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Correlation between Associated Trees, Cocoa Trees and Carbon Stocks Potential in Cocoa Agroforests of Southern Cameroon

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Abstract

This study was conducted in the Cocoa Agro-Forests (CAF) of Mengomo's locality. The aim was to evaluate the influence of some factors on carbon stocks. The sampling was done in 30 plots of 25 x 25 m 2 in which all trees with a dbh≥10 cm were inventoried. The Shannon, Simpson and Evernnessindexes were calculated to characterize the diversity of trees associated with cocoa. 62 species belonging to 48 genera and 27 families were identified, the Anacardiaceae, Moraceae, Caesalpiniaceae, Mimosaceae and Rutaceae, were revealed the most diverse families, with 5 species each. Shannon's (3.66), Evernness's (0.76) and Simpson's (0.96) indexes have reflected a low diversity, dominated by some few species. The average density of cocoa trees is 1028 trees/ha. They store about 22.51±5.86 Mg C/ha. Associated trees stored 124.20±60.05Mg C/ha for tree density of 113 trees/ha. These CAF sequestered about 146.71Mg C/ha. The multiple correspondence analyses showed that carbon stocks in the CAF are positively correlated with the associated trees and the age of the CAF and negatively correlated with the abundance of cocoa trees. The biomass of cocoa is independent of the associated trees, but is inversely related to the density of the associated trees.

Keywords

cacao agroforestry, biodiversity, carbon stock, Mengomo

1. Introduction

Cameroon, known in Africa for its specific diversity, has a variability of forests ecosystems, which represent about 41% of its total surface (Sonwa et al., 2002). It comprises about 10000 identified plants species (Onana, 2011), of which many are still unknown (Onana, 2003; Fongnzossie et al., 2011). Interests about forests in the last decades is still increasing due their socio-economical functions especially ecologically, for the purpose of the conservation of its biodiversity and to combat global change. Nowadays, forests are subjected to diverse form of exploitation, which does not always guarantee their intrinsic values. Among these land use types, Agriculture remains the main source of forest's degradation. In Cameroon, besides intensive agriculture, forests surfaces are essentially converted into agroforestry systems. For the Cocoa Agro-Forests (CAF), 75% are mainly in the Centre, south and East region (Sonwa et al., 2001). More over in the South region which are we are study rea, cocoa agro forests covers about 8.5% of the total surface of this area (Kotto-Same et al., 1997). Thought the species richness of those agro forests seems lower than those of natural forests, they however manage to maintain a significant ecosystem wealth, since these highly influenced landscape tends to mimic the landscape of natural forests (Foresta, 2013; Bhagwat et al., 2008). Moreover, many studies have shown the potential of those agro forests to store carbon, making them real actor in fighting climate change (Zapfack et al., 2002; Somarriba et al., 2013; Zapfack et al., 2013). Indeed, agro forestry offers a significant potential for poverty reduction and to support development, particularly rural development where it is really expanding. Apart from the revenues obtained from the sale of cocoa beans, farmers could get additional incomes from the sale of the carbon stocks, Non Timber Forest Products (NTFP), fruits, medicine, and of course timber (AbadaMbolo et al., 2016, 2014; Eboutou, 2009; Sonwa et al., 2002; Zapfack et al., 2002; Sonwa et al., 2014). CAF also do serves as a refuge for some endangered species; some species of the red list of the IUCN have been identified in CAF (Noiha et al., 2015). This study is therefore a contribution in assessing the multifunctionality of CAF. For a better understanding of agroforestry systems, all components must be taken into account (Eboutou, 2009). CAF represents the principal form of forests conversion in the Mengomo's locality, given that they contribute to the conservation of the initial forest (Clough et al., 2009; Oke Yamala, 2013), this study is therefore to evaluate the contribution of these ecosystems in the conservation of global changes. One of the key questions that this study reveals is that the influence of some environmental factors on carbon stocks. In order to answer this question, this study has set the objectives of (1) determining the flora of associated woody species in CAF of Southern Cameroon, (2) assess carbon stocks in these CAF, and (3) to study the influence of some factors that can influence the carbon stocks.

2. Materials and Methods

2.1 Study Site

This study was conducted in Southern Region of Cameroon from July to August 2014, in the locality of Mengomo, capital of the Ambam District, Department of Ntem Valley. It is located on the Ebolowa-Ambam subway, in full equatorial forest, between the coordinates 2'15-2'55 North and 5510'50-11'50 East. The climate is equatorial with four seasons, two rainy seasons (from mid-March to mid-June and mid-Augustto late October) and two dry seasons (November to mid-March and mid-June to mid-August. The area where the cocoais grown is very active and is easily accessible.

2.2 Sampling Design

The sampling was carried out in 30 plots of 625 m^2 (25 m×25 m) each, i.e., a total surface of 1.875 ha. Plots orientation' were functions of farm's dimensions (Zapfack et al., 2002, 2003).

2.3 Cocoa and Shade Tree Sampling

Cocoa tree sampling in each plots consisted of measuring their diameter at 0.30 m from the floor, and take down their abundance. This was also achieved with shade trees with the only difference that diameter was taken at 1.30 m from the sol, and or species having but tresses, it was measured above he buttresses. After having sampled a tree, it was marked with a ribbon to avoid repetition. Trees species identification was achieved by the aid of the existing flora, en by comparison with species at the national herbarium Cameroon.

2.4 Factors Related to the CAF

Carbon stocks values are not constant in CAF. They are sometimes influenced by many environmental variables (Wade et al., 2010). Some factors like the age, were directly taken from the owners of the farm. Others factor like the abundance of cocoa and shade tree species were collected on site. The shading percentage was obtained by image analyses with the software "Get Leaf Cover" of 4 pictures taken vertically at 5 m from the diagonal, from each side to the centre. The average cocoa tree diameter was obtained for each plot. Data on diameter and density for tree species were used to evaluate the biomass in each plot, with allometric equations. The latitude and longitude have been obtained using GPS records.

2.5 Data Analysis

2.5.1 Horizontal Distribution and Carbon Stocks in CAF

1) Tree diameter class of associated trees

Eight diameter class with an amplitude of 10 cm were established for shading trees. This allows to appreciate the expression of the vegetation and the dominant species. The defines classes were as such: [10-20 cm], [20-30 cm], [30-40 cm], [40-50 cm], [50-60 cm], [60-70 cm], [70-80 cm]≥80.

2) Above ground biomass and carbon stocks of CAF

The allometric equation developed by Chave et al. (2014) has allowed to determine the above ground biomass of cocoa and shade trees. This equation was chosen because it takes into account the tree' dbh, the species density, and environmental index (E), which depends on environmental factors. On the Contrary, Chave et al. (2005) depends only on the species dbh and density, on the same way as Brown (1997) which takes only the dbh into account.

Chave et al. (2014) is defined as such: BA (kg)=$\exp[1.803-0.976*E+0.976*\ln(\rho)+2.673*\ln(D)-0.00299*\ln[(D)]^2]$: B.A=above ground biomass (kg); E=environmental index; ρ=wood species density considéré (g.cm^{-3}) ; D=tree diameter (cm).

For each sampled CAF (plot), the E was obtained from the latitude and longitude data. Wood density values were those of "Global Wood Density Data Base" (Zanne et al., 2009). For unidentified species, an average wood density of present species was used. For species like *Elaies guineensis*, tha allometric equation B.A (kg)=4.5+7.7 * hauteur (Frangi, 1985; Cummings et al., 2002) was rather used. This takes only into account the height of the palm tree (in meter). The obtained biomass values were extrapolated to the hectare level for the whole sampled plots, using the formulae: $FE = \frac{10000m^2}{Surfacedelaplacette\ (m^2)}$ (Brown, 2005). F.E. is a Extrapolation Factor.

The total carbon quantity per hectare was obtained by multiplying the total biomass by a conversion factor: 0.47 (Zapfack et al., 2013).

2.5.2 Characterization of the Shade Tree Flora and Principal Components Analysis

The data was encoded with Excel, and analyzed with the R software (version 3.1.3). The accumulation curve for shade tree diversity was drawn to assess the size of the sampling. Indices values, i.e., Shannon, Simpson and Evernness for all the sampled plots were obtained using the "Biodiversity R" package of the R software. Carbon stocks comparison between cocoa and shade tree species was achieved using the ANOVA test. Principal components analysis were run with de "ade4" package of R. To assess the biomass within each plot, values of the E index were extracted from the world map (extension "tif") in the R console ("raster" package), following the geographical coordinates (latitude and longitude) of each sampled point.

3. Results

Investigations a have made possible the identification 198 associated shade trees, distributed into 27 families, 48 genera and 62 species. Only 42 species have been taxonomically identified (See Appendix 1).

3. 1 Accumulation Curve of Shade Trees Species in Cocoa Agro-Forests

The accumulation curve of shade tree species (Figure 1) is still increasing. The plateau-state that indicate the sampling of almost all the species in the agro forest is not yet reached. A more sampling effort therefore should be considered.

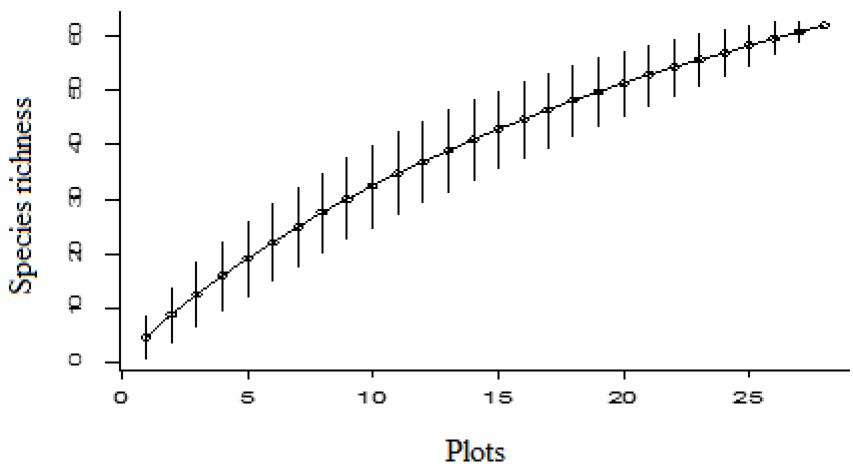

Figure 1. Accumulation Curve of Cocoa Shade Trees

The Shannon index for all sampled cocoa agro forests gave a value of 3.66, 0.79 for the Evernnessindex and 0.96 for the Simpson index.

3.2 Family Diversity of Shade Trees in CAF

The most diverse families were the Anacardiaceous and the Moraceae, with 5 species each. The Caesalpiniaceae, Mimosaceae and Rutaceae accounted 4 species each, while the Apocynaceae, Euphorbiaceae and Meliaceae were having 3 species each and the Annonaceae, Burseraceae, Fabaceae, Hypericaceae, Irvingiaceae and Tiliaceae scored only 2 species. The 13 remaining families (Bombacaceae, Cecropiaceae, Combretaceae, Lauraceae, Loganiaceae, Malvaceae, Myristicaceae, Ochnaceae, Olacaceae, Arecaceae, Sapindaceae, Sapotaceae, Verbenaceae) were having a single species. Most of the sampled shade trees species were having a small diameter. From the 198 identified species, 69% were having a diameter less than 50 cm (Table 1). Diameter classes of species like *Elaies guineensis* and *Ficus etrangle* have not been determined.

Table 1. Diameter Class Distribution of Shade Trees

Diametric Class (cm)	Abundance	Diametric frequencies (%)
[10-20]	34	17
[20-30]	35	18
[30-40]	35	18
[40-50]	33	17
[50-60]	14	7
[60-70]	11	6
[70-80]	6	3
≥80	19	10
Total	198	100

3.3 Ground Surface and Carbon Stock in CAF

An average of 1028 cocoa trees per hectare have been identified; this represent a ground surface of 10.33±3.95m^2/ha. Shade trees occupy almost 70% of the ground surface of the CAF, with an average density of 113 trees/ha. Despite their low density, shade tree stock about 85% of the total carbon of CAF (Table 2). There is a significant difference between cocoa trees and shade trees, in terms of ground surface, biomass and carbon stock; Shade trees stock five times more carbon than cocoa trees. About 27% of the ground surface (m^2/ha) is occupied by cocoa trees which stock about 22.51±5.86 Mg C/ha, representing 15% of the total carbon stocks of those CAF. Significant different exist between cocoa tree and shade tree seeing the ground surface and biomass or carbon stock (ANOVA, $p<0.0001$).

Table 2. Biomass, Ground Surface and Carbon Stocks in CAF

Types	Abondance (tree/ha)	Basal area (m^2/ha)	Biomass (t/ha)	Carbon stock (t C/ha)
Cocoatrees	1028±399	10.33±3.95a	47.89±12.46a	22.51±5.86a
Shadowtrees	113±60	24.52±19.31b	264.25±128.78b	124.20±60.53b
Total		34.85	319.98	146.71

Probability P=0.05.

3.4 Variables Influencing Carbon Stocks in CAF

Carbon stocks are dependent upon ground surface, which in turn are dependent upon the dbh wherein biomass is correlated. The increase of carbon biomass/stock of cocoa is depending on the diameter of the tree. However, this biomass is negatively linked to the age of the agro forest, and the density of shade trees, when looking at the dimension 1 of the ACP (Figure 2). Shade tree biomass on the other side is positively correlated with the age of the CAF, but strongly decreases with the abundance of cocoa trees. This shade tree biomass seems to be independent from the density of the shade trees, and the biomass of the cocoa trees (Dimension 1 of the ACP). Nevertheless, the older a cocoa agro forest is, the lesser the abundance of cocoa trees/ha and the greater the biomass of shade trees. The diameter 2 of the ACP shows that the average diameter of the cocoa tree is not correlated to the age of the CAF. Cocoa trees abundance is inversely linked to the abundance of shade trees.

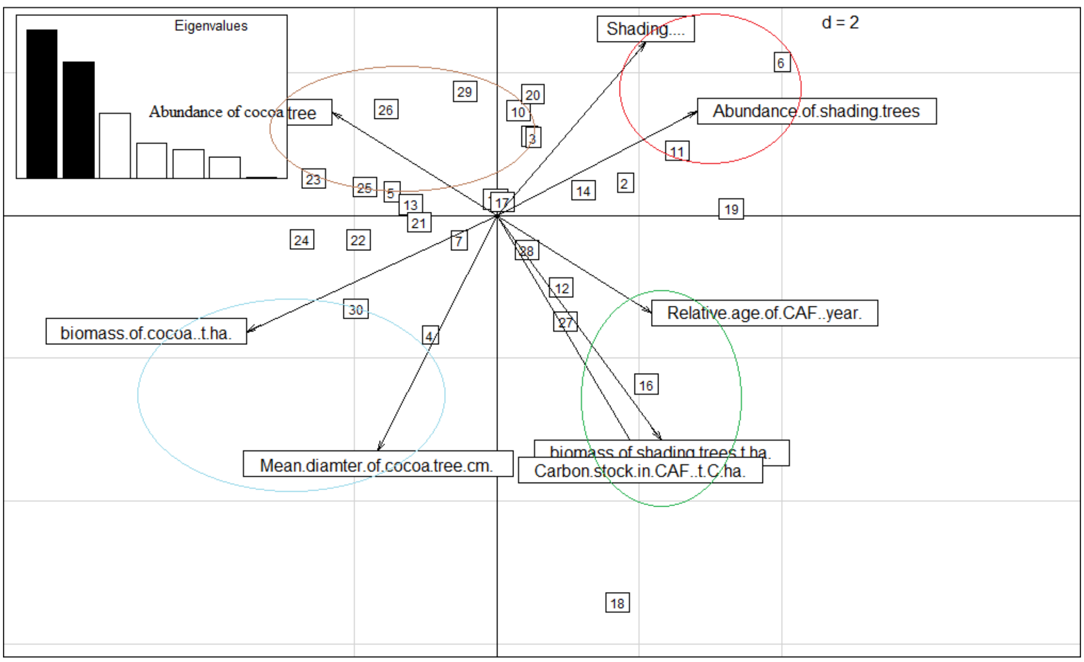

Figure 2. Influence of Some Factors on Carbon Stocks in CAF

Eigen values=percentage of information on the two principal axis Vertical axis is dimension 1 and horizontal axis is dimension 2 of the PCA. The plot sampled are represented by number in the square. The information located on one side of the axis are correlated positively and two arrows side by side and going in the same direction are strongly correlated.

Considering carbon stocks, the ANOVA hypothesis testing have shown that there is a significant link carbon stocks and shade trees ($p<0.001$) and, age of the agro forest ($P=0.04$). Abondance of cocoa tree, shading and average diameter of the cocoa tree have not asignificant link with carbonstocks in CAF ($P>0.05$).

4. Discussion

The flora sampling of CAF in the surroundings of Mengomo revealed the presence of 62 trees species associated to cocoa trees. This value seems to not reflect the total diversity of CAF given that, the grown accumulation curve has not reached the plateau enhancing that more sampling needs to be achieve. Nevertheless, the value of 62 species is similar to that of Jiofack et al. (2013), who sampled 59 species on 10.4 ha in the Centre region of Cameroon. However, this value seems very low to the 116 species sampled in CAF of south Cameroon by Zapfack et al. (2002) with the only difference that they sampled species with a dbh≥2.5 cm, unlike the dbh≥10 cm which we sampled. On the same way, Jagoret et al. (2014) identified 122 species in 3 localities, i.e., 70 in Bokito, 64 in Zima and 84 in Ngomed zap. When considering only the localities, we note a similarity with this study.

The Anacardiaceae, Moraceae, Caesalpiniaceae, Rutaceae, Euphorbiaceae, Apocynaceae, Meliaceae wre revealed the most diversified familes. These results corroborate with those of the Nigerian CAF (Okeet Odebiyi, 2007). From a species point of view, the presence or the absence of a tree in a cocoa farm depends partly on the farmer's interest with respect to their nutritive values (*Dacryodes edulis*, *Persea americana Mangifera indica*, *Citrus* sp., etc.), medicine (*Alstonia boonei*, *Picralimanitida*, etc.), and microclimatics values given the shade provided to the cocoa trees. Other species presence in CAF was attributed to the difficulty of felling the tree and to timber interest (Sonwa et al., 2007; Mbondji, 2010). 31% of trees have had a diameter≥50 cm, with most been forest species. On the contrary, the abundance of species with small diameter was justified by the farmer's interest to introduce new species (mostly fruit trees) when putting in place the farm. Moreover, non fruit trees species with low diameter were mostly found in abandoned farms, which the lap time favored their development.

The high values of the Shannon (3.66), Pielou (0.79) and Simpson (0.96) indexes have shown that those agroforêts exhibit a low diversity with some species been dominants, i.e., *Ficus mucuso*, *Dacryodes edulis*, etc. These results are similar to those found by Sonwa et al. (2007) in CAF of the South and Centre regions, but lower than those found by Zapfack et al. (2002) (Shannon index 4.39) in cocoa agroforest of the same area. However, the obtained Shannon index remains higher than the average obtained by Jagoret et al. (2014) for the three sampled localities (2.42), similarly Bisseleua et al. (2008) obtained some different values lower than 2.23 in cocoa agro forests under different management. The setting down techniques of the cocoa farm, the intensification, maintenance as well as climatic conditions could account for the principal differences observed between the sampled floras of those regions.

The average density of 1028 cocoa trees per hectare obtained were similar to those of 1086, 1111 and 1242 cocoa tress per hectares, preconised by Somariba et Beer (2011) in Costa Rica, and found by Gockowski et al. (2013) in Ghanean CAF and Jagoret et al. (2012) in old CAF of the savannah region of Cameroon respectively. According to Somariba et al. (2013), the average cocoa tree density in Central America is≤600 trees/ha which contrast those of this study. The average density of 113 associated trees species were similar to 108 and 135 found by Jagoret et al. (2014) in Zima and Ngomedzap, but far from the 277 and 278 associated trees found by the same author in the locality of Bokito. Nevertheless, the obtained average density of shade trees species was far greater than the 55 trees per hectare found by Gockowski et al. (2013).

The carbon stocks (146.71 Mg C/ha) in CAF were close to the 171.02 Mg C/ha obtained by Zekeng (2014) in CAF of Mbankomo. These quantities remain higher than those of 107.5 Mg C/ha obtained in some plants communities of the forests in the East region of Cameroon (Noiha et al., 2015), confirming the potential of CAF to stock carbon, even though it appear low as compared to the carbon stock in tropical forests 122.8 Mg C/ha (Tabue, 2014). As it is generally the case with big trees, the more wide the diameter, the carbon stocked by the tree. The PCA have shown that there is a positive correlation between the average diameter of cocoa trees, their biomass and quantity of stocked carbon; this was equally the same for neighboring trees (Zekeng, 2014; Zapfack et al., 2002). The fact that farmers selectively replace dying or less productive cocoa trees by plantlets or by favoring the development of "greedy species" where the most vigorous species are conserved to ensure the sustainability of individuals, confirms the negative correlation found between the average diameter of cocoa trees and the age of the CAF (Chimi, 2014).

The shade tree potential conserved in CAF contribute in mitigating climate change (Seidu, 2010). The removal of shade trees seriously impact the carbon stock of the agro forest (Bisseleua et al., 2009). Those trees sequester large amount of carbon independently from cocoa trees given their nature and the variability of their diameter as some are planted into the farm, and others are conserved when setting down the farm. There seems no clear correlation between the carbon stock of those trees and their abundances; however the increase in shade trees which is positively correlated to the abundance of those shade trees, is inversely linked to the cocoa tree biomass. Thus, in hands with the work of Wade et al. (2010), cocoa farms with a shade percentage more than 25% are having a low total biomass. On the contrary, in cocoa agro forests where the shading percentage is less than 25%, the total biomass is high. Intensive cocoa farming represent one of the most appreciated methods by farmers, to increase their yields; that was then achieved by a reduction of shade trees species (Bisseleua & Vidal, 2008). To favor better yielding, farmers do rely on ameliorated varieties of cocoa; these have the capacities to develop rapidly, thus stock more carbon.

5. Conclusion

CAF can be regarded as a degrading factor for the forests, but they however contribute in maintain an important ecosystemic richness, while offering a multi—functionality system in mitigating climate change as well as sustaining local population revenues (Sonwa et al., 2014). Nevertheless, CAF are capable of stocking important amount of carbon, even though they mostly depend on some factors, which can exert a negative impact on those carbon stocks. Thus, CAF of south Cameroon could therefore be considered as a real factor to work more on the implementation of the REDD+project.

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Appendix

Appendix 1. List and Frequency of Tree Species Recorded in Cocoa Agroforestry

Species	Families	Frequency
Albizia sp	Mimosaceae	0.07
Allanblackia sp	Clusiaceae	0.04
Alstonia boonii De Wild	Apocynaceae	0.07
Annonidiummanii (Oliv. Engl, & Diels)	Annonaceae	0.04
Anthocleista schweinfurthii Gilg	Loganiaceae	0.21
Baillonella toxisperma Pierre	Sapotaceae	0.04
Canarium schweinfurthii Engl	Burseraceae	0.04
Cassia sp	Caesalpiniaceae	0.04
Ceiba pentandra (Linne) Goertner	Bombacaceae	0.11
Citrus grandis L	Rutaceae	0.04
Citrus sp	Rutaceae	0.07
Cola acuminate (P Beauv.) Schott & Endl	Malvaceae	0.07
Coula edulis Baill	Olacaceae	0.07
Dacryodes edulis (G.Don) H.J. Lam	Burseraceae	0.18

*Desplasia*sp	Tiliaceae	0.04
Disthemonanthus benthamianus Baill	Caesalpiniaceae	0.04
Dubosciamacrocarpa Bocq	Tiliaceae	0.07
Elaeis guineensis Jacq	Arecaceae	0.11
Entanda macrophylla	Mimosaceae	0.04
Eriocoelum sp	Sapindaceae	0.04
Erythrophleum ivorense A.Chev	Caesalpiniaceae	0.04
Ficus etrangle	Moraceae	0.07
*Ficus exasperata*Vahl	Moraceae	0.39
*Ficus mucuso*Welw. Ex Ficalho	Moraceae	0.21
Garcinia kola Heckel	Clusiaceae	0.04
Indéterminé 1	Rutaceae	0.07
Indéterminé 2	Caesalpiniaceae	0.11
Indéterminé 3	Apocynaceae	0.04
Indéterminé 4	Fabaceae	0.04
Indéterminé 5	Meliaceae	0.04
Indéterminé 7		0.04
Indéterminé 8		0.04
Indéterminé 9		0.04
Indéterminé 10		0.04
Indéterminé 11		0.04
Indéterminé 12		0.04
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill	Irvingiaceae	0.11
Klainedoxa macrophylla Pierre ex Van Tiegh	Irvingiaceae	0.04
Lophira alata Banks ex C.F. Gaertn	Ochnaceae	0.04
*Lovoatrichiloides*Harms	Meliaceae	0.04
Macaranga sp	Euphorbiaceae	0.04
Mangifera indica L	Anacardiaceae	0.11
*Margaritariadiscoidea*Baill	Euphorbiaceae	0.07
Milicia excelsa (Welw.) C. C. Berg	Moraceae	0.07
Musanga cecropioides R. Br. Ex Tedlie	Cecropiaceae	0.07
Myrianthus arboreus P. Beauv	Moraceae	0.11
Pentaclethra macrophylla (Schumach & Thonn.) Taub	Caesalpiniaceae	0.04
Persea americana Mill	Lauraceae	0.43
Picralimanitida (Stapf) T. Durand et H. Durand	Apocynaceae	0.04
Piptadeniastrum africanum Brenan	Mimosaceae	0.11

*Pseudospondiasmicrocarpa*Engl	Anacardiaceae	0.04
*Pterocarpus soyauxii*Hooker	Fabaceae	0.04
Pycnanthus angolensis (Welw.) Warb	Myristicaceae	0.14
Ricinodendron heudelotii	Euphorbiaceae	0.04
Terminalia superba Engl & Diels	Combretaceae	0.07
Trichoscyphaabut Engl	Anacardiaceae	0.04
Trichoscyphaacumulata Engl	Anacardiaceae	0.04
*Trichoscypha*sp	Anacardiaceae	0.04
Triplochyton scleroxylon K. Schum	Malvaceae	0.07
Vitex spp	Verbenaceae	0.11
Xylopiaaethiopica (Dunal) A. Rich	Annonaceae	0.14
Zanthoxilumheitzii Engl	Rutaceae	0.07