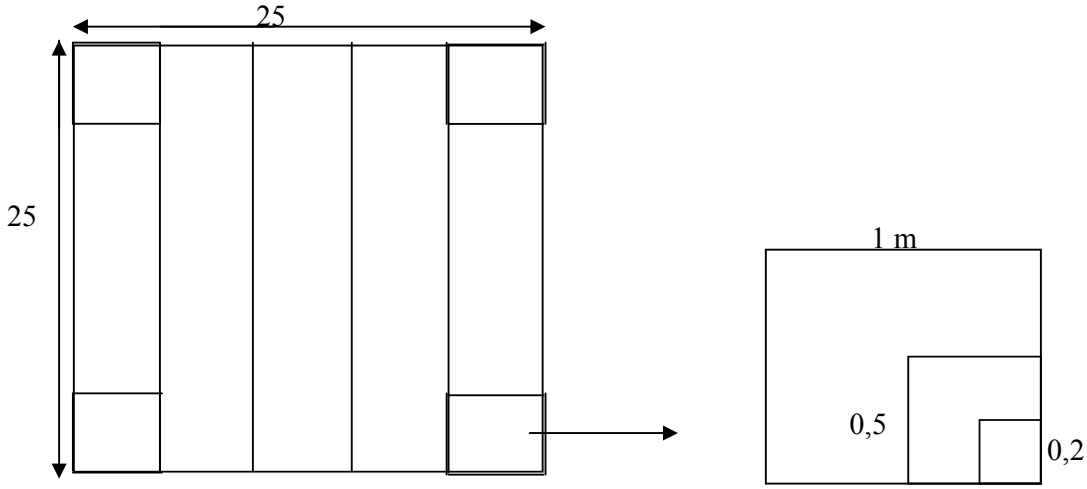

Figure 2. Sampling plots (at right 625 m^2; at left detail of carbon sampling method for herbs, litter and small roots.

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 indexesfor theirimportancehave beenused inthis work:

-Shannondiversity index(ISH) (FrontierandPichod-Viale, 1992)

ISH=-Σ (Ni/N)$\log_2$(Ni/N), with Ni =size ofspecies i, N = size ofall species.ISHis expressedin bits.

-Pielou evenness(EQ)EQ=ISH/Log_2N(Dajoz, 1982).

-Simpsondiversity index(D)

(D) =1/D' (Begon*et al*.,1998), whereD' = Σ(Ni/N)²(Colinvaux, 1986inSonke, 1998).

- 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 (Brown *et al*., 1989; Shave *et al*., 2004; Shave *et al*., 2005):

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

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

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

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 $\alpha = 0.58$ 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 obtainedbyweighing until getting constant weight.

Total carbon was obtained bysumming thecarbon in timbers, bananas, undergrowth(grass), litters, and roots.

2.5.4. Analysis of variance (ANOVA)

Theanalysis of variancewas conductedthroughANOVA 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 %).

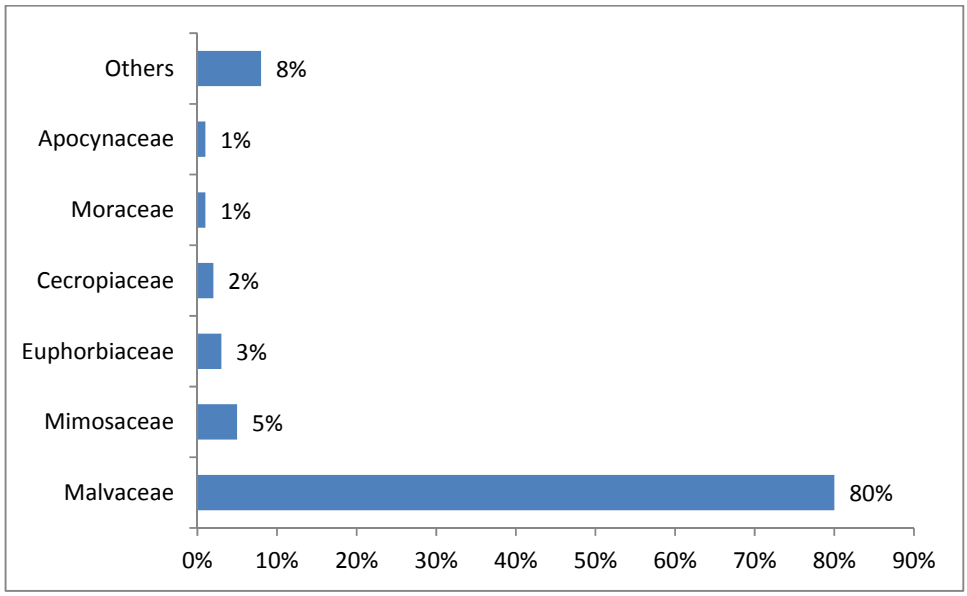

Figure 3.Proportion of families

Beside *Theobromacacao* which is the main species of the agrosystem, *Albiziazygia* (21.17%), *Macarangahurifolia* (7.66 %), *Celtiszenkeri* (5.47%), *Oncobagilgiana* (5.29%), *Brideliamicrantha* (4.19 %) *Markhamialutea* (4.01 %) were the most abundant species; while *Ricinodendronheudelotii* (one of species used as spice), *Petersianthusmacrocarpus*, *Omphalocarpum*, *Rauvolphiamacrophylla*, *Zanthoxylumheitzii* were rare.

3.2. Indexes of diversity

Only timbers were concerned in this analysis. The different indexes are recorded in tableI. TheShannon indexhas almost the samevalue in allthreehabitats: youngcocoa(1.91), medium cocoa(1.75) andoldcocoa(1.53).

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 indexshows alarge number of rarespecies namely *Pycnanthusangolensis*, *Piptadeniastrumafricanum*, *Nesogordoniapapaverifera* (red data listed, IUCN criteria; see Noiha *et al*., 2015a), *Markhamiatomentosa*,*Lanneawelwitschii*). ThePielou evenness is very low in all type of cocoa. This low value explains that a few dominantspecies namely*Theobromacacao*, *Albiziazygia*, *Macarangahurifolia*, *Celtiszenkeri*,*Oncobagilgiana*and*Musangacecropioides* were very important in the flora. The value of theSimpson indexwas thesame 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 *Theobromacacao*. Values are much higher than those previously computed with *Theobromacacao* (Table 1). Values justify that there was floristic diversity in these habitats in spite of the strong dominance of *Theobromacacao*.

3.4. Sorenson's similarity

SimilaritycoefficientofSorensenassessed thefloristicaffinity betweenthe two surveys. The threestudiedhabitatsform a singleplant community.Young, medium, old cocoa farmshave between themover 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 *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

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 them. They are applicable in tropical forests.

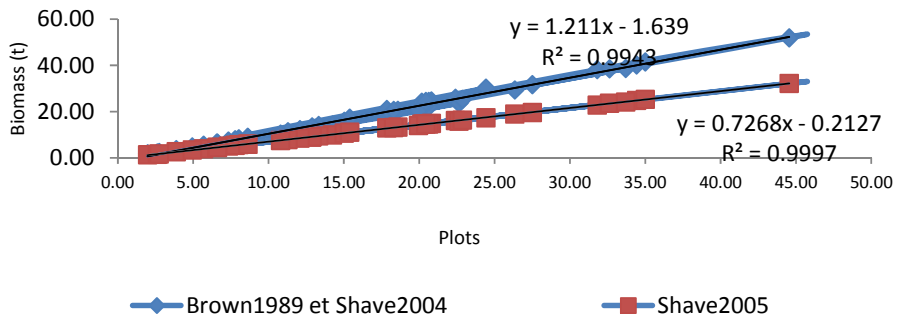

Figure 4.Curves of regression showing similarity between Brown *et al*. (1989) and Shave *et al*. (2004) allometric equation.

4. DISCUSSION

4.1. Abundance and diversity

The flora is less diverse in cocoa agro-ecosystem which constitutes a homogeneous densely stand of *Theobromacacao*. 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 agrosystem 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; Nguegui*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 agrosystem 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 *Theobromacacao*.

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 tree 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. As we can see, agrosystem could lead to the regeneration of the previous vegetation.

4.3. Biomass

For the entire work, the biomass is estimated at 140.20 Mg C/ha. This value represents more than ¼ of the biomass harvested in a homogeneous natural forest of Gilbertiodendron dewevrei in the Dja biosphere reserve in Cameroon (Djuikouo*et al*., 2010) and approximately comparable with many anterior results in tropics (Clark and Clark, 2000; Dewaltand 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 stockswere significant andmuch higher than thoseobtained inagro-ecosystemsin the centre ofthe Himalayasin India, intropical moistlowland forestsinCostaRicaandin young standsofAnnona reticulata and Annona squamosa in the Campus of Aurangabad University (Prakash&Lodhiyal,2009,William*et al*., 2011;Chavanand Rasal, 2012).Although this workis nottaken into account the carbon stock of soil asconsideredinCostaRica,the importance of thestockisdependentto theage ofagro-ecosystems; in CostaRica,carbon stockswere evaluated inplantations of 0-16years andthose inIndia in the plantations of 0-8years.This study shows thatthe age of theecosystemis an importantfeature incarbon sequestration. As the natural forests are under degradation, such ecosystems could be used as a measure of attenuation of climate changes.Analysis of varianceusing ANOVA of the three allometricformulasshowsthat there is ahighly significant difference(5.24; 44;p<0.0065), while twoformulashave nosignificant 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 notapplicablein tropical Africa.This analysis leads toanother problemwhich isthe needof establishinga standard formula fortheTNSandthe Congo Basin.

5. CONCLUSION

The physiognomy of the cocoa agro-ecosystem is close to that of secondary forests; in fact, mostspecieswere those usually found in secondary forestsnamely *Terminaliasuperba, Albiziazygia,Musangacecropioides, Antiarisafricana,Funtumiaelastica, 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 than 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.

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