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Diversity, structure and health of a cocoa based agroforest system in the Humid dense forest, East Cameroon

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Cocoa is a major cash crop in Cameroon, where its production and export contributes significantly to the national economy and in poverty alleviation. Cocoa-based agroforestry systems (cAFS) have been recognised as a fair strategy for natural resource management, combining both the agricultural and conservation objectives. This study aims to (1) assess the diversity, (2) analyses the floristic and structural characteristics as well as (3) the dendrological features of the (Exploitation Agricole Betti) (EAB), a cAFS vast of 120 ha, located in the East region of Cameroon. Cocoa and associated tree species were counted in 21 sampling plots of 0.25 ha systematically settled all over the system (EAB) between 28 August and 22 October 2016. A total number of 3 147 stems was recorded and distributed in 2,599 cocoa trees and 548 associated trees. The overall diversity of the system is low. The density of the cocoa trees is 495.0 stems/ha, correponding to a success rate of 44.6%. The EAB is attacked by the black pod disease. The average Pod Rot Attacked Index (PRAI) is 0.35 ± 0.38; and this varies significantly according to the associated trees density and the season. Further studies should aim to (1) identify different cocoa varieties planted in the system, (2) identify correctly all the pests and diseases of the system, (3) assess the impact of associated tree thinning and cocoa tree Pruning on the pests or diseases attack and on the cocoa production, and (4) to explore the usage of associated trees in the system. This with the view to come out with a fair model cFAS to use in tropical humid forest zones.

Key words: Exploitation Agricole Betti, cocoa, success rate, associated trees, density, stand basal area, dendrological features, Black pod disease, Pod Rot Attacked Index.

INTRODUCTION

Cocoa or Theobroma cacao L., is a tropical tree, the most important genus of the Malvaceae family because of its commercial value. Cocoa was introduced in Cameroon since 1886 by the German colonial administration and is a major cash crop in Cameroon and many other countries of the tropical world, where its production and export contributes significantly to the national economy and in poverty alleviation. The cocoa sector is a source of employment for about four million individuals and it is Cameroon's major agricultural export crop. The revenue
generated from cocoa exports accounted for about 14% of non-oil exports in 2012, particularly to Europe (Ngoe et al., 2016, 2018). In the past years, Cocoa was cultivated mostly by smallholders who usually farm on 1 to 3 ha of land (Sonwa et al., 2007; ICCO, 2014). Today, many persons have versed in growing cocoa in large areas (10 ha and +). This has been made possible due to the huge work of sensitisation made by the Cameroon government, the Ministry of agriculture and rural development (MINADER) and the Society for Cocoa development (SODECAO) to be precise. The Cameroon’s rural development strategy, adopted in 2005, and whose implementation was intensified within 2012-2020 aims to “Ensure food security, the sustainability of performance and achieve integration in exchanges”. Cameroon government is set to increase cocoa and coffee production to an appreciable level through the rehabilitation and creation of new seed farms; production and dissemination of plant material; setting up of systematic and integral phytosanitary treatment of cocoa and coffee farms; emergency programs to save production as well as boosting financial resources (Achancho, 2013; République du Cameroun, 2006, 2009).

The adult cocoa tree (Theobroma cacao L.) is a tree that can reach 12 to 15 m in height when growing in the wild. Its size and the importance and development of its foliage depend very much on the space available. Thus, when planting, the usual spacings allow the adult tree to reach an average height of 5 to 7 m. When it comes from the germination of a seed, the cocoa tree reaches its full development around the age of 10 years. However, it is productive well before this age since flowers and fruits appear in the third or fourth year, with full yield generally being obtained around six or seven years old. A well-managed plantation can remain profitable for at least 25 to 30 years. The cocoa tree fruit, called cherella while it is ing and then pods when it reaches its final size, reaches maturity after five to six months depending on the origins (Mossu, 1990). The pod, before maturity, can be either green, or more or less dark red-violet, or green, particularly pigmented with red-violet. The varieties cultivated in Cameroon are not homogeneous. In the space of sixty years, and under the effect of several administrations, the first introduced varieties hybridized. Most of the cocoa trees in place are of the Forastero variety made up of the forms Amelonado (with yellow pods) and Cudeamor (with red pods), the latter being the most numerous (Champaud, 1966).

There are 600,000 cocoa farmers across Cameroon, and it is a vital sector for rural communities. But cocoa is a fragile crop with yields that tend to decrease over time, putting farmers’ livelihoods at risk. That’s why the African Development Bank has committed to provide funding to IRAD, the Institute of Agriculture Research for Development, where research is focused on creating adapted seed varieties. The second-generation seed varieties developed by IRAD allow for an average yield of 2 tons per hectare, compared to the first generation developed in the 1970s and 1980s that produced around 1 ton per hectare (https://www.afdb.org/en/success-stories/cameroon-new-seed-varieties-help-cocoa-crops-bloom-and-farmers-thrive-33940).

Forest stand structure refers to the stand structural attributes and stand structural complexity (McElhinney et al., 2005; Zenner, 2000 cit. Sonwa et al., 2016). Stand structural attributes include measures such as abundance, diversity, basal area, richness. Such measures can thus help in having a quantitative idea on the habitat created by combination of many components on a forest stand. In the case of cocoa agroforest, the forest structure is altered by the opening of forest stand to grow cocoa trees. The main aim of the manager is to alter the forest structure in such a manner that it provides suitable conditions to the growing of cocoa. In the past, management was mainly constituted by the introduction of cocoa seedling and regular management to maintain certain amount of shade and understorey slashing to reduce competition with cocoa seedling/trees. With the recent cocoa crisis (Sonwa et al., 2005) characterized by the liberalization of the cocoa value chain, the constant management of associated plants include elimination of some trees and introduction of more socio-economically useful ones to provide shade but also timber and non-timber forest products such as food, medicinal and service plants to household (FAO, 2002; Sonwa et al., 2007; Bobo et al., 2006; Zapfack et al., 2002). The result of this management is a structurally complex system with abiotic (e.g. microclimate, humidity, etc.) and biotic elements (e.g. trees, vines, etc.) which, depending on the age and plants species composition, define a habitat structure different from the one of mono-species system such as pure cocoa orchard or cocoa with one or two associated species cultivated in an intensive manner (Sonwa et al., 2016).

Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland. Agroforestry has its roots in tropical food production systems. The diversification of the farming system initiates an agroecological succession, like that in natural ecosystems, and so starts a chain of events that enhance the functionality and sustainability of the farming system. Trees also produce a wide range of useful and marketable products from fruits/nuts, medicines, wood

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products, etc. This intentional combination of agriculture and forestry has multiple benefits, such as greatly enhanced yields from staple food crops, enhanced farmer livelihoods from income generation, increased biodiversity, improved soil structure and health, reduced erosion, and carbon sequestration (USDA National Agroforestry Center. Agroforestry practices, https://www.fs.usda.gov/nac/practices/index.shtml).

Carbon sequestration is an important ecosystem service that agroforest systems can provide. Agroforestry practices can increase carbon stocks in soil and woody biomass. Trees in agroforestry systems, like in new forests, can recapture some of the carbon that was lost by cutting existing forests. They also provide additional food and products. The rotation age and the use of the resulting products are important factors controlling the amount of carbon sequestered. Agroforests can reduce pressure on primary forests by providing forest products (Montagnini et al., 2004). Agroforestry practices are highly beneficial in the tropics, especially in subsistence smallholdings in sub-Saharan Africa (Kuyah et al., 2016) and have been found to be beneficial in Europe and the United States (Schoeneberger, 2017).

Cocoa-based agroforestry systems (cAFS) have been recognised as a fair strategy for natural resource management, combining both the agricultural and conservation objectives. These systems dominate in Cameroon, and are different to the intensive systems of monoculture, due to their diversification and resilience, which ensure long term cocoa production (Sonwa et al., 2007; Jagoret et al., 2009). Cocoa agroforests generally result from the clearing of some large forest trees and the thinning of part of the understory in order to introduce young cocoa plants. Other large trees are left during the establishment of the agroforest. Crops such as banana and plantain are used to shade the cocoa seedlings. A cAFS is a multi strata artificial system which look alike the natural forest. The main characteristic being the mixture of many species which are in perpetual competition within or between different species. The farmer seeks to enhance the productivity and the resilience of the system through the mixture of cocoa and other trees or crops (Sonwa et al., 2016).

Plant in the forest can be easily influenced by light, water, air humidity, wind, nutrient, heat and other biotic components. Such variables are likely to be modified by the structure of the forest or agroforest. A structure with high shade intensity is known to slow the cocoa development and favors black pod disease (Ruf, 2011; Kouadio et al., 2018). While with less shade, mirid attack can be a serious problem. Anyway, the main disease of cocoa in Cameroon is the black pod rot in cocoa causing 80-90% losses without chemical control with Phytophthora Megakarya as causal agent (Mfegue, 2012). Plant diversity can also be linked to the structure of cocoa plantation. It is generally admitted that complex cocoa agroforests are richer in biodiversity than cocoa orchards.

Studying plant diversity of cocoa agroforest has revealed that land intensification, market access and population density was affecting agroforests composition (Sonwa et al., 2007).

The Exploitation Agricole Betti (EAB), is a cAFS vast of 120 ha, based in the East region of Cameroon. The first plots were settled between 2008 and 2015, with the Cocoa being the main culture. This crop is associated with bananas and many tree species which were left for different purposes including shade, biodiversity conservation and valorisation in terms of timber and non-timber forest products. Till now, no specific study has been conducted in that complex. The knowledge of the diversity of this complex in term of species composition, stand tree structure and cocoa health is essential as this is the first step for proposing fair management measures with the view to better sustain and ensure the resilience of that system. It is clearly admitted that one cannot manage what he does not know. The key assumptions formulated for the EAB cAFs are : (1) the EAB is diversified and this diversity may influence (2) the density and (3) the health of the cocoa. This paper aims therefore to (1) assess the diversity, (2) analyses the floristic and structural characteristics as well as (3) the dendrological features of the Exploitation Agricole Betti as key elements for sustaining that cAFS and make it a model for cAFS settled in the humid forest zone of Cameroon.

MATERIALS AND METHODS

Study site

The Exploition Agricole Betti or EAB is a cAFS, vast of 120 ha, located between the community forest of Mbeth II in the Diang subdivision (Lom and Djerem division) and the communal forest of Doumé in the Doume subdivision (Haut Nyong division), East Region of Cameroon. The EAB is situated between 4°22’-4°58’ latitude North and 13°34’-13°61’ longitude East, on the axis Bouam (on the national road n°1)- Dimako (on the national road n°10). The average altitude is 691 m.

The climate is an equatorial and Guinean type, characterized by four in-equal seasons: a great dry season which goes from December to mid-March; a small rainy season from mid-March to May; a great rainy season from mid-September to November; and a small dry season from June to mid-August. Climatic data (Figure 1) considered are those found in the city of Bertoua, based at about 35 km of the EAB (https://fr.climatedata.org/afrique/cameroun/east/bertoua-1000032/). The average temperature is 23.7°C, with the maximum at 24.8°C in March and the minimum in July (22.5°C). The average annual rainfall varies between 1 000 and 1 600 mm. October is the most rainy month (280 mm), while January is the less rainy month (20 mm). Figure 1
Figure 1. Climatic data of the Bertoua city located at 30 km from the EAB for the period 2011-2016.

Table 1. Distribution of blocs in different farms found in the EAB, East region of Cameroon.

| Farm    | Surface area (ha) | Blocs | Total surface area of the bloc (ha) | Useful surface area of the bloc (ha) | Year of settlement of the cocoa |
|---------|-------------------|-------|-----------------------------------|-------------------------------------|-------------------------------|
| Farm 1  | 47.5              | 1     | 21.5                              | 18                                  | 2008/2009                     |
|         |                   | 2     | 8                                 | 7                                   | 2009                          |
|         |                   | 3     | 12.5                              | 10                                  | 2013                          |
|         |                   | 4     | 4 (fallow)                        | 0                                   | No cocoa                      |
|         |                   | 5     | 5 (fallow)                        | 0                                   | No cocoa                      |
|         |                   | 6     | 6                                 | 5                                   | 2013                          |
| Farm 2  | 36                | 7     | 14                                | 12                                  | 2013                          |
|         |                   | 8     | 7                                 | 6                                   | 2011                          |
|         |                   | 9     | 4 (fallow)                        | 0                                   | No cocoa                      |
|         |                   | 10    | 4                                 | 3                                   | 2011                          |
| Farm 3  | 36.5              | 11    | 20.5                              | 18                                  | 2013                          |
|         |                   | 12    | 12.5                              | 11                                  | 2015                          |
| Total   | 120               | 120   | 90                                | 2008-2015                           |

illustrates the climatic data obtained for the Bertoua city, located close to the EAB for the period 2011-2016 (https://fr.climate-data.org/afrique/cameroun/east/bertoua-1000032/).

Soils are iron soils type. The EAB is located in the Guinean Congolese floristic region, in the low and medium altitude, in the domain of dense and rain semi-deciduous forest of Sterculiaceae and Ulmaceae (Letouzey, 1985). This zone has already been subjected to forest logging by the year 1970, which explains the general feature of old secondary forests observed in the field.

The EAB was chosen for this study both because it allows comparison of different farms or blocs with different ages and because its management and plantation structure are typical of the whole region, making it especially useful for a case study. The exploitation is composed of three farms (plantations). Each farm is composed of several blocs settled in different years between 2008 and 2015 as shown in Table 1.

The first plots of the EAB were settled in 2008. The
main culture consists of the Cocoa, which is associated to the bananas (plantain and sweet bananas). The main objective of the promoter (the farmer) of the EAB is to ensure that the agriculture development is not detrimental to the conservation of the forest. The specific objective is to yield cocoa and bananas with a less disturbance of the natural milieu. For all plots, the technical itinerary is almost the same: preparation of the nursery during the dried season, December (year 1)- January (year 2) with seeds obtained from the Institute for research on agriculture and rural development (IRAD), clearing of the forest by removing herbs and lianas by February-March of the year 2, cutting of shrubs and sappings in April-May, planting of the cocoa at 3 m × 3 m with seedlings of at least 6 months bred in the local nursery from mid August-October, and felling of medium and big trees with the chain saw on November year 2. The first clearing of the planted cocoa occurs in February-March of year 3, and this is done every four months. The felled trees are left on the ground, with the view to ensure the good return of the material (minerals). The promoter of the EAB does not use fires nor fertilizers.

**Data collection**

The method used to assess the abundance of cocoa and associated tree species in the EAB is the one call "method for forest management inventories". This method consists of counting the number of stems of the resource on a representative sampling area with sampling plots (counting units) settled systematically all over the farm (EAB) and to (if needed) estimate the stock at the level of the useful forest area. Cocoa and associated tree species were counted in sampling plots of 0.25 ha (100 m long × 25 m large) from 28th August to 22th October 2016, in blocs 1 (8 years; 18 ha) and 2 (7; 7) of farm 1, and in blocs 10 (5; 3) and 11 (3; 18) of farm 3. Table 2 presents the characteristics of the inventories. Twenty one sampling plots totalising 5.25 ha for a sampling rate (ratio of sampled area/useful area in %) of 4.77% were systematically settled and distributed as follow: Bloc 1 (10 plots; 2.5 ha; 13.9% as the sampling rate), Bloc 2 (3; 0.75; 10.7%), Bloc 3 (2; 0.5; 16.7%), Bloc 4 (6; 1.5; 8.3%).

In each plot, we identified the cocoa trees and the associated tree species trough their trade or common names, and we recorded dendrometrical and dendrological parameters. Dendrometrical parameters include circumference of the tree at 20 cm above the ground for the cocoa, and circumference at breast high (CBH) for associated tree species. Dendrological parameters were recorded with the view to assess both the productivity and the health of the system. Those parameters were recorded only on cocoa trees, in two phases : the first phase from August 28th to September 5th 2016, and the second phase from 17th to 22th October 2016 in the same plots. Information recorded included the number of healthy and sicked or rotten fruits (pods) per cocoa tree. For this first study, all pods with any sign of illness (or attack) including rotting and necrosed pods were classified as sick pods. Health pods were those which were not seen with any visible sign of attack. Plants were identified in the field with the aid of Mr DJENDJ MIASSE, the local botanical technician, responsible of the Community forest of Mbeth II. Specimens were collected and brought to the National Herbarium of Cameroon, Yaounde. Identification were made with the assistance of Dr Barthelemy TCHENGUE and Mr Eric NGANSOP. Databases on plants taxonomy including LEBRUN and STORK (https://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php?langue=fr), JSTOR (https://plants.jstor.org/compilation/Erythrophleum.ivorense), PROTA (https://uses.plantnet-project.org/fr) and the Plant List (http://www.theplantlist.org/tpl1.1/search?q=) were used for eventual verifications.

**Data analysis**

Diversity was analyzed, the floristic and the structural characteristics, as well as the dendrological features of

| Table 2. Characteristics of the inventories conducted in the EAB. |
|---|---|---|---|---|---|---|
| Farm | Bloc | Useful surface of the bloc (ha) | Number of sampling plot | Surface area of a single plot (ha) | Area sampled per bloc (ha) | Sampling rate (%) |
| Farm 1 | 1 (8) | 18 | 10 | 0.25 | 2.5 | 13.9 |
| Farm 1 | 2 (7) | 7 | 3 | 0.25 | 0.75 | 10.7 |
| Farm 3 | 10 (5) | 3 | 2 | 0.25 | 0.5 | 16.7 |
| Farm 3 | 11 (3) | 18 | 6 | 0.25 | 1.5 | 8.3 |
| Total | 4 | 46 | 21 | 0.25 | 5.25 | 11.4 |
the two farms inventoried.

Diversity

Diversity indices include the Shannon Weaver index, the Simpson index and the regularity or the equitability index of Pielou. The Shannon Weaver index (H') allows to assess the diversity level of each group (farm) taking into account the proportion of each plant in the group. Shannon weaver index is calculated as shown in Equation 1.

$$H' = \sum p_i \log_2(p_i)$$  \hspace{1cm} (1)

Where, \( p_i = N_i/N \), \( N_i \) = number of individuals (trees) of the species i, and \( N \) = total number of individuals for all plant species in the group. The Shannon index is sensitive to the variations of importance of scarce species (Peet, 1974). It is equal to zero when there is only one specie, and its maximal value is \( \log_2(S) \) when all species have the same dominance (Dajoz, 2006). The Simpson index (D) measures the probability for two individuals withdrawn randomly from a given group, to belong to the same plant specie (Dajoz, 2006). Simpson index is calculated as shown in Equation 2.

$$D = \sum (p_i)^2$$  \hspace{1cm} (2)

The Simpson index is sensitive to the variations of importance of dominant or abundant species (Peet, 1974). The regularity or the equitability index of Pielou allowed to note the relative mess disorder of the population. It measures the diversity level reached by a group compared to its maximal level of diversity. It compares two groups which have different number of individuals (Grall and Coïc, 2005). The regularity index tends to zero when almost all stem or individuals are concentrated on one single plant species. It tends to 1 when all species have the same abundance. A weak regularity illustrates the importance of a few dominant plant species. The regularity is calculated as follow: \( E = H'/\log_2(S) \), with \( S \) being the total number of species (Dufrène and Legendre, 1997). The concomitance usage of the three indices including the Shannon, Simpson, and Pielou allows to make a complete analysis of the structure of the communities of plants (Grall and Coïc 2005).

Floristic characteristics

Floristic characteristics used include the habitat, the phytogeographic range, and the type and mode of scaterring of seeds. The habitats of the plants refer to the habitat frequently used by the specie in the nature. These were identified as defined in Letouzey (1970-1972) who distinguished five types based mostly to the degree of perturbation including: the primary forest (or the forest which is less perturbed), the secondary forest (perturbed), the culture (plantation), the forest edge and the swamp forest.

The phytogeography of the associated trees was evaluated based on the typology made in Central and West Africa by Lebrun (1947), modified by White (1979, 1985) and later used by Sonke (1998) in the Dja Reserve, East Cameroon. This system recognises four levels of species distribution including: (1) species with large distribution in the world (pan-tropicals or species found in all tropical areas in the world), (2) species largely distributed in Africa or pluri-regionals (afro-tropical or species found in tropical africa and tropical oceanic islands such as Madagascar, Seychelles), (3) species with regional distribution (afro-malagasy or species found in Africa and Madagascar, western guinean or species which range extends from the West Africa to Cameroon and the Congo basin, Guinean congolese or species found in the guinean region), and (4) species with reduced distribution (central guinea-congo or species which distribution area ranges from Cameroon to the Democratic Republic of Congo).

The types and modes of scaterring of seeds were defined according to the model used by Danserau and Lems (1957) and which includes: (1) plants or fruits scaterring by animals or humans (hanging and adhesive fruits-HgAd, fleshy and indehiscent fruits-FliIn), (2) by the wind (fruits with aliform appendages-AIAp, fruits with feathery or silky appendages-FeSi, fruits not fleshy and relatively light-FilI), (3) by the same tree or self-scattering (dried or fleshy fruits scaterring by the plant itself-DrFi; dried or fleshy fruits but heavy and indehiscent-Heln).

Structural characteristics

Structural characteristics are distinguished in two groups including horizontal and vertical structures. Horizontal structure was expressed using the density, the success rate and the dominance of each specie. The density expresses the number of trees or stems per surface area as seen in Equation 3.

$$D_i = N_i/S_a$$  \hspace{1cm} (3)

where \( N_i \) = the number of individuals for the species « i » in the group, \( S_a \) = the sampling area in hectare (ha) and \( D_i \) = the density of the specie « i ». It is expressed in number of stems or trees/ha. The success rate (Sr) is the ratio in percent of the number of living cocoa trees (current density) to the number of planted trees (initial density= 1 111 trees/ha). As stated above (study site), cocoa was planted at 3 m × 3 m, which guives a planting density of 1 111 stems/ha. The success rate (Sr)
Table 3. Diversity parameters of the EAB on associated trees.

| Plantation | Bloc (Age) | Richness | Shanon (H) | Pielou (€) | Simpson (D)) | Density |
|------------|-----------|----------|------------|------------|--------------|---------|
| Farm 1     | 1 (8)     | 58       | 2.578      | 0.440      | 0.0043       | 83.2    |
|            | 2 (7)     | 55       | 2.191      | 0.379      | 0.0030       | 226.67  |
| Farm 3     | 10 (5)    | 34       | 0.958      | 0.165      | 0.0007       | 134     |
|            | 11 (3)    | 46       | 0.959      | 0.188      | 0.0006       | 68.67   |
| Total      | 4         | 78       | 2.690      | 0.428      | 0.0121       | 104.38  |

Therefore will be \( Sr = \frac{100 \times Ni}{111} \). The species dominance corresponds to its stand basal area expressed in \( m^2/ha \). The stand basal area of a population is the sum of the stand basal area of each tree within hectare. It is expressed in Equation 4.

\[
G = \sum (\pi D^2/4)
\]

Where \( D \) is the diameter of the tree, \( \pi = 3.14 \), \( G \) is the stand basal area. The basal area is known to be a good indicator (of species dominance) in several silvicultural management and is gradually admitted as useful also in agroforestry management (Sun Hong-gang et al., Nissen and Midmore cit Sonwa et al., 2007). The relative dominance of the species corresponds to the ratio of the basal area of the \( i \)-th specie over the total basal area of all the plants in the sampling area.

Vertical structure was expressed using the Letouzey (1982) classification in forest, and later adapted in cAFS based in the humid forest zone of Southern Cameroon by Sonwa et al. (2016). According to this classification, plants with diameter below 20 cm can be classified as shrubs, those with diameter ranging from 20 to 50 cm are saplings, trees comprised within 50-100 cm of diameter can be considered as average trees, and plants with diameter above 100 cm are big trees.

**Dendrological characteristics.**

Dendrological characteristics in this study refers to the health of the cocoa pods. We evaluated the intensity of the diseases through the Pod Rot Attacked Index (PRAI) expressed as Equation 5.

\[
PRAI = \frac{\sum \text{attacked fruits}}{\sum \text{total fruits}}
\]

**Statistical analysis**

Data analysis was performed using the R version 3.5.1 (2018-07-02), RI 386 computer packages. This bundleage served to make the one way ANOVA, for example to assess the variance of the PRAI in different farms and different periods of counting.

**RESULTS**

**Diversity of the EAB - cAFS**

A total of 3 147 trees distributed in 2 599 cocoa trees and 548 associated trees was recorded. Associated trees are distributed in 78 species, 73 genera and 30 families. The ten most represented families are: Euphorbiaceae (7.7% of species; 7.8% of individuals), Ulmaceae (7.7 and 7.7%), Meliaceae (6.4 and 9.9%), Rubiaceae (6.4 and 4.0%), Sapotaceae (6.4 and 3.6%), Anacardiaceae (5.12 and 2.35%), Annonaceae (5.12 and 9.12%), Burseraceae (5.12 and 4.2%), Moraceae (5.12 and 11.3%), Sterculiaceae (5.12 and 9.7%). Table 3 presents diversity parameters calculated for associated plant species. We observed that the Shanon Weaver (H) is 2.69, while the global Pielou index is 0.428. Farm 1 is the most diversified compared to farm 3.

**Floristic characteristics**

Table 4 presents the list of the associated trees with their floristic characteristics. Species of the primary and secondary forests abound, with 96% of stems. Plants with regional distribution are most represented (65.2%), with the Guinean congolese being the most important phytogeographic type (52.2%). For what concerns the types and mode of scattering of fruits (seeds), plants which are scattered by animals are the most important; 74.1% of the trees having fleshy and indehiscent fruits (FlIn).

**Structural characteristics**

The density and the dominance (illustrated by the stand basal area) of each tree specie are presented in Table 5. Table 6 presents the synthesis for associated trees and cocoa. The overall density of the whole system is 599.43 trees/ha. The density of the associated tree species is 104.4 stems/ha for a stand basal area of 16.21 m²/ha, while the density of the cocoa is 495 stems/ha representing a success rate of 44.6% for a stand basal area of 9.74 m²/ha. In general, Farm 1 (average age 7.5
| Trade name   | Scientific names                               | Family                  | Phytogeographic type | Type of scatter fruits | Mode of scattering | Habitat | Number of stems |
|--------------|------------------------------------------------|-------------------------|----------------------|------------------------|-------------------|---------|-----------------|
| Doussier     | *Afzelia bipindensis* Harms                   | Leguminosae-caesalpinioideae | CG                   | DrFl                   | Ss                | Pf      | 1               |
| Albisia      | *Albizia ferruginea* (Guill. & Perr.)         | Leguminosae-mimosoideae  | GC                   | HeIn                   | Ss                | Pf      | 28              |
| Emien        | *Alstonia boonei* De Wild.                   | Apocynaceae             | GC                   | FlIn                   | An                | Sf      | 3               |
| Latip        | *Amphimas pterocarpoides* Harms               | Leguminosae-papilionoideae | CG                   | AlAp                   | Wi                | Pf      | 16              |
| Anigré R     | *Anigeria robusta* (A. Chev.) Aubrév. & Pellegr. | Sapotaceae             | GC                   | FlIn                   | An                | Pf      | 1               |
| Mouambé jaune | *Annickiachlorantha* (Oliv.) Setten & Maas    | Annonaceae              | CG                   | FlIn                   | An                | Pf      | 26              |
| Ebom         | *Anonidiummannii* (Oliv.) Engl. & Diels       | Annonaceae              | CG                   | FlIn                   | An                | Pf      | 14              |
| Antidesma    | *Antidesmamadagascariense* Lam                | Euphorbiaceae           | GC                   | FlIn                   | An                | Sf      | 7               |
| Pau rosa     | *Bobgunnia fistuloides* (Harms) J.H. Kirkbr. & Wiersema | Leguminosae             | GC                   | Heln                   | Ss                | Pf      | 3               |
| Kapokié      | *Bombax buonopozense* P. Beauv.              | Bombacaceae             | CG                   | FeSi                   | Wi                | Pf      | 2               |
| Aïélé        | *Canariumschweinfurthii* Engl.               | Burseraceae             | GC                   | FlIn                   | An                | Pf      | 4               |
| Eougong      | *Canthiumarnoldianum* (De Wild. & T. Durand) Hepper | Rubiaceae              | CG                   | FlIn                   | An                | Pf      | 4               |
| Fromagé      | *Ceiba pentandra* (L.) Gaertn.               | Bombacaceae             | Pan-tropical         | FeSi                   | Wi                | Sf      | 7               |
| Djana A      | *Celtis adolfi-friderici* Engl.              | Ulmaceae                | GC                   | FlIn                   | An                | Pf      | 6               |
| Odoutembéré  | *Celtis africana* Burm. f.                   | Ulmaceae                | GC                   | FlIn                   | An                | Pf      | 1               |
| Ohia         | *Celtis mildebraedi* Engl.                   | Ulmaceae                | GC                   | FlIn                   | An                | Pf      | 3               |
| Djana T      | *Celtistessmannii* Rendle                    | Ulmaceae                | GC                   | FlIn                   | An                | Pf      | 5               |
| Djana Z      | *Celtiszenkeri* Engl.                        | Ulmaceae                | GC                   | FlIn                   | An                | Pf      | 23              |
| Avom G F     | *Cleistopholis patens* (Benth.) Engl. & Diels | Annonaceae              | GC                   | FlIn                   | An                | Pf      | 7               |
| Ekoune       | *Coeilocaryonpreussii* Varb.                 | Myristicaceae           | CG                   | FlIn                   | An                | Pf      | 2               |
| Cordia       | *Cordiaplathyrsa* Baker                      | Boraginaceae            | WG                   | FlIn                   | An                | Sf      | 11              |
| Nomeakéla    | *Corynanthe pachyceeras* K. Schum.           | Rubiaceae               | CG                   | FlLi                   | Wi                | Pf      | 8               |
| Prunier      | *Dacryodesendulis* (G. Don) H. J. Lam        | Burseraceae             | CG                   | FlIn                   | An                | Cu      | 5               |
| Atom         | *Dacryodesmacrophylla* (Oliv.) H. J. Lam     | Burseraceae             | GC                   | FlIn                   | An                | Sf      | 4               |
| Alep         | *Desbordesia glaucescens* (Engl.) Tiegh.     | Combretaceae            | CG                   | FlIn                   | An                | Pf      | 3               |
| ébène 3      | *Diospyros cyclobalbis* Liern                | Ebenaceae               | CG                   | FlIn                   | An                | Pf      | 2               |
| Olem         | *Diospyros sanza-minika* A. Chev.            | Ebenaceae               | CG                   | FlIn                   | An                | Pf      | 3               |
| Dambala      | *Discoglyptema caloneura* (Pax) Prain        | Euphorbiaceae           | GC                   | FlIn                   | An                | Pf      | 12              |
| Abamekoum    | *Donella ubanguiensis* (De Wild.) Aubrév.    | Sapotaceae              | GC                   | FlIn                   | An                | Pf      | 6               |
| Akak         | *Duboscia macrocarpa* Bocq.                  | Tiliaceae               | GC                   | FlIn                   | An                | Pf      | 10              |
| Sapeli       | *Entandrophragma cylindricum* (S. prague) Sprague | Meliaceae              | GC                   | AlAp                   | Wi                | Pf      | 1               |
| Tohl         | *Ficus mucuso* Welw. ex Ficalho              | Moraceae                | CG                   | FlIn                   | An                | Sf      | 13              |
| Mutondo      | *Funtumia elasta* (Preuss) Stapf             | Apocynaceae             | CG                   | FeSi                   | Wi                | Sf      | 11              |
| Longui rouge | *Gambeya africana* (A. DC.) Pierre           | Sapotaceae              | WG                   | FlIn                   | An                | Pf      | 2               |
| Abam à poil rouge | *Gambeya beguei* (Aubrév. & Pellegr.) Aubrév. & Pellegr. | Sapotaceae              | WG                   | FlIn                   | An                | Pf      | 10              |
| Bossé C       | Guarea cedrata (A.Chev.) Pellegr. | Meliaceae | GC | FlIn | An | Pf | 1 |
|--------------|----------------------------------|-----------|----|------|----|----|---|
| Kekele       | Holoptelea grandis (Hutch.) Mildbr. | Ulmaceae | GC | FlIn | An | Pf | 4 |
| Ndok         | Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill. | Irvingiaceae | GC | FlIn | An | Pf | 2 |
| Abibélé      | Keayodendron bridelioides Leandri | Phyllanthaceae | WG | FlIn | An | Pf | 10 |
| Acajou blanc | Khaya anthotheca (Welw.) C.DC. | Meliaceae | GC | FlIn | An | Pf | 1 |
| Eveus G      | Klainedoxa gabonensis var. microphylla Pellegr. | Irvingiaceae | GC | FlIn | An | Pf | 3 |
| Kumbi        | Lannea welwitschii (Hiern) Engl. | Anacardiaceae | GC | DrFl | Ss | Pf | 2 |
| Assas        | Macaranga barteri Müll.Arg. | Euphorbiaceae | GC | FlIn | An | Sf | 5 |
| Manguier     | MangiferaindicaL. | Anacardiaceae | GC | FlIn | An | Sf | 1 |
| Bété         | Mansonia altissima (A.Chev.) A.Chev. | Sterculiaceae | GC | FlIn | An | Pf | 1 |
| Nomeangossa  | Markhamia lutea (Benth.) K.Schum. | Bignoniacae | GC | FlIn | An | Sf | 4 |
| Angossa      | Markhamia tomentosa (Benth.) K.Schum. exEngl. | Bignoniacae | GC | AlAp | Wi | Sf | 2 |
| Iroko        | Milicia excelsa (Welw.) C.C.Berg | Moraceae | GC | FlIn | An | Sf | 4 |
| Nom ding     | Monodora tenuifolia Benth. | Annonaceae | AMA | FlIn | An | Sf | 1 |
| Akeng        | Morinda lucida Benth. | Rubiaceae | Atr | FlIn | An | Forest edge | 4 |
| Parassolier  | Musanga cecropioides R.Br. ex Tedlie | Urticaceae | GC | FlIn | An | Sf | 3 |
| Mirianthusarbus | Myrianthus arboreus P.Beauv. | Urticaceae | GC | FlIn | An | Sf | 28 |
| Bilinga      | Nauclea diderrichii (De Wild.) Merr. | Rubiaceae | GC | FlIn | An | Pf | 20 |
| Moka         | Ochthocosmus calothyrsus Hutch. & Dalziel | Ixonanthaceae | GC | FlIn | An | Pf | 3 |
| Nommeebegvahousou | Ododionidendron micranthum (Harms) Baker f. | Leguminosae-caesalpinioideae | CG | FlIn | An | Pf | 9 |
| Atane        | Panda oleosa Pierre | Pandaceae | GC | FlIn | An | Pf | 22 |
| Akela        | Pausinystalia talbotii Wernham | Rubiaceae | GC | FlIn | An | Pf | 1 |
| Avocatier    | Persea americana var. americana | Lauraceae | Pan-tropical | FlIn | An | Cu | 4 |
| Abalé        | Petersianthus macrocarpus (P.Beaux.) Liben | Lecythidaceae | CG | AlAp | Wi | Sf | 2 |
| Dambala      | Piptadeniastrum africanum (Hook. f.) Brenan | Leguminosae-mimosoideae | GC | FlIn | An | Pf | 9 |
| Padouk rouge | Pterocarpus soyauxii Taub. | Leguminosae-papilionoideae | CG | AlAp | Wi | Pf | 2 |
| Ilomba       | Pycnanthus angolensis (Welw.) Warb. | Myristicaceae | GC | FlIn | An | Pf | 10 |
| Djansang     | Ricinodendron heudaloti (Baill.) Heckel | Euphorbiaceae | GC | FlIn | An | Sf | 6 |
| Ebapélé      | Santiria trimera (Oliv.) Aubrèv. | Burseraceae | GC | FlIn | An | Pf | 1 |
| Niévé        | Staudtia kamerunensis Warb. | Myristicaceae | GC | FlIn | An | Sf | 10 |
| Nkanang/lotofa | Sterculia rhinopetala K.Schum. | Malvaceae | GC | FlIn | An | Pf | 2 |
| Poréporé     | Sterculia tragacantha Lindl. | Malvaceae | GC | FlIn | An | Sf | 29 |
| Strombosia   | Strombosia pustulata Oliv. | Olacaceae | GC | FlIn | An | Pf | 9 |
| Biboloafoam  | Syzygium rowlandii Sprague | Myrtaceae | GC | FlIn | An | Pf | 2 |
| Fraké        | Terminalia superba Engl. &Diels | Combretaceae | GC | AlAp | Wi | Pf | 5 |
Dendrological characteristics

A total of 23,904 and 29,692 cocoa fruits (pods) was recorded in phase a (dry season) and phase b (rainy season) respectively in the EAB as shown in Table 7. Number of trees and pods increase in phase b (+256 trees, +5788 pods) compared to phase a. The productivity expressed by the average number of pods per tree is 17.49 and does not vary significantly between the different blocs (ANOVA, df = 3, F = 27.45, P < 2<sup>-16</sup>), and ANOVA for phase 2, df = 3, F = 27.45 P < 2<sup>-16</sup>). Bloc 1 (0.19 in phase a and 0.58 in phase b) and bloc 2 (0.31; 0.54) having the highest PRAl compared to blocs 10 (0.12; 0.10) and 11 (0.05; 0.14). The PRAl varies significantly from one farm to another (ANOVA, df = 1, F = 342.5, P < 2<sup>-16</sup>). The PRAl obtained in farm 1 (0.41) being time 4 high than the one obtained in farm 3.

**DISCUSSION**

**Diversity**

The age of the blocs varies from 3 to 8 years. This exploitation can be considered as very young, the cocoa being a perennial plant (Jagoret, 2011). The technical itinerary used in the EAB is different to the one proposed by the agricultural services and the Food and Agriculture Organisation for Cameroon (FAO, 2002). In fact, FAO (opcit.) suggests that the preparation of the field should be done using the following logistical steps: (1) clearing of the herbs, shrubs, and sappings, (2) felling of the incompatible or antagonist trees, (3) planting the cocoa one or two years later, with seedlings coming from the nursery. The main difference resides on the fact that, the EAB plants cocoa before cutting shrubs, sappings, and before felling trees.

Sterculiaceae and Sterculiacaeae figure among the ten most cited families, which confirms the position of the surrounding forest in the domain of dense and rain semi-deciduous forest of Sterculiacaeae and Ulmaceae (Letouze, 1985). The overall diversity of the system characterized by the Shanow Weaver (H) is = 2.69 which

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Table 4. Contd.

| Akpwa          | Tetrapleura tetraplera (Schum. &Thonn.) Taub. | Leguminoseae | GC | HeIn | Ss | Pf | 19 |
|----------------|-----------------------------------------------|--------------|----|------|---|----|----|
| Ebegbenvahoussoue | Trichilia dregeana Sond.                      | Meliaeae     | CG | FlIn | An | Pf | 10 |
| Ebegbenvahoussoue | Trichilia welwitschii C.DC.                   | Meliaeae     | CG | FlIn | An | Pf | 1  |
| Amvout         | Trichocynpha acuminata Engl.                 | Anacardiacaeae| GC | FlIn | An | Pf | 1  |
| Ayous          | Triplochyon sclerxylon K.Schum.              | Malvaeae     | GC | AlAp | Wi | Sf | 18 |
| Rikio          | Uapaca guineensis Müll.Arg.                  | Euphorbiaceae| GC | FlIn | An | Swampf | 8 |
| Evoula         | Vitex grandifolia Gürke                      | Verbenaceae  | Afro-tropical | FlIn | An | Pf | 3  |

(1) type of scattering of fruits: (1) plants or fruits scattered by animals or humans:An (hanging and adhesive fruits-HgAd, fleshy and indehiscent fruits-FlIn), (2) plants or fruits scattered by the wind-Wi (fruits withaliform appendages-AlAp, fruits withfethery or silky appendages-FeSi, fruits not fleshy and relatively light-FlIn), (3) plants or fruits scattered by the same tree or self-scattering-Ss (dried or fleshy fruits scattered by the plant itself-DrFl; dried or fleshy fruits but heavy and indehiscent-Heln).

(2) Phytogeographic types: Central guinea-congo (CG), Guinea-congoese (GC), Pan-tropical (Pantr), Western guinean (WG), Afro-malagasy (AMA), Afrotropical (Atf).

(3) Habitat: Primary forest (Pf), Secondary forest (Sf), Culture (Cu), Swamp (Sw).
| Scientific name of the plant | Farm 1 | Farm 3 | Total |
|-----------------------------|--------|--------|-------|
|                             | Ns     | Sba (m²/ha) | Rsba (%) | Ds (stems/ha) | Ns     | Sba (m²/ha) | Rsba (%) | Ds (stems/ha) | Ns     | Sba (m²/ha) | Rsba (%) | Ds (stems/ha) |
| *Afzelia bipindensis*       | 1      | 0.01  | 0.08 | 0.31 |          |          |          |          |          |          |          |          |          |
| *Albizia ferruginea*        | 22     | 0.57  | 3.17 | 6.77 | 6        | 0.43 | 3.42 | 3.00 | 28        | 1.01 | 6.20 | 5.33 |
| *Alstonia boonei*           | 3      | 0.46 | 2.55 | 0.92 |          |          |          |          |          |          |          |          |          |
| *Amphimas pterocarpoides*   | 13     | 0.88 | 4.85 | 4.00 | 3        | 0.17 | 1.36 | 1.50 | 28        | 1.05 | 6.46 | 3.05 |
| *Aningeria robusta*         | 1      | 0.09 | 0.52 | 0.31 |          |          |          |          |          |          |          |          |          |
| *Anickia chlorantha*        | 21     | 0.69 | 3.82 | 6.46 | 5        | 0.25 | 1.96 | 2.50 | 26        | 0.94 | 5.78 | 4.95 |
| *Anonodium mannii*          | 11     | 0.50 | 2.75 | 3.38 | 3        | 0.09 | 0.69 | 1.50 | 14        | 0.58 | 3.60 | 2.67 |
| *Antidesma madagascariense* | 6      | 0.11 | 0.62 | 1.85 | 1        | 0.02 | 0.14 | 0.50 | 7         | 0.13 | 0.80 | 1.33 |
| *Bombax buonopozense*       | 1      | 0.00 | 0.02 | 0.31 | 1        | 0.02 | 0.18 | 0.50 | 2         | 0.03 | 0.16 | 0.38 |
| *Canarium schweinfurthii*   | 3      | 0.03 | 0.19 | 0.92 | 1        | 0.03 | 0.25 | 0.50 | 4         | 0.07 | 0.41 | 0.76 |
| *Canthium arnoldianum*      | 3      | 0.15 | 0.84 | 0.92 | 1        | 0.01 | 0.07 | 0.50 | 4         | 0.16 | 1.00 | 0.76 |
| *Ceiba pentandra*           | 5      | 1.61 | 8.91 | 1.54 | 2        | 0.88 | 6.92 | 1.00 | 7         | 2.49 | 15.35 | 1.33 |
| *Celtis adolfi-friderici*   | 5      | 0.25 | 1.40 | 1.54 | 1        | 0.12 | 0.98 | 0.50 | 6         | 0.38 | 2.33 | 1.14 |
| *Celtis africana*           | 1      | 0.06 | 0.35 | 0.31 |          |          |          |          |          |          |          |          |          |
| *Celtis mildbraedii*        | 3      | 0.11 | 0.86 | 1.50 | 3        | 0.11 | 0.67 | 0.57 |
| *Celtis tessmannii*         | 4      | 0.16 | 0.88 | 1.23 | 1        | 0.01 | 0.10 | 0.50 | 5         | 0.17 | 1.05 | 0.95 |
| *Celtis zerkeri*            | 15     | 0.25 | 1.37 | 4.62 | 8        | 0.19 | 1.53 | 4.00 | 23        | 0.44 | 2.72 | 4.38 |
| *Cleistopholis patens*      | 7      | 0.53 | 2.96 | 2.15 |          |          |          |          |          |          |          |          |          |
| *Coelocaryon preussii*      | 2      | 0.08 | 0.45 | 0.62 |          |          |          |          |          |          |          |          |          |
| *Cordia platythyrs*         | 10     | 1.40 | 7.75 | 3.08 | 1        | 0.01 | 0.09 | 0.50 | 11        | 1.41 | 8.70 | 2.10 |
| *Corynanthe pachyceras*     | 7      | 0.07 | 0.40 | 2.15 | 1        | 0.03 | 0.26 | 0.50 | 8         | 0.11 | 0.65 | 1.52 |
| *Dacyodes edulis*           | 4      | 0.00 | 1.23 | 1.01 | 0.06 | 0.50 | 5    |          |          |          |          |          |          |
| *Dacyodes macrophylla*      | 3      | 0.03 | 0.17 | 0.92 | 1        | 0.00 | 0.03 | 0.50 | 4         | 0.03 | 0.21 | 0.76 |
| *Desbordesia glaucescens*   | 2      | 0.01 | 0.05 | 0.62 | 1        | 0.03 | 0.22 | 0.50 | 3         | 0.04 | 0.23 | 0.57 |
| *Diospyros crassiflora*     | 2      | 0.04 | 0.21 | 0.62 |          |          |          |          |          |          |          |          |          |
| *Diospyros sanza-minika*    | 2      | 0.01 | 0.06 | 0.62 | 1        | 0.01 | 0.06 | 0.50 | 3         | 0.02 | 0.12 | 0.57 |
| *Discoglyprema caloneura*   | 10     | 0.29 | 1.61 | 3.08 | 2        | 0.02 | 0.17 | 1.00 | 12        | 0.31 | 1.93 | 2.29 |
| *Donella ubanguensis*       | 3      | 0.05 | 0.28 | 0.92 | 3        | 0.02 | 0.12 | 1.50 | 6         | 0.07 | 0.40 | 1.14 |
| *Duboscia macrocarpa*       | 7      | 0.62 | 3.46 | 2.15 | 3        | 0.13 | 1.03 | 1.50 | 10        | 0.76 | 4.66 | 1.90 |
| *Entandrophragma*           | 0      | 0.00 | 0.00 | 1.18 | 3.42 | 1.38 | 0.50 | 1.18 | 0.18 | 1.08 | 0.19 |
| *Ficus mucuso*              | 10     | 0.22 | 1.23 | 3.08 | 3        | 0.06 | 0.47 | 1.50 | 13        | 0.28 | 1.74 | 2.48 |
| *Funtumia elastica*         | 5      | 0.06 | 0.33 | 1.54 | 6        | 0.28 | 2.22 | 3.00 | 11        | 0.34 | 2.11 | 2.10 |
|                  |  1 |    2 |    3 |    4 |    5 |    6 |    7 |    8 |    9 |   10 |   11 |   12 |   13 |   14 |   15 |
|------------------|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| *Gambeya* africana |  2 | 0.02 | 0.13 | 0.62 | 0.00 | 0.00 | 2    | 0.02 | 0.14 | 0.38 |
| *Gambeya* beguei  |  7 | 0.19 | 1.06 | 2.15 | 3    | 0.07 | 0.58 | 1.50 | 10   | 0.26 | 1.63 | 1.90 |
| *Guarea* cedrata  |    | 0.00 | 0.00 | 1    | 0.16 | 1.23 | 0.50 | 1    | 0.16 | 0.96 | 0.19 |
| *Holoptelea* grandis |  2 | 0.01 | 0.05 | 0.62 | 2    | 0.02 | 0.16 | 1.00 | 4    | 0.03 | 0.18 | 0.76 |
| *Irvingia* gabonensis |  2 | 0.01 | 0.06 | 0.62 | 0.00 | 0.00 | 2    | 0.01 | 0.06 | 0.38 |
| *Keayodendron* bridelioides |  5 | 0.07 | 0.41 | 1.54 | 5    | 0.06 | 0.50 | 2.50 | 10   | 0.14 | 0.85 | 1.90 |
| *Khaya* anthotheca |  1 | 0.35 | 1.96 | 0.31 |    | 0.00 | 0.00 | 1    | 0.35 | 2.18 | 0.19 |
| *Klainedoxa* gabonensis |  3 | 0.05 | 0.28 | 0.92 |    | 0.00 | 0.00 | 3    | 0.05 | 0.31 | 0.57 |
| *Lannea* welwitschii |  1 | 0.31 | 1.71 | 0.31 | 1   | 0.01 | 0.11 | 0.50 | 2    | 0.32 | 1.99 | 0.38 |
| *Macaranga* barteri |  5 | 0.05 | 0.27 | 1.54 |    | 5    | 0.05 | 0.30 | 0.95 |
| *Mangifera indica* |  1 | 0.01 | 0.08 | 0.31 |    | 1    | 0.01 | 0.08 | 0.19 |
| *Mansonia* altissima |  1 | 0.00 | 0.31 |    |    | 1    | 0.00 | 0.19 |
| *Markhamia* lutea  |    | 0.00 | 0.00 | 4    | 0.77 | 6.04 | 2.00 | 4    | 0.77 | 4.73 | 0.76 |
| *Markhamia* tomentosa |  1 | 0.05 | 0.25 | 0.31 | 1   | 0.02 | 0.14 | 0.50 | 2    | 0.06 | 0.39 | 0.38 |
| *Lannea* welwitschii |  1 | 0.01 | 0.05 | 0.31 | 3   | 0.11 | 0.88 | 1.50 | 4    | 0.12 | 0.74 | 0.76 |
| *Milicia* excelsa  |  1 | 0.01 | 0.05 | 0.31 |    | 1    | 0.01 | 0.05 | 0.19 |
| *Monodora* tenuifolia |  2 | 0.00 | 0.03 | 0.62 | 2   | 0.02 | 0.15 | 1.00 | 4    | 0.02 | 0.15 | 0.76 |
| *Morinda* lucida   |  3 | 0.29 | 1.60 | 0.92 | 0.00 | 0.00 | 3    | 0.29 | 1.78 | 0.57 |
| *Musanga* cecropioides | 22 | 2.26 | 12.53 | 6.77 | 6   | 2.88 | 22.67 | 3.00 | 28   | 5.14 | 31.72 | 5.33 |
| *Myrianthus* arboresus | 13 | 0.45 | 2.49 | 4.00 | 7   | 0.18 | 1.41 | 3.50 | 20   | 0.63 | 3.87 | 3.81 |
| *Nauclea* diderrichii |  1 | 0.00 | 0.01 | 0.31 | 2   | 0.35 | 2.76 | 1.00 | 3    | 0.35 | 2.18 | 0.57 |
| *Ochthocosmus* calothyrsus |  5 | 0.33 | 1.85 | 1.54 | 4   | 0.14 | 1.10 | 2.00 | 9    | 0.47 | 2.92 | 1.71 |
| *Oddoniodendron* micranthum | 15 | 0.67 | 3.69 | 4.62 | 7   | 0.37 | 2.93 | 3.50 | 22   | 1.04 | 6.41 | 4.19 |
| *Panda* oleosa    |  1 | 0.13 | 0.72 | 0.31 |    | 1    | 0.13 | 0.80 | 0.19 |
| *Paussinystylia* talbotii |  3 | 0.05 | 0.28 | 0.92 | 1   | 0.04 | 0.30 | 0.50 | 4    | 0.09 | 0.55 | 0.76 |
| *Persea* americana |  2 | 0.05 | 0.25 | 0.62 | 0.00 | 0.00 | 2    | 0.05 | 0.28 | 0.38 |
| *Petersianthus* macrocarpus |  8 | 0.85 | 4.72 | 2.46 | 1   | 0.14 | 1.13 | 0.50 | 9    | 1.00 | 6.14 | 1.71 |
| *Piptadeniastrium* africana |  0.00 | 0.00 | 2    | 0.02 | 0.14 | 1.00 | 2    | 0.02 | 0.11 | 0.38 |
| *Pterocarpus* soyauxii |  3 | 0.15 | 0.85 | 0.92 | 7   | 0.99 | 0.73 | 3.50 | 10   | 0.25 | 1.52 | 1.90 |
| *Pycnanthus* angolensis |  4 | 0.12 | 0.64 | 1.23 | 2   | 0.29 | 2.26 | 1.00 | 6    | 0.40 | 2.49 | 1.14 |
| *Ricinodendron* heudelotii |  1 | 0.13 | 1.01 | 0.50 | 1   | 0.13 | 0.80 | 0.19 |
| *Sanitaria* trimera |  6 | 0.22 | 1.24 | 1.85 | 4   | 0.05 | 0.43 | 2.00 | 10   | 0.28 | 1.71 | 1.90 |
| *Sauditia* kamerunensis |  1 | 0.00 | 0.02 | 0.31 | 1   | 0.01 | 0.06 | 0.50 | 2    | 0.01 | 0.07 | 0.38 |
| *Sterculia* rhinopetala | 15 | 0.74 | 4.12 | 4.62 | 14  | 0.69 | 5.43 | 7.00 | 29   | 1.43 | 8.84 | 5.52 |
| *Sterculia* tragacantha |  5 | 0.05 | 0.29 | 1.54 | 4   | 0.06 | 0.45 | 2.00 | 9    | 0.11 | 0.67 | 1.71 |
| *Strombosia* pustulata |  3 | 0.06 | 0.34 | 0.92 |    | 0.00 | 0.00 | 3    | 0.06 | 0.37 | 0.57 |
| *Bobgunnia* fistuloides |  0.00 | 0.00 | 2    | 0.03 | 0.24 | 1.00 | 2    | 0.03 | 0.19 | 0.38 |
Table 5. Contd.

| Species                          | Ns  | Sba  | RSba | Ds  |
|----------------------------------|-----|------|------|-----|
| Syzygium rowlandii               | 2   | 0.02 | 0.14 | 0.62 |
| Terminalia superba               | 19  | 1.06 | 8.33 | 3.00 |
| Tetrapleura tetraptera           | 2   | 0.17 | 1.32 | 1.50 |
| Trichilia dregeana               | 1   | 0.00 | 2.15 | 2   |
| Trichilia welwitschii            | 1   | 0.00 | 0.01 | 0.05 |
| Trichoscypha acuminata           | 2   | 0.01 | 0.05 | 1.00 |
| Triplochiton scleroxylon         | 5   | 0.01 | 0.05 | 1.50 |
| Uapaca guineensis                | 3   | 0.01 | 0.05 | 1.50 |
| Vitex grandifolia                | 3   | 0.01 | 0.05 | 1.50 |
| **Total**                        | 378 | 116.31| 170 | 12.71 |

Ns: number of stems, Sba: stand basal area, RSba: relative stand basal area; Ds: density.

Table 6. Stand basal area and density of farms found in the EAB.

| Farm   | Bloc | Cocoa initial density (stems/ha) | Area sampled (ha) | Tree (stems) | Tree density (stems/ha) | Tree stand basal area (m²/ha) | Cocoa stems | Cocoa density (stems/ha) | Cocoa Success rate = Sr (%) | Cocoa stand basal area (m²/ha) |
|--------|------|----------------------------------|-------------------|--------------|-------------------------|--------------------------------|--------------|--------------------------|-------------------------------|-----------------------------|
| Farm1  | 1    | 1111                             | 2.5               | 208          | 83.2                    | 5.97                           | 1227         | 490.8                    | 44.2                          | 4.16                        |
|        | 2    | 1111                             | 0.75              | 170          | 226.7                   | 5.40                           | 379          | 505.3                    | 45.5                          | 2.21                        |
| Farm3  | 10   | 1111                             | 0.5               | 67           | 134.0                   | 2.14                           | 264          | 528                      | 47.5                          | 1.78                        |
|        | 11   | 1111                             | 1.5               | 103          | 68.7                    | 2.71                           | 729          | 486                      | 43.7                          | 1.59                        |
| Total or average                   | 1111 | 5.25                            | 548              | 104.4         | 16.21                    | 2599                           | 495          | 44.6                     | 9.74                          |                             |

is low (H < 3 bits) according to Frontier and Pichod-Viale (1995). It is even too low compared to the 3.06 obtained in the cAFS found in the Centre and South regions of Cameroon (Jagoret and Messie, 2008). Cocoa farmers maintain a high diversity in their farms with the view to have a permanent shade, and also to combat the quick invasion of weeds (Jagoret and Messie, 2008). The Pielou index is also low (E = 0.42 < 0.5), showing that a small number of tree species have the high number of individuals (Djego et al., 2012). Globally, H and E are low, indicating that the EAB is an homogenous and specialized milieu (Djego et al., 2012). Six tree species including Musanga cecropioides, Ceiba pentandra, Terminalia superba, Sterculia rhinopetala, Cordia platygyrsa, Triplochiton scleroxylon totalise more than 80% of the species dominance. A study tour was conducted in Cameroon, Côte d'Ivoire, Ghana and Nigeria. Preferred trees by farmers that cut across the four countries include Milicia excelsa, Terminalia superba, Triplochiton scleroxylon, Alstonia boonei, Recinodendron heudelotti. Those tree species are found in our system. (Asare, 2005).

Floristic characteristics

Species of the primary and secondary forest
The average diameter of associated trees or the diameter of the medium associated tree is $34.7 \pm 28.10$ cm, and this does not vary from one bloc to another (ANOVA, df = 3, $F = 0.273$, $P < 0.845$). The average diameter of the cocoa trees is $6.78 \pm 2.03$ cm and this diameter varies significantly in different blocs (ANOVA, df = 3, $F = 174.5$, $P < 2 \times 10^{-16}$) with Bloc 1 having the high diameter, 7.51 cm.

### Table 7. Cocoa pods recorded in the EAB cAFS during the dry and wet seasons with their productivity/healthy features.

| Phase | Bloc (age) | Number of trees | Attacked pods | Healthy pods | Total pods | Productivity Pods/tree | Pod rot attack index (PRAI) |
|-------|------------|-----------------|---------------|--------------|------------|------------------------|----------------------------|
|       |            |                 |               |              |            | Heathy pods/tree | Total pods/tree |
| Phase a | B1 (8) | 920 | 4366 | 16335 | 20701 | 18.01 | 22.50 | 0.20 |
|         | B2 (7) | 211 | 772 | 991 | 1763 | 4.70 | 8.36 | 0.32 |
|         | B10 (5) | 127 | 90 | 923 | 1013 | 7.27 | 7.98 | 0.12 |
|         | B11 (3) | 143 | 26 | 401 | 427 | 2.80 | 2.99 | 0.05 |
|         | Total a | 1401 | 5254 | 18650 | 23904 | 13.44 | 17.06 | 0.19 |
| Phase b | B1 (8) | 997 | 14640 | 9925 | 24565 | 10.01 | 24.64 | 0.58 |
|         | B2 (7) | 324 | 2081 | 1368 | 3449 | 4.22 | 10.65 | 0.55 |
|         | B10 (5) | 155 | 76 | 1070 | 1146 | 6.90 | 7.39 | 0.11 |
|         | B11 (3) | 181 | 70 | 462 | 532 | 2.55 | 2.94 | 0.14 |
|         | Total b | 1657 | 16867 | 12825 | 29692 | 7.76 | 17.92 | 0.48 |

abound, with 96% of stems. The high proportion of species of the primary forest can be justified by the fact that the exploitation was settled in a less perturbed forest habitat. In fact, the initial forest of the EAB has been in 1970, subject to a selective forest logging. That forest has have the time to reconstitute itself. Our results are different to those obtained at Ngomedzap, in the Centre region of Cameroon, where cultivated species abound in cFAS (Jagoret and Messie, 2008).

Plants with regional distribution are more represented (65.2%), with the Guinean congolese being the most important phytogeographic type (52.2%). This also confirms the position of the surrounding and initial forest of the EAB in the Guineo-congoles forest domain (Letouzey, 1985). Plants which are scattered by animals are the most important; 74.1% of the trees having fleshy and indehiscent fruits, indicating the key role of wildlife (animals) in the forest regeneration (Kidikwadi et al.,...
2015; Beina, 2011). It also illustrates the vestiges or traces of primary forests in the area.

**Structural characteristics**

In theory, the cocoa density is supposed to be 1 111 stems/ha, since the seedlings were settled at 3 m × 3 m. The current cocoa density of the system is 495.0 stems/ha which is too low, at least times 2 low compared to the initial density. This density is also too low compared to the agronomic norms recommended by Braudeau (1969). It is even low compared to the 900 stems/ha suggested by FAO (2002) for Cameroon. Densities of 1 911 stems/ha were obtained for young cocoa farms in the Centre region of Cameroon (Jagoret, 2011), 1 168 stems/ha in the humid forest zone of the Centre and South regions of Cameroon (Sonwa et al., 2016) while 1 111 trees/ha were found in the South west region of Cameroon (Bobo et al., 2006). Our cocoa density is too low compared to the range of 1 028 and 1 212 of the shaded plantations around Dalo and Gagnoa in Côte d’Ivoire (N’goran, 2003). According to Sonwa et al. (2016), three reasons explain the reduction of cocoa density including: (1) destruction of cocoa trees during the felling of big associated trees, (2) cocoa trees which died due to pest and disease or (3) non-replacement of dead trees with the intention of managing more associated plants. Some villages in the Centre region of Cameroon presented the same cocoa density obtained in our study, 495.0 stems/ha with the high management of exotic fruit trees being the main reason. In our case, the reduction of the cocoa density is mainly due to the destruction caused by the felling of trees, as the technical itinerary used consists of felling trees after plantation of the cocoa. The age of the EAB varies from 3 to 8 years with a cocoa stand basal area of 9.74 m²/ha. This value is high compared to the 5 m²/ha found in humid forest zones of Centre and South regions of Cameroon. The stand basal area of associated trees of our system is 16.21 m²/ha, which is low compared to results obtained in other agroforest systems in Cameroon (Sonwa et al., 2016). The total stand basal area of our system (cocoa and trees) is 25.95 m²/ha. This value is low compared to the 30 - 36 m²/ha, obtained in cFAS of the humid forest zones of Centre and South regions of Cameroon (Zapfack et al., 2002; Sonwa et al., 2016). This tends to show that the EAB system is less shaded compared to cFAS cited in other forest zones of Cameroon. In contrary, our system is too shaded, at least times 5, compared to the system of annual culture (4.9 m²/ha) obtained in the South West Region of Cameroon (Bobo et al., 2006). In natural forests, 48.7 m²/ha and 40.0 m²/ha were obtained in near-primary and secondary forest respectively in the South West region (Bobo et al., 2006), while a basal area of 35.68 m²/ha were found in a forest stand in South Cameroon (Guedje, 2002). These results confirm the fact that the cFAS basal area is somewhere between those of forests and the one of annual culture, and more specifically closer to a forest basal area value. Cocoa value for land restoration, enrichment of biodiversity and provision of sustainable incomes in less advanced regions has been appreciated (Dropdata, 2015). The total density of 599.3 stems/ha obtained in our case, is too low compared to the 1 489 and 1 560 trees/ha obtained in other regions of Cameroon (Sonwa et al., 2016; Zapfack et al., 2002). The density of the associated tree species of the EAB is 104 trees/ha. This density is low compared to the 204 trees/ha and 321 trees/ha obtained in the forest humid zone of Cameroon (Jagoret, 2011; Sonwa et al., 2016).

Dendrological characteristics and the healthy of the EAB

Cocoa is affected by a range of pests and diseases with some estimates putting losses as high as 30 to 40% of the global production. Cocoa can be attacked by many pest species including fungal diseases, insects and rodents. Common diseases affecting cocoa production include witches broom, frosty pod rot, black pod disease, vascular streak Die back. Pod rot, also known as phytophthora pod rot is caused by the fungus *Phytophthora* spp. Three fungal species of the same genus are capable: *P. palmivora*, *P. capsici*, and *P. megakarya*. *P. capsici* and *P. citrophthora* cause pod rots in Central and South America, whereas *P. megakarya* causes significant pod rot and losses due to canker, and it is the most important pathogen in Central and West Africa, known as the aggressive of pod Rot pathogens. Visible symptoms for *P. megakarya* are the rotting or necrosis of pods. Pods can be attacked at any stage of development, and the initial symptoms are small, hard, dark spots on any part of the pod (ICCO, 2013; 2014; 2015; Guest, 2007; Ngoe et al., 2018). Although we did not yet identified the correct disease, we can say that the EAB cocoa pods were mainly attacked by the *P. megakarya*, according to the symptoms noted. The productivity of our system ranges from 2.99 pods/tree in
bloc 11 of 3 years to 23.6 pods/tree in bloc 1 of 8 years old. It is clear that this productivity increases with the age of the plots. The productivity in healthy pods ranges for the oldest bloc (bloc 1 of 8 years old) from 10 pods/tree in phase b to 18 pods/tree in phase a. The productivity of this specific bloc during heavy rainfall is within the range of 9-16 healthy pods/tree obtained in the cFAS of 15-25 years studied in the regions of Centre and South West Cameroon (Ndoumbé-Nkeng et al., 2009). The average Pod Rot Attacked Index (PRAI) obtained for the two phases of counting is 0.35 ± 0.38. This PRAI varies significantly from one phase of counting to another, from one bloc to another and from one farm to another. The PRAI increased significantly in one month interval, ranging from 0.19 in phase one (28th August-5th September) to 0.48 in phase two (17-22th October). This can be justified by the increase in humidity through the high rainfall. In fact the first counting phase occurred during the small dry season (August), while the second counting phase occurred during the big rainy season, in October considered as the most humid month of the area. The PRAI obtained in the rainy month is time 2.5 higher than the PRAI obtained in dry month, meaning that higher rainfall may increase the PRAI. The expansion of the black pod disease (Phytophthora megakarya) during heavy rains is very common in the equatorial rainforest of Cameroon (Opoku et al., 2002; Atangana et al., 2013). A study conducted in the Centre and South West regions of Cameroon clearly showed that disease, pod rot to be more precised, increased with increasing quantity of rainfall (Ndoumbé-Nkeng et al., 2009). Ndoumbé-Nkeng et al. (2009) found that the highest pod rot rate (PRR) incidence occurred in 2003 at Barombi-Kang (70.3%) located in the South West Region of Cameroon and Mbankomo (64.76%) in the Centre Region when the quantity of rainfall was very high (>200 mm). In contrast, the lowest losses were obtained in Goura (Centre region) in 2001 (1.15%) when rainfall was low (751 mm). However, in this case, (Goura), the production of healthy pods per tree was also low, probably meaning that the rainfall was not sufficient to induce good fructification. We obtained a maximum PRAI of 0.48, corresponding to the Pod Rot Rate (PRR) it is 48% in rainy season in our system. This value is in concordance with the annual rainfall of our system which ranges from 1000-1600 mm; classifying the EAB between the low and very high rainfall sites as indicated above (Ndoumbé-Nkeng et al., 2009). It is generally indicated that a minimum of 1000-1200 mm of rainfall is required in a cocoa plantation to get a good yield (Mossu 1990 cit. Ndoumbé-Nkeng et al., 2009). The best cacao yield is obtained with an intermediate rainfall regime (1100-2000 mm), and our system is in this interval, which explains the good productivity (average number of pods/tree) observed (17.5 pods/tree). Similar results were observed in southwest of Ghana, where rainfall is higher and more regular than in any other cocoa region (Ruf, 2011). The cocoa tree grows well in combination with other tree species that give shade to the cacao trees and provide other benefits for the farmer, like food, fruit, timber and fuel wood. Shade trees reduce the stress of coffee (Coffeea spp.) and cacao (Theobrom a cacao) by ameliorating adverse climatic conditions and nutritional imbalances, but they may also compete for growth resources (Beer et al., 1988). In Ghana, farmers stressed the negative effect of competition for light. Under heavy shade, cocoa trees tend to grow tall in search of light, which makes harvesting more difficult (Ruf, 2011).

The PRAI varies significantly from one farm to another. The PRAI obtained in farm 1 is time 4 high compared to the one obtained in farm 3. Two reasons may explain the high value of the PRAI in Farm 1 including the productivity and the shade intensity. The high level of PRAI in farm 1 is firstly explained by the relative productivity of different blocs, and which is itself justified by the age of each bloc. It has been proved that the disease incidence increases with the production (Ndoumbé-Nkeng et al., 2009). The risk of black pod is exacerbated by shade trees (Ruf, 2011). The variation of the PRAI in different farms may also be explained by the shade intensity, which is the link to the density of the associated trees. The average density of the associated tree species of the EAB is 104.4 stems/ha, with Farm 1 (bloc 1 and bloc 2) having the high density (116.3 stems/ha) compared to Farm 3 (85 stems/ha). The level of shade increases progressively with the proportion (density) of associated forest trees. The high density of trees in the plantation, tends to create dense shading and subsequently permanent moisture, favorable to the development of the disease. An excessif shade creates a more humid microclimate which induces the proliferation of diseases such as the black pod diseases and reduces the cocoa yield (Mossu, 1990 ; Bouley 1998 cit. Kouadio et al., 2018). This tends to confirm the assumption which states that agroforestry systems are traditionally seen as one of the causes of increased pest and disease incidence, in contrast with full-sun monocultures (Armengot et al., 2020). Studies have proved that shading reduces the final yields of the cocoa in term of healthy pods. The shade modifies the quantity of the light, temperature, the air movements, which have direct effects on the photosynthesis, the growth and the yield of the cocoa (de Almeida et Vallee 2007 cit. Kouadio 2018 ; Braudeau 1969). The most relevant arguments why the farmers in Ghana would like to have (more) shade trees on their cocoa farm are “improvement of air and water quality” and “the increased lifetime of cocoa trees” (Hoogendijk, 2012).

Musanga cecropioides, Ceiba pentandra, and Triplochiton scleroxylon are listed by the Cocoa Research Institute of Ghana (CRIG) as un-desired tree species in a cFAS for different reasons including competition for water and other resources and also they harbour some diseases (Asare, 2005). The three species total 28 stems.
CONCLUSION AND RECOMMENDATIONS

This study aimed to assess the diversity, to analyse the floristic and structural characteristics, as well as the healthy of the EAB, a cFAS based in the forest zone of the East region of Cameroon. The current cocoa density of the system is 495.0 stems/ha, for a success rate of 46.4%. Higher shading coupled to the high rainfall tend to increase the black pod disease attacks. Further studies should aim to (1) identify different cocoa varieties planted in the system, (2) identify correctly all the pests and diseases of the system, (3) assess the impact of associated tree thinning and cocoa tree prunung on the pests or diseases attack and on the cocoa production, and (4) to explore the usage of associated trees in the system. This with the view to come out with a fair model cFAS to use in tropical humid forest zones.

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