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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 systematicaly 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 precised. 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 growing 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 (McElhinny 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 intensifification, 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 diffefrent 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 assomptions 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 Exploittion 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.climate-data.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

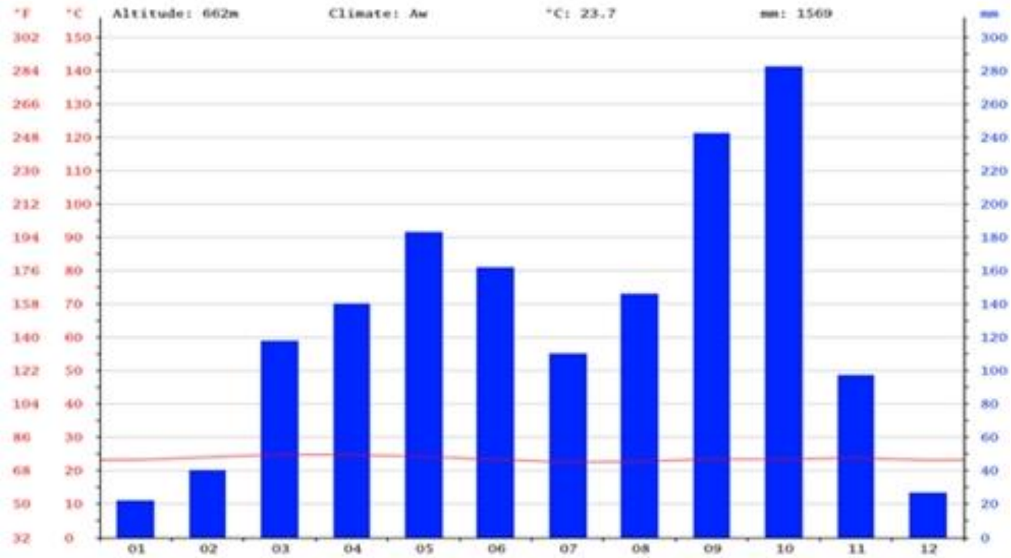

Figure 1. Climatic data of the Bertoua city located at 30 km from the EAB for the period 2011-2016.

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
Farm 2	36	5	5 (fallow)	0	No cocoa
		6	6	5	2013
		7	14	12	2013
		8	7	6	2011
		9	4 (fallow)	0	No cocoa
Farm 3	36.5	10	4	3	2011
		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

Table 2. Characteristics of the inventories conducted in the EAB.

Farm	Bloc (Age)	Useful suface area 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
	2 (7)	7	3	0.25	0.75	10.7
Farm 3	10 (5)	3	2	0.25	0.5	16.7
	11 (3)	18	6	0.25	1.5	8.3
Total	4	46	21	0.25	5.25	11.4

main culture consists of the Cocoa, which is associated to the bananas (plantain and sweet bananas). The main objective of the promotor (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 sapplings 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 promotor 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 systematicaly 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 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.

$$H' = \Sigma pi Log_2(pi) \quad (1)$$

Where, Pi = Ni/N, Ni = 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.

$$D = \Sigma(pi)^2 \quad (2)$$

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'/Log2S, with S being the total number of species (Dufrêne 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 mostely 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 scattering of seeds were defined according to the model used by Danserau and Lems (1957) and which includes: (1) plants or fruits scattered by animals or humans (hanging and adhesive fruits-HgAd, fleshy and indehiscent fruits-FlIn), (2) by the wind (fruits with aliform appendages-AlAp, fruits with feathery or silky appendages-FeSi, fruits not fleshy and relatively light-FlLi), (3) by the same tree or self-scaterring (dried or fleshy fruits scattered by the plant itself-DrFl; dried or fleshy fruits but heavy and indehiscent-HeIn).

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.

$$Di = Ni/Sa \quad (3)$$

where Ni = the number of individuals for the species « i » in the group, Sa = the sampling area in hectare (ha) and Di = 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 = 100*Ni/1 111. The species dominance corresponds to its stand basal area expressed in m²/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.

$$G = \sum (\pi D^2/4) \quad (4)$$

Where D is the diameter of the tree, π = 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 specie 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 Attaked Index (PRAI) expressed as Equation 5.

$$PRAI = \sum \text{attacked fruits} / \sum \text{total fruits} \quad (5)$$

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 0.9%), Rubiaceae (6.4and 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 abund, 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 coacoa 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

Table 4. Floristic characteristics of associated trees found in the EAB- cAFS.

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
Lati p	*Amphimas pterocarpoides* Harms	Leguminosae-papillonoideae	CG	AlAp	Wi	Pf	16
Anigré R	*Aningeria 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	Leguminoseae	CG	HeIn	Ss	Pf	3
Kapokié	*Bombax buonopozense*P.Beauv.	Bombacaceae	CG	FeSi	Wi	Pf	2
Aiélé	*Canariumschweinfurthii*Engl.	Burseraceae	GC	FlIn	An	Pf	4
Ebougbong	*Canthiumarnoldianum* (De Wild. &T.Durand) Hepper	Rubiaceae	CG	FlIn	An	Pf	4
Fromagé	Ceibapentandra *(L.) Gaertn.*	Bombacaceae	Pan-tropical	FeSi	Wi	Sf	7
Djana A	*Celtisadolfi-friderici*Engl.	Ulmaceae	GC	FlIn	An	Pf	6
Odoutembéré	*Celtisafricana*Burm.f.	Ulmaceae	GC	FlIn	An	Pf	1
Ohia	*Celtismildbraedii*Engl.	Ulmaceae	GC	FlIn	An	Pf	3
Djana T	*Celtistessmannii*Rendle	Ulmaceae	CG	FlIn	An	Pf	5
Djana Z	*Celtiszenkeri*Engl.	Ulmaceae	CG	FlIn	An	Pf	23
Avom G F	*Cleistopholis patens* (Benth.) Engl. &Diels	Annonaceae	GC	FlIn	An	Pf	7
Ekoune	*Coelocaryonpreussii*Warb.	Myristicaceae	CG	FlIn	An	Pf	2
Cordia	*Cordiaplatythyrsa*Baker	Boraginaceae	WG	FlIn	An	Sf	11
Nomeakéla	*Corynanthepachyceras*K.Schum.	Rubiaceae	CG	FlLi	Wi	Pf	8
Prunier	*Dacryodesedulis (G.Don) H.J.Lam*	Burseraceae	CG	FlIn	An	Cu	5
Atom	*Dacryodesmacrophylla* (Oliv.) H.J.Lam	Burseraceae	GC	FlIn	An	Sf	4
Alep	*Desbordesiaglaucescens* (Engl.) Tiegh.	Combretaceae	CG	FlIn	An	Pf	3
ébène 3	*Diospyroscrassiflora*Hiern	Ebenaceae	CG	FlIn	An	Pf	2
Olem	*Diospyros sanza-minika*A.Chev	Ebenaceae	CG	FlIn	An	Pf	3
Dambala	*Discoglypremna caloneura* (Pax) Prain	Euphorbiaceae	GC	FlIn	An	Pf	12
Abamekouk	*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. exFicalho	Moraceae	CG	FlIn	An	Sf	13
Mutondo	*Funtumia elastica* (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

Table 4. Contd.

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* Leand ri	Phyllanthaceae	WG	FlIn	An	Pf	10
Acajou blanc	*Khaya anthotheca* (Welw.) C.DC.	Meliaceae	GC	FlIn	An	Pf	1
Eveus G	*Klainedoxa gabonensis* var. micro phylla 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	*Mangiferaindica*L.	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.	Bignoniaceae	GC	FlIn	An	Sf	4
Angossa	*Markhamia tomentosa* (Benth.) K.Schum. exEngl.	Bignoniaceae	GC	AlAp	Wi	Sf	2
Iroko	*Milicia excelsa* (Welw.) C.C.Berg	Moraceae	GC	FlIn	An	Swamp forest	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
Mirianthusarborus	*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
Nomeebegbenvahou ssoue	*Oddoniodendron micranthum (Ha rms) Baker f.*	Leguminosae-caesalpinioideae	CG	FlIn	An	Pf	9
Afane	*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.Be auv.) 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-papillonoideae	CG	AlAp	Wi	Pf	2
Ilomba	*Pycnanthus angolensis* (Welw.) Warb.	Myristicaceae	GC	FlIn	An	Pf	10
Djansang	*Ricinodendron heudelotii* (Baill.) Heckel	Euphorbiaceae	GC	FlIn	An	Sf	6
Ebapélé	*Santiria trimera* (Oliv.) Aubrév.	Burseraceae	GC	FlIn	An	Pf	1
Niové	*Staudtia kamerunensis* Warb.	Myristicaceae	GC	FlIn	An	Sf	10
Nkanang/lotofa	*Sterculia rhinopetala* K.Schum.	Malvaceae	CG	FlIn	An	Pf	2
Poréporé	*Sterculia tragacantha* Lindl.	Malvaceae	GC	FlIn	An	Sf	29
Strombosia	*Strombosia pustulata* Oliv.	Olacaceae	GC	FlIn	An	Pf	9
Biboloafoum	*Syzygium rowlandii* Sprague	Myrtaceae	GC	FlIn	An	Pf	2
Fraké	*Terminalia superba* Engl. &Diels	Combretaceae	GC	AlAp	Wi	Pf	5

Table 4. Contd.

Akpwa	*Tetrapleura tetraptera* (Schum. &Thonn.) Taub.	Leguminoseae	GC	HeIn	Ss	Pf	19
Ebegbenvahoussoue	*Trichilia dregeana* Sond.	Meliaceae	CG	FlIn	An	Pf	10
Ebeugbenvahoussoue	*Trichilia welwitschii* C.DC.	Meliaceae	CG	FlIn	An	Pf	1
Amvout	*Trichoscypha acuminata* Engl.	Anacardiaceae	GC	FlIn	An	Pf	1
Ayous	*Triplochiton scleroxylon* K.Schum.	Malvaceae	GC	AlAp	Wi	Sf	18
Rikio	*Uapaca guineensis* Müll.Arg.	Euphorbiaceae	GC	FlIn	An	Swampf orest	8
Evoula	*Vitex grandifolia* Gürke	Verbenaceae	Afro-tropical	FlIn	An	Pf	3

(1) type of scaterring 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 withfeathery or silky appendages-FeSi, fruits not fleshy and relatively light-FlLi), (3) plants or fruits scattered by the same tree or self-scaterring-Ss (dried or fleshy fruits scattered by the plant itself-DrFl; dried or fleshy fruits but heavy and indehiscent-HeIn).
(2) Phytogeographic types : Central guinea-congo (CG), Guinea-congolese (GC), Pan-tropical (Pantr), Western guinean (WG), Afro-malagasy (AMA), Afro-tropical (Atr),
(3) Habitat ; Primary forest (Pf), Secondary forest (Sf), Culture (Cu), Swamp (Sw).

years old) has the high tree density, low cocoa density and high cocoa stand basal area compared to farm 3 (4.5 years).

The six most important tree species according to their dominance or relative stand basal area are *Musanga cecropioides, Ceiba pentandra, Terminalia superba, Sterculia rhinopetala, Cordia platytyrsa, Triplochyton scleroxylon*.

Figure 2 illustrates the distribution of stems in different diameter groups. Saplings (45% of stems; 47 stems/ha) and shrubs (35%; 36 stems/ha) are more represented. Average and big trees are les represented but totalise 12.18 m²/ha for stand basal area, representing 75.18% of the total basal area of the system.

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 two phases of counting (ANOVA, df = 1, F = 2.152, P < 0.143). But this productivity varies significantly between different blocs (ANOVA, df = 3, F = 342.8, P < 2e-16), with bloc 1 having the highest productivity (23.61 pods/tree). The number of attacked fruits increases from phase a to phase b, while that of healthy fruits decreases. This is expressed by the Pod Rot Atacked Index (PRAI) which varies significantly from one counting phase to another (ANOVA, df = 1, F = 516.1, P < 2e-16). We can note that the PRAI increased, the value obtained in the second counting phase (0.48) being times 2 of that of the first phase (0.19). The PRAI also varies significantly from one bloc to another, whatever be the phase of counting (ANOVA for Phase 1, df = 3, F = 27.45, $P < 2^e$-16, and ANOVA for phase 2, df = 3, F = 27.45 $P < 2^e$-16). Bloc 1 (0.19 in phase a and 0.58 in phase b) and bloc 2 (0.31; 0.54) having the highest PRAI compared to blocs 10 (0.12; 0.10) and 11 (0.05; 0.14). The PRAI varies significantly from one farm to another (ANOVA, df = 1, F = 342.5, $P < 2^e$-16). The PRAI 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 sapplings, (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, sapplings, and before felling trees.

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

Table 5. Horizontal structure of the EAB.

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					1	0.01	0.08	0.19
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					3	0.46	2.84	0.57
Amphimas pterocarpoides	13	0.88	4.85	4.00	3	0.17	1.36	1.50	16	1.05	6.46	3.05
Aningeria robusta	1	0.09	0.52	0.31				0.00	1	0.09	0.57	0.19
Annickia chlorantha	21	0.69	3.82	6.46	5	0.25	1.96	2.50	26	0.94	5.78	4.95
Anonidium 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			0.00	0.00	1	0.06	0.39	0.19
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 zenkeri.	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					7	0.53	3.30	1.33
Coelocaryon preussii	2	0.08	0.45	0.62					2	0.08	0.50	0.38
Cordia platythyrsa	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
Dacryodes edulis	4		0.00	1.23	1	0.01	0.06	0.50	5	#VALEUR!	#VALEUR!	0.95
Dacryodes 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					2	0.04	0.23	0.38
Diospyros sanza-minika	2	0.01	0.06	0.62	1	0.01	0.06	0.50	3	0.02	0.12	0.57
Discoglypremna caloneura	10	0.29	1.61	3.08	2	0.02	0.17	1.00	12	0.31	1.93	2.29
Donella ubanguiensis	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			0.00	0.00	1	0.18	1.38	0.50	1	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

Table 5. Contd.

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 L.	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 arboreus	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
Pausinystalia 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
Piptadeniastrum africanum			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	0.09	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
Santiria trimera	6	0.22	1.24	1.85	4	0.05	0.43	2.00	10	0.28	1.71	1.90
Staudtia 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.

Syzygium rowlandii	2	0.02	0.14	0.62	3	0.24	1.87	1.50	5	0.26	1.62	0.95
Terminalia superba	13	0.65	3.58	4.00	6	1.06	8.33	3.00	19	1.70	10.52	3.62
Tetrapleura tetraptera	7	0.13	0.71	2.15	3	0.17	1.32	1.50	10	0.29	1.82	1.90
Trichilia dregeana	1	0.11	0.60	0.31					1	0.11	0.67	0.19
Trichilia welwitschii	1	0.03	0.16	0.31					1	0.03	0.18	0.19
Trichoscypha acuminata	7		0.00	2.15	2	0.01	0.05	1.00	9		0.00	1.71
Triplochiton scleroxylon	5	0.09	0.48	1.54	6	1.30	10.25	3.00	11	1.39	8.57	2.10
Uapaca guineensis	5	0.15	0.83	1.54	3	0.10	0.78	1.50	8	0.25	1.53	1.52
Vitex grandifolia	3	0.04	0.23	0.92					3	0.04	0.26	0.57
Total	**378**	**18.05**		116.31	**170**	**12.71**		**85.00**	**548**	**16.21**		**104.38**

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

Table 6. Stand basal area and density of farmsfound 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 platytyrsa, Triplochyton 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

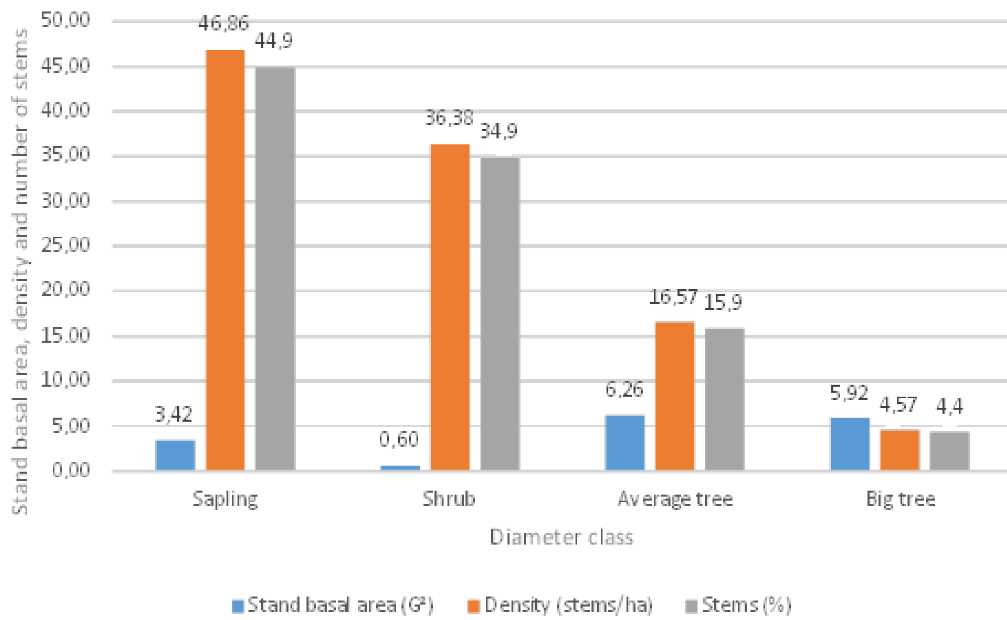

Figure 2. Distribution of associated trees in different diameter groups.
The average diameter of associated trees or the diameter of the medium associaed tree is 34.7 ± 28.10 cm, and this does not vary from one bloc to another (ANOVA, df = 3, F = 0.273, P < 0.845). The average diameter of the cocoa trees is 6.78±2.03 cm and this diameter varies significantly in different blocs (ANOVA, df = 3, F = 174.5 P < 2e-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	Heathy pods	Total pods	Productivity		Pod rot attack Index (PRAI)
						Heathy pods/tree	Total pods/tree	
	B1 (8)	920	4366	16335	20701	18.01	22.50	0.20
	B2 (7)	211	772	991	1763	4.70	8.36	0.32
Phase a	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
	B1 (8)	997	14640	9925	24565	10.01	24.64	0.58
	B2 (7)	324	2081	1368	3449	4.22	10.65	0.55
Phase b	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 primay 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-congolese 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 Cameoon (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 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 1560 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).

Saplings (45% of stems) and shrubs (35%) are the most represented groups. This corresponds to an inverse J shape structure and remains the same in the four blocs of the system. This structure is quite different to the same inverse J shape obtained in the humid forest zone of Cameroon (Sonwa et al., 2016), where shrubs were the most important group (56% of stems) followed by saplings (33%). The average diameter of the associated tree species found in our system is 34.7 cm, which is too high compared to the 26.7 obtained in the Centre and South regions (Sonwa et al., 2016). The density of big trees (4.6 trees/ha) is low compared to results obtained in the Centre, South and South west regions of Cameroon (Bobo et al., 2006; 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, frostry 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 necrosed 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 (bloc1 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 (Ndoumbè-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 2 (17-22th October). This can be justified by the increase in humidity through the high rainfall. In fact the first counting phase occured during the small dry season (August), while the second counting phase occured 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 high 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 precised, increased with increasing quantity of rainfall (Ndoumbè-Nkeng et al., 2009). Ndoumbè-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 (>2 200 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) of 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 (Ndoumbè-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. Ndoumbè-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 (Coffea spp.) and cacao (Theobroma 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 difficul (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 (Ndoumbè-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 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 Valle 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 *Triplochyton scleroxylon* are listed by the Cocoa Research Institute of Ghana (CRIG) as un-desired tree species in a cAFS for different reasons including competition for water and other resources and also they harbour some diseases (Asare, 2005). The three species total 28 stems for a density of 5.33 trees/ha. *Piptadeniastrum africanum* and *T. scleroxylon* are undesire tree species in a cAFS since they use to compete for water and other resources with cocoa (Adou et al., 2016). *Celtis* sp, *Klainedoxa gabunensis, Lannea welwitschii, Macaranga* sp, *Myrianthus arboreus*, *Piptadeniastrum africanum, Tretrapleura tetraptera* are known as undesirable tree species in a cFAS (Lavabre, 1959). All these informations may also explain the high level of the PRAI in our system. Optimization of shade is an strategy to control pests and diseases (Staver et al., 2001; Atangana et al., 2013). Disease losses can be reduced through integrated management practices that include regular tree pruning and shade management, leaf mulching, regular and complete harvesting, sanitation and pod case disposal, frequent pod harvest, regular removal of infested pods, weed management, appropriate fertilizer application and targeted fungicide use (Guest, 2007; Armengot et al., 2020).

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 succes 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 varieries 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 humid forest zone in the East region ofi Cameroon.

This study aimed to assess the diversity and to analyse the floristic and structural characteristics of the Exploittion Agricole Betti (EAB), a Cocoa-based agroforestry systems (cAFS) vast of 120 ha, 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 succes rate of 46.4%. The density of the associated trees is 104 trees/ha. The overall diversity is low (H < 3 bits and E < 0.5) indicating that the EAB is an homogenous and specalized system. Nineteen out of the 78 associated tree species identified are incompatible with the cocoa for different reasons The cocoa pods are mainly attacked by *Phytophthora* spp, the average Pod Rot Attacked Index (PRAI) being 0.35 ± 0.38. This PRAI varies significantly according to the associated trees density (degree of shade) and to the season. Higher shading coupled to the high rainfall tend to increase the PRAI.

Further studies should aim to (1) identify different cocoa varieries 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.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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