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Full Length Research Paper

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 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 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 Exploitation 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

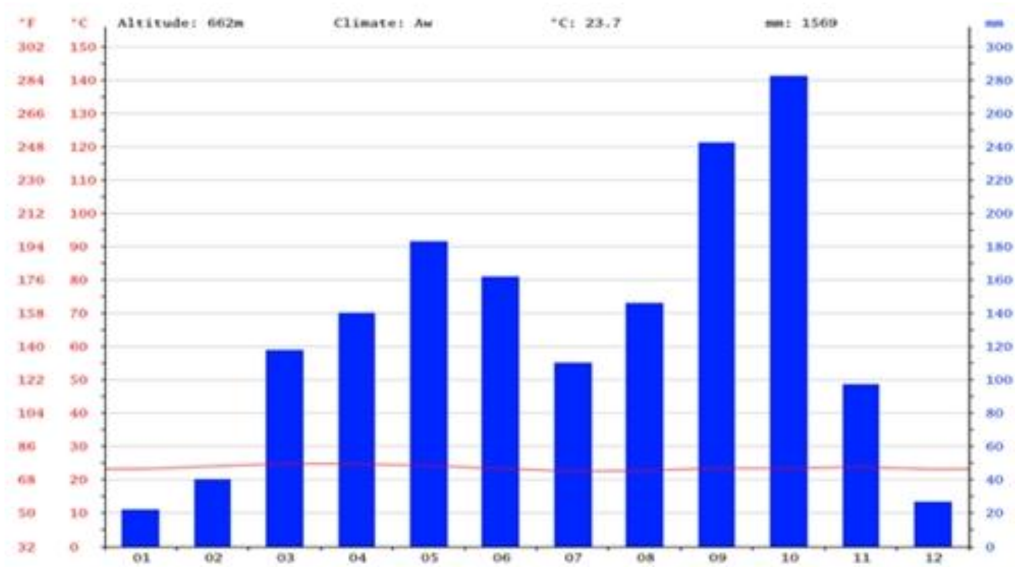

Figure 1. Climatic data of the Bertoua city located at 30 km from the EAB for the period 2011-2016.

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
		1	21.5	18	2008/2009
Farm 1	47.5	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

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	*Annickia chlorantha* (Oliv.) Setten & Maas	Annonaceae	CG	FlIn	An	Pf	26
Ebom	*Anonidium mannii* (Oliv.) Engl. & Diels	Annonaceae	CG	FlIn	An	Pf	14
Antidesma	*Antidesma madagascariense* 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	*Canarium schweinfurthii* Engl.	Burseraceae	GC	FlIn	An	Pf	4
Ebougbong	*Canthium arnoldianum* (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 mildbraedii* Engl.	Ulmaceae	GC	FlIn	An	Pf	3
Djana T	*Celtis tessmannii* Rendle	Ulmaceae	CG	FlIn	An	Pf	5
Djana Z	*Celtis zenkeri* Engl.	Ulmaceae	CG	FlIn	An	Pf	23
Avom G F	*Cleistopholis patens* (Benth.) Engl. & Diels	Annonaceae	GC	FlIn	An	Pf	7
Ekoune	*Coelocaryon preussii* Warb.	Myristicaceae	CG	FlIn	An	Pf	2
Cordia	*Cordia platythyrsa* Baker	Boraginaceae	WG	FlIn	An	Sf	11
Nomeakéla	*Corynanthe pachyceras* K. Schum.	Rubiaceae	CG	FlLi	Wi	Pf	8
Prunier	*Dacryodes edulis* (G.Don) H.J.Lam	Burseraceae	CG	FlIn	An	Cu	5
Atom	*Dacryodes macrophylla* (Oliv.) H.J.Lam	Burseraceae	GC	FlIn	An	Sf	4
Alep	*Desbordesia glaucescens* (Engl.) Tiegh.	Combretaceae	CG	FlIn	An	Pf	3
Ebène 3	*Diospyros crassiflora* 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* (Sprague) 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 A 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* 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	*Mangifera indica* 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	Swampforest	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
Nomeebegbenvahoussoue	*Oddoniodendron micranthum (Harms) 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.Beauv.) 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
Porépore	*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
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

Table 4. Contd.

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	Swampforest	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 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

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

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 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

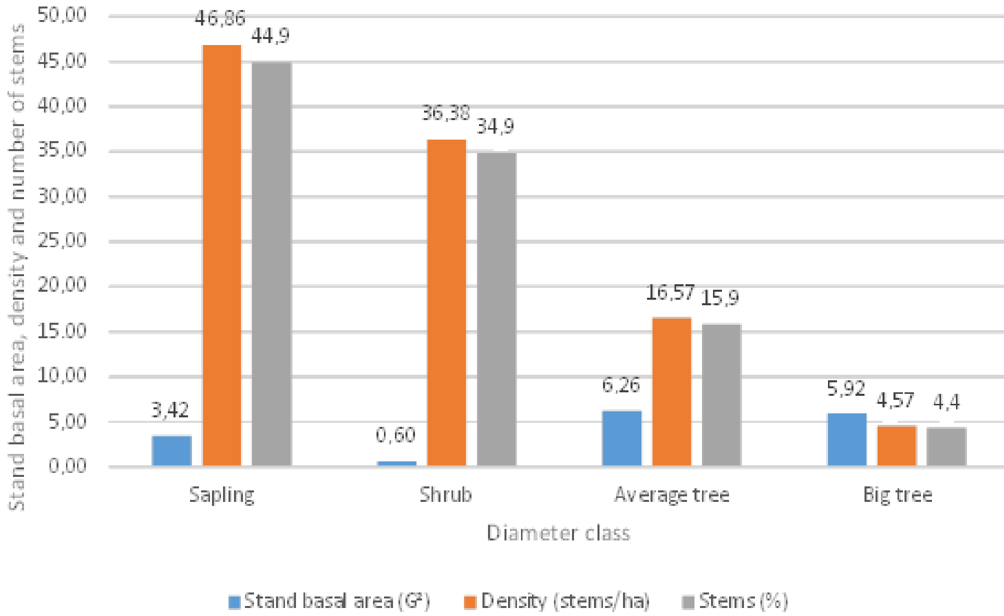

Figure 2. Distribution of associated trees in different diameter groups.
The average diameter of associated trees or the diameter of the medium associaed tree is 34.7 ± 28.10 cm, and this does not vary from one bloc to another (ANOVA, df = 3, F = 0.273, P < 0.845). The average diameter of the cocoa trees 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	
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

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 health 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.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Floristic composition, diversity and community structure in a secondary rainforest in Ibadan, Nigeria

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Secondary forests may act as buffer area and serve as reservoir for biotic components that are lost from primary forest due to anthropogenic disturbances. This study investigated the floristic composition, diversity and community structure of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Nigeria. Twenty-five main plots (each 50 m × 50 m) were randomly mapped out to enumerate tree species, five 10 m × 10 m sub-plots were systematically mapped out within each main plot to enumerate shrubs and three quadrats (1 m × 1 m) were laid in each sub-plot to enumerate herbaceous species in Wet Season (WS) and Dry Season (DS). Relative Importance Value (RIV), Taxa, Individuals, Dominance, Shannon-Wiener, Equitability and Jaccard similarity index were determined. A total of 181 plant species from 145 genera and 54 families which included 63 trees, 33 shrubs and 85 herbaceous species were enumerated. In wet season, *Triplochiton scleroxylon*, *Lonchocarpus griffonianus* and *Chromolaena odorata* had the highest RIV while in dry season, *Terminalia superba*, *Lonchocarpus cyanescens* and *C. odorata* were the highest for trees, shrubs and herbs, respectively. Low dominance but high equitability and Shannon-Weiner values indicated inter-specificity among trees, shrubs and herbs. It was only in herbs that Jaccard-similarity was less than 100% across seasons. Resilience for keystone species conservation is possible due to flora species heterogeneity of the study site.

Key words: Forest ecosystem, biodiversity, anthropogenic activities, relative importance value, ecosystem services.

INTRODUCTION

Secondary forests constitute a large and growing component of forest cover and are crucial in the provision of various goods and services in the ecosystem (Jenkins and Schaap, 2018). Forest resources exploitation and associated industries create employment and revenue base which suggests its roles in socio-economic development policies (World Bank, 2016). Forest ecosystems provide habitat for biodiversity, provides food stuff and other important resources for humans to survive on land (Atomsa and Dibbisa, 2019). Since biodiversity occupies a crucial role in provision of goods and services for forest ecosystems, human activities through exploitation of some of the available goods and services symbolizes ecosystem degradation which is inimical to

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biodiversity conservation. The increasing exploitation of tropical rainforests for silviculture and anthropogenic activities such as habitation, agriculture and industry are devastating and of a great concern due to their ecological impacts (Monarrez-Gonzalez et al., 2020). It has been reported that conversion and degradation of forest for agriculture has destroyed about 55% of the world's original area of tropical moist forest leading to biodiversity loss across the world (Green et al., 2005; Awodoyin et al., 2013). Impact of forest conversions includes changes in soil, vegetation, hydrological functions, climate change and depletion of natural resources and biodiversity (Jenkins and Schaap, 2018). Halting anthropogenic activities such as timber harvesting, logging, agriculture and promotion of sustainable forestry management practices would contribute to the resilience of a secondary forest in biodiversity and other ecosystem services (Olajuyigbe and Jeminiwa, 2018). However, adequate monitoring, protection and sustainable management of a tropical secondary rainforest require a good knowledge of flora component, diversity and structure (Fang Zeh et al., 2019). Information on the floristic composition and structure of the secondary forest is key to understanding the larger dynamics of forest area and finding key elements of plant diversity (Akinyemi and Oke, 2014; Van Rooyen et al., 2016). Therefore, changes in species distributions, composition and abundance are measured through biological components of an ecosystem (O'Connor et al., 2017). Awodoyin et al. (2013) enumerated flora species composition, diversity and community structures in Cocoa plots in Nigeria, as an inventory of Nigeria flora status due to agriculture. Studies on floristic assessment will assist in the current state and future prediction of an ecosystem. This study enumerated composition, diversity and community structure of herbs, shrubs and trees in secondary forest of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Nigeria.

MATERIALS AND METHODS

The study was carried out in the secondary Forest of Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Oyo State, Nigeria (Figure 1). The CRIN was established by the Federal Government of Nigeria through the Nigeria Research Institute in 1964 (Atanda, 1977). The CRIN estate falls within the transitory rainforest-savanna vegetation of Nigeria and located within coordinates 07° 12.157' and 07° 13.260' North and 03° 51.093' and 03° 52.290' East (Obatolu, 2014). Sampling was conducted in 25 quadrats that were randomly located and established using Global Positioning System (GPS; Garmin Map78 model).

The geographical coordinates of each main quadrat (50 m × 50 m) (Figure 2) were recorded using Garmin map 78 GPS in a total area of 482.63 ha of CRIN stratified zones. The number of plots selected in each zone depended upon area of the forest fragment, and it was 2, 3, 4, 5 or 6 sampled plots per zone. A total of 25 main quadrats (50 m × 50 m) were established per season. The quadrat size established for the enumeration depended on plant life form. Trees were enumerated within each main quadrat (50 m × 50 m). Shrub species were enumerated in five sub-quadrats (10 m × 10 m each) laid within each main quadrat. The sub-quadrats were located at the four corners and one at the centre of the main quadrat. A total of 125 sub-quadrats per season were established for enumeration of shrubs. Three sub-sub-quadrats of 1 m × 1 m each were located randomly in each sub-quadrat to enumerate herbaceous species. Hence, a total of 375 sub-sub-quadrats were laid to collect data on herbaceous species per season. A complete inventory of plant species was done in the main quadrat (trees), sub-quadrat (shrubs) and sub-sub-quadrats (herbaceous) and was carried out between July and August for the wet season and January to February for the dry season. The trees and shrub plants were identified by their local and scientific names with the help of a forester who speaks the local language (Yoruba) and the herbaceous were identified with the help of a flora on West African weeds (Akobundu et al., 2016) and those that could not be identified were collected each day, preserved and taken to the CRIN Laboratory for identification with the help of a taxonomist.

Data analysis

From the data, measure of relative importance value for each species in each site was determined as mean of relative density and relative frequency for each species following the methods in Kent and Coker (1992) and Awodoyin and Egberongbe (2010).

$$[(RD + RF)/2] \times 100$$

where RD=Relative Density and RF=Relative Frequency.

$$RD = (d/D) \times 100$$

where d = the density of a species; D = total density of all species.

$$RF = (f/F) \times 100$$

where f = the frequency of a species; F = total frequency of all species.

Also, the biological community structure as informed by the ecological diversity of the plant species was determined by alpha and beta diversity. The alpha diversity, which is the diversity of species within a particular community, was determined by Species Richness (R), Shannon-Wiener (H`), Evenness (J) and Dominance (D) indices using Paleontological Statistics (PAST) software version 3.0 (Hammer, 2011). The beta diversity, which is the expression of between-habitat diversity, was determined by the Jaccard index of similarity (Spellerberg, 1993).

Species richness is the total number of species occurring within a specified area of the community.

The Shannon-Wiener index of species diversity is calculated as:

$$H` = -\sum_{i=0}^{n} Pi.\,lnpi$$

where pi is the proportion which is the number of individuals in a species (n) in relation to the total number of all individuals in a community (N):

$$pi = n/N$$

ln is the Naperian logarithm $ln = 2.303 \times \log_{10}$

The species equitability index (J) is calculated as:

$$J = H`/lnS$$

where H` is Shannon-Wiener index and S is total number of species in the community. The Dominance index (D) is calculated as:

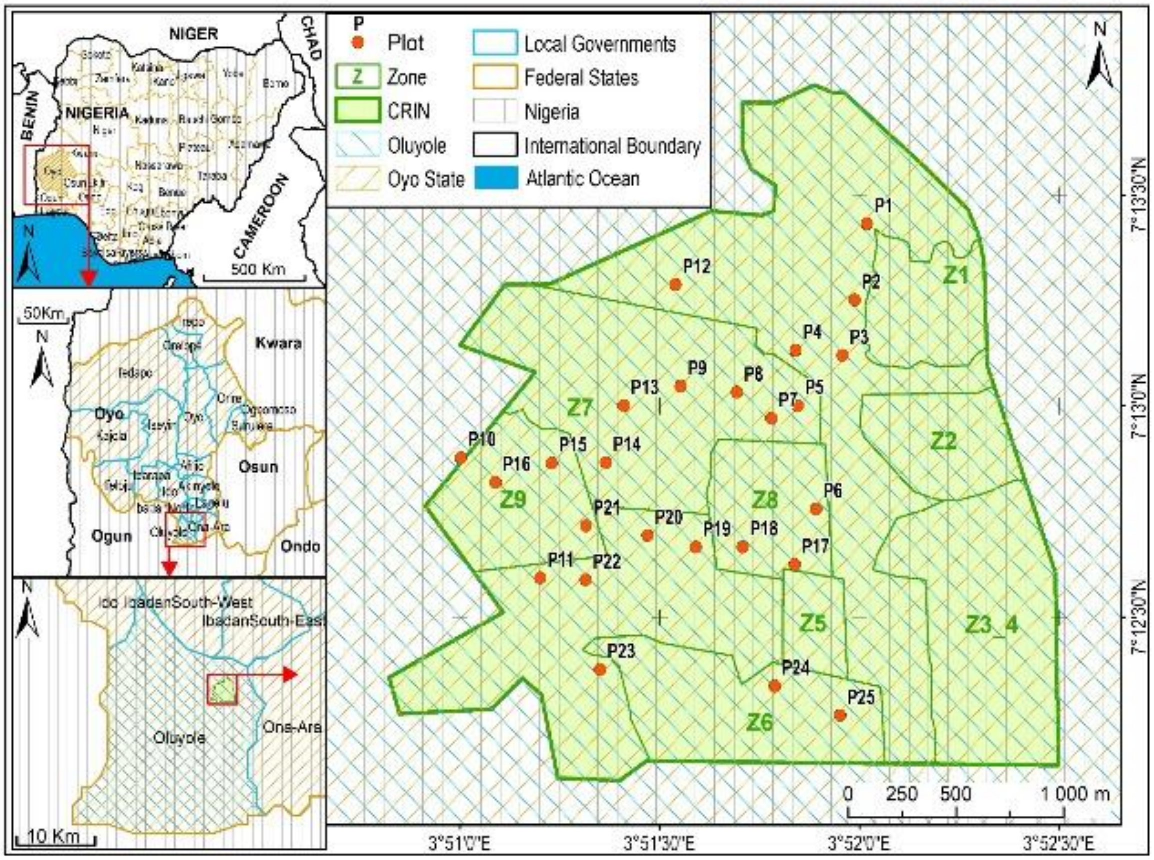

Figure 1. Selected plots and transects in CRIN Headquarters Ibadan, Oluyole LG and Oyo State widen and inset map of Nigeria.

$D = \sum (n/N)^2$

where n is number of individuals of a particular species and N is the total number of individuals found in the community.
Jaccard index of community similarity (SCj) is calculated as:

$SCj (\%)=W/(A+B-W)\times 100$

where W is the number of common species, A is the number of species in community A, and B is the number of species in community B.

RESULTS AND DISCUSSION

The result of enumeration gave a total number of 181 plant species including 85 herbaceous (Table 1), 33 shrubs (Table 2) and 63 trees (Table 3) belonging to 145 genera and 54 families (21 for herbaceous, 17 for shrubs and 29 for trees) in both wet and dry seasons. Among these families, Fabaceae had the highest number of species (25) followed by Poaceae (20 species), Asteraceae and Rubiaceae had 12 species each, Euphorbiaceae (11 species), Malvaceae (10 species), Apocynaceae (seven species), Moraceae and Solanaceae families had six species each, Cyperaceae (five species), Acanthaceae and Commelinaceae had four species each, Combretaceae, Nyctaginaceae, Sapindaceae and Ulmaceae had three species each.

Eleven families namely Amaranthaceae, Boraginaceae, Connaraceae, Convolvulaceae, Irvingiaceae, Meliaceae, Rutaceae, Tiliaceae, and Verbenaceae had two species each while the remaining 23 families like Agavaceae, Anacardiaceae, Annonaceae, Bignoniaceae, Bombacaceae, Capparidaceae, Clusiaceae, Cucurbitaceae, Dennstaedtiaceae, Dioscoreaceae, Icacinaceae, Lamiaceae, Loganiaceae, Myristicaceae, Meliaceae, Musaceae, Ochidaceae, Pedaliaceae, Phyllanthaceae, Piperaceae, Portulacaceae, Sapindaceae, and Sapotaceae had one species each.

The micro-habitat of CRIN secondary forest was closely similar in vegetation types and species composition but varied slightly in individual species (structure) enumerated in the wet and dry seasons. The species composition in shrubs and trees species was similar in the wet and dry season, but there was difference in the herbaceous species composition in the wet and dry seasons. The finding of this study indicated high species richness and abundance for herbs, shrubs and trees species but herbaceous had the highest

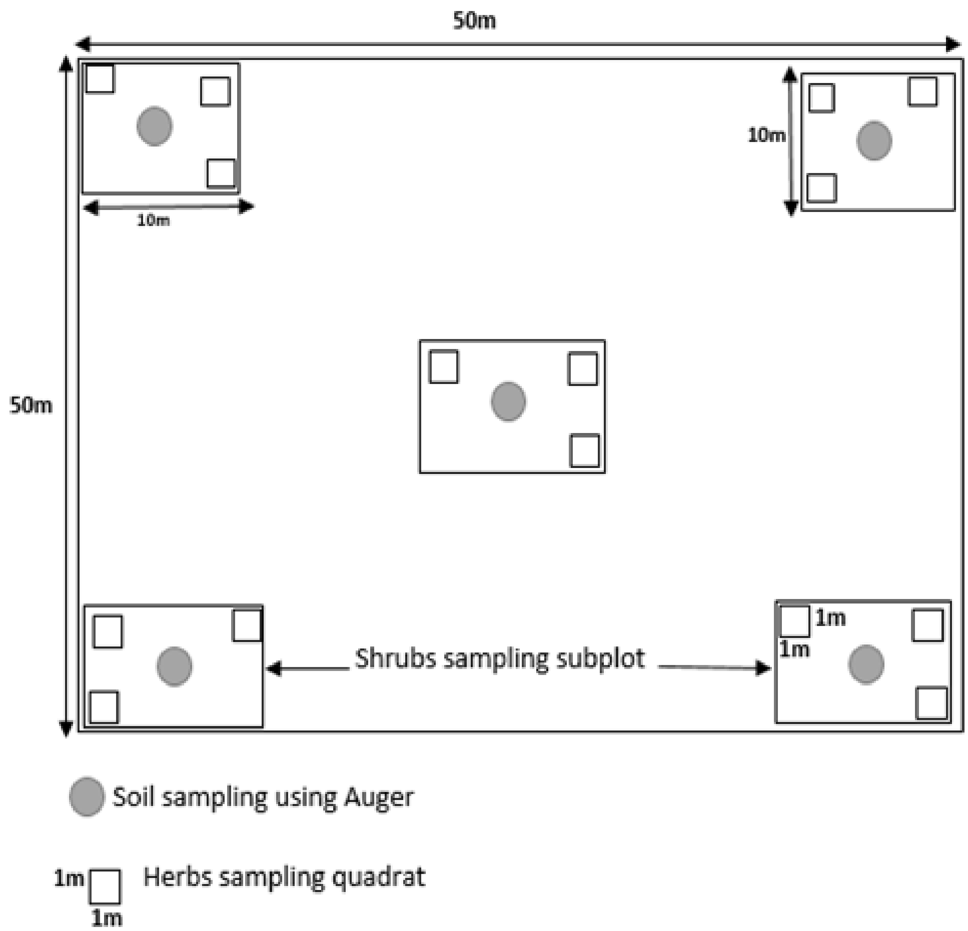

Figure 2. Sampling layout for trees, shrubs and herbs enumeration at Cocoa Research Institute of Nigeria, CRIN.

species richness and abundance. This was similar to the findings of Komolafe et al. (2017) who opined that Ibodi forest of Southwest Nigeria contains 47 herbs and 93 trees while Tang et al. (2010) reported high species composition of 222 plant species in secondary vegetation communities of China comprising 113 herbaceous species, 109 woody species (trees, shrubs, and lianas) with 79 families and 183 genera. The high species composition and abundance may be attributed to human perturbations in the CRIN forest. This was similar to the assertion of Mishra et al. (2008) that herbaceous species dominance over shrubs and trees composition in a disturbed forest may be attributed to the presence of anthropogenic activities including the harvest of food tree plantations (Oluwatosin and Jimoh, 2016). Also, Kessler et al. (2005) attributed the presence of high number of herbaceous flora in a recovery forest to the presence of few mature trees, which allows the penetration of light thereby promoting the growth of light-loving plants known as heliophytes (Bobo et al., 2006; Awodoyin et al., 2013). The most abundant number of herbaceous species was found in Poaceae and Asteraceae in both seasons while Rubiaceae and Fabaceae contained the most abundant shrub species and Fabaceae, Moraceae and Malvaceae were the most abundant tree species. The abundance of Asteraceae in both wet and dry season conforms to the study of Awodoyin et al. (2013) who reported that Asteraceae was found to be among the highest families of herbs in cocoa agroforest of tropical rainforest zone of Nigeria and Ahmed et al. (2015) who reported same for semi-desert region of Egypt. Notwithstanding the number of species identified for herbs, shrubs and trees, the abundance of individuals for most herb species was higher in the wet season than the dry season, which may be attributed to adequate moisture availability.

Relative importance values of herbaceous species in wet and dry seasons of CRIN Secondary Forest, Ibadan, Nigeria

The result showed the herbaceous species that were enumerated (85 species in wet season and 69 species in dry season). Among the herbaceous species identified,

Table 1. Annual and Perennial herbaceous species composition on selected plots in Secondary Forest of Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species	Life forms
1	Acanthaceae (4)	*Acanthus montanus* (Nees) T. Anders	Perennial
		Asystasia gangetica (linn.) T. Anders	Perennial
		Blepharis maderaspatensis (Linn.) Heine & Roth	Perennial
		Rungia dimorpha S. Moore	Perennial
2	Amaranthaceae (2)	*Celosia argentea* L.	Perennial
		Pupalia lappacea (linn.) Juss.	Perennial
3	Asteraceae (12)	*Ageratum conyzoides* Linn.	Annual
		Aspilia africana (Pers.) C.D. Adams	Perennial
		Bidens pilosa Linn.	Annual
		Chromolaena odorata (L.) R.M. King & Robinson	Perennial
		Cleome rutidosperma D.C.	Annual
		Conyza sumatrensis (Retz.) walker	Annual
		Emilia coccinea (Sims) G. Don	Annual
		Melanthera scandens (Schum. &Thonn) Roberty	Perennial
		Sclerocarpus africanus Jacq.ex Murr.	Annual
		Synedrella nodiflora Gaertn.	Annual
		Tithonia diversifolia (Hermsl.) A. Gray	Annual
		Tridax procumbens Linn.	Perennial
4	Combretaceae (1)	*Combretum hispidum* Laws.	Annual
5	Commelinaceae (4)	*Aneilema beniniense* (P. Beauv.) Kunth	Perennial
		Commelina benghalensis L.	Perennial
		Commelina erecta L.	Perennial
		Palisota hirsuta (Thunb) K.Schum.	Perennial
6	Convolvulaceae (2)	*Ipomoea aquatica* Forsk	Perennial
		Ipomoea triloba Linn	Perennial
7	Cucurbitaceae (1)	*Momordica charantia* Linn.	Annual
8	Cyperaceae (5)	*Cyperus amabilis* Vahl	Annual
		Cyperus esculentus Linn.	Annual
		Cyperus rotundus Linn.	Annual
		Fuirena umbellata Rottb.	Perennial
		Mariscus longibracteatus Cherm.	Perennial
9	Dennstaedtiaceae (1)	*Pteridium aquilinum* (Linn.) Kuhn	Perennial
10	Dioscoreaceae (1)	*Tacca leontopetaloides* (L.)	Perennial
11	Euphorbiaceae (6)	*Croton lobatus* L.	Annual
		Euphorbia hirta Linn.	Annual
		Mallotus oppositifolius (Geisel.) Mull. Arg.	Annual
		Phyllanthus amarus (schum. & thonn.)	Annual
		Phyllanthus niruri (Schum. & Thonn.)	Annual
		Spurge heterophylla Linn.	Perennial
12	Fabaceae (7)	*Calopogonium mucunoides* Desv.	Perennial

Table 1. Contd.

		Chamaecrista mimosoides (L.)	Annual
		Crotalaria retusa Linn.	Annual
		Desmodium scorpiurus (Sw.) Desv.	Perennial
		Mimosa pudica Linn.	Perennial
		Schrankia leptocarpa DC.	Perennial
		Senna hirsuta (Linn.) Irwin & Barneby	Perennial
13	Lamiaceae (1)	*Solenostemon monostachyus* P. Beauv.	Annual
	Loganiaceae (1)	*Spigelia anthelmia* Linn.	Annual
14	Malvaceae (3)	*Abutilon mauritianum* (Jacq.)	Perennial
		Sida acuta Burn. F.	Perennial
		Sida linifolia Juss. Ex Cav.	Perennial
15	Nyctaginaceae (3)	*Boerhavia coccinea* Mill.	Perennial
		Boerhavia diffusa L.	Perennial
		Boerhavia erecta L.	Perennial
16	Pedaliaceae (1)	*Sesamum alatum* Thonning	Annual
17	Piperaceae (1)	*Peperomia pellucida* (L.) Kunth	Perennial
18	Poaceae (19)	*Andropogon tectorum* Schum. & Thonn.	Perennial
		Axonopus compresus (Sw.) P. Beauv.	Perennial
		Brachiaria deflexa (Schumach.) C. E. Hubbard	Annual
		Brachiaria falcifera (Trin.) Stapf	Annual
		Brachiaria lata (Schumach.) C.E. Hubbard	Annual
		Cynodon dactylon (Linn.) Pers.	Perennial
		Digitaria exilis (Kippist) Stapf.	Annual
		Digitaria horizontalis Willd.	Annual
		Eleusine indica (L.) Gaertn.	Annual
		Eragrostis tremula Steud.	Annual
		Imperata cylindrica (L.) Raeusch	Perennial
		Oplismenus burmannii (Retz.) P.Beauv.	Annual
		Panicum laxum Sw.	Annual
		Panicum maximum Jacq.	Annual
		Paspalum scrobiculatum Linn.	Perennial
		Perotis indica (Linn.) O. Ktze	Annual
		Setaria barbata (Lam.) Kunth	Annual
		Setaria longiseta P. Beauv.	Perennial
		Setaria megaphylla (Steud.) Dur. & Schinz	Perennial
19	Portulacaceae (1)	*Talinum fruticosum* (L.) Juss.	Perennial
20	Rubiaceae (6)	*Oldenlandia corymbosa* Linn.	Annual
		Richardia scarbra L.	Annual
		Spermacoce ocymoides Burm.F.	Annual
		Solanum macrocarpon L.	Perennial
		Solanum nigrum L.	Annual
		Solanum torvum Swartz	Perennial
21	Urticaceae (3)	*Laportea aestuans* (Linn.) Chew.	Annual
		Laportea avalifolia (Schum.) Chew	Annual

Table 1. Contd.

		Pouzolzia guineensis Benth.	Perennial
Total	21	85	Annual : 41 Perennial : 44

Chromolaena odorata had the highest Relative Importance Value (RIV) of 25.26% (WS) and 12.27% (DS), followed by *Cyperus rotundus* (8.13%) in wet, *Aspilia africana* (5.72%) in dry, *Setaria megaphylla* (5.14% in wet) and (1.31% in dry) (Table 4). The lowest RIV belongs to *Panicum maximum* with 0.03% in wet season and *Combretum hispidum* with 0.14% in dry season.

Table 5 shows the shrub species in both seasons. *Lonchocarpus griffonianus* had 8.8% RIV (the highest in wet season) and 7.8% of RIV in dry season (Table 5). *Lonchocarpus cyanescens* had 9.0% of RIV (the highest in dry season) and 8.5% of RIV in wet season. *Solanum erianthum* had 7.7 and 1.33% of RIV in wet and dry season while *Rauwolfia vomitoria* had 6.7 and 4.3% of RIV in dry and wet season, respectively. The lowest RIV belonged to *Dracaena deisteiliana* with 0.1% of RIV in wet and in dry season followed by *Keetia venosa* 0.5 and 0.7% of RIV in wet and dry season, respectively.

A total of sixty-three trees species were enumerated in the wet and dry seasons (Table 6). The most abundant species was *Triplochiton scleroxylon* with 5.64% of RIV (the highest in wet season) and 4.96% of RIV in dry season (Table 6). *Terminalia superba* followed with 5.66% of RIV (the highest in dry season) and 4.99% of RIV in wet season followed by *Pterygota macrocarpa* which had 3.91 and 3.97% of RIV in wet and dry season while *Cedrela odorata* had 1.31 and 1.32% of RIV in wet and dry season, respectively. The lowest common RIV (0.24%) in wet and dry season belonged to the four species namely *Afzelia africana*, *Brachyestegia eurycoma,* *Gambeya albida* and *Lecaniodiscus cupanioides*.

The heavy presence of *C. odorata* might have influenced the number of herbaceous species composition in the CRIN forest. The high occurrence of *C. odorata,* a ubiquitous species of disturbed forest in the rainforest supports the assertion of Oke and Isichei (1997) who reported that *C. odorata* is a common herb of tropical rainforest. The *C. odorata* like many in Asteraceae family has the peculiar intense competitive ability, fast growth, efficient seed dispersal mechanism and high regeneration rate. The invasion of the study site by *C. odorata* might have influenced the number of herbaceous species flora due to previous land-use change, especially deforestation for cultivation. This agrees with the findings of Agboola and Muoghalu (2015) that reported a decrease in plant species composition and diversity in sites invaded by *Tithonia diversifolia* and *C. odorata*.

The high number of Rubiaceae among shrub species composition in the secondary rainforest of CRIN was supported by Ndah et al. (2013) who mentioned that Rubiaceae was the most prominent family of shrub in species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroun. The RIV of *L. griffonianus* (Fabaceae) remains prominent in both wet and dry season but it was second in its occurrence to *L. cyanescens* (Fabaceae) in the dry season. *L. griffonianus* and *L. cyanescens* (Fabaceae) are pioneer species that have fast regeneration ability. They are usually abundant in disturbed forest or forest in their transition state (Bobo et al., 2006). However, the low number of *L. griffonianus* in the dry season may be its inability to tolerate vagaries of weather, resource and nutrient competition. This was supported by the findings of Ogwu et al. (2016) who reported that limited access to water resources may affect the survival of young trees (shrubs) in the dry season. Similarly, *L. cyanescens* which belongs to Fabaceae alongside *L. griffonianus* may be a better nitrogen pump in the dry season where the decomposition by microorganism would be low due to low humidity. In a tropical rainforest, some Fabaceae like *L. cyanescens* and *L. griffonianus* have root nodules that could sequester and fix atmospheric nitrogen into the soil with the aid of *Rhizobium*. This was corroborated by Chen (2006) who reported seasonal (water and temperature) influence on the performance of nitrogen fixation. Fabaceae had the highest number of tree species (12), followed by Moraceae and Malvaceae, each with six species. The high number of species composition of Fabaceae and Moraceae in Nigeria rainforest has widely been documented (Salami and Lawal, 2018). This aligns with the findings of Adekunle et al. (2010) and Adekunle (2016) who reported that families such as Sterculiaceae, Meliaceae, Moraceae and Ebenaceae dominate the tropical rainforest of southwest Nigeria. The ability of Moraceae to produce a large number of seeds and quickly establish itself may account for their high presence and this was confirmed by Deka et al. (2012). Also, the high species composition of Fabaceae may be attributed to high competitive ability for water and other growth resources (Ogwu et al., 2016). The trees with the highest RIV values in both wet and dry seasons were the most commonly found trees in the study site; *T.*

Table 2. Perennial shrubs species composition on selected plots in secondary Forest Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species composition	Life forms
1	Agavaceae (1)	*Dracaena deisteiliana* Engl	Perennial
2	Apocynaceae (3)	*Hunteria umbellata* (K.Schum) Hailier	Perennial
		Pleioceras barteri Baill.	Perennial
		Rauwolfia vomitoria Afzel	Perennial
3	Arecaceae (1)	*Elaeis guineensis* Jacq.	Perennial
4	Bignoniaceae (1)	*Markhamia tomentosa* (Benth) K.Schum ex Engl	Perennial
5	Capparidaceae (1)	*Euadenia trifoliata* Oliv.	Perennial
6	Connaraceae (2)	*Agelaea obligua* (P.Beauv.) Baill.	Perennial
		Cnestis ferruginea DC	Perennial
7	Euphorbiaceae (3)	*Alchornia cordifolia* (Schum. & Thonn.)	Perennial
		Jatropha curcas Linn.	Perennial
		Microdesmis puberula Hook. F. ex Planch	Perennial
8	Fabaceae (4)	*Acacia macrostachya* Reichenb. ex Benth.	Perennial
		Angylocalyx oligophyllus Bak. F.	Perennial
		Lonchocarpus cyanescens (Schum. & Thonn.) Benth	Perennial
		Lonchocarpus griffonianus (Baill.) Dunn.	Perennial
9	Icacinaceae (1)	*Icacinia trichanta* Oliv.	Perennial
10	Meliaceae (1)	*Trichilia prieuriana* A. Juss	Perennial
11	Musaceae (1)	*Musa paradisiaca* L.	Perennial
12	Ochidaceae (1)	*Rytiginia umbellata* Thom.	Perennial
13	Rubiaceae (8)	*Coffea canephora* Pierre ex A.Froehner	Perennial
		Corynanthe pachyceras K.Schum	Perennial
		Euclinia longifolia Salisb.	Perennial
		Keetia venosa (Oliv.) Bridson	Perennial
		Pavetta corymbosa (DC.) F.N. Williams	Perennial
		Psilanthus ebracteolatus (Hiern) Hiern.	Perennial
		Psychotria fimbriatifolia R.D. Good	Perennial
		Psychotria sciandephora Hiern	Perennial
14	Sapindaceae (1)	*Deinbollia pinnata* Schum. & Thonn.	Perennial
15	Solanaceae (2)	*Solanum erianthum* D. Don	Perennial
		Solanum torvum Sw	Perennial
16	Tiliaceae (2)	*Desplatsia subericarpa* Bocq.	Perennial
		Grewia mollis Juss.	Perennial
17	Verbanaceae (1)	*Clerodendron capitatum* Willd	Perennial
Total	17	34	34

scleroxylon (Malvaceae) and *T. superba* (Combretaceae). Therefore, trees with such economic importance to human may have suffered exploitation and responsible for the decline in the number of tree species in a secondary forest. This assertion was supported by Komolafe et al. (2017), who reported that the economic

Table 3. Perennial trees species composition on selected plots in secondary Forest of Cocoa Research Institute of Nigeria, Ibadan.

S/N	Family	Species composition	Life forms
1	Anacardiaceae (1)	*Anacardium occidentale* L.	Perennial
2	Annonaceae (1)	*Cleistopholis patens* Engl. & Diels	Perennial
3	Apocynaceae (4)	*Alstonia boonei* De Wild.	Perennial
		Funtumia africana (Benth.) Stapf	Perennial
		Plumeria rubra L.	Perennial
		Rauvolfia vomitoria Afzel.	Perennial
4	Arecaceae (1)	*Elaeis guineensis* Jacq.	Perennial
5	Bignoniaceae (1)	*Newbouldia laevis* (P.Beauv.) Seem.	Perennial
6	Bombacaceae (1)	*Ceiba pentandra* (L.) Gaertn.	Perennial
7	Boraginaceae (2)	*Cordia millenii* Baker	Perennial
		Cordia platythyrsa Baker	Perennial
8	Celtidaceae(1)	*Celtis zenkerii* Engl.	Perennial
9	Clusiaceae (1)	*Garcinia kola* Hecke	Perennial
10	Combretaceae (2)	*Terminalia ivorensis* A. Chev.	Perennial
		Terminalia superba Engl. & Diels	Perennial
11	Euphorbiaceae (2)	*Ricinodendron heudelotii* Pierre ex Hecke	Perennial
		Macaranga barteri Mull.Arg	Perennial
12	Fabaceae (13)	*Afzelia africana* Sm. & Pers.	Perennial
		Albizia adianthifolia Schumach.	Perennial
		Albizia coriaria [Welw. ex] Oliv.	Perennial
		Albizia ferruginea (Guill. & Perr.) Benth.	Perennial
		Albizia glaberrima (Schumach. & Thonn.).	Perennial
		Albizia gummifera (J.F.Gmel) C.A.Sm.	Perennial
		Albizia julibrissin Baker	Perennial
		Anthonotha marcrophyla P. Beauv.	Perennial
		Brachyestegia eurycoma Harms.	Perennial
		Senna abbreviata Oliv.	Perennial
		Erythrophleum suaveolens Guill. & Perr.	Perennial
		Gliricidia sepium (Jacq.) Walp.	Perennial
		Millettia thonningii Schumach. & Thonn.	Perennial
13	Irvingiaceae (2)	*Irvingia gabonensis* Baill.	Perennial
		Irvingia grandifolia (Engl.) Engl.	Perennial
14	Lamiaceae (1)	*Tectona grandis* L.f.	Perennial
15	Loganiaceae (1)	*Anthocleista nobilis* G.Don	Perennial
16	Malvaceae (6)	*Bombax buonopozense* P.Beauv.	Perennial
		Cola millenii K.Schum	Perennial
		Pterygota macrocarpa K.Schum.	Perennial
		Sterculia setigera Delile	Perennial
		Theobroma cacao L.	Perennial
		Triplochiton scleroxylon K.Schum.	Perennial

Table 3. Contd.

17	Meliaceae (2)	*Cedrela odorata* L.	Perennial
		Trichilia emetica Vahl	Perennial
18	Mimosaceae (1)	*Albizia zygia* (DC.) J.F.Macbr.	Perennial
19	Moraceae (6)	*Artocarpus heterophyllus* Lam.	Perennial
		Ficus asperifolia Miq.	Perennial
		Ficus capensis Thunb.	Perennial
		Ficus exasperate Vahl	Perennial
		Ficus thonningii Blume	Perennial
		Milicia excelsa (Welw.) C.C.Berg	Perennial
20	Myristicaceae (1)	*Pycnanthus angolensis* Carl L.	Perennial
21	Phyllanthaceae (1)	*Bridelia micrantha* (Hochst.) Baill.	Perennial
22	Rubiaceae (1)	*Morinda lucida benth*	Perennial
23	Rutaceae (2)	*Citrus sinensis* (L.) Osbeck	Perennial
		Zanthoxylum zanthoxyloides Lam.	Perennial
24	Sapindaceae (2)	*Blighia sapida* K. D. Koenig	Perennial
		Lecaniodiscus cupanioides Planch.	Perennial
25	Sapotaceae (1)	*Gambeya albida (G. Don)*	Perennial
26	Solanaceae (1)	*Solanum aethiopicum* L.	Perennial
27	Sterculiaceae (2)	*Cola acuminata* Schott & Endl	Perennial
		Cola gigantea A. Chev.	Perennial
28	Ulmaceae (2)	*Celtis integrifolia* L.	Perennial
		Holoptelea grandis (Hutch.) Mildbr.	Perennial
29	Verbenaceae (1)	*Gmelina arborea* Roxb. ex Sm	Perennial
Total	29	63	63

value of trees may influence its selection for exploitation.

Species diversity indices in wet and dry seasons

The diversity indices revealing the plant community structure at CRIN secondary forest in wet season of 2018 and dry season of 2019 are presented in Table 7. The results obtained revealed that the highest numbers of taxa (87) and individuals (26,304) were obtained among herbaceous species in the wet season. However, trees had similar higher number of species (64) in wet and dry season than shrubs that also had similar number of species (49) in the wet and dry season. However, shrubs had higher number of individuals in wet (3481) and dry (2617) seasons than trees in wet (953) and dry (928) seasons. Dominance values 0.16, 0.03 and 0.03 in the wet season and 0.06, 0.03, and 0.03 in the dry season, respectively for herbaceous, shrubs and trees were low. The low values indicates that there was no predominance of a single species, all species were randomly distributed in the area in both seasons. Simpson index values 0.84, 0.97 and 0.97 in the wet season and 0.94, 0.97, 0.97 in dry season respectively for herbaceous, shrubs and trees were very high, which revealed the richness of species in the area in both seasons. The Shannon index (H') values were 2.94, 3.56 and 3.81 in the wet season and 3.54, 3.63, and 3.80 in dry season, respectively for herbaceous, shrubs and trees were high and close to the highest value in each life form type. The values obtained indicate that there are many species in both seasons, each with few individuals that are randomly distributed and none was dominant. Equitability index was higher in herbaceous in the dry season (0.83) than wet season

Table 4. Relative Importance Values of Herbaceous Species in Wet and Dry Seasons of CRIN Secondary Forest, Ibadan, Nigeria.

S/N	Species composition	RIV-WS (%)	RIV-DS (%)
1	*Abutilon mauritianum*	0.26	-
2	*Acanthus montanus*	0.16	0.35
3	*Ageratum conyzoides*	1.99	0.27
4	*Andropogon tectorum*	4.14	2.94
5	*Aneilema beniniense*	0.67	-
6	*Aspilia africana*	1.64	5.72
7	*Asystasia gangetica*	1.78	0.99
8	*Axonopus compresus*	0.76	2.31
9	*Bidens pilosa*	0.36	2.31
10	*Blepharis maderaspatensis*	0.98	1.13
11	*Boerhavia coccinea*	0.35	0.5
12	*Boerhavia diffusa*	0.19	0.61
13	*Boerhavia erecta*	0.14	1.69
14	*Brachiaria deflexa*	0.16	0.66
15	*Brachiaria falcifera*	1.47	0.37
16	*Brahiaria lata*	0.11	1.25
17	*Calopogonium mucunoides*	0.36	0.41
18	*Celosia argentea*	0.05	-
19	*Chamaecrista mimosoides*	0.23	0.25
20	*Chromolaena odorata*	25.26	12.49
21	*Cleome rutidosperma*	0.11	1.4
22	*Combretum hispidum*	0.69	0.14
23	*Commelina benghalensis*	1.15	0.39
24	*Commelina erecta*	2.45	1.19
25	*Conysa sumatrensis*	1.31	1.53
26	*Crotalaria retusa*	1.06	3.32
27	*Croton lobatus*	2.20	1.72
28	*Cynodon dactylon*	0.39	1.68
29	*Cyperus amabilis*	3.20	3.63
30	*Cyperus esculentus*	0.43	0.65
31	*Cyperus rotundus*	0.57	4.73
32	*Desmodium scorpiurus*	8.13	0.53
33	*Digitaria exilis*	0.19	-
34	*Digitaria horizontalis*	0.26	-
35	*Eleusine indica*	1.70	-
36	*Emilia coccinea*	1.36	0.94
37	*Eragrostis tremulla*	0.12	-
38	*Euphorbia hirta*	0.19	0.66
39	*Fuirena umbellata*	0.23	0.46
40	*Imperata cylindrica*	2.42	-
41	*Ipomoea aquatica*	1.02	-
42	*Ipomoea triloba*	0.07	-
43	*Laportea aestuans*	0.89	-
43	*Laportea avalifolia*	0.97	-
45	*Mallotus oppositifolius*	0.05	0.6
46	*Mariscus longibracteatus*	0.15	2.06
47	*Melanthera scandens*	0.26	1.69
48	*Mimosa pudica*	0.13	0.37
49	*Momordica charantia*	0.16	0.3
50	*Oldenlandia corymbosa*	0.05	-

Table 4. Contd.

51	*Oplismenus burmannii*	1.15	0.67
52	*Palisota hirsuta*	0.92	1.81
53	*Panicum laxum*	0.19	1.61
54	*Panicum maximum*	1.21	0.85
55	*Paspalum scrobiculatum*	0.03	-
56	*Peperomia pellucida*	0.89	3.25
57	*Perotis indica*	0.49	1.23
58	*Phyllanthus amarus*	0.13	-
59	*Phyllanthus niruri*	0.68	1.31
60	*Pouzolzia guineensis*	0.71	0.33
61	*Pteridium aquilinum*	0.31	-
62	*Pupalia lappacea*	0.53	0.49
63	*Richardia scarbra*	0.29	0.83
64	*Rungia dimorpha*	0.94	0.51
65	*Schrankia leptocarpa*	0.73	0.52
66	*Sclerocarpus africanus*	0.18	0.41
67	*Senna hirsuta*	0.10	1.58
68	*Sesamum alatum*	1.06	1.17
69	*Setaria barbata*	0.79	1.17
70	*Setaria longiseta*	0.34	1.55
71	*Setaria megaphylla*	5.14	1.31
72	*Sida acuta*	0.56	1.53
73	*Sida linifolia*	0.35	0.35
74	*Solanum macrocarpon*	2.34	0.69
75	*Solanum nigrum*	0.34	1.13
76	*Solanum torvum*	0.62	1.33
77	*Solenostemon monostacyus*	0.34	0.62
78	*Spermacoce ocymoides*	0.95	1.03
79	*Spigelia anthelmia*	0.65	0.76
80	*Spurge heterophylla*	0.56	2.02
81	*Synedrella nodiflora*	0.62	2.18
82	*Tacca leontopetaloides*	0.64	0.34
83	*Talinum fructicosum*	0.62	0.39
84	*Tithonia diversifolia*	0.22	0.49
85	*Tridax procumbens*	1.38	3.98
	Total	100.03	100

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

(0.66) and very high in shrubs in the dry season (0.93) and wet season (0.92) and trees in the wet season (0.92) and dry season (0.91). These values indicate that individuals are randomly distributed among all species in each season. There was highest similarity index (100%) between shrubs enumerated in the wet season (WSS) and shrubs enumerated in the dry season (DSS) on one hand and trees enumerated in the wet season (WST) and trees enumerated in dry season trees (DST) on another hand (Table 8). This was followed by the similarity index (76.40%) observed between WSH and DSH while the lowest similarity (1.03%) was observed between WSS and DSS compared to WST and DST. There were no similarity among herbaceous compared to shrubs and trees, respectively in both seasons.

The CRIN forest is an ecosystem with a high diversity of species in distribution and abundance. This was explained by the high Shannon-Wiener values (2.94 - 3.81) obtained for herbs, shrubs and trees in both wet and dry seasons. There were, however, deviations across seasons for the diversity of each of shrubs, herbs and trees. The trees had the highest diversity in the wet season but the shrubs had the highest diversity in the dry season. There was insignificant diversity in both wet and

Table 5. Relative importance values of shrubs species in wet and dry season of CRIN Secondary Forest, Ibadan, Nigeria.

S/N	Species	RIV-WS (%)	RIV-DS (%)
1	*Acacia macrostachya*	2.1	2.7
2	*Agelaea obligua*	4	4.1
3	*Alchornia cordifolia*	0.8	1.0
4	*Angylocalyx oligophyllus*	1.4	1.7
5	*Clerodendron capitatum*	1.3	1.7
6	*Cnestis ferruginea*	3.1	3.9
7	*Coffea canephora*	2.7	2.6
8	*Corynanthe pachyceras*	3.5	3.7
9	*Deinbollia pinnata*	2.2	2.8
10	*Desplatsia subericarpa*	0.6	0.7
11	*Dracaena deisteiliana*	0.1	0.1
12	*Euadenia trifoliata*	1.5	1.9
13	*Euclinia longifolia*	3.7	4.1
14	*Grewia mollis*	0.8	1.0
15	*Hunteria umbellata*	1.7	2.1
16	*Icacinia trichanta*	1.3	1.6
17	*Jatropha curcas*	3.2	2.0
18	*Keetia venosa*	0.5	0.7
19	*Lonchocarpus cyanescens*	4.7	5.8
20	*Lonchocarpus griffonianus*	8.8	7.8
21	*Markhamia tomentosa*	8.5	9.0
22	*Microdesmis puberula*	2.4	2.6
23	*Musa paradisiaca*	3.5	3.1
24	*Pavetta corymbosa*	5.3	2.1
25	*Pleioceras barteri*	0.6	3.0
26	*Psilanthus ebracteolatus*	4.4	0.7
27	*Psychotria fimbriatifolia*	1.3	5.6
28	*Psychotria sciandephora*	6.7	1.7
29	*Rauwolfia vomitoria*	4.3	6.7
30	*Rytiginia umbellata*	3.1	4.8
31	*Solanum erianthum*	7.7	1.3
32	*Solanum torvum*	2.2	5.6
33	*Trichilia prieuriana*	1.3	1.7
		99.3	100.0

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

dry season for herbaceous species. The seasonal similarity in herbs diversity may be attributed to the fallow management in a historically less stressed landscape. This supported the findings that soil conditions, inadequate rainfall pattern and excessive temperature may alter diversity and allows the support of few numbers of herbaceous flora in the forest ecosystem (Thakur, 2018). The forest is diverse with mixed species of herbs, shrubs and trees. This was responsible for the low dominance values in the vegetation structure (herbs, trees and shrubs) of both seasons in the CRIN forest. The seasonal changes did not affect dominance of trees, but shrubs and herbs species dominance increased in the dry season. The few species that can survive the low moisture in the dry season were all well represented. This was also explained by high evenness values obtained for trees, shrubs and herbs in both seasons. The seasonal variation in species diversity of herbs and shrubs agreed with the report of Lu et al. (2010) that suggested high species diversity of herbs with seasonal changes. Also, the increase in diversity of species of herbs and shrubs in the dry season as shown by evenness values may further be attributed to other factors apart from the climate. Moreno and Halffter (2001) and Tuomisto et al. (2003) suggested that landscape pattern and climatic conditions may influence species diversity of an ecosystem. It was

Table 6. Relative importance values of trees species in wet and dry seasons of CRIN Secondary Forest of Ibadan, Nigeria.

S/N	Species	RIV-WS (%)	RIV-DS (%)
1	*Afzelia africana*	0.24	0.24
2	*Albizia adianthifolia*	3.89	0.59
3	*Albizia coriaria*	2.06	1.97
4	*Albizia ferruginea*	0.4	1.1
5	*Albizia glaberrim.*	1.41	0.69
6	*Albizia gummifera*	1.01	0.41
7	*Albizia julibrissin*	2.95	2.85
8	*Albizia zygia*	1.36	1.38
9	*Alstonia boonei*	1.12	1.13
10	*Anacardium occidentale*	0.62	0.64
11	*Anthocleista nobilis*	3.6	3.65
12	*Anthonotha marcrophyla*	1.6	0.58
13	*Artocarpus heterophyllus*	1.23	1.61
14	*Blighia sapida*	0.94	1.25
15	*Bombax buonopozense*	2.63	0.95
16	*Brachyestegia eurycoma*	0.24	0.24
17	*Bridelia micrantha*	0.46	2.66
18	*Cedrela odorata*	1.31	1.32
19	*Ceiba pentandra*	2.19	2.21
20	*Celtis integrifolia*	3.2	3.24
21	*Celtis zenkerii*	3.84	3.89
22	*Citrus sinensis*	0.29	0.3
23	*Cleistopholis patens*	0.7	0.65
24	*Cola acuminata*	1.49	1.51
25	*Cola gigantea*	0.46	0.47
26	*Cola millenii*	2.57	2.6
27	*Cordia millenii*	1.6	1.61
28	*Cordia platythyrsa*	1.36	1.37
29	*Elaeis guineensis*	0.57	0.52
30	*Erythrophleum suaveolens*	0.51	0.96
31	*Ficus asperifolia*	0.96	2.31
32	*Ficus capensis*	2.28	1
33	*Ficus exasperate*	0.99	0.84
34	*Ficus thonningii*	0.83	0.96
35	*Funtumia africana*	0.96	3.95
36	*Gambeya albida*	0.24	0.24
37	*Garcinia kola*	3.13	0.95
38	*Gliricidia sepium*	0.94	1
39	*Gmelina arborea*	1.03	0.97
40	*Holoptelea grandis*	0.99	0.47
41	*Irvingia gabonensis*	0.95	3.07
42	*Irvingia grandifolia*	3.03	3.16
43	*Lecaniodiscus cupanioides*	0.24	0.24
44	*Macaranga barteri*	0.59	1.1
45	*Milicia excelsa*	0.86	0.88
46	*Millettia thonningii*	0.53	0.54
47	*Morinda lucida*	2	1.05
48	*Newbouldia laevis*	1.23	1.97
49	*Plumeria rubra*	0.53	1.25
50	*Pterygota macrocarpa*	3.91	3.97

Table 6. Contd.

51	*Pycnanthus angolensis*	1.12	0.54
52	*Rauvolfia vomitoria*	0.48	1.13
53	*Ricinodendron heudelotii*	1.74	0.48
54	*Senna abbreviata*	1.08	1.78
55	*Solanum aethiopicum*	0.53	0.54
56	*Sterculia setigera*	3.5	3.56
57	*Tectona grandis*	1.88	1.93
58	*Terminalia ivorensis*	0.35	0.35
59	*Terminalia superba*	4.99	5.66
60	*Theobroma cacao*	2.75	2.8
61	*Trichilia emetica*	2.02	2.05
62	*Triplochiton scleroxylon*	5.64	4.96
63	*Zanthoxylum zanthoxyloides*	1.85	1.71
		100	100

RIV = Relative Importance Value, WS = Wet Season, DS = Dry Season.

Table 7. Species diversity indices in wet and dry seasons in CRIN Secondary Forest, Ibadan, Nigeria.

Diversity index	RSH	DSH	RSS	DSS	RST	DST
Taxa_S	86	70	49	49	63	63
Individuals	26304	13490	3481	2617	953	928
Dominance_D	0.16	0.06	0.03	0.03	0.03	0.03
Simpson_1-D	0.84	0.94	0.97	0.97	0.97	0.97
Shannon_H`	2.94	3.54	3.56	3.63	3.81	3.8
Equitability_J	0.66	0.83	0.92	0.93	0.92	0.91

RSH= Field herbaceous in Wet Season, RSS = Field shrubs in Wet Season, RST = Field trees in Wet Season, DSH = Field herbaceous in Dry Season, DSS = Field shrubs in Dry Season, and DST = Field trees in Dry season.

similarly reported that ecological legacies including anthropogenic perturbation especially deforestation, intermediate succession and regeneration potential in the ecosystem of a forest which has not reached is a climax. Though herbs had less number of taxa in the dry season than wet season, the diversity was higher in the dry season than wet season. The implication of this result is that the few species that survived the stress of dry season were all randomly distributed with no particular species dominant. This agreed with the findings of Thakur (2018) that the diversity of herbaceous species in the mixed forest was highest in a study conducted in the dry tropical forest of India. The CRIN forest recorded high species richness (taxa) for herbs, shrubs and trees in both seasons. The species richness of herbs was high in the wet season but for the species richness of shrubs and trees, there was no difference across the season. The openness and closure of forest may influence species richness. The secondary forest may have a closed canopy of trees in the wet season, which may favour the shade loving species (sciophytes), annuals and perennials. However, the open canopy in the dry season may result in the loss of sciophytes and annuals. This was further stressed in the reports of Tang et al. (2010) and Awodoyin et al. (2013) that varying herbaceous species that are shade-loving (sciophytes), annuals and perennial plants are favoured in a closed canopy forest. However, high species diversity of trees indicates a resilience forest with mixed tree species population which may, however, enhance vegetation restoration for the continuous growth of the forest to climax (Tang et al., 2010).

Conclusion

This study revealed a recovering forest from previous degradation due to unsustainable anthropogenic practices. The flora species abundance and composition indicated heterogeneity among trees, herbs and shrubs

Table 8. Similarity between various vegetation types based on their species composition in CRIN secondary forest, Ibadan, Nigeria.

Correlation	WSH	DSH	WSS	DSS	WST	DST
WSH	-					
DSH	76.4	-				
WSS	0	0	-			
DSS	0	0	100	-		
WST	0	0	1.03	1.03	-	
DST	0	0	1.03	1.03	100	-

WSH= Herbaceous in Wet Season, WSS = Shrubs in Wet Season, WST = Trees in Wet Season, DSH = Herbaceous in Dry Season, DSS = Shrubs in Dry Season, and DST = Trees in Dry season.

enumerated. The presence of *C. odorata* in both wet and dry season indicated an ubiquitous herbaceous species which must have been introduced through anthropogenic activities since the plant is a known invasive species in Nigeria. Meanwhile, *T. scleroxylon* and *T. superba* are commonest trees species enumerated in wet and dry season, respectively. These are endemic tree species of importance in Nigeria, suggesting presence of degraded primary forest remnants. The abundance of shrub species however suggested the potential of the forest for resilience. High species diversity and similarity in species across seasons also indicated wide and random distribution of various herbs, shrubs and tree species in the study site. It is recommended that endangered trees endemic to Nigeria such as *T. scleroxylon* and *T. superba* should be adequately protected for sustainable forest resources conservation. Invasive species such as *C. odorata* should be managed in order to prevent homogeneity of the forest landscape. CRIN secondary forest has a potential to improve biodiversity and other ecosystem goods and services due to its resilience potential with its high diversity. Therefore, it should be protected from illegal exploitation of forest resources in order to ensure an *in-situ* conservation of genetic resources present.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Traditional uses of African rosewood (*Pterocarpus erinaceus* Poir. Fabaceae) through the sociolinguistic groups and the pathways of conservation and sustainable management in Benin

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***Pterocarpus erinaceus* Poir, a spontaneous species from Guinean savannahs of West Africa, functions as socio-economic and cultural livelihood in rural areas of Benin. This study improved the knowledge of people about the uses of *P. erinaceus* organs connected to the sociolinguistic diversity in Benin, intending to enhance the pathways of conservation and sustainable management of the species. A total of 506 respondents from nine big sociolinguistic groups were interviewed using a survey questionnaire. To show the diversity of the organs/parts used as well as the categories of uses, principal component analyzes were performed to matrices including the relative frequencies of citation grouping the socio-demographic factors and the categories of uses, together under the packages FactoMineR and factoextra. The results revealed the use of all *P. erinaceus* organs in various forms of use for various purposes and make it an important species of livelihood for the local people. Sixty-four diseases, symptoms, or pathologies are cured by using *P. erinaceus* organs. These various uses of *P. erinaceus* varied among the sociolinguistic groups. The results of the study suggest the need to define conservation strategies for the natural stands of *P. erinaceus* to ensure sustainable management of the species.**

Key words: Forest livelihoods, traditional uses, ethnomedicinal knowledge, conservation, principal component analysis, West Africa.

INTRODUCTION

To satisfy their staple needs, people strongly use plant species on which they depend. For that, many people value species as a source of food and medicine, providing means of subsistence and wealth to humans (IUCN Red List Committee, 2013). That leads scientists to be interested in the studies about traditional knowledge

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of plant species in consideration to socio-demographic, ecological, and botanical factors, such as sociolinguistic groups, livelihood activities, age, gender, habitats, areas of occurrence of species, etc. (Agbo et al., 2020; Wanjohi et al., 2020; Salako et al., 2018; Assogbadjo et al., 2008). Such studies have grown very interesting in sustainable management of endangered species because they allow assessing the differences of knowledge about the choice and use of plant resources by sociodemographic groups for defining priorities, planning, and monitoring conservation (Dovie et al., 2008). The ecological knowledge of people about plant species and their habitats could contribute to working out co-management strategies of plant resources for sustainable management of the environment (Wanjohi et al., 2020). Knowledge of local names facilitates the identification and assessment of species because they provide more information about the uses of species, ecology, plant interactions, and morphological traits (Agbo et al., 2020).

Pterocarpus erinaceus Poir is among those polyvalent species listed as endangered on the IUCN Red List (Barstow, 2018). It is also listed on CITES Appendix II since 2016. It is quite threatened throughout its distribution range because the wood has higher trade value (Dumenu, 2019; EIA, 2017). The leaves have higher nutrient quality and are used like fodder in ruminant breeding (Ouachinou et al., 2018; Rabiou et al., 2017a). Traditionally, the species is used in the treatment of many diseases, and symptoms in animals (Ouachinou et al., 2019; Dassou et al., 2015) and humans. Consequently, the natural stands have experienced decline and tend to extinction in several countries. The first affected countries were Benin, Guinea Bissau, Côte d'Ivoire, Gambia, Ghana, and Nigeria. Facing that issue, some exporting countries of the wood of *P. erinaceus*, including Benin, Burkina Faso, Côte d'Ivoire, Mali, Nigeria, and Sierra Leone have taken restrictions to forbid the wood logging and export for some years but, much quantity of the wood continues to quit these countries to China (EIA, 2017).

P. erinaceus occurs in Guinean savannahs of West Africa. Its distribution range stretches from the south to the north of Benin. It is found in the three ecological zones (Guinean, Guinean-Sudanese, and Sudanese zones) as natural stands in woodlands and savannahs. Though the banning of cutting and export of the timber, *P. erinaceus* is overexploited for other uses which bring about serious consequences on its relict stands as well as the environment. Currently, *P. erinaceus* is subjected to strong disturbances caused by the use forms of the organs in some regions of Benin while the previous studies on the traditional uses are mainly based on its potential in the treatment of diseases and symptoms in cattle (see Ouachinou et al., 2019, 2018; Dassou et al., 2015). Thus, the importance of the plant in the livelihood of people is still unappreciated. Agbani et al. (2018) reported that at Atakora Mountain Range, *P. erinaceus* is used by the people to substitute others threatened woody species, such as *Khaya senegalensis* (Desv.) A. Juss, *Afzelia africana* Smith ex Pers., *Borassus aethiopum* Mart., but they do not provide quite details about the local uses of *P. erinaceus*. That is required to understand the importance of the plant for the people life, its specific uses, and which potential risk for the conservation and restoration of relict stands. By spreading the study to the three ecological zones and several big sociolinguistic groups, we can provide detailed knowledge on the local uses of the species and additional insights on its forest livelihood potential. The study's purposes were to examine the various uses made with the organs of *P. erinaceus* in Benin connected to the sociolinguistic diversity, to enhance the body of knowledge in local practices on *P. erinaceus*, and to highlight the pathways for its conservation and sustainable management. Specifically, the study was designed to determine the (i) ethnoecological knowledge on *P. erinaceus* across the three ecological zones of Benin, (ii) uses made of the organs of *P. erinaceus* by the sociolinguistic groups, and (iii) implications of the local uses of the species on its conservation status.

MATERIALS AND METHODS

Study area

This study was conducted in the Republic of Benin, West Africa. It is bordered by the Atlantic Ocean to the south, Togo to the west, Nigeria to the east, Burkina Faso, and Niger to the north. The country covers a 114,763 km^2 area, whose total population is 10,008,749 inhabitants, making a population density of 87.2 inhabitants per square kilometer (INSAE, 2013). Although it is a sub-Saharan country in the eastern part of the Guinean Dense Humid Forests Ecoregion, it is outside the natural ranges of the Diversity Centres of Upper and Lower Guinea. The surveys were conducted across eighteen townships out of seventy-seven: Covè, Bohicon, Abomey (in the Guinean zone), Djidja, Dassa, Savalou, Bantè, Glazoué, Savè, Ouèssè, Tchaourou, Parakou, Kalalé (in the Guinean-Sudanese zone), Péhunco, Ségbana, Kandi, Malanville, Djougou (in the Sudanian zone). The total population in these eighteen townships is 2,794,728 inhabitants, corresponding to 27.92% out of the total population of Benin. The Figure 1 shows an overview of the study area.

Sampling and data collection

Data were collected from September to November 2018. The eighteen townships considered for the study were picked out based on the local distribution range and the abundance of the target species. Nine sociolinguistic groups were surveyed across the eighteen townships. The sample size was calculated per sociolinguistic group. Preliminary surveys with fifty respondents picked out at random per sociolinguistic group enabled us to determine the proportion (p) out of respondents who know *P. erinaceus* and directly use it, or its organs as a source of livelihoods, such as selling of organs, food, medicine, fodder, or any other uses for specific purposes. Thereafter, the number of respondents in each sociolinguistic group was calculated as follows (Levy and Lemeshow, 2008; Dagnelie, 1998):

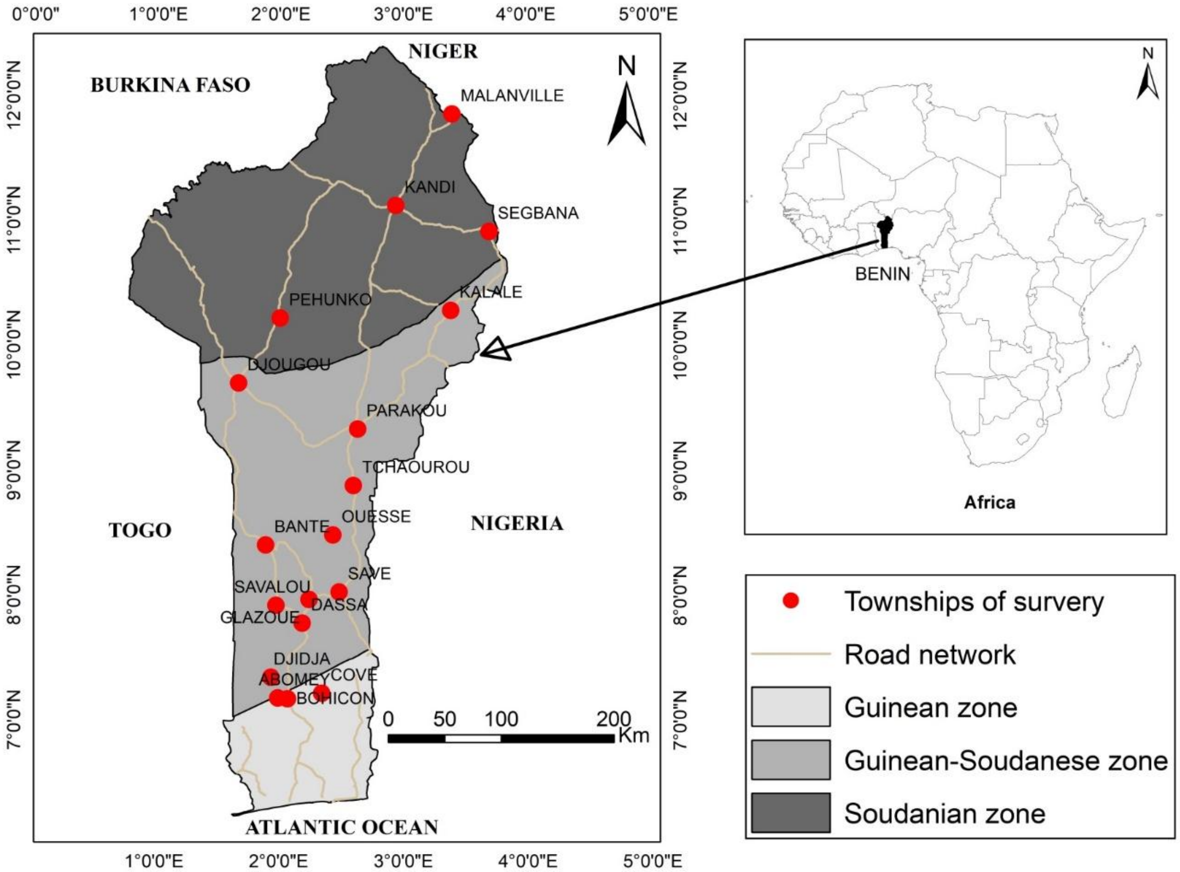

Figure 1. Location of the country and townships of the study.

$$N = \left[U^2_{(1-\alpha/_2)} \Big/ _{d^2} \right] \times [p(1-p)]$$

N is the sample size per sociolinguistic group, *p* is the proportion of respondents who use the plant in each sociolinguistic group, computed after the preliminary surveys, d = *9%* is the sampling error admitted, and $U_{(1-\alpha/_2)}$ is the normal random variable (with α = 5%, $U_{(1-\alpha/_2)}$ = 1.96). The proportion of respondents on the sociolinguistic groups Nago and Fon were p = 0.88 and 0.76, respectively. That means N = 50 and 87 respondents were interviewed on the sociolinguistic groups Nago and Fon, respectively. The same approach was used to determine the sample size for the other sociolinguistic groups (Table 1). A total of five hundred and six (506) respondents were surveyed across the three ecological zones.

Data analysis

Data analysis was carried out based on five factors: ecological zones (EZ); sociolinguistic groups; age; gender; and livelihood activities. Three age classes were made according to Assogbadjo et al. (2008): young respondents (age ≤ 30 years); adult respondents (30 < age < 60); old respondents (age ≥ 60 years). To describe the people's perception of the ecology (habitat) of *P. erinaceus*, we performed the chi-square test of independence on the *n x p* matrix (with *n* the ecological zones, and *p* the habitats of the species). The relative frequencies of citation (RFC) (Salako et al., 2018; Houehanou et al., 2011; Tardío and Pardo-de-Santayana, 2008) for each habitat were then calculated to describe the habitat variation according to the EZ using the following formula:

$$RFC = {}^{x}/_{N}$$

x is the absolute frequency and N is the total number of respondents for each modality of the considered factor (eg: x = *20* and N = *100* to mean twenty respondents out of one hundred respondents specified woodland as habitat of *P. erinaceus*).

To highlight the categories of uses and the most organs/parts reported, multiple proportion comparison tests were performed and proportions were structured under the libraries multcompView (Graves et al., 2019) and PMCMR (Pohlert, 2014). We performed principal component analyses to describe the diversification of the categories of uses, such as human food (as a vegetable), animal food (as fodder), handicraft, carbonization, timber, firewood, and symbolic uses in traditional ceremonies such as dowry. We used the matrices comprising the RFC grouping the socio-demographic factors (sociolinguistic group, gender, age, and livelihood activities) and the categories of uses, together under the libraries FactoMineR (Le et al., 2008) and factoextra (Alboukadel and Mundt, 2020). All statistical analyses were performed in R software version 3.6.0 (R Core Team, 2019).

Table 1. Number of respondents per sociolinguistic group in the eighteen townships.

Sociolinguistic groups	Local names of *P. erinaceus*	Townships	Sample size		
			p	*N*	Relative frequencies (%)
Fon	Kosso/Kozo	Abomey, Bohicon, Covè, Djidja	0.76	87	17.13
Dendi	Tolo	Djougou, Malanville, Parakou	0.78	81	16.12
Idaatcha	Akpékpé	Dassa	0.80	76	15.03
Boo	Kpinli	Ségbana	0.84	64	12.62
Bariba	Tonan	Kandi, Parakou	0.86	57	11.31
Nago	Egui-Enian/Aïkpé	Savè, Tchaourou	0.88	50	09.92
Itcha	Akpékpé	Bantè	0.90	44	08.71
Mahi	Kosso	Glazoué, Savalou, Ouèssè	0.94	27	05.30
Peulh	Banouhi	Kalalé, Péhunco	0.96	20	03.96
Total				506	100.00

p: Proportion of respondents who know *Pterocarpus erinaceus* and directely use it, or its organs as a source of livelihood, *N*: sample size.

RESULTS

Sociodemographic and economic characteristics of the respondents

Table 2 shows the sociodemographic and economic characteristics of the respondents. The number of male respondents was 428 (84.58%) while the number of female respondents was 78 (15.42%). Regarding the ecological zones, a great number of respondents lived in Guinean-Soudanese (39.72% males and 7.51% females) and Soudanian (32.21% males and 6.13% females) zones. Regarding the age, 36.17% of respondents were between 30 and 60 years old while 48.81% of respondents were >60 years old. Regarding the livelihood activities, seven categories were considered. Farmers (39.92%) and traditherapists (36.17%) were the majority while the nurserymen were the minority (2.17%). Regarding the sociolinguistic groups, Fon, Dendi, Idaatcha, Boo, and Bariba were the majority while the sociolinguistic groups Mahi and Peulh were the minority (Table 2).

Ethnoecological knowledge on *Pterocarpus erinaceus*

According to the respondents, *P. erinaceus* occurred in woodlands (44.8% of respondents), farms (34.82% of respondents), fallows (15.56%), and savannahs (4.78%). However, woodlands and savannahs were suitable habitats known in ancient times. People's perceptions of the species' habitat differed significantly among ecological zones ($\chi 2$ = 81.91, df = 6, Prob. < 0.001). Thus, whatever the ecological zone, the respondents indicated that farms and forests were suitable habitats. Additionally, the people living in the Sudanian, and the Guinean-Soudanese zones have also mentioned fallows as a suitable habitat. In the Guinean-Soudanese zone, the respondents exclusively mentioned savannahs as a suitable habitat for the species.

Traditional uses of *Pterocarpus erinaceus* and their importance for the livelihood of people

P. erinaceus is known and directly used as a medicinal plant for fifty-seven pathologies, symptoms, and diseases listed by respondents (Table 3). However, knowledge on the use of the species in traditional medicine varied among the sociolinguistic groups. The plant is used to cure numerous human health disorders, including malaria, fever, hernia, anemia, metrorrhagia, menstrual pain, irregular menses, abscess, hemorrhoid, headaches, stomach hurt, tooth decay, mental disorders, skin infections, oedema, paralysis of limbs, sight troubles, women infertility, gastric ulcer, intestinal worms, general tiredness, typhoid fever, dizziness, urinary tract infections (Table 3). Leaves, barks, and roots were the organs used more in traditional medicine. The sociolinguistic group Peulh used the barks and roots to treat wounds, colic, constipation, viral anemia, diarrhea, calving difficulties, hemorrhage, infectious disorders, toothache, the bite of a snake, peripneumonia, and for giving cattle an appetite (Table 3). The sociolinguistic group Itcha used the plant to treat infections and measles while the sociolinguistic group Boo used the plant to treat abscess, acne pimples, whitlow, and stings of the scorpion. The sociolinguistic group Bariba used the plant to treat ringworm and wounds while sociolinguistic group Dendi used it to treat the bite of snake in cattle, stings of the scorpion, and sight troubles. In addition, Bariba, Nago, and Boo reported that leaves, roots, and bark were used for evil spirits, and to prevent bewitchments. These organs are particularly used by Bariba for wedding officiation to ensure peace and love in the households (Table 3).

Table 2. Sociodemographic and economic characteristics of the respondents.

Variable	Modalities	Ecological zones			
		Guinean	Guinean-Soudanese	Soudanian	Total (%)
Gender	Females	9(1.78)	38(7.51)	31(6.13)	78(15.42)
	Males	64(12.65)	201(39.72)	163(32.21)	428(84.58)
Age (years)	Young: <30	14(2.77)	37(7.31)	25(4.94)	76(15.02)
	Adult: 30 - 60	31(6.13)	117(23.12)	99(19.57)	247(48.81)
	Old: >60	49(9.68)	83(16.40)	51(10.08)	183(36.17)
Livelihood activities	Farming	26(5.14)	92(18.18)	84(16.60)	202(39.92)
	Traditional medicine (Traditherapists)	16(3.16)	51(10.08)	116(22.92)	183(36.17)
	Charcoal production	6(1.19)	13(2.57)	20(3.95)	39(7.71)
	Logging (Sawyers)	4(0.79)	9(1.78)	13(2.57)	26(5.14)
	Carpenters	11(2.17)	5(0.99)	9(1.78)	25(4.94)
	Cattle breeding	3(0.59)	7(1.38)	10(1.98)	20(3.95)
	Forest plants production (Nurserymen)	2(0.40)	5(0.99)	4(0.79)	11(2.17)
Sociolinguistic groups	Fon	68(13.44)	19(3.75)	-	87(17.19)
	Dendi	-	24(4.74)	57(11.26)	81(16.01)
	Idaatcha	-	62(12.25)	14(2.77)	76(15.02)
	Boo	-	-	64(12.65)	64(12.65)
	Bariba	-	13(2.57)	44(8.70)	57(11.26)
	Nago	-	45(8.90)	5(0.99)	50(9.88)
	Itcha	-	44(8.70)	-	44(8.70)
	Mahi	2(0.40)	25(4.94)	-	27(5.34)
	Peulh	3(0.59)	7(1.38)	10(1.98)	20(3.95)

Values without brackets are numbers of respondents and values in brackets are percentages of respondents. Dashs in the table indicate no respondent.

Sociodemographic factors influencing the uses of *Pterocarpus erinaceus*

The frequencies of citation of the use categories differed significantly (χ^2 = 967.93, ddl = 7, Prob. < 0.001; Table 4). Thus, respondents primarily used the species like timber and service wood (25.66% and 25.41% as RFC values, respectively; Figure 2). They also make use of it for medicinal purposes and fodder sources in cattle (20.96% and 19.67% as RFC values, respectively; Figure 2). In addition, there was dependence of the use categories with the ecological zones (EZ), gender, sociolinguistic groups, and livelihood activities of the respondents (Prob. < 0.05). Thus, only men used *P. erinaceus* in handicrafts. The uses like firewood and lumber had the same importance for both men and women. On the other hand, men used more of the species for charcoal production while women used its leaves in food, like a vegetable. The use of handicraft was noted in both Guinean-Sudanese and Sudanian zones while the symbolic use was noted in both Guinean and Guinean-Sudanese zones. The use as food in humans was noted exclusively in Guinean-Sudanese zone.

Principal component analysis (PCA) performed on the RFC of the use categories and sociolinguistic groups showed that the first two PC saved 85.7% of the initial information (Figure 3a). The use categories, such as food (vegetable and fodder), firewood, timber (technology), and handicraft were correlated strongly (| Correlation | ≥ 0.5) with the first PC while carbonization (charcoal production) correlated with the second PC. Thus, the projection of the sociolinguistic groups into the two PC showed that the sociolinguistic groups Bariba, Boo, Dendi, Fon, Itcha, and Mahi used more *P. erinaceus* like vegetable (for human food), fodder, firewood, timber, and handicraft whereas the sociolinguistic group Idaatcha used more of it for carbonization (Figure 3a). On the other hand, the PCA performed on the RFC of the use categories and livelihood activities showed that the first two PC saved 61.3% of the initial information (Figure 3b). The use categories, such as timber, firewood, carbonization, and human food were correlated strongly (| Correlation | ≥ 0.5) with the first PC while the use for animal food correlated with the second PC. The projection of the livelihood activities into the two PC showed that charcoal makers, farmers, and lumberjacks

Table 3. Traditional knowledge and medicinal importance of *Pterocarpus erinaceus* through the sociolinguistic groups surveyed in Benin.

Local uses for diseases, symptoms or pathologies	Organs / parts	Use categories	Sociolinguistic groups
Abortion	Barks, leaves, roots	Medicinal	Bariba, Boo
Abscess	Barks, leaves, sap	Medicinal	Bariba, Boo, Mahi
Acne pimples	Sap	Medicinal	Boo
Anemia	Barks, leaves, roots	Medicinal	Bariba, Peulh, Dendi, Nago, Boo, Mahi, Fon, Idaatcha, Itcha
Asthenia in human and cattle	Barks, roots, leaves	Medicinal, veterinary	Peulh, Boo
Babies fontanel	Roots	Medicinal	Bariba
Bewitchment	Barks, roots, leaves	Magic	Peulh, Nago, Boo
Bite of snake	Barks	Veterinary	Peulh, Dendi, Boo
Bloated belly	Barks	Medicinal, veterinary	Boo
Calving difficulties	Barks	Veterinary	Peulh
Colic in cattle	Barks	Veterinary	Peulh
Constipation in cattle	Barks	Veterinary	Peulh
Cough	Barks	Medicinal	Nago, Boo
Couple union	Barks	Magic	Bariba
Dental carrie	Barks, leaves	Medicinal	Bariba, Dendi
Diabetes	Barks, roots, leaves	Medicinal	Nago, Fon, Itcha
Diarrhea in human and cattle	Leaves, barks	Medicinal, veterinary	Peulh, Boo, Itcha
Dizziness	Barks, leaves	Medicinal	Bariba
Emaciation in cattle (Loss in weight)	Barks, leaves, roots	Fodder, veterinary	Bariba, Peulh
Evil spirits	Barks	Magic	Bariba, Dendi, Nago
Fever	Barks, leaves	Medicinal	Bariba, Dendi, Nago, Mahi, Fon, Idaatcha
Gastric ulcer	Barks, roots	Medicinal	Bariba, Dendi, Nago
Gonorrhea	Roots, leaves, barks	Medicinal	Bariba, Mahi, Itcha
Headache	Barks, leaves	Medicinal	
Hemorrhage in cattle	Barks, leaves, roots	Veterinary	Bariba, Peulh, Dendi
Hemorrhoid	Barks, leaves, roots	Medicinal	Bariba, Peulh, Dendi, Fon, Idaatcha, Itcha
Hernia	Barks, leaves, roots	Medicinal	Bariba, Idaatcha
High blood pressure	Leaves	Medicinal	Mahi
Hypertension	Barks, roots	Medicinal	Peulh
Hypotonia in children	Barks, roots	Medicinal	Peulh, Dendi, Nago, Mahi, Fon, Idaatcha
Infectious disorders	Barks, sap	Medicinal, Veterinary	Peulh, Dendi, Nago, Mahi, Itcha
Infertility in women	Barks, roots	Medicinal	Peulh, Mahi, Fon, Itcha
Intestinal worms	Barks, roots	Medicinal, veterinary	Bariba, Peulh, Itch
Irregular menstruation	Barks	Medicinal	Bariba, Dendi, Nago, Boo, Mahi
Itching	Barks, roots, leaves	Medicinal	Nago, Itcha
Leprosy	Barks	Medicinal	Mahi
Lower abdomen pain	Roots	Medicinal	Itcha
Malaria	Barks, roots, leaves		Peulh, Dendi, Boo, Mahi, Fon, Itcha
Mange in cattle	Leaves	Veterinary	Peulh
Measles	Barks, roots, sap	Medicinal	Nago, Mahi, Idaatcha, Itcha
Menstrual pain	Barks, leaves, roots	Medicinal	Bariba, Peulh, Dendi, Boo, Mahi, Idaatcha, Itcha
Mental disorders	Barks, leaves	Medicinal	Bariba
Metrorrhagia	Barks, leaves	Medicinal	Bariba, Dendi
Oedema	Barks, leaves, roots	Medicinal	Bariba
Paralysis of the lower limbs	Barks, leaves	Medicinal	Bariba
Pleuropneumonia in cattle	Barks	Veterinary	Peulh
Ringworm	Sap	Medicinal	Bariba, Peulh
Rheumatism	Roots	Medicinal	Boo
Sickle cell	Leaves, roots	Medicinal	Peulh, Fon
Sight troubles	Barks, roots, sap	Medicinal	Bariba, Peulh, Dendi, Nago

Table 3. Contd.

Skin infections	Barks, leaves, sap	Medicinal	Bariba, Peulh, Dendi
Spoiling of appetite	Barks	Veterinary	Peulh, Boo
Stings of scorpion	Sap, roots	Medicinal	Dendi, Boo
Stomach hurt	Barks, leaves, roots	Medicinal	Bariba, Peulh, Dendi, Mahi, Fon, Idaatcha, Itcha
Teething	Barks, roots	Medicinal	Dendi, Fon
Tiredness	Barks, leaves, roots	Medicinal	Bariba, Peulh, Nago, Mahi, Fon, Idaatcha, Itcha
Tooth hurt	Barks	Medicinal	Peulh
Typhoid fever	Barks, leaves	Medicinal	Bariba
Urinary tract infections	Barks, leaves	Medicinal	Bariba
Vaginal bleeding	Roots, leaves	Medicinal	Bariba, Boo
Viral diarrhea in cattle	Barks	Veterinary	Peulh
Virility	Roots	Medicinal	Nago, Boo, Fon
Whitlow	Sap	Medicinal	Boo
Wounds	Sap, barks	Medicinal	Bariba, Peulh, Mahi

Table 4. Dependence of the frequencies of citation with use categories and sociodemographic factors.

Sociodemographic factors	Df	χ^2	P-value
Ecological zone	12	58.27	< 0.001
Age	12	13.92	0.306
Gender	06	19.99	0.003
Sociolinguistic group	48	80.21	0.002
Livelihood activities	48	115.05	< 0.001

used more *P. erinaceus* for carbonization, firewood, and timber while breeders used more of it as fodder for feeding cattle (Figure 3b).

Uses of the organs of *Pterocarpus erinaceus* accross the sociolinguistic groups

The most organs harvested are the trunks (25.43%), branches (23.90%), leaves (23.14%), and barks (22.09%) (Figure 4).

Figure 5 shows the results of the PCA performed on the RFC of the organs of *P. erinaceus* and the sociodemographic factors. It shows that the first two PC saved 70% of the initial information on the sociodemographic factors and the organs of the species. The correlation matrices show a strong correlation (|Correlation| ≥ 0.5) among both the Guinean and Sudanian zones and the first PC while the Guinean-Soudanese zone correlated with the second PC. Thus, the projection of the organs into the first two PC showed that the trunk, leaves, barks, branches, and seeds were the most organs used in both the Guinean and Sudanian zones while the roots and latex were used more in the Guinean-Sudanese zone (Figure 5a). Figure 5b shows that both young and adult categories of age correlated strongly (|Correlation| ≥ 0.5) with the first PC while the category old correlated with the second PC. Thus, the projection of the organs into the two PC showed that the trunk, leaves, roots, branches, seeds, and latex were heavily harvested by young and adult respondents while barks were sought more by old respondents (Figure 5b). Regarding the sociolinguistic groups, Bariba, Boo, Peulh, Dendi, Mahi, and Nago correlated strongly with the first PC while Itcha correlated with the second PC and Fon with the third PC. Thus, the projection of the organs into the first three PC showed that the trunk, leaves, barks, and branches were the most organs used by Bariba, Boo, Peulh, Dendi, Mahi, and Nago while both the roots and latex were used more by Itcha, and the seeds were used more by Fon (Figure 5c and d). Figure 5e shows that the livelihood activities, traditional medicine (traditherapists), and logging (sawyers) correlated strongly with the first PC while both farming (farmers) and forest plants production (nurserymen) correlated strongly with the second PC. The projection of the organs into the two PC showed that the trunk, leaves, barks, and branches were used more by the respondents who practice traditional medicine and logging while farmers and nurserymen used more of the roots (Figure 5e).

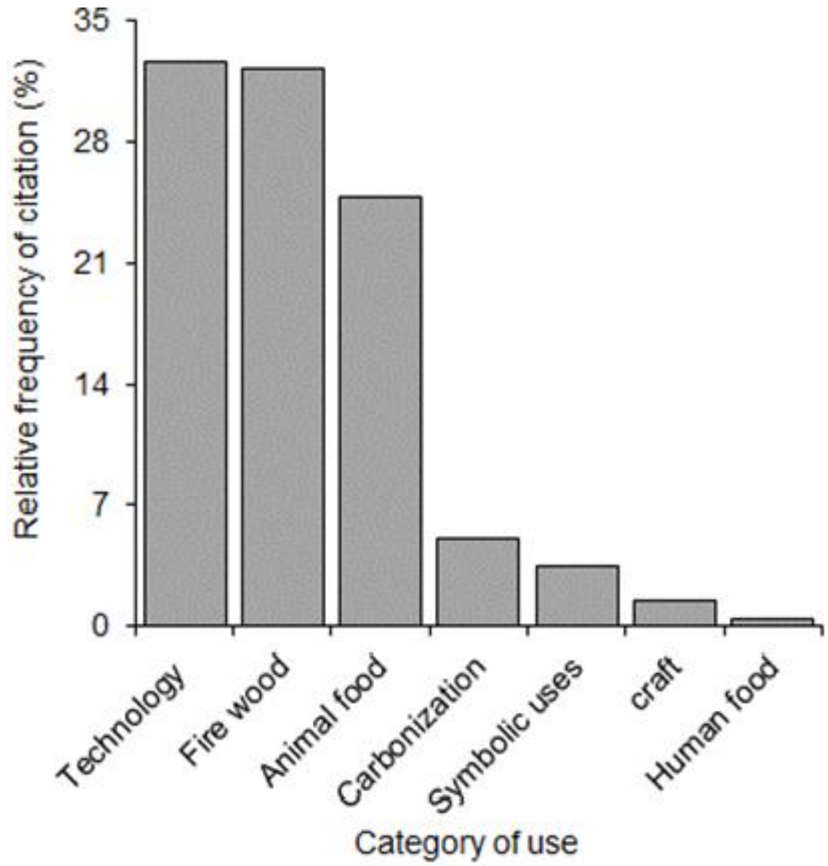

Figure 2. Importance of the use categories of *Pterocarpus erinaceus* for the respondents.

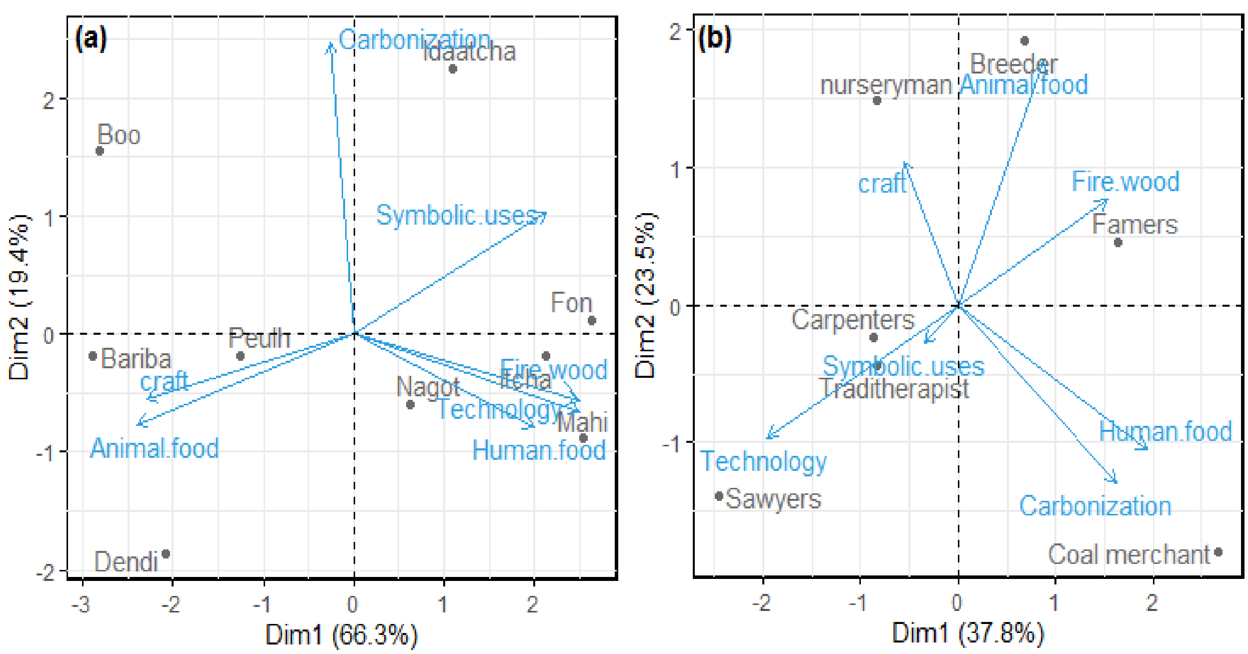

Figure 3. Relationship among the sociolinguistic groups (a), livelihood activities (b), and the use categories of *Pterocarpus erinaceus.*

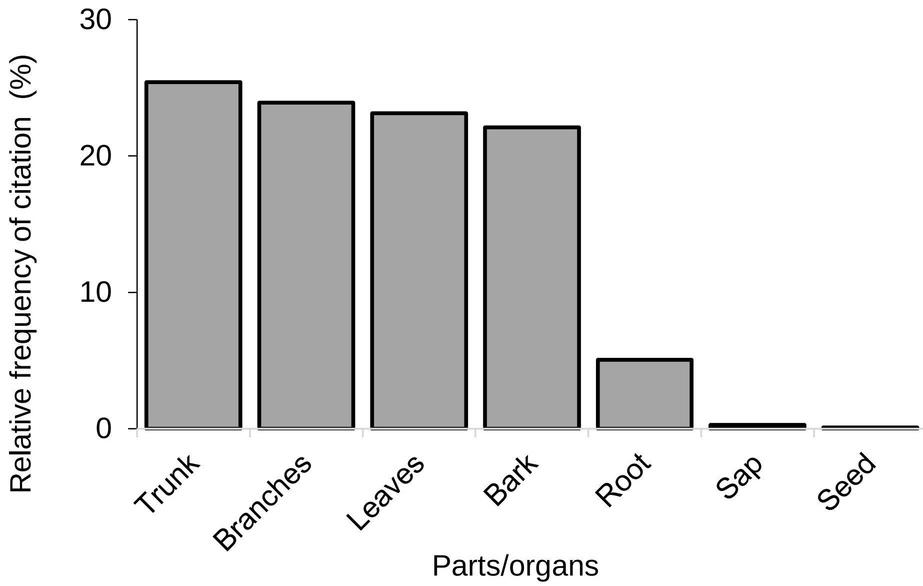

Figure 4. Relative importance of the organs of *Pterocarpus erinaceus* harvested by the respondents.

DISCUSSION

Implication of the traditional uses of *Pterocarpus erinaceus* in people's livelihood

P. erinaceus is a valuable species of forest livelihood for local people. This study enabled us to identify seven categories of uses and sixty-four diseases, symptoms, or pathologies for which the organs of the species are harvested. Some local uses and traditional knowledge on *P. erinaceus* are part of the ones noted in Niger, Burkina Faso (Rabiou et al., 2017a), and Togo (Sègla et al., 2015a) on the same species. Apart from the local uses reported in these studies, many other uses are revealed in this study. More than thirty supplementary diseases, symptoms, and pathologies cured by using the organs of *P. erinaceus* are reported, whose abortion, abscess, acne pimples, asthenia in humans and cattle, baby's fontanel, the bite of a snake, cough, couple union, diabetes, dizziness, gonorrhea, hernia, hypertension, infectious disorders, infertility in women, intestinal worms, leprosy, metrorrhagia, teething, whitlow, ringworm, and pleuropneumonia in cattle. To treat these diseases, symptoms, or pathologies, people use the bark, roots, leaves, and sap. This medicinal property of the organs of *P. erinaceus* is reported by Gbohaïda et al. (2015) and Tittikpina et al. (2013) who revealed in the roots, barks, and leaves of *P. erinaceus*, the presence of chemicals (flavonoids, saponins, and alkaloids) with antifungal and antibacterial effects. Also, Ouédraogo et al. (2012) revealed in the organs of *P. erinaceus*, the presence of friedeline, a compound with anti-tumor, anti-inflammatory, anti-analgesic, and antipyretic effects.

The wood of the species is strongly sought by carpenters, joiners, and craftsmen in construction and for making movables, such as tables, chairs, closets, doors, windows, mortars, butts, the haft of farming tools, and musical instruments, whose sale provided them livelihood income. The leaves, barks, and roots are sold by women in markets and contribute to livelihood income for many households. All the respondents perceived *P. erinaceus* as an important source of forest livelihoods. The "Tamaré", a powder made with the heartwood is used by the sociolinguistic group Peulh for evil spirits to protect children specifically. The wood sized 2.2 m long and 20-25 cm width is sold like the timber, whose sale price varied from XOF12,000 ($21.48) to XOF25,000 ($44.75) according to the regions. The leaves are bound and sold at XOF50 ($0.09) or XOF100 ($0.18) through the rainy season and XOF150 ($0.27) through the dry season. The barks and roots which are more and more expensive are also bound and sold to XOF150 ($0.27) or XOF200 ($0.36) according to the regions. The respondents declared that incomes are used for own or family needs, such as school fees, clothing, and construction. In the international markets of Glazoué and Malanville, we noted that the leaves and barks are exported to Nigeria and Burkina Faso. Apart from the uses in traditional medicine, joinery, arts, and crafts, *P. erinaceus* is also used for firewood and charcoal production. Furthermore, the uses on *P. erinaceus* allow the respondents to improve their livelihood sources. Most of the respondents reported that the quantity of the organs (wood, leaves, barks, and roots) that they harvested to provide for their subsistence has decreased drastically because of the species scarcity. That poses threats to health and

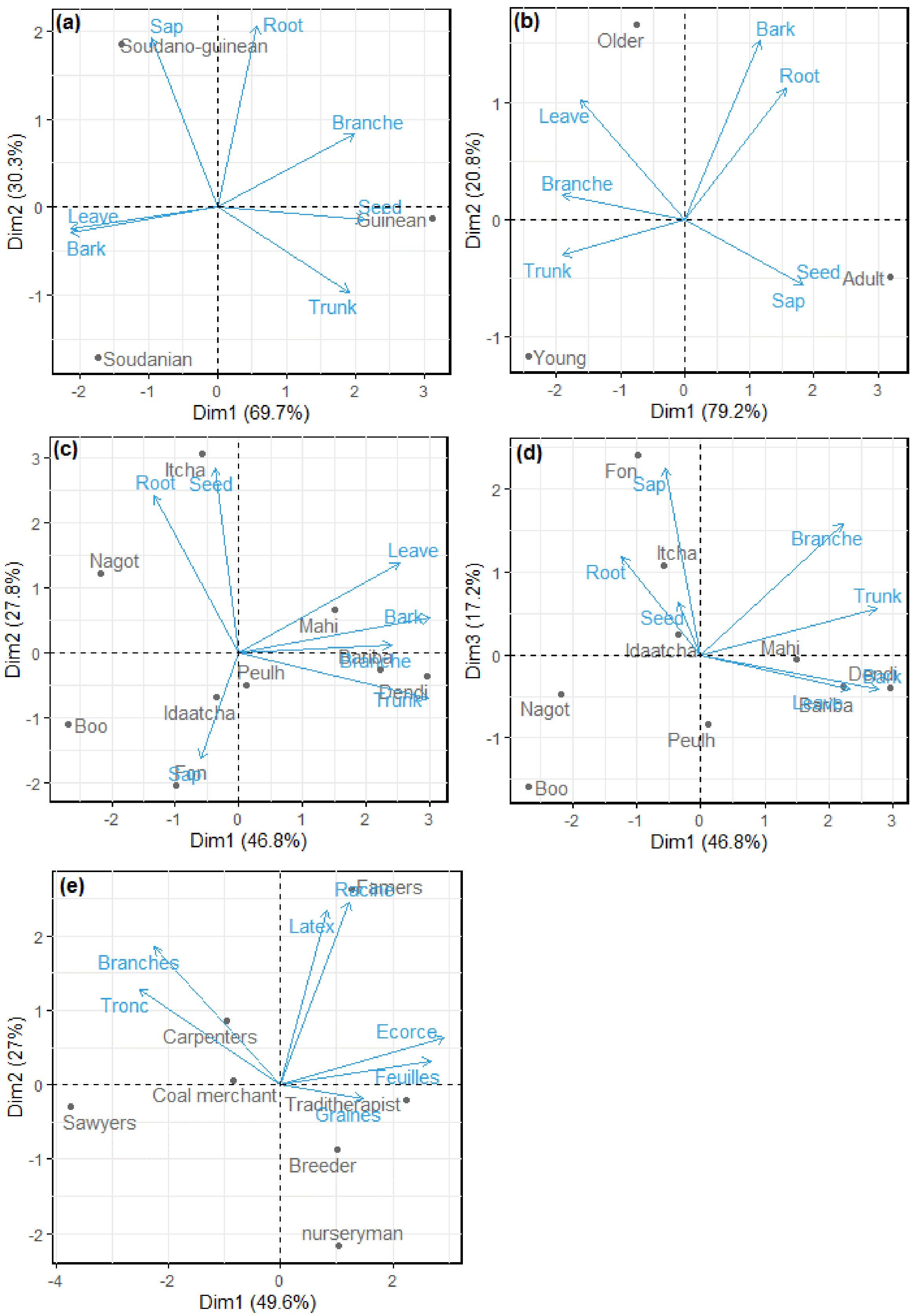

Figure 5. Relationship among local uses of the organs of *Pterocarpus erinaceus* and the (a) ecological zones, (b) age (c & d) classes, sociolinguistic groups, and (e) livelihood activities.

livelihood activities for people and fodder for cattle. The leaves constitute an important source of fodder for cattle in the dry season because they contain a high proportion of crude protein, organic matter, fibers, and mineral elements for keeping health in cattle (Nantoumé et al., 2018). The use of wood more extensively for the livelihood activities, such as carpentery, joinering, arts and crafts is linked to its better physical and mechanical properties (density and hardness) compared to other timber species (Sègla et al., 2017, 2015b).

Relationship among the uses of *Pterocarpus erinaceus* and the sociodemographic factors

The results showed that traditional knowledge on the uses of the organs of *P. erinaceus* depend on ecological zone, sociolinguistic group, gender and livelihood activity. The use on *P. erinaceus* for handicraft and charcoal production by men could be justified by the fact that these activities are carried out by men while cooking is the appanage of women in households. That would justify women's knowledge on the use of the species in food like vegetable. Predominance of handicraft use in Guinean-Sudanese and Sudanian zones is linked to the fact that there are more craftsmen in these zones. The uses of leaves like vegetable in Guinean-Sudanese zone is linked to the fact that this culinary recipe is a particular of the sociolinguistic groups Itcha in Bantè and Nago in Savè, two townships located in Guinean-Sudanese zone. The distribution of the categories of uses in relation to the ecological zones is therefore linked to the traditional knowledge of the sociolinguistic groups who are living there. The harvesting capacity on the organs also depends on the livelihood activities and traditional knowledge of the sociolinguistic groups in each ecological zone. Indeed, the strong use of leaves and barks by the sociolinguistic groups Peulh, Dendi, and Bariba in Sudanian zone is linked to the dominance of the practice of ruminant breeding in this part of Benin.

Impacts of the traditional uses of *Pterocarpus erinaceus* on the conservation of the species in Benin

The leaves are used to feed cattle and sheep while the barks and roots are often used to treat many diseases in humans and animals. On this fact, the trees of *P. erinaceus* are often pruned in forests, farms, fallows, wherever the species is found in Benin (Figure 6). The strongly anthropogenic pressures exerted on the natural stands decreased drastically the survival chance of the species. The frequently pruning on the trees drove to irregular fructification and threatens the availability of the seeds. The barking affects the plant's growth slowly threatening the availability of the wood. According to Adjonou et al. (2010) in Togo, uncontrolled and repeated harvesting of the organs of *P. erinaceus* for livelihood activities such as farm, breeding, and traditional medicine as well as the bad harvesting practices of the species affected seriously the plant growth and the natural regeneration. The strong pressures exerted on *P. erinaceus* by humans mean that the species is very important for the livelihood of people. Despite the importance of *P. erinaceus* in Benin, the species did not receive sustained attention for the sustainable management of the natural stands.

Pathways for conservation and sustainable management of *Pterocarpus erinaceus* in Benin

The legal protection enjoyed by *P. erinaceus* in Benin through the prohibition of logging and timber exportation, its inclusion on CITES Appendix II, and conservation status on the IUCN Red List as endangered (EN) species are not sufficient for its sustainable management. It therefore appears imperative that additional conservation and restoration strategies be taken to preserve the species in Benin. Regarding the current conservation status of *P. erinaceus* and the quickness degradation of the natural stands, it is advisable to combine both *in-situ* and *ex-situ* conservation forms as urgent conservation and restoration strategies to keep the genetic diversity of *P. erinaceus* and to ensure its survival. A key strategy for the conservation of *P. erinaceus* could be improved habitat management to enable connectivity among the relict populations. Agroforestry systems, if well managed, could help to establish this connectivity across the landscape by playing the role of biological corridors among populations (Ouinsavi and Sokpon, 2008). Relict populations of the species which should be a high conservation priority as well as protected areas in savannah regions could also serve as a corridor among the planting plots of the species. This method of conservation was already proposed for the relict populations of *Milicia excelsa* Welw. Cc. berg) in Benin (Ouinsavi et al., 2009; Ouinsavi and Sokpon, 2008). Assogbadjo (2006) qualifies it as "*ex-situ* conservation on-farm" for natural stands of *Adansonia digitata* L. in Benin. Practically, this strategy will consist of conserving plots containing *P. erinaceus*, cultivated within the ecological niche of the species so that the young populations establish a bridge in terms of gene flow among various sub-populations. Thus, the research work carried out by Johnson et al. (2020), Ouinsavi et al. (2019), and Rabiou et al. (2017b) on the isolation of microsatellites and vegetative propagation of *P. erinaceus*, respectively, could serve as a basis to ensure the species preservation.

Conclusion

This study revealed many other uses of *P. erinaceus* in

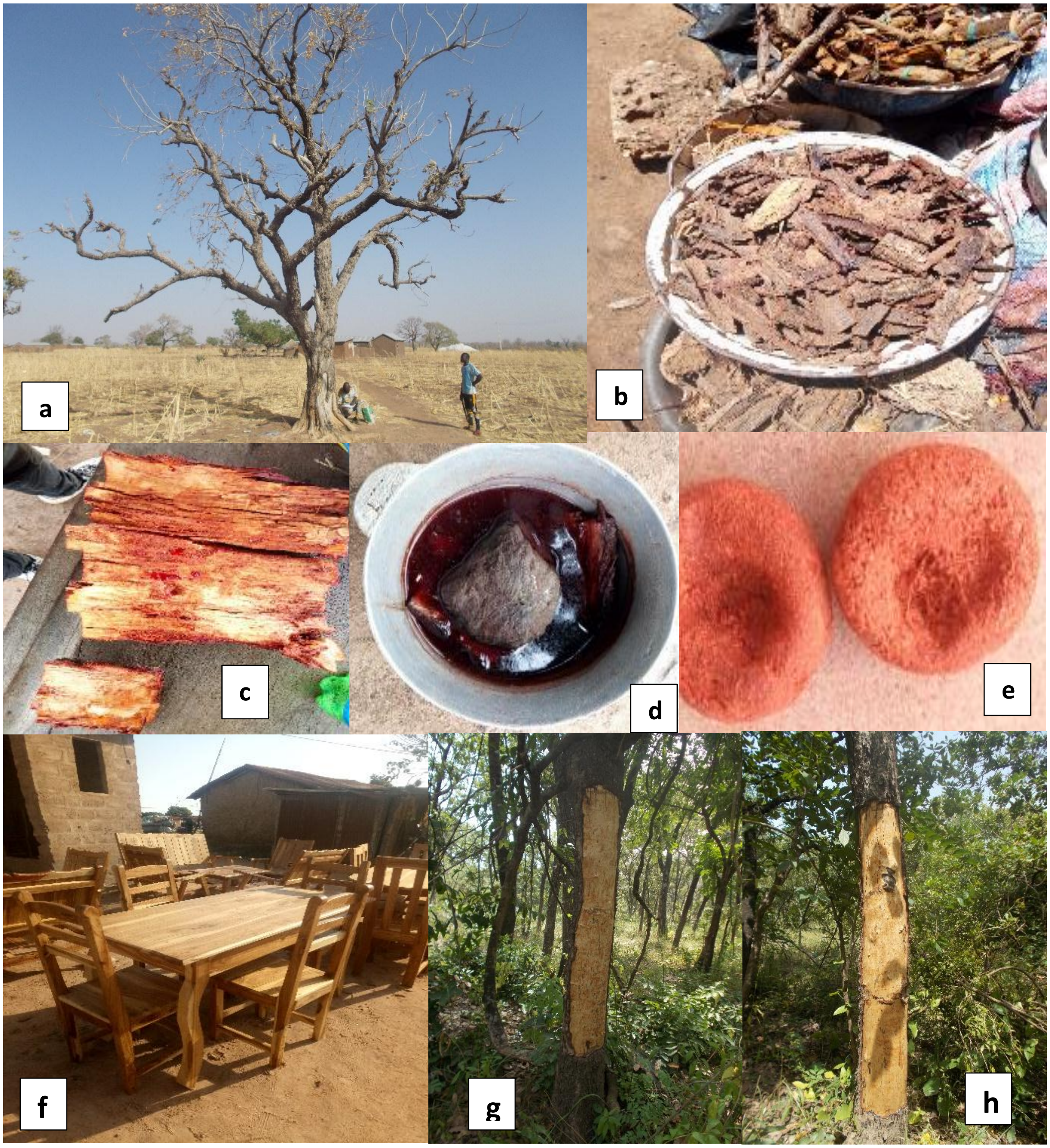

Figure 6. Some local uses of *Pterocarpus erinaceus* in Benin (a) Tree pruned frequently, (b, c) barks in herbalists' market, (d) decoction of the barks, (e) the "Tamaré" made with the heartwood is used as incense by the sociolinguistic groups Peulh and Bariba for evil spirits, (f) movables made with the wood, and (g, h) tree barked.

Benin mostly in traditional medicine. Sixty-four diseases, symptoms, and pathologies cured by using the organs of *P. erinaceus* were identified. All the organs of the species are used and valued for various purposes, making *P. erinaceus* an important multi-use species that appears as a source of livelihood for a significant part of the population in Benin. Consequently, the species is subjected to anthropogenic pressures which can cause the species disappearance from natural habitats and even from farms and fallows. The various use forms of the organs of *P. erinaceus* revealed the need to define conservation strategies for the relict populations with a view to the sustainable use of the species. The scarcity of the species could impact on the income and health of people. To reverse the trends for livelihood activities and for improving the conservation status of the species, it is needed to combine both *in-situ* and *ex-situ* conservation forms in addition to the restriction provisions already taken against the extinction of the species. That should be possible with a participatory approach involving the sociolinguistic groups to design conservation schemes. Future investigations shall include the value chain studies on several products that could send signals to farmers to conserve the species. With regard to the medicinal importance of *P. erinaceus*, a panel study to diagnose the uses/demand of the species before and through the COVID-19 pandemic could reveal more the medicinal potential of the species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Short Communication

Biodiversity loss and conservation challenges in Chimit Kolla, Gozamen District, East Gojam Zone, Amhara Region, Ethiopia

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A field study in Chimit Kolla, Gozamen District, Ethiopia was conducted in November, 2020. The study aimed to evaluate the biodiversity loss and major conservation challenges in the area. Direct sighting of the animals in the field and indirect evidences like scats, prey leftover and evidence from native key informants revealed higher wildlife potential of the area. However, intensive agricultural investment, deforestation and habitat degradation, uncontrolled charcoal production and induced fire for agricultural expansion remain the principal biodiversity conservation challenges. Although sustainable agriculture is part of the Sustainable Development Goals, in Chimit area intensive agriculture resulted ecosystem degradation and biodiversity loss in an alarming rate. Therefore, the area calls for active conservation intervention measures to harmonize the investment activities with biodiversity conservation priorities.

Key words: Agricultural investment, biodiversity loss, charcoal production, conservation challenges, induced fire.

INTRODUCTION

Due to the combination of climatic and geologic factors, Ethiopia is gifted with massive biological resources, and is listed as one of the biodiversity hotspots in the world (EBI, 2014). Although the country is known for the higher biological diversity and endemism, the status of biodiversity is highly threatened due to over exploitation, habitat degradation, agricultural expansion, settlement and infrastructure development (Mekonen et al., 2017; EBI, 2014; Zerubabel and Zerihun, 2020). Most of the threats are linked with the deep rooted rural poverty where survival of local communities is primarily dependent on natural resource exploitations. Successful biodiversity conservation efforts require on-site investigation of the status of biodiversity and implement conservation education programs for local communities and stakeholders to enhance conservation and sustainable utilization of the resources. Chimit Kolla is one of the districts found in the lowlands of East Gojam zone, Amhara Regional State. The rich biodiversity and agricultural productivity potential, the serious conservation challenges (Misganaw et al., 2017), lack of ecological study in Chimit Kolla calls for documenting the

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biodiversity potential and the major anthropogenic pressures in the area. Therefore, this study aimed to assess biodiversity and to investigate the major anthropogenic threats influencing biodiversity conservation and sustainable utilizations in Chimit Kolla, East Gojam Zone, Amhara Region, Ethiopia.

MATERIALS AND METHODS

Field observation to assess the biodiversity and major conservation challenges was conducted in Chimit Kolla in November, 2020. Chimit Kolla is one of the Kebeles (sub districts) in Gozamen District, East Gojam Zone, located between 10° 0' 0" to 10° 20' 0"N latitudes and 37° 30' 0" and 37° 40' 0"E longitudes, found 35 km away from Debre Markos, capital of East Gojam Zone. The climate of Chimit is considered as *Kolla* (Tropical) being found below 1800 m.a.s.l (Sileshi, 2018). The vegetation is dominated by grassland and dispersed acacia woodland, representing a savannah ecosystem.

Data was collected through direct sighting of the animals in the field and indirect evidences like scats, and prey leftover, as well as evidence from key informants (Zerubabel and Zerihun, 2020). Wild animal assessment was conducted in the morning (6:00 to 10:00 am) and in the afternoon (3:00 to 5:00 pm), by walking and driving through the different habitats (that is, farmland, bushland, grassland, and riverine habitat). Opportunistic sampling and visual encounter survey methods were also employed to assess herpetofauna potential of the area (Ehwan et al., 2016). Moreover, open ended interview guide questions were used to extract relevant data on the status of biodiversity and major biodiversity conservation challenges in the area. Natural resource experts in the district and elderly native community representatives were included for the key informant interview. During key informant interview open ended questions was administered to assess knowledge on the wildlife resources of the area, whether the presence of different wildlife species benefits the community, whether there is human-wildlife conflict exists; the major conservation challenges, the trend of wildlife population across time, and the desired conservation strategies for conservation and sustainable utilization of the wildlife resources around Chimit Kolla.

RESULTS AND DISCUSSION

The direct evidences confirmed that the wooded grassland and the riverine ecosystem is rich in butterfly diversity, higher primate abundance, diverse lizard species, and rich in avian fauna, dominated by large and medium sized carnivores such as: lion (*Panthera leo*), golden jackal (*Canis aureus*), hyena (*Crocuta crocuta*), and caracal (*Felis caracal*). The area is also rich in small mammal diversity (that is, rodents, shrews, and hyrax) as well as bats. Chimit Kolla is crossed by Chemoga River which is an important source of drinking water as well as habitat for diverse herpetofauna and aquatic bird species. According to the native key informants the area was once dominated by large browsers and grazers like: buffalo (*Syncerus caffer*), greater kudu (*Tragelaphus strepsiceros*), lesser kudu (*Tragelaphus imberbis*), bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*), and gazelle species. The natural resource experts also reported that the savannah ecosystem was once dominated by diverse wildlife species, however, the severe anthropogenic activities resulted loss of habitat and wild animal species in Chimit Kolla.

Major threats to biodiversity

Like other wilderness areas in Ethiopia, Chimit Kolla is highly threatened due to unsustainable resource exploitation, habitat loss and degradations. More significantly in Chimit there is a huge agricultural investment (Figure 1) mainly producing maize, sesame, Teff, and haricot bean. As noted in the field, there are around twenty licensed investors, and yet many more are processing their investment license from Gozamen District, Trade and Investment Office. Hence, more natural ecosystems will be converted into agricultural fields, resulting local extinction of wildlife populations and loss of ecosystem services in the area. Such intensive agriculture also use inputs like fertilizers, herbicides, and insecticides which either join the atmosphere or ground water bodies where it affects the ecosystem integrity and functioning.

Induced fire for agricultural expansion, settlement, and charcoal production is also a major concern in Chimit (Figure 2). Intense human-wildlife conflict is also a common phenomenon in the area, where crop raiding by primates, porcupine, rodents, warthog, and different bird species are the main incidences. Thus, intervention measures taken by investors to avoid crop loss are negatively affecting the wild animal populations. Moreover, agricultural expansion is also intensified even in peak mountainous areas by local communities, resulting habitat loss and fragmentation that can be used by the surviving wild animal populations.

CONCLUSION AND RECOMMENDATIONS

The higher biodiversity especially amphibians, insects, reptiles, small and large mammals in Chimit reveals its potential to develop community based conservation area. However, the anthropogenic activities remain the major biodiversity conservation challenge in the area. In this regard, the Regional as well as Zonal Trade and Investment Offices should revise the agricultural investment policy and licensing procedures considering biodiversity conservation priorities without compromising local livelihoods. The extraordinary level of charcoal production demands urgent interventions, unless the remaining habitat patches will be lost very soon. More importantly, detailed, seasonal wildlife study should be conducted and urgent participatory biodiversity conservation intervention measures should be conducted in Chimit Kolla in order to safeguard the remaining ecosystem and surviving wild animal populations.

Figure 1. Maize investment in Chimit Kolla.

Figure 2. Induced fire for agricultural expansion and charcoal production by local communities in Chimit Kolla.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Environmental sustainability of consumptive and non-consumptive wildlife tourists: The case of a game reserve in Namibia

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Africa as a tourism destination is seen as a wildlife tourism hotspot that contributes significantly to job creation, community upliftment, and conservation. Wildlife tourism is based on encounters with non-domestic animals that can occur in either the animal's natural environment or in captivity. The interaction with the animals includes activities that are historically classified as consumptive and non-consumptive. This research aims to determine the environmental impacts of wildlife tourists (consumptive and non-consumptive) based on their behaviour as perceived by senior staff managing a game reserve in Namibia. The study applied qualitative research, namely interviews, to encapsulate in-depth information. From the results, it can be concluded that, although both consumptive and non-consumptive wildlife tourists impact the environment at the game reserve, the behaviour of non-consumptive wildlife tourists seems to be more negative than that of consumptive wildlife tourists. The study further found that hunters behave in an eco-friendlier manner towards the environment and tend to be more concerned about their own impact on nature.

Key words: Wildlife tourism impacts; environmental impact; natural area tourism; protected area tourism; wildlife tourism.

INTRODUCTION

Throughout the 20th century, the increasing desire of tourists to experience and interact with the natural environment had stimulated significant growth in wildlife tourism, with Africa being one of the most affected continents (Backman and Munanura, 2015; Reynolds and Braithwaite, 2001: 32). This resulted in higher visitor numbers to the protected areas (Rodger et al., 2007:162; Sadikin et al., 2017), adding more pressure on the already over-utilised protected resources in Africa, which jeopardises the sustainability of nature-based products in protected areas (Newsome et al., 2005).

Sustainable tourism can be defined as the type of tourism that is developed and maintained in an area (community, environment) in such a manner and at such a scale (visitor numbers, development size) that it remains viable over an indefinite period and does not degrade or alter the (host) environment to such an extent that it prohibits the successful development and well-being of other activities and processes. It is thus acknowledged that tourism is not taking place in a

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vacuum (Ioannides, 2001: 59). Sustainable management of wildlife tourism in protected areas is based on three main pillars (Ioannides, 2001: 57), which indicate that to achieve genuinely sustainable development, a delicate balance should be struck between conflicting economic, environmental, and socially equitable objectives, also known as the three Es. This balance will then result in the equal distribution of economic growth and the minimisation of environmental impacts. All three pillars are fundamental to sustainable wildlife tourism, but this research focuses on the environmental management indicators thereof.

Wildlife tourism has been defined in different ways. Reynolds and Braithwaite (2001: 32) define wildlife tourism as “the travelling to a destination to view wild animals and the environment”. In 2004, Higginbottom (2004: 2) referred to wildlife tourism as “tourism based on encounters with non-domestic animals … [that] can occur in either the animal’s natural environment or in captivity. The interaction with the animals includes activities that are historically classified as consumptive and non-consumptive”. Consumptive wildlife tourism includes activities such as hunting and fishing, whereas non-consumptive wildlife tourism refers to ecotourism-related activities. Curtin (2005: 2) adds that “pleasure in wildlife tourism derives from factors such as viewing animals in their natural habitat, observing a wide range of species, interacting with wild animals in close proximity, experiencing the sense of habitat (place), and sharing experiences with others”. Both consumptive and non-consumptive types of wildlife tourism impact the environment (positively and negatively). Wildlife tourists want to escape the rush of their cities or towns and the consequence is that it may increase the risk of hit-and-run tourism, resulting in a rapid increase of nature lovers to the latest wild spot discovered. A degraded state of nature might thus follow their activities and even cause the abandonment thereof. This will lead to detrimental impacts on the natural environment.

There are, however, also positive impacts, since ecotourism (that is, non-consumptive) can provide much-needed revenues for the protection of national parks and other natural areas, as well as increase the funding for local communities (The Nature Conservancy, 2016). Lindsey et al. (2007) and Saayman et al. (2018) indicate that consumptive wildlife tourism also impacts local communities positively, especially in rural settings; these impacts can include income generation, job creation, skills development, and conservation of wildlife. Therefore, from the literature, it is evident that wildlife tourism (consumptive and non-consumptive) impacts the environment, thereby impacting the sustainability of protected areas (Shackley, 2006: 868).

This research hence aims to determine the environmental impacts and behaviour of consumptive and non-consumptive wildlife tourists as perceived by the selected management staff of a game reserve (30 000 ha in size) in Namibia; the researchers want to ascertain which one of the two groups is considered to be contributing to higher levels of environmental sustainability. From the literature studied regarding wildlife tourism (Gössling et al., 2012:4; Hunter and Green, 1995; Newsome et al., 2013; Roe et al., 1997), it has become evident that this type of tourism contributes greatly to the management and conservation of protected areas. Some of the benefits of wildlife tourism include foreign exchange revenues, employment opportunities, improving awareness of conservation objectives, and stimulation of economic activity (Roe et al., 1997). The opposite is also accurate, since wildlife tourism can cause a depletion of natural resources, for example water resources, local resources, and land, due to certain behaviour (Gössling et al., 2012:4; Hunter and Green, 1995; Newsome et al., 2013). The ideal is to increase the positive impacts of wildlife tourism in order to contribute to higher levels of sustainable management of these areas.

Roe et al. (1997) and INTOSAI WGEA (2013) divide the areas of wildlife tourism impacts into three categories, namely environmental, economic, and social (cultural) groups (which also form the pillars of sustainability). This research focuses on the first category (the environmental impact), which will be discussed next. In the literature review, the environmental impacts of consumptive and non-consumptive wildlife tourism will not be addressed in a comparative manner, but collectively.

The environmental impacts of wildlife tourism

The literature studied (George, 2007:308; Gössling et al., 2012:7; Islam, 2013:124; Newsome et al., 2013:159; Roe et al., 1997) on the environmental impacts of wildlife tourism divides environmental impacts into three categories, namely natural elements, ecosystems, and the human environment; each of these categories is also divided into subcategories.

The natural elements

Water

Water, especially freshwater, is one of the most critical natural resources. Wildlife tourism can gradually overuse this resource, either through the accommodation sector, for example building luxury lodges and facilities such as swimming pools, or through overuse by the wildlife tourists when showering, bathing, and using toilets. All of these can result in water shortages and degradation of the freshwater supply in the immediate area of the game reserve (George, 2007: 308; Gössling et al., 2012:7; Newsome et al., 2013:159; Roe et al., 1997).

The most appropriate example of water pollution relates to wastewater (from accommodation facilities, kitchens and other installations) being discharged into the water systems (surface and underground) in a natural or protected area that hosts wildlife tourists (George, 2007: 307). The construction of different facilities for consumptive and non-consumptive wildlife tourists, such as camping sites, lodges and recreational areas, often leads to sewage pollution due to an increase in the volume of generated wastewater. This wastewater can pollute the surface and underground water bodies and therefore damage the fauna and flora of such areas (Page and Connell, 2009: 430). Sewage pollution also causes health hazards for humans as well as animals (Islam, 2013: 124).

Wildlife

Wildlife is impacted by tourists in the following ways: indiscriminate hunting and fishing; poaching for souvenirs; wildlife harassment from viewing and photography; and development of highways and trails through natural areas. It can result in changes in species composition, the disappearance of rare species, the reduction of wildlife numbers, the disruption of feeding and breeding patterns of wildlife, and the disruption of predator-prey relationships. Relocation of feeding and breeding areas, or even destruction of wildlife habitats and disturbance of wildlife migrations, can impact wildlife (Newsome et al., 2013: 147; Roe et al., 1997; Saayman, 2009). The seasonal character of the wildlife tourism industry is another concern, as many destinations in wildlife areas experience an influx of tourists during the high (busy) season, causing a high demand on these resources in order to meet the expectations of tourists (Gössling et al., 2012: 7).

Vegetation

Land degradation occurs when the land in natural areas is cleared of vegetation for the construction of wildlife tourism facilities (e.g., accommodation, paths and roads), and because of an increased use of firewood, the careless use of fire in forests and parks, pedestrian and vehicular traffic at campsites and trails, the collection of flowers, plants and fungi, and the introduction of alien species. This causes a disturbance in the natural wildlife found in the area and the degradation of the minerals in the soil, the fertility of the soil, as well as the surface and underground water supply (Hunter and Green, 1995; Newsome et al., 2013:147; Roe et al., 1997).

Atmosphere

Wildlife tourists also contribute to air pollution. According to Andereck and Robert (1993: 27), Belsoy et al. (2012: 68) and Mehta (2013: 5), the most significant tourism-related pollution of wildlife air is caused by the industry's automobiles, which emit by far the most carbon monoxide of all transportation modes. This, together with the production and use of energy, can all be linked to acid rain, global warming, and photochemical pollution. Roe et al. (1997) state that air and noise pollution within peak seasons may result in a loss of recreational value; it may harm fauna and flora, and increase the use of non-renewable fossil fuels, creating greenhouse gases and resulting in ozone depletion.

The aesthetic value of the area: Solid waste and littering occur where there is a high concentration of wildlife tourism activities at natural attractions. Improper disposal of waste can cause significant damage to the natural environment, rivers and scenic areas. For example, when solid waste collection and disposal are poorly managed, such as wildlife tourists leaving their litter at accommodation areas and camping sites, it can severely impact the natural environment and threaten human and animal life (Islam, 2013: 120).

A lack of land-use planning and building regulations by owners of wildlife tourism establishments, for example game farms or ranches, can facilitate the sprawling development of accommodation facilities such as lodges and campsites, as well as other supporting wildlife tourism infrastructures, for example roads, parking areas, service areas, and waste disposal facilities. The aesthetic appearance of these destinations is diminished by the construction and building of such facilities if they clash with the surrounding environment. It creates architectural or visual pollution and results in low aesthetic value (Roe et al., 1997; Shannon et al., 2017: 40; Sunlu, 2003: 265).

The ecosystem

The impact on the ecosystem is mainly due to the construction of facilities (e.g., lodging and roads for wildlife tourists) that causes the elimination of plant and wildlife habitats, interference with breeding habits of wildlife, erosion, obliteration of geological features by excavation or water pollution, loss of natural beauty, unsightly urban-like development, disruption of soil stability, alteration of the drainage system, and water runoff that may result in floods and negative visual impact on the landscape (Roe et al., 1997).

The human environment

The physical impacts on the environment that are most likely caused by wildlife tourists can be divided into impacts caused by development and those caused by activities.

Developmental impacts

The construction of various wildlife tourism facilities requires the clearing and filling of large areas of land in natural or sensitive areas. These actions cause severe disturbance to the natural environment and also lead to the disturbance of communities (Roe et al., 1997; Sunlu, 2003:265).

Activities' impacts

The impacts of wildlife tourists' activities are aspects such as trampling, and disturbance of wildlife. The trampling of vegetation and soil occurs when wildlife tourists use the same trail or road over and over again. This can happen when a variety of activities take place, for example when taking photographs, investigating flora, or creating an informal path (trail) for these purposes, thereby causing damage such as the prevention of seed germination, which can lead to erosion and, finally, a loss of natural biodiversity (Newsome et al., 2013: 14).

Developments associated with tourist infrastructure and activities can lead to the displacement of local people, a loss of amenity to remaining residents due to traffic congestion and overloaded infrastructure, as well as increased pollution and noise. The excessive use for tourist purposes leads to overcrowding, which can result in trampling, littering, alteration of traditional use and function, desecration, and exclusion of traditional users (Islam, 2013: 121; Newsome et al., 2013: 14; Roe et al., 1997).

It is clear that wildlife tourism activities in protected areas impact the environment; all tourism products in protected areas must thus strive to reduce their impacts on the environment and encourage wildlife tourists to act in a more responsible manner. Therefore, the question this research wishes to answer is as follows: What are the environmental impacts and behaviour of consumptive and non-consumptive wildlife tourists with regard to this case study, and which of the two types is seen as more sustainable as perceived by the management of the game reserve?

MATERIALS AND METHODS

Research method and sampling

A game reserve in Namibia was selected for the study; it is large in size and offers both consumptive and non-consumptive wildlife tourism products. In this research, a non-experimental research design was applied. Qualitative research (action research) was performed by means of semi-structured interviews to determine the perceived environmental impacts of wildlife tourists (consumptive and non-consumptive) as viewed by the game reserve management, who have been working with these different types of wildlife tourists for a prolonged period. A non-probability sampling approach (Maree and Pietersen, 2016), namely purposive sampling, was applied in which the owner, the general manager, and the consumptive and non-consumptive tourism managers were purposefully selected based on their knowledge and previous experiences in working with both groups of wildlife tourists. Table 1 provides an overview of the participants in this study.

Semi-structured interviews were used to collect data from participants invested in the supply and demand side; these interviews were based on research conducted by Solberg (2017) and O'Conner (2009). The interviews provided the researchers with the opportunity to use some predetermined core questions, but as the interviews progressed, follow-up questions were posed (Maree, 2007). The interviews were conducted on-site during the last week of September 2019, which added to the insights regarding the discussions and observations by the researcher. Each participant gave verbal consent before commencing with the interview and given the depth of the topic, the average length of the interviews held were 45 min.

Development of the interview guide

The interview guide was developed after reviewing similar studies conducted on the environmental impacts of wildlife tourism. These studies include the works of Chen (2015), O'Connor (2009), Silent (2017), Solberg (2017) and Sucheran (2013). The interview guide included questions related to the management of the game reserve regarding non-consumptive and consumptive wildlife tourism environmental impacts. Ethical clearance (NWU-01319-19-A4) was obtained from the ethics committee of a higher education institution whose members reviewed the measuring instrument and method of study.

Data analysis

To ensure objective interpretation of the discussions, the interviews were recorded using an audio voice recorder. This contributed to high-quality transcriptions and enabled the researcher to listen to the interviews again where clarity was needed. During these interviews, handwritten notes were also taken by the researcher. The handwritten notes and recorded interviews were then merged to have one data set; all the data were transferred to Microsoft Office Excel 2010. For the analysis, Creswell's (2009) six steps for analysing and interpreting qualitative data were applied, which led to the identification of specific themes. These six steps are as follows: Step 1: Organise and prepare the data for analysis (All the data [handwritten and recorded] were captured in Microsoft Excel). Step 2: Read through all the data (The researchers read through the responses of the participants to identify different themes). Step 3: Start detail analysis with a coding process. (Data were coded according to previous literature regarding wildlife tourists' environmental impacts). Step 4: Identify themes (Different themes were listed based on previous literature regarding the various environmental impacts of wildlife tourism; therefore, thematic analysis was applied). Step 5: Report the data (This was done in the Results section of the article). Step 6: Interpret the data (This was done in the Discussion section of the article).

RESULTS

The results are presented in three parts: Parts 1 and 2 contain the results related to the perceived negative environmental impacts of non-consumptive and consumptive wildlife tourists, whereas Part 3 focuses on the positive impacts/contributions of both groups to conservation and the environment.

Part 1: Non-consumptive wildlife tourism

A brief background situation analysis is given on non-consumptive wildlife tourism and the facilities offered to

Table 1. Participant (interviewees) information.

Participant	Gender	Job description	Years employed in the position
1	Female	Owner	37
2	Male	General manager	15
3	Male	Consumptive tourist manager	40
4	Female	Consumptive tourist assistant manager	18
5	Female	Non-consumptive tourist manager	8
6	Female	Non-consumptive tourist assistant manager	3
7	Female	Non-consumptive tourist assistant manager	5

tourists who visit the game reserve. For the non-consumptive tourists, also known as ecotourists, the following came forward:

The lodge offers a lounge area, dining area, bar area, kitchen area, and a variety of accommodation options. Up to 50 guests can be accommodated at a time; they also have access to the garden, a large lawn area and a swimming pool. The average price of the smaller rooms is N$1640 (US$99) per person per night, whereas the luxury rooms cost up to N$2500 (US$150) per person per night. These prices include all meals. Regarding return visitation, Respondent 1 estimated that of the 14 600 non-consumptive wildlife tourists who visit the game reserve each year, 4 to 7% of them make return visits. It was also clear that differences exist with regard to preferences related to the time of visit, with international tourists favouring the lodge from July to November and local tourists between December and January. A critical element noted by Respondent 6 is that the ecotourists only stay at the lodge for one night.

Based on the responses, the conclusion is that the lodge offers various facilities to the ecotourists and there is enough space for tourists to enjoy their stay. The low return rate and limited duration of stay are, however, two aspects of concern.

Negative environmental impacts regarding non-consumptive wildlife tourism as perceived by management

The interviewees (participants) were asked to give their opinion on the most significant adverse environmental impacts of the tourists and the lodge. Based on the semi-structured interviews, the following themes were established: impacts on water resources, general waste generation, and impacts on wildlife.

Water resources

Respondent 1: "*The tourist lodge uses approximately 20 500 litres of water on a daily basis. This is due to the fact that bedding, towels, linen, preparation of food and general cleaning need to be done on a daily basis before new guests arrive."*

Respondent 2: "*The amount of water usage at the tourist lodge is [sic] seven times more than that of the hunting lodge (consumptive side). This puts a big demand on the underground water source of the reserve. Non-consumptive tourists impact the environment with the amount of water they use. The daily cleaning of bedding, towels, et cetera put[s] additional pressure on water resources, which can be managed differently."*

Respondent 6: "*... the guests' selfish behaviour towards the environment when they want to use the jacuzzi, [even] when they see how dry the surrounding environment is. They feel they have paid for that service and they want it.*"

Respondent 1: "*Greywater is also another big challenge at the tourists' lodge."*

Waste food and general waste generation

Respondent 5: "*The volume of food prepared at the ecolodge on a daily basis has to cater for at least 40 to 50 guests. Every day, three meals (breakfast, lunch and dinner) are prepared for the guests. Lunch is only prepared according to pre-orders made by the tourists themselves. Added to the above are [sic] a coffee station, where snacks and refreshments are served daily for the guests of the ecolodge."*

Respondent 6: "*The generating of waste materials and the wasting of water are the biggest negative impacts at the tourist lodge. We are trying to minimise the amount of plastic water bottles used at the tourist lodge. For example, the tourists each receives a mug to drink water [from] while on a game drive; [water is] provided in glass bottles that has [sic] been refilled at the lodge."*

Respondent 1: "*The waste generated at the tourist lodge adds up to 10 500 kilograms in a month and consists mostly of leftover food, plastic, paper waste, consumables in the room (soap and shampoo), and personal waste the ecotourists bring with them to the reserve."*

Management perceptions regarding impacts on wildlife

Respondent 2: "*The use of six vehicles for game drives at the tourist lodge can cause a variety of impacts that range from air pollution, soil compaction, damaging of vegetation, and the disturbance of wildlife, to name but a few examples.*"

Respondent 5: "*The majority of the tourists are so detached from everything around them that they show no interest in nature or wildlife. Other times, the tourists also want to know why they have to pay a rhino levy; then we as staff have to explain to them the whole rhino-poaching scenario and that we are trying to protect the rhinos on the reserve.*"

Respondent 2: "*The majority of ecotourists who visit the lodge are there to enjoy themselves, regardless [of] what impact they might have on the environment; for example, they don't switch off the lights and the air-conditioning systems if they leave their rooms. They overfill their plates with food at dinner and only eat a little bit; the rest of the food then needs to be thrown away. During game drives, they are usually noisy and they also litter more than the hunters do. Their mindset is one like, they will use it because they have paid for it. It is evident that tourists show no real interest in or might have no insight into wildlife and are more concerned about their own welfare. There is almost a "do not care" attitude visible as they leave lights on, dish up too much food and use plastics. The results indicate tourists are there to enjoy themselves.*"

The responses from management regarding non-consumptive wildlife tourism environmental impacts at the lodge revealed significant results. First, the scale of operations, with reference to the number of visitors per day and year, impacts water use and creates a significant amount of waste. The scale of operations in natural areas does matter. Second, although the effect of visitor numbers was evident, it was also their behaviour that raised concerns. Participants felt that non-consumptive tourists were nonchalant towards the environment; as stated by one respondent, they are "detached from nature". Respondents indicated that non-consumptive wildlife tourists behave selfishly regarding water use, do not switch off their lights in the rooms, create unnecessary food waste by overfilling their plates, litter while on game drives, make a lot of noise while on game drives (safari), and tend to be more concerned about their own welfare than that of the wildlife. This research is in accordance with previous work done by George (2007: 308), Gössling et al. (2012: 7) and Rabbany et al. (2007: 120), which indicated that non-consumptive wildlife tourists affect the natural environment via impacts on water resources, waste generation, food waste, and noise pollution.

Part 2: Consumptive wildlife tourism

The wildlife tourism products and facilities offered to consumptive tourists (also known as hunting tourists) are different. In terms of facilities, the hunting lodge consists of a lounge area, dining area, bar area, kitchen area, and a total of six en-suite rooms that can accommodate 12 hunters at a time; there are also a small lawn and swimming pool. The average price per hunter is N$7497 (US$450) per night. This price includes the accommodation, meals, a private guide (professional hunter), the hunting vehicle, and any additional activities on offer at the reserve. It excludes all species hunted and the trophy-handling fees. Although trophy hunting is open from February to November, hunters prefer to hunt during the winter months (from May till the end of August). Respondents 1, 2, and 3 indicated that of the 50 consumptive wildlife tourists who visit the game reserve each year, 40 to 50% of them return to hunt again. There are also exceptions, though; one client has already revisited the reserve 26 times.

Respondent 1 indicated that hunters originate from North America, Canada, and Europe, with an average group size made up of two people who are most of the time couples (husband and wife). On average, hunters tend to stay 14 days, depending on the type of hunt (plain game or big five). The average number of animals hunted by one person varies between four and ten, with kudu and gemsbok (oryx) the most preferred species to hunt.

Negative environmental impacts regarding consumptive wildlife tourism as perceived by management

Similar to non-consumptive wildlife tourists, interviewees (participants) were asked to give their opinion/perception on the most significant environmental impacts of the hunting lodge and hunters. Based on the structured interviews, the following themes were identified: impacts on water resources, food and general waste generation, and wildlife disturbance.

Impacts on water resources

Respondent 2: "*The water source used at the hunting lodge is ... a borehole. This water is used for daily chores like the cleaning of the rooms, the washing of linen and towels, the preparation of food, the washing of clothes, and the watering of the lawn in front of the lodge. The greywater that the lodge generates is also treated by means of a French drain system. This water then gets drained out into watering troughs for animals to drink, usually in the dry season; otherwise, it is used to water the grass.*"

Respondent 4: "*… wasting of water through the huge* *bathtubs in the rooms that use at least 200 litres of water to fill."*

Food and general waste generation

Respondent 4: "*Two meals (breakfast and dinner) have to be prepared for the hunters on a daily basis. Lunch consists of light snacks and refreshments, pre-packed in a lunch bag that the hunters enjoy in the veld where they are hunting. The hunters are satisfied with less food and smaller portions of food compared to the ecotourist[s].*"

Respondent 2: "*The waste at the hunting lodge consists mostly of leftover food and recyclable waste such as tin cans and the accumulation of wastewater from the kitchen and bathrooms."*

Management perceptions regarding impacts on wildlife

Respondent 4: "*… the spooking of animals when the hunters use rifles that are not fitted with silencers to hunt with."*

The interviews with management led to the following significant findings related to the impacts of consumptive wildlife tourists and its sustainability: First, the results revealed that the hunting lodge operates in a more environmentally friendly manner, which may be due to the smaller scale of operations (it accommodates 12 tourists at most). This coincides with Saayman's (2009) finding that a smaller scale of operations in nature is more sustainable and reduces the impact on the environment. Second, less waste is generated, which is also better managed, again as a direct result of the scale of operations. Third, the big baths available in the accommodation units result in high water use, but this is also a development issue. Management should consider changing these bathrooms in the long term.

Part 3: Positive impacts and behaviour of consumptive and non-consumptive wildlife tourists

Interviewees (participants) were asked to give their view on what they perceive the positive impacts of visitors on conservation and the environment are. The following aspects emerged:

Non-consumptive wildlife tourists

Respondent 7: "*The biggest positive impact the tourist lodge has on the environment is that it generates extra funding for the wildlife. It also helps to increase job employment and provides primary education for children of the staff."*

Consumptive wildlife tourists

Respondent 2: "*Trophy hunters' overall attitude and knowledge about nature and animals help to benefit conservation at the game reserve, and the hunters understand why they have to shoot the older bulls or rams in a herd in order for the younger bull[s] or ram[s] to mate with the females so that new genes can be established within the herd. They also have an understanding that the animal numbers on the reserve need to be managed according to the reserve's carrying capacity."*

Respondent 3: "*All of the trophy hunters' behaviours who have hunted here before are [beneficial] for conservation, and the professional hunter plays a big role regarding this, because it is his task to establish and instil a sense of conservation towards nature in the hunter's mind. Trophy hunters also do a lot of research beforehand of [sic] the animals that they want to hunt, and from my own personal experience, I can say that hunters' overall knowledge about nature is much better than that of the ecotourists."*

Respondent 4: "*Trophy hunters are more environmentally orientated, with a better understanding about nature. They are also willing to learn more about the environment and they want to be in nature, hiking or driving, while looking for a trophy animal to hunt. It is as if they have a completely different mindset than the ecotourist[s]. It seems that they are still connected to nature. The hunting lodge indirectly helps to contribute towards conservation through the professional hunters that exchange their own personal knowledge about the environment with the [other] hunters."*

Respondent 2: "*The hunting lodge has different ways of recycling. Firstly, all the leftover food that can't be used again, such as peels, bones et cetera, are turned into compost, which are [sic] then used again in the vegetable garden of the hunting lodge. Secondly, the food that can be used again is frozen and reused the following day or is given to the staff. All plastics, such as water bottles, eating utensils et cetera, are replaced by aluminium ones.*"

It was clear that the participants perceived hunters to be more environmentally friendly and showing more supportive behaviour towards nature conservation than ecotourists. Although they hunt animals and have an impact in that regard, they seem to be more in sync with nature than non-consumptive wildlife tourists. It is also evident that knowledge about nature is exchanged between hunters and hunting guides while hunting. It was further revealed that hunters do research regarding animals they plan to hunt and thus gain knowledge of these species. This is an essential characteristic in wildlife tourism, namely to learn more about nature.

On the other hand, it was mentioned that non-consumptive tourism contributes positively to job creation in the area and schooling of employees' children. One can assume that due to its scale of operations, more staff are employed at the non-consumptive lodge than in the case of consumptive wildlife tourism. Another positive factor is that the children of the employees are schooled on the premises. This was not measured in the study, but came forward in the discussions. The nearest town is approximately 100 km away, which makes this a significant contribution.

DISCUSSION

Based on the results, notable differences were identified in consumptive and non-consumptive wildlife tourists' impacts on the environment and their behaviour in the environment.

First, the old saying that size does matter is an essential concept when looking at sustainable tourism and the environmental impacts of wildlife tourism. As indicated by Saayman (2009), in the case of nature-based tourism, it is better for one tourist to spend $100 than for 10 tourists to spend $10 each. A higher number of people naturally generate more impacts on the environment and influence the conservation area/reserve's sustainability on a larger scale (Davis, 2009; Roe et al., 1997: 43). In the case of this study, approximately 14 to 500 non-consumptive wildlife tourists visit the lodge annually compared to the approximately 50 consumptive wildlife tourists visiting the hunting lodge. These consumptive wildlife tourists spend around three times more per night on accommodation, excluding the game hunted. If the latter was to be included, it doubles the total amount spent per hunt, as research by van der Merwe and Saayman (2013) has found. This leads to a more significant economic impact per person than in the case of non-consumptive wildlife tourists, thereby supporting the notion of fewer visitors paying higher prices.

The consequences of larger groups are that more resources are used and more waste materials are generated (Saayman, 2009). In the case of this study, it seems that consumptive wildlife tourists' behaviour is more in line with ecotourism principles than that of non-consumptive wildlife tourists (ecotourists); the former tourists consist of smaller groups, pay a higher price to stay, and generate less environmental impacts such as waste generation and water use. The lesson to be learned here is the ability to attract the more lucrative markets, which can be more environmental friendly with fewer impacts on nature. Therefore, if the non-consumptive lodge wants to be more environmentally sustainable with fewer environmental impacts, it is recommended the lodge focuses on the high-end ecotourism market, as fewer tourists in conservation areas will have fewer impacts (Saayman, 2009).

Second, the results revealed that the consumptive wildlife tourists tend to support conservation actions and efforts more, have more knowledge of wildlife and the environment, and educate others about nature and wildlife. Radder (2005) researched the motives and behaviour of trophy hunters in South Africa and found that their reasons for hunting are to discover new experiences, increase personal growth, have fun, experience excitement, and improve their interpretation of the environment, thereby learning more about nature. Freeman and Wenzel (2005) research points out those polar bear hunters provide an example of a successful conservation programme and that hunting contributes to wildlife management and sustainable economic and community development. Consequently, hunting is seen as a more sustainable product than ecotourism. However, with non-consumptive wildlife tourists, it would appear that they are more concerned about their own needs than about wildlife and conservation. They are also more demanding and egotistic regarding services delivered at accommodation units. Therefore, this study finds that consumptive wildlife tourists are more educated and knowledgeable about wildlife and nature, and are therefore a more sustainable wildlife tourism market.

Third, the results disclosed that consumptive wildlife tourists stay for substantially longer periods. In tourism terms, it is more sustainable (with regard to natural resources) to have tourists who stay longer and have more return visits (40-50% of these consumptive tourists are return visitors), as there is no need to find new visitors all the time (Saayman, 2009). This is confirmed by Dunford (2020) from *The Guardian*, who writes about greener tourism, stating that "we want to attract visitors for longer stays and encourage a 'slower' type of tourism". Because consumptive wildlife tourists stay longer, they have a more positive impact on the hunting lodge.

Fourth, consumptive and non-consumptive tourists do not leave the same trace regarding wasted food. It is true that there are more ecotourists visiting the lodge, but what is of great concern to the researchers is non-consumptive tourists' selfish behaviour, which is also evident when they are on safari (a game drive), where they are guilty of littering (and noise pollution). Therefore, higher levels of awareness are needed to encourage tourists to limit their waste generation, which has a big impact on the environment.

Fifth, both these groups impact negatively on wildlife through noise pollution. The respondents indicated that both groups spook the animals, either through hunting or, in the case of ecotourists, making noises on a game drive. This is in line with previous research by Green and Higginbottom (2001), who found that negative impacts of wildlife tourism and related human activities on wildlife can be grouped into the following three main categories: (1) disruption of activity; (2) direct killing or injury; and (3) habitat alteration (including the provision of food). Therefore, there will always be some negative impacts. One needs to weigh the positive and negative impacts and then make operational decisions based on the finding.

Last, as was stated by Ioannides (2001: 57), "to achieve genuinely sustainable development, a delicate balance should be found between conflicting economic, environmental, and socially equitable objectives". This research concurred with the statement and showed the difficulty in balancing economic objectives with environmental sustainability in nature-based tourism.

Conclusion

The aim of this research was to determine the environmental impact of consumptive and non-consumptive wildlife tourists as perceived by the management of a game reserve in Namibia. Our study reveals that, according to the perceptions of the management of this game reserve, consumptive wildlife tourists, based on their behaviour, have less impact on the environment; this type of tourism is therefore seen as more sustainable in the long run. Regarding non-consumptive wildlife tourism, the authors are also of the opinion that a smaller scale of non-consumptive wildlife tourism operations, focusing on the high-end market, can have the same results as consumptive tourism (as was found in the case of this study).

From the results, it seems that consumptive wildlife tourists adhere to a greater extent to the principles of eco- and sustainable tourism than non-consumptive wildlife tourists. The research makes the following contributions: First, it was expected that non-consumptive wildlife tourists are natural ecotourists, but it proved not to be the case. The results of this research show that consumptive wildlife tourists at the game reserve display more environmentally sustainable behaviour and fit the requirements and profile of typical ecotourists better. Second, the size (scale of operations) of nature-based tourism products does matter, and to be lucrative while having a limited environmental impact, the high-end wildlife tourism market should be targeted. The lodge also has a role in changing the behaviour of consumptive and non-consumptive tourists to act more responsibly while enjoying nature.

Limitations of the research are as follow: This study did not investigate non-consumptive operations on a smaller scale or more lucrative high-end ecotourism market operations. In addition, the study did not test the tourist behaviour of these groups towards the environment, and a possible study in future is to see if the smaller scale of operations and the high-end ecotourism market expose similar behaviour to that of the ecotourists in our research. The opinions of the wildlife tourists can therefore be tested, but the problem is that one will always consider one's own behaviour as good; the view of management is thus important. A last factor to do research can be to test the high-end ecotourists' economic contributions to wildlife areas to see if they spend the same amount of money as hunters.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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