Vol. 11(9), pp. 127-142, October-December 2019
DOI: 10.5897/JENE2019.0799
Article Number: A3C45E862300
ISSN 2006-9847

http://www.academicjournals.org/JENE

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Journal of Ecology and The Natural Environment

Full Length Research Paper

Forest land use and native trees diversity conservation in Togolese mega hotspot, Upper Guinean, West Africa

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Received 14 September, 2019; Accepted 22 October, 2019

In tropics, species diversity in agricultural systems is often assessed without distinction between native and exotic species. However, the conservation value of an ecosystem depends on its richness in native species. This study was conducted to determine the conservation value of agricultural systems in Togo megahotspot, one of the species-rich sites in Upper Guinean. Specifically, the study compares fallow systems (FS), coffee systems (COFS), cocoa systems (COCS) to forest relics (FR) on the one hand, and on the other hand the agricultural systems (FS, COFS, COCS) between them base on natives tree species diversity and composition. Sites have been selected to represent different forest lands use types. Plots (n = 233) of different sizes (400, 500 and 625 m²) were used for data collection. In each plot, all living trees (DBH ≥ 10 cm) were counted. Rarefaction, generalized linear models (GLM) and ecological distance approach were used to standardized and compare the data. A total of 183 species were recorded, of which 42% were absent from the agricultural plots. Difference in diversity index were significant between the FR and agricultural systems (p<0.001), but not between agricultural systems (p=0.23). Guineo-Congolian climax and endemic species were seriously under threat. The study poses a real problem of regeneration dynamic of these species in human-dominated landscapes that requires further specific work.

Key words: Rainforests, agricultural practices, biodiversity conservation, Reducing Emissions from Deforestation and Forest Degradation (REDD+), Togo, Upper Guinean.

INTRODUCTION

Agroforestry is generally defined as association of trees with crops and livestock. There are several agroforestry practices; including shade trees with perennial crops such as coffee and cocoa. Several studies on tropical ecosystems have shown that agroforestry systems, especially traditional ones, play an important role as refuges of tropical biodiversity by providing habitat for many species of plants and animals in human-dominated landscapes (Cicuzza et al., 2011; Cassano et al., 2012; Maas et al., 2015; Gras et al., 2016). Thus, it is widely

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accepted that agroforestry is the only alternative to meet the ecological and economic challenges posed by slash-and-burn agriculture practices (Fischer and Vasseur, 2000). These ideas have contributed immensely to the growth of agroforestry projects across the tropics in the recent decades. Some of these studies have also highlighted the importance of these systems for carbon sequestration (Schroth and Harvey, 2007). Today, forest policies of many counties aim at increasing forest areas through the promotion of agroforestry systems for carbon and biodiversity. The conservation of this latest (biodiversity) is a critical component of the development and implementation of UN-led Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Bustamante et al., 2016). However, in recent decades, there have been major changes in agroforestry practices in the coffee-cocoa sector around the world because of the declining productivity due to tree age, soil poverty and increased disease. In West Africa, facing declining productivity, traditional cocoa and coffee systems had been the subject of several managements by producers to make them more productive. These included the rehabilitation and replanting of fields, the use of Upper Amazon hybrid cocoa without shade, intensification by the planting of additional trees and fruit trees, and the conversion of secondary forest and fallow areas to agroforestry and monoculture plantations (Wessel and Quist-Wessel, 2015). These changes in agroforestry management practices and their potential impact on tropical biodiversity raise today the question of the conservation value of agroforestry systems that requires research, especially in Africa where the conservation value of agroforestry systems are poorly evaluated compared to Asia or Latine America (Fischer and Vasseur, 2000; Paruelo et al., 2001; Siebert, 2002; Rolim and Chiarello, 2004; Ashley et al., 2006; Harvey et al., 2007; Schroth and Harvey, 2007b; Philpott et al., 2008; Chazdon et al., 2009; Gardner et al., 2009; Wanger et al., 2009; Feeley and Silman, 2010; Hoehn et al., 2010; Williams Guillén and Perfecto, 2010; Cicuzza et al., 2011; Tscharntke et al., 2011; Cassano et al., 2012; Pelletier et al., 2012; Dawson et al., 2013; Bustamante et al., 2014; Maas et al., 2015; Sariyildiz et al., 2015; Sharma and Vetaas, 2015; Valencia et al., 2015; Barsoum et al., 2016; Gasperini et al., 2016; Gras et al., 2016; ; Farah et al., 2017; Almazán-Núñez et al., 2018; Benítez-Badillo et al., 2018; Jesse et al., 2018; Rodrãguez-Echeverry et al., 2018; Santos-Heredia et al., 2018). Few studies in Africa now compare agriculture systems to natural forests and each other to assess their conservation value based on forest species richness (Eilu et al., 2003; Augusseau et al., 2006; Bobo et al., 2006; Norris et al., 2010; Pinard et al., 2013). In Africa, several studies have been conducted on agroforestry systems for coffee and cocoa. However, these studies have rather addressed issues related to the decline in productivity and the socio-economic aspects of these systems (Wessel and Quist-Wessel, 2015). In addition, the few studies carried out on the conservation value of agroforestry systems in Africa have taken into account exotic species, that is, species richness and not forest species richness (Aerts et al., 2011). In Cameroon, for example, cocoa systems are rich with 206 species of trees while this richness included one third of exotic species with densities which double those of native species (Sonwa et al., 2007). The disadvantage is that, exotic species can greatly influence diversity index whose calculations are often based on abundance data, with as consequence the overestimation of the conservation value of these agroforestry systems. Otherwise, **human** land use causes major changes in species abundance and composition, yet native and exotic species can exhibit different responses to land use change. Native species populations generally decline in human-impacted habitats while exotic species often benefit (Jesse et al., 2018). Exotic species are often generalist species or species that adapt easily to human disturbance. It is often those taxa that are of the highest priority for conservation, such as regional forest endemics, that are the most extinction prone in modified tropical landscapes (Gardner et al., 2009). For these reasons, ecologists think that a better indicator of the conservation value of agroforest systems would be the forest species richness. Thus, to estimate accurately the value of modified landscapes for conserving regional forest biodiversity we need to know the proportion of species that inhabit human-modified systems that were also inhabitants of the original forest landscape (Gardner et al., 2009).

The Upper Guinean forests are among the 25 most important hotspots in the world (Poorter et al., 2004). They are estimated to contain 2,800 forests plant species among which 650 are endemics, and about 400 are considered rare. Within Upper Guinean, three areas of high diversity are distinguished and need protection and attention (Poorter et al., 2004). Togo megahotspot is one of the three areas of high diversity in Upper Guinean that owes its immense biodiversity to its past climate but also to the current ecological conditions of humidities and fogs which contributed to the installation of a great diversity of forest communities (Akpagana, 1989). These forests of the mountains of Togo have been assigned to agriculture, particularly for shifting, coffee and cocoa cultivation, which has led to repeated clearings. The conservation of biodiversity in this area largely depends of a deeper comprehension of the impact of forest land-use types on native species diversity. However, this information is absent today on this area. Togo Mountains vegetation was the subject of several works (Aké Assi, 1971; Brunel, 1977, 1978; Akpagana, 1989, 1992; Guelly, 1994; Adjossou, 2004, 2009; Kokou et al., 2008; Adjossou and Kokou, 2009;). Recent works have been focused on agroforestry systems in the area (Adden et al., 2016, 2018; Koda et al., 2016; Adden et al.). Nevertheless, there is an important lack of information on conservation value of forests land-use types of this area. The present study is significant in providing clear answers to questions regarding the biodiversity value of different forest land-use types in order to help policymakers and managers to conserve and manage the native trees species in most species-rich site of Togo. Togo has signed the World Bank forest carbon partnership. This study will guide the policies in the strategic choices and implementations of REDD + projects in order to conserve and manage the native tree species in Togolese meagahotspot. The aim of this study was to evaluate the conservation value of agricultural systems in the Togo Mgahotspot. Specifically, the study compares fallow systems (FS), coffee systems (COFS), cocoa systems (COCS) to forest relics (FR) on the one hand, and on the other hand the agricultural systems (FS, COFS, COCS) between them base on natives tree species diversity and composition.

METHODS

Study area

Forest growth conditions

The studied area (6°15' N - 8°20' N; 0°30' E -1° E) covers 6,441 Km² in the southern part of the Atakora mountains, south-west of Togo, on the border between Togo and Ghana called Togo Mountains or Togo highlands or Ecological Zone IV (Figure 1). It is adjacent to Dahomey Gap, an extension of the woodland savannas of the Sahel to the Gulf of Guinea, which separates the Upper Guinea forests from the rest of the African rainforests (Poorter et al., 2004). The subhumid mountainous area of Togo owes its immense biodiversity not only to its past climate but also to the current ecological conditions of humidities and fogs which contributed to the installation of a great diversity of forest communities. The areas are mainly covered with deciduous forest (Akpagana, 1989) intersected with Guinean savannas (Guelly, 1994). Six types of upland semi-deciduous forest were distinguished: (1) Forest with Sterculiaceae and Sapotaceae; (2) Forest with dominant *Celtis mildbraedii*; (3) Forest with dominant *Terminalia superba*; (4) Forest with dominant *Ricinodendron heudelotii*; (5) Forest with Meliaceae and Moraceae; (6) Forests with *Parinari excelsa* (Akpagana, 1989). Adjossou et al (submitted) found that the forest vegetation of the site is rather a mixture of Guineo-Congolese forest types. The climate in this area is of Guinea Mountain type (Papadakis, 1966) characterized by a long rainy season (8-10 months). The mean annual temperatures range from 21 to 25°C and the total annual rainfall ranges from 1250 to 1900 mm.. Landforms are diverse and complex. The main geologic component is of the late Precambrian (Hall and Swaine, 1976). The main edaphic component consists of schist.

History of forest land-use

Three main forestry uses can be distinguished in the mountains of Togo, which are shifting, coffee and cocoa cultivation. Coffee and cocoa were introduced into the humid forest zone of Togo around 1945. The varieties introduced at the time were *Coffea canefera* (GNAWLUI) *Coffea robusta* (ROBOSCA) for coffee and *Theobroma* sp (TETEKOSSI) for cocoa. These traditional varieties were grown in rainforests understory and did not pose a real threat to plant biodiversity. From 1975, sun-loving hybrids (Agric varieties) were introduced into the forest zone. Until 1989, most of Togo's rainforests were converted into high-yielding coffee and cocoa fields through massive fertilizer use. Conversion was possible thanks to the introduction and use of chainsaws. Since 1990, producers could no longer buy fertilizer because of falling purchase prices following the fall in world prices causing a drastic drop in productivity. In response to the declining productivity of traditional coffee-cocoa systems in the 1990s, farmers have chosen the management method based on intensification by the planting of additional trees and fruit trees. Currently, the use of Upper Amazon hybrid cocoa without shade is emerging in the area. The conversions of secondary forest and fallow areas to agroforestry and monoculture plantations are also underway in Togo's forest zone. What remains of these forests today is very fragmented and primarily localized in the zones difficult to reach, and along the rivers. Because of a high demographic growth rate in Togo (3.3% annually), the forest remnants are also affected, contrary to those along the rivers which are still relatively saved by the local populations, partly for traditional reasons (Adjossou, 2009).

Sampling methods

The forest land-use types were identified and inventoried through reconnaissance survey in the field, involving local populations but also on the basis of available historical vegetation maps which distinguishes forest areas from savannas. This approach was used because of the unavailability of accurate geographic information on each forest land- use types in the study area. These reconnaissance survey and data collections were carried out between 2007 and 2012. Sites were selected to represent study land-use types. In each site, sampling points were selected systematically to represent the physiognomy of different land-use. Plots (n=223) of different sizes (400, 500 and 625 m²) corresponding to an area of 16 ha were used to study the native plant communities under different forest land use: FS (n= 41; 3.35 ha), COFS (n=43; 3.12 ha), COCS (n=72; 5.13 ha), FR (n=67, 4.41 ha). Plots 0.04 ha in area (20 m × 20 m) were used to study the native plant communities under forests relic land-use type. But, if the habitat of a plant community was long and narrow such as for ones located near a stream, 10 m × 50 m plots were used (Kokou, 1998; Natta, 2003). Under coffee and cocoa systems, plots 0.0625 ha in area (25 m × 25 m) were used. Under FS, plots 0.04 ha in area (20 m x 20 m) and 0.0625 ha (25 m × 25 m) were used. In these different plots, all living natives' trees with a DBH ≥10 cm (diameter at 1.3 m height) were counted.

Data analysis

Species richness and diversity

To compare species richness and diversity between land-use types, species accumulation curves, gamma, alpha, beta, and Shannon diversity were used. According to Gotelli and Colwell (2001), if the sampling methods are not identical, different kinds of species may be over or under-represented in different samples. To solve the problem of inequality samples size in this study (400, 500 and 625 m ²), different data standardization techniques were used. Firstly, richness of different plot sizes were standardized to the same 400 m² plot following Vandermeer et al. (2000). Secondly, samples-based species accumulation curves were used to standardize and compare total species richness between the four forest land-use types based on a sampling area of 400 m². This rarefaction method is especially useful when comparing species richness between subsets of different sizes (Kindt and Coe, 2005) because it allows comparing the same number of plots for each subset. Species accumulation curves of each forest land use were calculated from

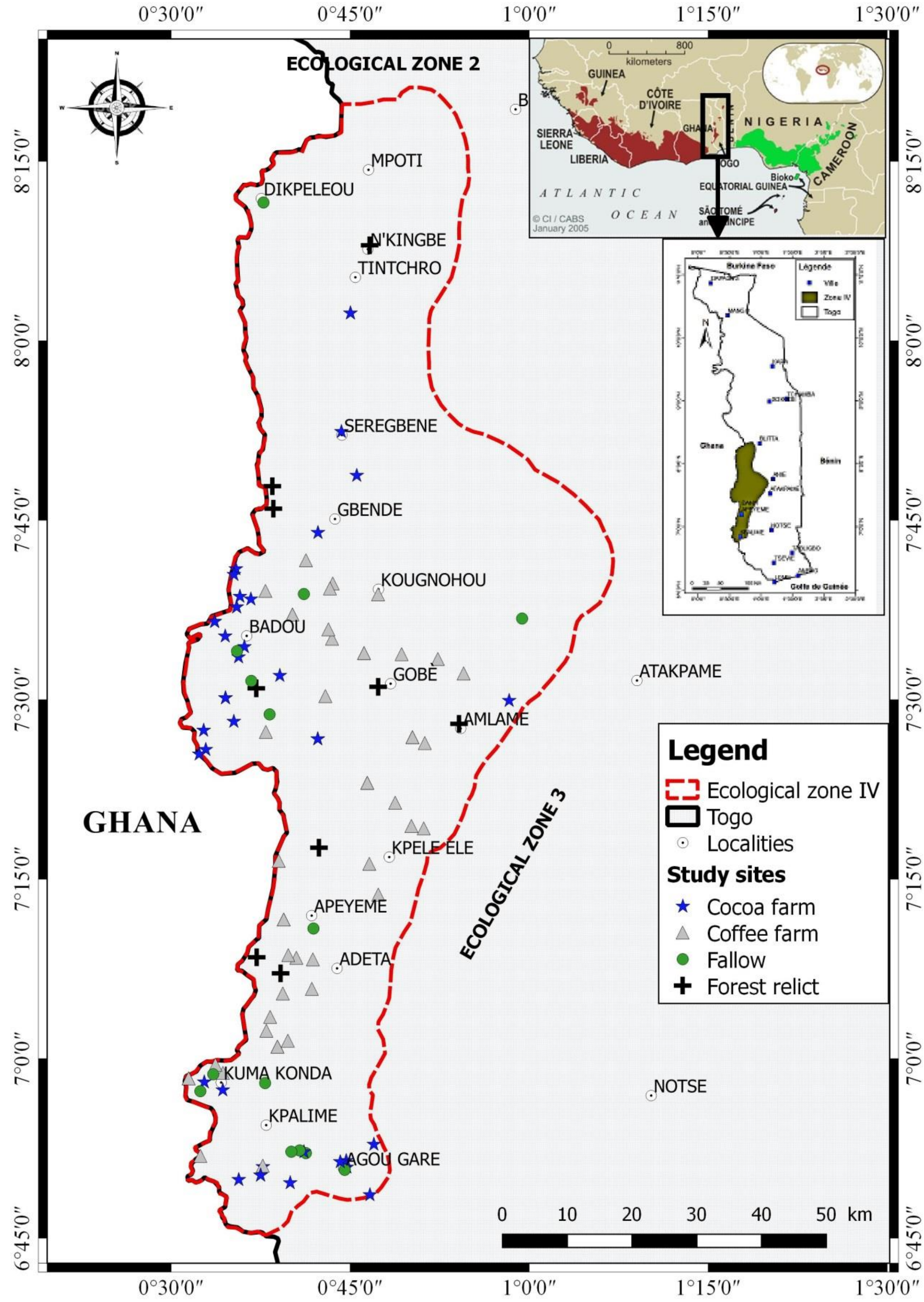

Figure 1. Map showing the location of the study sites in Togo megahotspot (Ecological zone IV).

Table 1. A comparison of total observe species number, number of unique species, number of climax species, mean species richness, mean Shannon diversity index; mean abundance of native trees species (DBH> 10 cm) on different forest land used types in Togo megahopspot mixed evergreen/semidecidous forest zone

Parameter	FR	COCS	COFS	FS
Total area sampled (ha)	4.41	5.13	3.12	3.35
Gamma diversity (Area sampled)	165	72	67	65
Number of unique species (Area sampled)	77	8	4	3
Alpha diversity per plot (400m²)	13.76 (SD=5.66)	4.15 (SD=3.11)	4.72 (SD=2.75)	4.88 (SD=4.43)
Beta diversity per plot (400m²)	10.99	16.33	13.19	12.32
Mean Shannon diversity index per plot (400 m²)	2.54 (SD=0.42)	1.15 (SD=0.79)	1.40 (SD=0.59)	1.28 (SD=0.82)
Mean abundance per plot (400m²)	10.07 (SD=5.52)	2.25 (SD=1.64)	2.55 (SD=1.30)	2.38 (SD=2.32)

FR: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems.

the cumulative number of species based on the number of species present in the plot sample using bootstrap's randomization (200 times) re-sampling techniques.

Gamma, alpha and beta diversity were used as the basic diversity index (Whittaker, 1972). Gamma diversity is the landscape-level diversity estimated as the total number of species or total richness across plots. Alpha diversity is calculated as the average species richness per plot. Beta diversity is a measure of heterogeneity in the data or habitats diversity (McCune et al., 2002), defined as: βw = (Sc/S)-1, where βw is the beta diversity, *Sc* is the number of species in the whole data set and *S* is the average species richness in the sample units. The one is subtracted to make zero beta diversity correspond to zero variation in species abundance. If $\beta w = 0$, then all sample units have all of the species. The larger the value of βw, the more heterogeneous the data set is. As a rule of thumb in that context, values of $\beta w < 1$ are rather low and $\beta w > 5$ can be considered high. The maximum value of βw is Sc-1. The maximum value is obtained when no species are shared among sample units. Shannon–Wiener index (H) was computed following Magurran (1988):

$$H = -\Sigma\,(pi)\,\mathrm{Log}_2\,(pi)$$

Where $pi=Ni/N$ is the proportional abundance of species *i* and Log_2 is the base of the logarithm.

Generalized linear models (GLM) was used with binomial (link= logit) variance functions to standardize and compare alpha and Shannon index between forests land use. This technique offer the best approach because it does not require that sample sizes to be equal, as required to compare the total number of species (Kindt and Coe, 2005). Analysis of variance is carried out to examine whether the data are consistent with a simpler ('null') model in which there are no differences.

Floristic similarity and species abundance

To assess differences in species composition among forest land use types, similarity method based on abundance of species was performed using Bray-Curtis ecological distance. Bray-Curtis distance was chosen because it is the most widely used abundance based measure, due to its strong relationship to ecological distance under varying conditions (Bray and Curtis, 1957). To diminish the influence of the dominant species, logarithmic transformation technique has been applied to the species matrix. To assess haw species abundance varied among forest land use types species abundance as the number of individuals per ha was calculated following Misra (1968). All the data supporting this paper are available at https://data.mendeley.com/datasets/kymphvj2cj/draft?a=52c6ccfd-fdb2-4c2e-8a05-daaf46d2f10d

RESULTS

Species richness and diversity

A total of 183 native tree species (Appendix S1) comprising 2485 stems were recorded. They were divided into 165 (89% of the total species recorded) species and 1759 (61% of the total stems recorded) stems, 72 (39%) and 420 (15%), 67 (36%) and 330 (11%) and 65 (35%) and 366 (12%) on FR, COCS, COFS and the FS, respectively (Table 1). It is worth noting that the largest area was sampled in the Cocoa System (COCS). However, total species richness in this system, similar to that of Coffee System (COFS) and Fallow system (FS), remains the lowest compared to forest relics.

Comparison of the accumulation curves between the four forest land use types, based on the same number of plots (40 plots of 400 m² for each type of land use), showed that FR was the richest in observed species (143 species), followed by COFS and FS (63 species each) and COCS (57) (Figure 2). Thus, the species richness of agricultural systems accounted only for 40 to 44% of forest relics. Alpha and Shannon diversity were three times higher in the RF than in the three agricultural forest land use types (Table 1). However, the beta diversity results showed a high value in the COCS (16.33; SD=3.10), followed by COFS (13.19, SD=2.74), FS (12.32, SD=4), and FR (10.99; SD=5.66). Difference in alpha (LR Chisq = 135.38; P<0.001) and Shannon diversity (LR Chisq = 142.61; P<0.001) were significant between the FR and the three agricultural systems. But, there is no significant difference in alpha (LR Chisq = 1.41 P=0.23) and Shannon diversity (LR Chisq = 2.5 P=0.11) between the three agricultural systems indicating that the studied agroforestry systems for coffee and

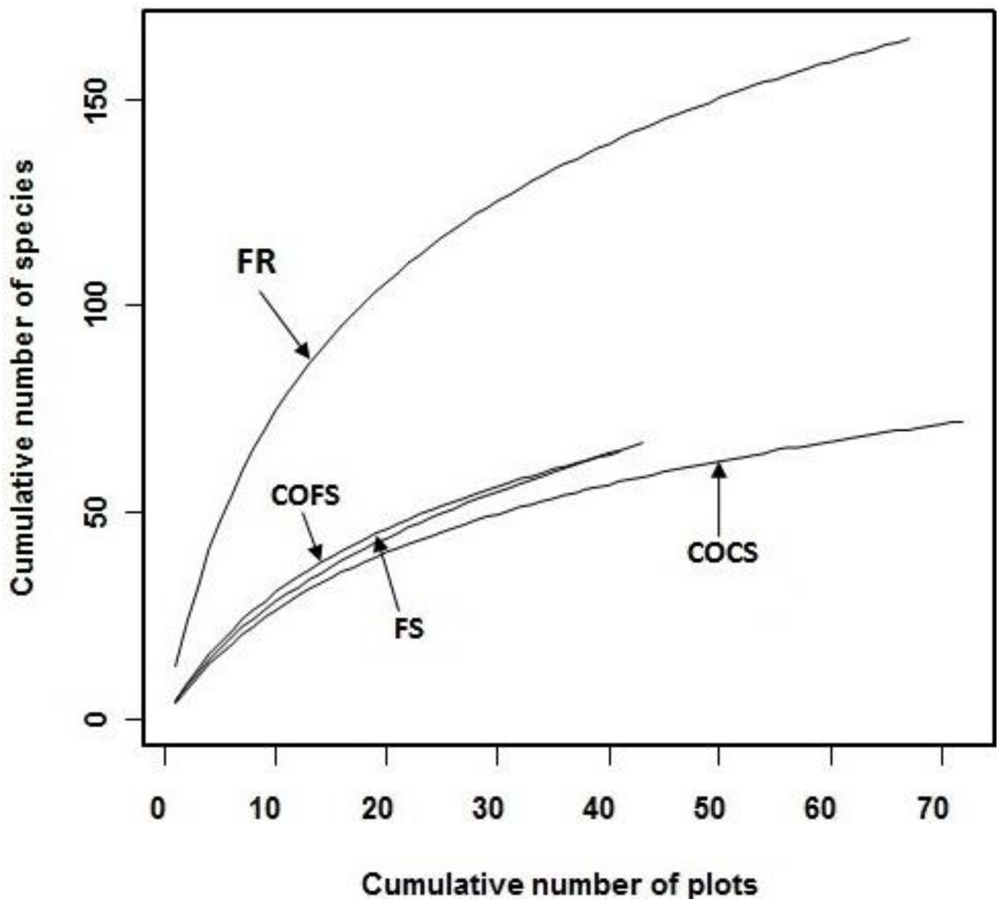

Figure 2. Samples-based species accumulation curves of the four forest land use types in the Togo Megahotspot. **FR**: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems. All curves are based on a sampling area of 400 m².

cocoa system have the same conservation value as fallows systems.

Floristic similarity and species abundance distribution

The overall Bray-Curtis distance values between forest lands use types ranged from 0.39 to 0.60. Highest Bray-Curtis distance (D=0.6) was observed between FR and agricultural systems and less Bray-Curtis distance (D = 0.39) was observed between the three agricultural systems (Table 2). FR shared 32 (17.3% of total species) species with the three agricultural systems, whereas 77 (42% of total species) species occurred on FR site only. Only 8 (4%), 4 (2%) and 3 (2%) species were unique to COCS, COFS and FS site, respectively.

Abundance distribution patterns showed that species individual abundance varied between forest lands uses types. The most abundant species by number of stems recorded in the FR was *Pseudospondias microcarpa* (30 ind /ha); followed by *Celtis mildbraedii* (22.22), *Funtumia africana* (21.35), *Pycnanthus angolensis* (13.60), *Sterculia tragacantha*, *Tabernaemontana pachysiphon*, *Pterocarpus mildbraedii*, *Cola gigantea*, *Albizia adianthifolia*, and *Antiaris toxicaria* subsp. Africana. In the COCS, *Milicia excelsa* (9.55 ind/ha) was the abundant species with the highest density, followed by *Terminalia superba (*5.06*), Funtumia africana* (4.28), *Ficus mucuso*, *Sterculia tragacantha, Ficus sur, Monodora myristica, Khaya grandifoliola etc.* In the COFS, *Xylopia aethiopica* (12.17 ind/ha) was the abundant species, followed by *Milicia excelsa (9. 29*), *Albizia adianthifolia (8.65)*, *Albizia zygia* (7.05), *Khaya grandifoliola*, *Terminalia superba*, *Anthocleista djalonensis*, *Morinda lucida*, Monodora *myristica*, *Aubrevillea kerstingii etc. (*Appendix S1)

The majority of species (78%) have low abundance (density <5 ind/ha) and could be considered rare. Of these, 57% were endemic to Guneo-Congolese rainforests (*Afzelia bella, Cordia platythyrsa, Drypetes aylmeri, Entandrophragma cylindricum, Erythrina vogelii, Gymnostemon zaizou, Homalium letestui, Parkia bicolor, Pterygota bequaertii etc*.), 21% of the transition species between Guneo-Congolese rainforests and dry

Table 2. Distance matrix between forest land use types in Togo megahopspot mixed evergreen/semidecidous forest zone using the Bray- Curtis , Kulczynski and Gower distances

Distance	FR-COCS	FR-COFS	FR-FS	COCS-COFS	COCS-FS	COFS-FS
Bray- Curtis distance	0.58	0.58	0.56	0.39	0.44	0.40
Kulczynski distance	0.56	0.56	0.53	0.39	0.44	0.40
Gower distance	0.76	0.75	0.72	0.30	0.35	0.31

FR: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems.

vegetation (*Afzelia Africana, Anogeissus leiocarpus, Cassia sieberiana, Eriocoelum kerstingii, Malacantha alnifolia, Manilkara multinervis* etc.) *(*Appendix S1),

DISCUSSION

Results showed a high species richness and diversity in the FR compared to the three agricultural systems (COCS, COFS and FS). Very few studies in the tropics have reported the impacts of cocoa and coffee agroforests practices on the richness and diversity of native tree species compared to those that included exotic species in the calculation of diversity index, or focused on the wildlife richness of these systems (Harvey and González Villalobos, 2007). Rolim and Chiarello (2004) have been reported that the cocoa agroforestry (cabruca forests) systems in southeastern Brazil were less diverse and less dense than secondary or primary forests of the region. In Densu Basin in Ghana, Attua (2003) (cited by Norris et al., 2010) showed that the plant community of existing pockets of forest are more species diverse than the vegetation associated with the cocoa or food crop farms.

Findings showed that native’s tree species richness was reduced by 70, 66 and 65% and Shannon index by 55, 45 and 50% in COCS, COFS and FS, respectively compared to FR. The reduction of regional species richness by coffee systems in this study (66%) can be considered high compared to that observed in similar systems in Ethiopia (25%) (Aerts et al., 2011). This difference could be due to the fact that the two studies did not use the same methods. In this study, trees of DBH ≥10 cm were considered, exotic species were not taken into account while Aerts et al. (2011) considered species ≥ 2 m tall and exotic species. This observations, with regard to Shannon diversity Index, are in agreement with those of Rodriguez-Echeverry et al. (2018) who have shown that the land-use change decreased Shannon diversity index in the Chilean temperate forests (Rodrãguez-Echeverry et al., 2018).

The results showed a high beta diversity index in the four forest land use types (> 5) showing a great heterogeneity in the data which could be explained by the variability of species abundance within and between forest land use types, justifying the differences observed in this results (SD) (Table 1). However, this heterogeneity was more pronounced in cocoa (beta = 16) and coffee (13) systems. This could be related to the different management schemes.

Very few studies have compared the native species richness and composition between agricultural systems in tropics. In general, both plant and animal diversity within cocoa agroforests is greater than those of other agricultural land uses, but lower than in the original forest habitats (Harvey et al., 2007). It has been shown that fallows are less diversified than cocoa systems (Trimble and Van Aarde, 2014). However, based on the native species, this study has shown that agricultural systems (COCS, COFS and FS), in Togolese megahotspot, have similar species diversity and composition, hence similar conservation values. This could be justified by changes in the management practices of coffee-cocoa agroforestry systems which are causing their change close to FS.

These changes affect native species identity and abundance distribution across the study area and the types of forest land use. At the scale of the study area, very few species were abundant (22%) (Table 4), while the majority could be considered rare (78%). In addition, 42% of species recorded were absent from agricultural systems; some species have low densities on agricultural systems compared to their density in FR. Moreover, it was noted that:

1. Species abundance varied according to the types of practices. For example *Milicia excels*a and *Terminalia superba* were abundant in the COCS and COFS, while *Albizia adianthifolia* and *Albizia zygia* in the COFS and FS. *Ficus mucuso* and *Funtumia africana* were abundant in the COCS, *Xylopia aethiopica* in the COFS and *Macaranga barteri* in the FS (Table 4);
2. The most abundant species at the scale of the study area included species with high economic values belonging to the categories of timber species (*Khaya grandifoliola*, *Milicia excelsa*, *Terminalia superba etc.*), medicinal species (*Alstonia boonei*, *Anthocleista djalonensis* and *Spathodea campanulata*) and spice species (*Monodora myristica* and *Xylopia aethiopica*) and multipurpose species (fertilization, soil restoration, shading, firewood, fruits, tools, etc.) and pioneer species like: *Albizia adianthifolia*, *Albizia adianthifolia*, *Funtumia Africana*, *Ficus exasperata*, *Ficus mucuso*, *Ficus* sur,

Table 3. Pioneer and farmers' preferred dominated tree species in Togo megahopspot mixed evergreen/semidecidous forest zone. The numbers represent the density per ha.

Species	Families	FR	COCS	COFS	FS	Total
Milicia excelsa (Welw.) C.C. Berg.	Moraceae	6.12	9.55	9.29	2.38	27.35
Funtumia africana (Benth.) Stapf	Apocynaceae	21.31	4.28	0.96	0.29	26.86
Albizia adianthifolia (Schum.) W. F. Wright	Fabaceae	7.48	1.16	8.65	6.86	24.17
Albizia zygia (DC.) J.F. Macbr.	Fabaceae	2.04	1.75	7.05	11.64	22.48
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	13.6	1.55	2.24	4.47	21.88
Sterculia tragacantha Lindl.	Sterculiaceae	12.01	3.89	1.6	3.88	21.39
Khaya grandifoliola DC.	Meliaceae	7.02	2.72	4.8	3.28	17.84
Ficus sur Forssk	Moraceae	4.98	3.89	1.6	6.86	17.35
Morinda lucida Benth.	Rubiaceae	4.08	2.72	4.16	6.26	17.24
Macaranga barteri Müll. Arg.	Euphorbiaceae	5.44	0.19	1.6	8.95	16.19
Terminalia superba Engl. & Diels	Combretaceae	4.76	5.06	4.48	0.29	14.61
Cola gigantea var. glabrescens Brenan & Keay	Sterculiaceae	8.39	1.55	0.96	3.28	14.19
Xylopia aethiopica (Dural) A. Rich.	Annonaceae	0.22	0.77	12.17	0.29	13.48
Monodora myristica (Gaertn.) Dunal	Annonaceae	5.66	3.31	3.84	0.29	13.12
Ficus exasperata Vahl.	Moraceae	4.08	1.36	1.6	5.37	12.42
Ficus mucuso Welw. ex Ficalho	Moraceae	5.21	4.09	0.64	1.79	11.74
Antiaris africana Engl.	Moraceae	7.48	0.97	0.96	2.08	11.5
Aubrevillea kerstingii (Harms)	Fabaceae	6.57	0.19	3.2	0.59	10.57
Anthocleista djalonensis A. Chev.	Loganiaceae	2.49	1.75	4.48	1.79	10.52
Alstonia boonei De Wild.	Apocynaceae	4.53	1.55	0.32	3.88	10.29
Ceiba pentandra (Linn.) Gaerth.	Bombacaceae	4.98	1.94	0.32	2.38	9.64
Canarium schweinfurthii Engel.	Burseraceae	6.12	0.19	0.32	1.49	8.13
Tetrorchidium didymostemon (Baill.) Pax & Hoffm.	Euphorbiaceae	3.85	0.58	0.32	1.49	6.25
Holarrhena floribunda (G. DON.) Dur. & Schinz.	Apocynaceae	2.26	1.36	1.6	0.59	5.83
Spathodea campanulata P. Beauv.	Bignoniaceae	0.9	1.36	1.28	1.79	5.34
Harungana madagascariensis Lam. ex Poir.	Guttiferae	0.9	0.38	2.24	1.49	5.03
Vitex doniana Sweet	Verbenaceae	1.36	1.16	1.28	1.19	5
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	1.36	1.94	0.32	0.29	3.92
Margaritaria discoidea (Baiil) Webster	Phyllanthaceae	0.22	0.38	0.64	2.38	3.64

FR: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems.

Harungana madagascariensis, *Holarrhena floribunda*, *Macaranga barteri*, Margaritaria discoidea, *Morinda lucida*, *Tetrorchidium didymostemon* etc.; among them, there are several pioneer species (Table 3).

These distribution patterns were a reflection of the selection of trees by farmers. These results are consistent with those of other authors. Indeed, works based on interviewed and tree inventories in coffee farms and forest sites in La Sepultura Biosphere Reserve in Chiapas, Mexico have showed that farmers are modifying agroforests according to their knowledge and tree preferences, and that the resulting agroforest is lower in tree diversity and dominated by pioneer and farmers' preferred tree species as compared to forests (Valencia et al., 2015). In Agroforestry system in southern Mexico and Central America, more than 30 native tree species are recognized and managed as potential facilitators of forest regeneration and direct human consumption of forest products. Immediate useful species were those plants that the farmers use for food, medicine, firewood, construction, or raw materials (Diemont et al., 2011). The results are also in line with those obtained by Adden et al. (2018) who studied the preference of trees by farmers in the coffee and cocoa agroforestry systems in Togo. Their study showed that Togolese farmers prefer in their plantation species like *Albizia* spp., *Khaya grandifoliola*, *Milicia excels* and *Terminalia superba*.

These patterns suggested also that agricultural systems block the natural succession of certain species especially climax and endemic species of Guineo-congolian. These results are in agreement with those of other authors. In semi-forest coffee agroforestry system in Ethiopian Afromontane rainforest fragments, climax species of the rainforest were underrepresented (Aerts et al., 2011). Waltert et al. (2011) assessed conservation values in tropical land use systems and found that

Table 4. Some Guineo-Congolian endemic and climax endangered species in Togo megahopspot mixed evergreen/semidecidous forest zone.

Species	Family	FR	COCS	COFS	FS	Total
Parinari glabra Oliv.	Chrysobalanaceae	3.4	-	-	-	3.4
Aningeria altissima (A. Chev.) Aubrév. et Pellegr.	Sapotaceae	3.17	-	-	-	3.17
Piptadeniastrum africanum (Hook. f.) Brenan	Fabaceae	2.26	0.58	0.32	-	3.17
Polyscias fulva (Hiern) Harms	Araliaceae	3.17	-	-	-	3.17
Hannoa klaineana Pierre et Engl.	Simaroubaceae	0.68	0.19	1.6	0.59	3.07
Nesogordonia papaverifolia (A.Chev.) R. Capuron	Sterculiaceae	2.72	-	0.32	-	3.04
Sterculia oblonga Mast.	Sterculiaceae	2.72	-	-	0.29	3.01
Bombax buonopozense P. Beauv.	Bombacaceae	0.22	0.97	0.32	1.19	2.71
Zanthoxylum macrophylla Engl.	Rutaceae	0.68	-	1.92	-	2.6
Holoptelea grandis (Hutch.) Mildbr.	Ulmaceae	2.26	0.19	-	-	2.46
Turraeanthus africanus Pellegr.	Meliaceae	2.26	-	-	-	2.26
Pterygota macrocarpa K. Schum.	Sterculiaceae	1.81	-	0.32	-	2.13
Distemonanthus benthamianus Baill.	Fabaceae	0.9	0.19	0.96	-	2.06
Maesopsis eminii Engl.	Rhamnaceae	2.04	-	-	-	2.04
Lovoa trichilioides Harms	Meliaceae	1.58	-	-	-	1.58
Amphimas pterocarpoïdes Harms	Fabaceae	0.22	0.38	0.64	0.29	1.55
Trichilia megalantha Harms	Meliaceae	1.13	0.38	_	_	1.52
Tetrapleura tetraptera (Schum.& Thonn.) Taub.	Fabaceae	1.13	-	0.32	_	1.45
Khaya anthotheca (Welw.) C.DC.	Meliaceae	0.45	-	0.32	0.59	1.37
Afzelia bella Harms var.gracilior Keay	Fabaceae	1.36	-	-	-	1.36
Morus mesozygia Stapf	Moraceae	0.68	-	0.32	0.29	1.29
Klainedoxa gabonensis Pierre ex Engl.	Irvingiaceae	0.68	0.38	-	-	1.07
Sterculia rhinopetala K. Schum.	Sterculiaceae	0.68	0.38	-	-	1.07
Treculia africana Decne	Moraceae	0.45	-	-	0.59	1.05
Parinari excelsa Sabine	Chrysobalanaceae	0.68	-	0.32	-	1
Gymnostemon zaizou Aubrév. & Pellegr.	Simaroubaceae	0.9	-	-	-	0.9
Homalium letestui Pellegr	Flacourtiaceae	0.9	-	-	-	0.9
Afrosersalisia afzelii (Engel.) A. Chev.	Sapotaceae	0.45	-	0.32	-	0.77
Blighia welwitschii (Hiern) Radlk	Sapindaceae	0.22	0.38	-	-	0.61
Nauclea diderrichii (de Wild. & Th. Dur. Merril.)	Rubiaceae	_	0.58	-	-	0.58
Drypetes gilgiana(Pax)(Pax)&K.Hoffm.	Euphorbiaceae	0.45	_	-	-	0.45
Entandrophragma cylindricum (Welw.) C.DC.	Meliaceae	0.45	_	-	-	0.45
Stereospermum acuminatissimum K. Schum.	Bignoniaceae	0.45	_	-	-	0.45
Tarenna pavettoides (Harv.) Sim	Rubiaceae	0.45	_	-	-	0.45
Mansonia altissima A. Chevalier	Sterculiaceae	0.22	0.19	-	-	0.42
Cordia platythyrsa Baker	Boraginaceae	0.22	-	-	-	0.22
Drypetes aframensis Hutch.	Euphorbiaceae	0.22	-	-	-	0.22
Drypetes aylmeri Hutct .& Dalz.	Euphorbiaceae	0.22	-	-	-	0.22
Drypetes leonensis Pax	Euphorbiaceae	0.22	-	-	-	0.22
Erythrina vogelii Hook. f.	Fabaceae	0.22	-	-	-	0.22
Irvingia robur Mildbr.	Irvingiaceae	0.22	-	-	-	0.22
Parkia bicolor A.Chev.	Fabaceae	0.22	-	-	-	0.22
Parkia filicoidea Welw. ex Oliv.	Fabaceae	0.22	-	-	-	0.22
Pterygota bequaertii De Wild.	Sterculiaceae	0.22	-	-	-	0.22
Rhodognaphalon brevicuspe (Sprague) Roberty	Sterculiaceae	0.22	-	-	-	0.22
Symphonia globulifera Linn. f.	Guttiferae	0.22	-	-	-	0.22
Erythrina mildbraedii Harms	Fabaceae	_	0.19	-	-	0.19

FR: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems. The numbers represent the density per hectare.

agroforestry systems, even traditional, reduced by 91% endemic plant species and concluded that even ecologically friendly agricultural matrices may be of much lower value for tropical conservation than indicated by mere biodiversity value. The results of this study confirm those of Barlow et al. (2007) who quantified the biodiversity value of tropical primary, secondary, and planting and found that almost 60% of plant species were only ever recorded in primary forest.

Finally, the study showed that some species have low density in both FR and agricultural systems. These results indicated that agroforestry is not the only cause of species rarity in the area. The exploitation of the timber could explain the rarity of species. *Pseudospondias microcarpa* was the most abundant species in FR because it is not a timber species.

Implication for management and biodiversity conservation

Agroforestry systems are often presented as a refuge for tropical biodiversity, only alternative to meet the ecological and economic challenges posed by slash-and-burn agriculture practices (Fischer and Vasseur, 2000). Bhagwat et al. (2008) reviewed evidence from studies across the tropics where species richness and composition of agroforestry systems are compared with that of neighbouring forest reserves and concluded that agroforestry systems are high in species richness and more similar to neighbouring forest reserves in species composition if (i) the forest land was fairly recently converted to agroforestry plantation; (ii) the management was less intensive; and (iii) the canopy cover of native trees was high. In traditional systems where these conditions are met, significant reductions in native species could have been observed. Waltert et al. (2011) have shown that traditional agroforestry systems could reduce more than 90% of native plant species. This reduction is not only related to the management practices of these systems but also their effect on microhabitats. Tropical forest ecosystems consist of a large number of microhabitats, each of which supports a high diversity of specialized organisms. Many organisms depend upon these microhabitats for a critical stage in their life cycle. Management that removes or modifies any of these microhabitats can potentially cause critical changes in overall diversity (Greenberg, 1998).

To counter the threats caused by agroforestry practices and conserve biodiversity over the long-term, auteurs (Siebert, 2002; Harvey et al., 2007; Magnago et al., 2015) thinks that land management should focus on conserving native forest habitat within cocoa production landscapes, maintaining or restoring floristically diverse and structurally complex shade canopies within cocoa agroforests, and retaining other types of on-farm tree cover to enhance landscape connectivity and habitat availability. These measures are good except that maintaining or restoring floristically diverse and structurally complex shade canopies within cocoa agroforests are at the origin of the problems that the cocoa sector is facing today (disease, rot, yield reduction). This study showed that 78% of the native species of the Megahotspot of Togo are threatened. Of these, 57% of climax and endemic species of the Guineo-Congolian region, 21% of the transition species between Guneo-Congolese rainforests and dry vegetation. In terms of conservation, transitional species are not endangered because of their wide distribution. They can be found in other types of vegetation. But the climax and endemic species of the Guineo-Congolian region deserve special attention (Table 4). Measures will be taken to ensure the renewal of these species in both FR and agricultural systems. This study poses a real problem of regeneration and succession of tropical rainforest species in human-dominated landscapes. Of the characteristic species, it is the anthropophilic and heliophilous species that colonize our agricultural and forest landscapes. Important ecological issues are required for the conservation and sustainable management of biodiversity in this area. This requires scientific and indigenous knowledge.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the local people of rainforest zone of Togo for their reception and field assistance. This research was sponsored by ITTO Fellowship (Ref. 071/03A), BES Overseas Research Grant (Project RE. 449 / 491), IFS-Comintech Research Grant (Project D/4037-1; Project D/4037-2; ProjectD/4767) and AUF Fellowship.

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Appendix S1

Appendix S1. Species abundance in Togo megahopspot mixed evergreen/semidecidous forest zone. The numbers represent the density per ha

Species	Fam	Succession	Chie	FR	COCS	COFS	FS	Total
Pseudospondias microcarpa (A. Rich.) Engl.	Anacardiaceae	Pioneer	GC-SZ	29,93	_	_	1,79	31,72
Milicia excelsa (Welw.) C.C. Berg.	Moraceae	Climax	GC	6,12	9,55	9,29	2,38	27,35
Funtumia africana (Benth.) Stapf	Apocynaceae	Pioneer	GC	21,31	4,28	0,96	0,29	26,86
Albizia adianthifolia (Schum.) W. F. Wright	Fabaceae	Pioneer	GC	7,48	1,16	8,65	6,86	24,17
Albizia zygia (DC.) J.F. Macbr.	Fabaceae	Pioneer	GC	2,04	1,75	7,05	11,64	22,48
Celtis mildbraedii Engl.	Ulmaceae	Climax	GC	22,22	_	_	_	22,22
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	Climax	GC	13,6	1,55	2,24	4,47	21,88
Sterculia tragacantha Lindl.	Sterculiaceae	Pioneer	GC-SZ	12,01	3,89	1,6	3,88	21,39
Khaya grandifoliola DC.	Meliaceae	Climax	GC	7,02	2,72	4,8	3,28	17,84
Ficus sur Forssk	Moraceae	Pioneer	GC-SZ	4,98	3,89	1,6	6,86	17,35
Morinda lucida Benth.	Rubiaceae	Pioneer	GC-SZ	4,08	2,72	4,16	6,26	17,24
Macaranga barteri Müll. Arg.	Euphorbiaceae	Pioneer	GC	5,44	0,19	1,6	8,95	16,19
Terminalia superba Engl. & Diels	Combretaceae	Climax	GC	4,76	5,06	4,48	0,29	14,61
Cola gigantea var. glabrescens Brenan & Keay	Sterculiaceae	Climax	GC	8,39	1,55	0,96	3,28	14,19
Xylopia aethiopica (Dural) A. Rich.	Annonaceae	Pioneer	GC-SZ	0,22	0,77	12,17	0,29	13,48
Monodora myristica (Gaertn.) Dunal	Annonaceae	Climax	GC	5,66	3,31	3,84	0,29	13,12
Ficus exasperata Vahl.	Moraceae	Pioneer	GC-SZ	4,08	1,36	1,6	5,37	12,42
Ficus mucuso Welw. ex Ficalho	Moraceae	Pioneer	GC	5,21	4,09	0,64	1,79	11,74
Antiaris africana Engl.	Moraceae	Pioneer	GC-SZ	7,48	0,97	0,96	2,08	11,5
Aubrevillea kerstingii (Harms)	Fabaceae	Climax	GC	6,57	0,19	3,2	0,59	10,57
Anthocleista djalonensis A. Chev.	Loganiaceae	Pioneer	GC-SZ	2,49	1,75	4,48	1,79	10,52
Alstonia boonei De Wild.	Apocynaceae	Climax	GC	4,53	1,55	0,32	3,88	10,29
Ceiba pentandra (Linn.) Gaerth.	Bombacaceae	Pioneer	GC-SZ	4,98	1,94	0,32	2,38	9,64
Cleistopholis patens (Benth.) Engl. & Diels	Annonaceae	Pioneer	GC	6,57	2,14	_	0,59	9,31
Tabernaemontana pachysiphon Stapf	Apocynaceae	Climax	GC	9,07	_	_	_	9,07
Pterocarpus mildbraedei Harms	Fabaceae	Climax	GC	8,61	_	_	0,29	8,91
Cola millenii K. Schum.	Sterculiaceae	Climax	GC	7,48	_	0,32	0,59	8,4
Canarium schweinfurthii Engel.	Burseraceae	Climax	GC	6,12	0,19	0,32	1,49	8,13
Trilepisium madagascariense DC.	Moraceae	Climax	GC	5,89	0,58	_	0,29	6,77
Tetrorchidium didymostemon (Baill.) Pax & Hoffm.	Euphorbiaceae	Pioneer	GC	3,85	0,58	0,32	1,49	6,25
Holarrhena floribunda (G. DON.) Dur. & Schinz.	Apocynaceae	Pioneer	GC-SZ	2,26	1,36	1,6	0,59	5,83
Erythrophleum suaveolens (Guill. & Pherr.) Brenan.	Fabaceae	Pioneer	GC-SZ	2,26	_	2,56	0,89	5,72
Myrianthus arboreus P. Beauv.	Moraceae	Pioneer	GC	4,76	_	0,64	0,29	5,7
Newbouldia laevis (P. Beauv.) Seemann. ex Bureau	Bignoniaceae	Pioneer	GC	4,76	0,58	0,32	_	5,66
Spondias monbin Linn.	Anacardiaceae	Pioneer	GC-SZ	4,3	0,97	0,32	_	5,6
Lecaniodiscus cupanioides Planch. & Benth.	Sapindaceae	Pioneer	GC	4,98	0,19	0,32	_	5,5
Spathodea campanulata P. Beauv.	Bignoniaceae	Climax	GC	0,9	1,36	1,28	1,79	5,34
Trichilia heudelotii Planch. ex Oliv.	Meliaceae	Climax	GC	3,17	0,97	0,96	_	5,11
Harungana madagascariensis Lam. ex Poir.	Guttiferae	Pioneer	GC	0,9	0,38	2,24	1,49	5,03
Vitex doniana Sweet	Verbenaceae	Pioneer	GC-SZ	1,36	1,16	1,28	1,19	5
Celtis zenkeri Engl.	Ulmaceae	Climax	GC	4,98	_	_	_	4,98
Macaranga hurifolia Beille	Euphorbiaceae	Pioneer	GC	4,08	0,38	0,32	_	4,79
Dialium guineense Willd.	Fabaceae	Pioneer	GC	2,94	_	0,32	1,49	4,76
Rauvolfia vomitoria Afzel.	Apocynaceae	Pioneer	GC-SZ	2,94	0,19	_	1,19	4,33
Triplochiton scleroxylon K.Schum.	Sterculiaceae	Climax	GC	3,4	0,38	_	0,29	4,08
Uapaca guineensis Müll. Arg.	Euphorbiaceae	Climax	GC	3,17	_	_	0,89	4,07
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	Climax	GC	1,36	1,94	0,32	0,29	3,92
Margaritaria discoidea (Baiil) Webster	Phyllanthaceae	Pioneer	GC-SZ	0,22	0,38	0,64	2,38	3,64

Appendix S1. Contd.

Parinari glabra Oliv.	Chrysobalanaceae	Climax	GC	3,4	_	_	_	3,4
Aningeria altissima (A. Chev.) Aubrév. et Pellegr.	Sapotaceae	Climax	GC	3,17	_	_	_	3,17
Aphania senegalensis (Juss.ex Poir.) Radlk.	Sapindaceae	Climax	GC	3,17	_	_	_	3,17
Canthium schimperianum A. Rich.	Rubiaceae	Pioneer	GC-SZ	3,17	_	_	_	3,17
Piptadeniastrum africanum (Hook. f.) Brenan	Fabaceae	Climax	GC	2,26	0,58	0,32	_	3,17
Polyscias fulva (Hiern) Harms	Araliaceae	Climax	GC	3,17	_	_	_	3,17
Lonchocarpus sericeus (Poir.) Kunth	Fabaceae	Pioneer	GC-SZ	1,13	1,36	_	0,59	3,09
Hannoa klaineana Pierre et Engl.	Simaroubaceae	Climax	GC	0,68	0,19	1,6	0,59	3,07
Macaranga heudelotii Baill.	Euphorbiaceae	Pioneer	GC	1,58	1,16	0,32	_	3,07
Nesogordonia papaverifolia (A.Chev.) R. Capuron	Sterculiaceae	Climax	GC	2,72	_	0,32	_	3,04
Discoglypremna caloneura (Pax) Prain.	Euphorbiaceae	Pioneer	GC	0,9	1,16	0,96	_	3,03
Sterculia oblonga Mast.	Sterculiaceae	Climax	GC	2,72	_	_	0,29	3,01
Afzelia africana Sm.	Fabaceae	Pioneer	GC-SZ	1,58	_	0,64	0,59	2,82
Baphia nitida Lodd.	Fabaceae	Climax	GC	2,72	_	_	_	2,72
Bombax buonopozense P. Beauv.	Bombacaceae	Climax	GC	0,22	0,97	0,32	1,19	2,71
Zanthoxylum macrophylla Engl.	Rutaceae	Climax	GC	0,68	_	1,92	_	2,6
Holoptelea grandis (Hutch.) Mildbr.	Ulmaceae	Climax	GC	2,26	0,19	_	_	2,46
Dacryodes klaineana (Pierre) H.J.Lam	Burseraceae	Climax	GC	2,04	_	_	0,29	2,33
Manilkara multinervis (Baker) Dubard.	Sapotaceae	Pioneer	GC-SZ	2,04	_	_	0,29	2,33
Cathormion altissimum Hook.f.)Hutch. & Dandy	Fabaceae	Climax	GC	2,26	_	_	_	2,26
Pentaclethra macrophylla Benth.	Fabaceae	Climax	GC	2,26	_	_	_	2,26
Turraeanthus africanus Pellegr.	Meliaceae	Climax	GC	2,26	_	_	_	2,26
Pterygota macrocarpa K. Schum.	Sterculiaceae	Climax	GC	1,81	_	0,32	_	2,13
Distemonanthus benthamianus Baill.	Fabaceae	Climax	GC	0,9	0,19	0,96	_	2,06
Maesopsis eminii Engl.	Rhamnaceae	Climax	GC	2,04	_	_	_	2,04
Mitragyna stipulosa O. Kuntze	Rubiaceae	Pioneer	GC-SZ	2,04	_	_	_	2,04
Ficus ovata Vahl.	Moraceae	Pioneer	GC	0,45	0,38	_	1,19	2,03
Blighia sapida Konig	Sapindaceae	Pioneer	GC	0,22	_	0,96	0,59	1,78
Canthium subcordatum DC.	Rubiaceae	Pioneer	GC	1,58	0,19	_	_	1,78
Berlinia grandiflora (Valh) Hutch. & Dalz.	Fabaceae	Pioneer	GC-SZ	1,13	_	_	0,59	1,73
Spondiathus preussii Engl.	Euphorbiaceae	Climax	GC	1,36	_	_	0,29	1,65
Eriocoelum kerstingii Gilg. & Engl.	Sapindaceae	Pioneer	SZ	1,58	_	_	_	1,58
Lovoa trichilioides Harms	Meliaceae	Climax	GC	1,58	_	_	_	1,58
Sorindea juglandifolia (A.Rich.)Planch.ex Oliv.	Anacardiaceae	Pioneer	GC-SZ	1,58	_	_	_	1,58
Vitex ferruginea Schum & Thonn.	Verbenaceae	Climax	GC	1,58	_	_	_	1,58
Amphimas pterocarpoïdes Harms	Fabaceae	Climax	GC	0,22	0,38	0,64	0,29	1,55
Trichilia prieuriana A. Juss.subsp. prieuriana	Meliaceae	Climax	GC	1,36	0,19	_	_	1,55
Millettia zechiana Harms	Fabaceae	Pioneer	GC	0,45	0,19	_	0,89	1,54
Trichilia megalantha Harms	Meliaceae	Climax	GC	1,13	0,38	_	_	1,52
Tetrapleura tetraptera (Schum.& Thonn.) Taub.	Fabaceae	Climax	GC	1,13	_	0,32	_	1,45
Khaya anthotheca (Welw.) C.DC.	Meliaceae	Climax	GC	0,45	_	0,32	0,59	1,37
Afzelia bella Harms var.gracilior Keay	Fabaceae	Climax	GC	1,36	_	_	_	1,36
Anogeissus leiocarpus (DC.) Guill. & Perr.	Combretaceae	Pioneer	SZ	1,36	_	_	_	1,36
Olax subscorpioidea Oliv.	Olacaceae	Pioneer	GC	1,36	_	_	_	1,36
Morus mesozygia Stapf	Moraceae	Climax	GC	0,68	_	0,32	0,29	1,29
Ficus populifolia Vahl	Moraceae	Pioneer	SZ	_	_	1,28	_	1,28
Albizia ferruginea (Guill.& Perr.)Benth.	Fabaceae	Climax	GC	_	0,19	0,96	_	1,15
Cassia sieberiana DC.	Fabaceae	Pioneer	GC-SZ	0,22	_	0,32	0,59	1,14
Dichapetalum oblongum (Hook.f.ex Benth.) Engel.	Dichapetalaceae	Climax	GC	1,13	_	_	_	1,13
Gaertneria paniculata Benth.	Rubiaceae	Pioneer	GC	1,13	_	_	_	1,13
Hexalobus crispiflorus A. Rich.	Annonaceae	Pioneer	GC-SZ	1,13	_	_	_	1,13
Mareya micrantha (Benth.) Muell.	Euphorbiaceae	Climax	GC	1,13	_	_	_	1,13

Appendix S1. Contd.

Pachystela brevipes (Bak) Baill.ex Engl.	Sapotaceae	Pioneer	GC	1,13	_	_	_	1,13
Peddiea fischeri Engl.	Thymelaeaceae	Climax	GC	1,13	_	_	_	1,13
Pentadesma butyraccea Sabine	Guttiferae	Pioneer	GC-SZ	1,13	_	_	_	1,13
Syzygium guineense (Willd.) DC.	Myrtaceae	Pioneer	SZ	1,13	_	_	_	1,13
Klainedoxa gabonensis Pierre ex Engl.	Irvingiaceae	Climax	GC	0,68	0,38	_	_	1,07
Sterculia rhinopetala K. Schum.	Sterculiaceae	Climax	GC	0,68	0,38	_	_	1,07
Treculia africana Decne	Moraceae	Climax	GC	0,45	_	_	0,59	1,05
Parinari excelsa Sabine	Chrysobalanaceae	Climax	GC	0,68	_	0,32	_	1
Sapium ellipticum (Hochst) Pax	Euphorbiaceae	Pioneer	GC-SZ	0,68	_	0,32	_	1
Macaranga spinosa Müll. Arg.	Euphorbiaceae	Pioneer	GC	0,68	_	_	0,29	0,97
Dracaena arborea Link.	Dracaenaceae	Pioneer	GC	0,22	0,38	_	0,29	0,91
Gymnostemon zaizou Aubrév. & Pellegr.	Simaroubaceae	Climax	GC	0,9	_	_	_	0,9
Homalium letestui Pellegr	Flacourtiaceae	Climax	GC	0,9	_	_	_	0,9
Phoenix reclinata Jacq.	Palmae	Pioneer	GC-SZ	0,9	_	_	_	0,9
Canthium horizontale (Schum. & Thonn.) Hiern	Rubiaceae	Pioneer	GC-SZ	0,68	0,19	_	_	0,87
Markhamia tomentosa (Benth.) K.Schum.	Bignoniaceae	Pioneer	GC	0,68	0,19	_	_	0,87
Detarium senegalense J.F.Gmi	Fabaceae	Climax	GC	_	0,19	0,32	0,29	0,81
Afrosersalisia afzelii (Engel.) A. Chev.	Sapotaceae	Climax	GC	0,45	_	0,32	_	0,77
Bridelia atroviridis Müll. Arg.	Euphorbiaceae	Pioneer	GC	0,45	_	_	0,29	0,75
Antidesma laciniatum Mül. Arg. var. membranaceum Müll. Arg.	Euphorbiaceae	Climax	GC	0,68	_	_	_	0,68
Ficus polita Vahl.	Moraceae	Pioneer	GC-SZ	0,68	_	_	_	0,68
Ekebergia senegalensis A. Juss.	Meliaceae	Pioneer	SZ	_	_	0,64	_	0,64
Blighia welwitschii (Hiern) Radlk	Sapindaceae	Climax	GC	0,22	0,38	_	_	0,61
Albizia coriaria Welw.ex Oliv.	Fabaceae	Pioneer	GC-SZ	_	_	_	0,59	0,59
Trema orientalis (Linn.) Bl.	Ulmaceae	Pioneer	GC-SZ	_	_	_	0,59	0,59
Nauclea diderrichii (de Wild. & Th. Dur. Merril.)	Rubiaceae	Climax	GC	_	0,58	_	_	0,58
Strombosia glauscescens J.Leonard var. lucida	Olacaceae	Climax	GC	_	0,58	_	_	0,58
Vernonia colorata (Willd.) Drake	Compositae	Pioneer	GC-SZ	_	0,58	_	_	0,58
Rothmannia longiflora Salisb.	Rubiaceae	Climax	GC	0,22	_	0,32	_	0,54
Anthocleista nobilis G. Don	Loganiaceae	Pioneer	GC	0,22	_	_	0,29	0,52
Albizia glaberrima (Schum. & Thonn.) Benth.	Fabaceae	Climax	GC	_	0,19	0,32	_	0,51
Blighia unijugata Bak.	Sapindaceae	Pioneer	GC	_	0,19	0,32	_	0,51
Ficus lyrata Warb.	Moraceae	Pioneer	GC	_	0,19	0,32	_	0,51
Drypetes gilgiana(Pax)(Pax)&K.Hoffm.	Euphorbiaceae	Climax	GC	0,45	_	_	_	0,45
Entandrophragma cylindricum (Welw.) C.DC.	Meliaceae	Climax	GC	0,45	_	_	_	0,45
Ficus tesselata Warb.	Moraceae	Climax	GC	0,45	_	_	_	0,45
Ficus umbellata Vahl.	Moraceae	Pioneer	GC-SZ	0,45	_	_	_	0,45
Lannea nigritana (Sc. Elliot) Keay var.nigritana	Anacardiaceae	Pioneer	GC-SZ	0,45	_	_	_	0,45
Malacantha alnifolia (Bak.) Pierre	Sapotaceae	Pioneer	GC-SZ	0,45	_	_	_	0,45
Millettia thonningii (Schum. & Thonn.) Bak.	Fabaceae	Pioneer	GC	0,45	_	_	_	0,45
Musanga cecropioides R.Br. ex Tedlie	Cecropiaceae	Pioneer	GC	0,45	_	_	_	0,45
Napoleonaea vogelii Hook. ex Planch.	Lecythidaceae	Pioneer	GC	0,45	_	_	_	0,45
Pancovia pedicellaris Radlk.& Gilg	Sapindaceae	Climax	GC	0,45	_	_	_	0,45
Rinorea yaundensis Engl.	Violaceae	Climax	GC	0,45	_	_	_	0,45
Rothmannia urcelliformis (Hiern) Bullock.ex Robyns	Rubiaceae	Climax	GC	0,45	_	_	_	0,45
Stereospermum acuminatissimum K. Schum.	Bignoniaceae	Climax	GC	0,45	_	_	_	0,45
Tarenna pavettoides (Harv.) Sim	Rubiaceae	Climax	GC	0,45	_	_	_	0,45
Uapaca heudelotii Baill.	Euphorbiaceae	Pioneer	GC-SZ	0,45	_	_	_	0,45
Mansonia altissima A. Chevalier	Sterculiaceae	Climax	GC	0,22	0,19	_	_	0,42
Dracaena mannii Bak.	Dracaenaceae	Pioneer	GC	_	0,38	_	_	0,38
Ficus lutea Vahl.	Moraceae	Pioneer	GC	_	_	0,32	_	0,32
Garcinia afzelii Engl.	Guttiferae	Pioneer	GC-SZ	_	_	0,32	_	0,32

Appendix S1. Contd.

Zanthoxylum leprieurii Guill. & Perr.	Rutaceae	Pioneer	GC	_	_	_	0,29	0,29
Aidia genipiflora (D.C.) Dandy	Rubiaceae	Climax	GC	0,22	_	_	_	0,22
Bertiera racemosa (D. Don.) K. Schum.	Rubiaceae	Climax	GC	0,22	_	_	_	0,22
Cordia platythyrsa Baker	Boraginaceae	Climax	GC	0,22	_	_	_	0,22
Cordia senegalensis Juss.	Boraginaceae	Climax	GC	0,22	_	_	_	0,22
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	Pioneer	SZ	0,22	_	_	_	0,22
Diospyros mespiliformis Hochst. Ex A. DC.	Ebenaceae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Dovyalis zenkeri Gilg. I.c	Flacourtiaceae	Pioneer	GC	0,22	_	_	_	0,22
Drypetes aframensis Hutch.	Euphorbiaceae	Climax	GC	0,22	_	_	_	0,22
Drypetes aylmeri Hutct .& Dalz.	Euphorbiaceae	Climax	GC	0,22	_	_	_	0,22
Drypetes leonensis Pax	Euphorbiaceae	Climax	GC	0,22	_	_	_	0,22
Erythrina vogelii Hook. f.	Fabaceae	Climax	GC	0,22	_	_	_	0,22
Ficus thonningii Blume	Moraceae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Flacourtia flavescens Willd.	Flacourtiaceae	Pioneer	SZ	0,22	_	_	_	0,22
Garcinia ovalifolia Oliv.	Guttiferae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Grewia pubescens P.Beauv.	Tiliaceae	Pioneer	SZ	0,22	_	_	_	0,22
Irvingia robur Mildbr.	Irvingiaceae	Climax	GC	0,22	_	_	_	0,22
Mimusops kummel Hochst.	Sapotaceae	Pioneer	SZ	0,22	_	_	_	0,22
Morelia senegalensis A.Rich.ex DC	Rubiaceae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Parkia bicolor A.Chev.	Fabaceae	Climax	GC	0,22	_	_	_	0,22
Parkia filicoidea Welw. ex Oliv.	Fabaceae	Climax	GC	0,22	_	_	_	0,22
Psychotria psychotrioides (DC.) Roberty	Rubiaceae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Pterygota bequaertii De Wild.	Sterculiaceae	Climax	GC	0,22	_	_	_	0,22
Rhodognaphalon brevicuspe (Sprague) Roberty	Sterculiaceae	Climax	GC	0,22	_	_	_	0,22
Symphonia globulifera Linn. f.	Guttiferae	Climax	GC	0,22	_	_	_	0,22
Voacanga africana Stapf.	Apocynaceae	Pioneer	GC	0,22	_	_	_	0,22
Zanha golungensis (Hiern)	Sapindaceae	Pioneer	GC-SZ	0,22	_	_	_	0,22
Erythrina mildbraedii Harms	Fabaceae	Climax	GC	_	0,19	_	_	0,19
Ficus vogeliana (Miq.) Miq.	Moraceae	Pioneer	GC	_	0,19	_	_	0,19
Monodora tenuifolia Benth.	Annonaceae	Pioneer	GC	_	0,19	_	_	0,19
Vernonia conferta Benth.	Compositae	Pioneer	GC	_	0,19	_	_	0,19

FR: Forest Relics; **COCS**: Coco System; **COFS**: Coffee System; **FS**: Follow Systems.
GC-SZ: species encountered in several phytochoria in continental tropical Africa, **GC**: Guinean-Congolese regional centre of endemism species, mainly consists of humid forest domains, **SZ:** Sudanese-zambezian regional centre of endemism , mainly consists of savannah or dry vegetation specie.

Pioneer : First stage of natural succession ; **Climax :** last stage of natural succession