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Typology of coffee-based agroforestry systems in the semi-deciduous forest zone of Togo (West Africa)

Donko Koudzo Koda[1,2*], Mamadou Chérif[3], Kossi Adjossou[2], Kossi Béssan Amégnaglo[2], Badabate Diwediga[2], Kodjovi Mawuégnigan Léonard Agbodan[2] and Atsu Kudzo Guelly[2]

[1]WASCAL Graduate Research Program on Climate Change and Biodiversity, University Felix Houphouët-Boigny, BP 165, Abidjan 31, Côte d'Ivoire.
[2]Department of Botany, Laboratory of Botany and Plant Ecology, University of Lomé, 01BP 1515, Lomé, Togo.
[3]UFR Biosciences, University Felix Houphouët-Boigny, 22BP 78 Abidjan 22, Abidjan, Côte d'Ivoire.

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This study contributes to the knowledge of the variants of coffee-based agroforestry systems (CAFS) of the semi-deciduous forest zone of Togo. To achieve this, forest, floristic and ecological data were collected in 163 random plots of 25 m × 25 m (625 m²), to analyze the typology of the CAFS and their characteristics across the study area. In the 10.1875 ha surveyed, results showed a total of 2510 stems of woody plants belonging to 138 species and 38 families. The average tree density was 246.38 trees/ha, whereas the basal area was 27.99 m²/ha. Four types of CAFS have been identified; the first type (G1) is the plant communities dominated by *Milicia excelsa* and *Persa americana* associated with coffee trees; the second type (G2) is characterized by CAFS with *Albizia* spp. and *Citrus sinensis* as dominant woody species; the third group (G3) is composed of communities dominated by *Albizia adianthifolia* and *Milicia excelsa* and the fourth group (G4) consists of CAFS dominated by *M. excelsa* and *Antiaris africana*. The floristic composition showed that the latter CAFS (G4) dominated by *M. excelsa* and *A. africana* was the most diversified, more rich in term of species (Species richness = 110, Shannon index = 4.06) and of which the basal area (Basal area = 34.32 m²/ha) is larger than the others.

Key words: Coffee-based agroforest system, typology, semi-deciduous forest zone, Togo.

INTRODUCTION

In the world, forests play an important role in maintaining fundamental ecological processes, such as water regulation, carbon storage, the provision of livelihoods and support economic growth (de Groot et al., 2002; Holvoet and Muys, 2004; Gurung and Seeland, 2008; Thompson et al., 2011; Abson et al., 2014; Sears et al., 2018). However, nowadays, these forests are facing serious degradation resulting from important over-exploitation, intensive agriculture, especially in developing countries (Lawson et al., 2014; Duguma et al., 2019). This situation is due to the fact that people are looking for more fertile lands to increase their food production and ensure their food security and economic well-being. Forest degradation started with the increase in human

*Corresponding author. E-mail: kdonkokoda@hotmail.com. Tel: +22890356792.

population and increasing food demand (Bargali et al., 2009). To overcome this situation, farmers began the agroforestry practices after clear-cutting the natural forests (Bradstock, 1981; Bargali and Singh, 1991; Bargali et al., 1992a, b) which have adversely affected the nutrient cycling and decomposition processes in the soil system (Bargali et al., 1993; Bargali, 1995; 1996). This happens most of the time through shifting agriculture (or slash and burn agriculture) consisting of the clearing of forest lands in order to grow crops until the soil is exhausted of nutrients and/or the site is overtaken by weeds. Once the soil is exhausted, they move elsewhere to clear more forests (Chakravarty et al., 2012). It is important to conciliate food production systems and the maintenance of ecosystem services of the vegetation. In this sense, agroforestry is reported to be an interesting and effective option to decrease the loss of forests, to conserve the biodiversity and to provide important sources of income for the local population (Current et al., 1995; Schroth et al., 2004a; Ashley et al., 2006; Steffan-Dewenter et al., 2007; Mbow et al., 2014a, b, c; Reed et al., 2017).

Agroforests are the most forest-like in their structure and appearance of all agroforestry systems. Some of them may be easily mistaken for the natural forests (de Foresta et al., 2000; Schroth et al., 2004b). Agroforestry systems occur in all tropical regions and can be based on many different tree crop species, among which are the coffee-based agroforestry systems (hereafter CAFS). According to Donald (2004), the wet lowland intertropical regions of Africa, America, and Asia are favorable to *Coffea robusta* agroforestry systems, whereas *Coffea arabica* agroforestry systems are found in highland regions of Africa and Latin America. CAFS conserve a large number of forest species (Correia et al., 2010) since coffee is grown in forest areas with high plant species diversity (Somarriba et al., 2004; Toledo and Moguel, 2012). Several studies have been carried out in coffee-based agroforestry systems in Latin America (Peeters et al., 2003; Lopez-Gomez et al., 2008; Valencia et al., 2015; González-Zamora et al., 2016), in Eastern Africa (Kenya: Pinard et al., 2014, Ethiopia: Aerts et al., 2011; Ouganda: Negawo and Beyene, 2017). In West Africa, studies on CAFS are scarce (Correia et al., 2010), and most of the works are focused on cocoa-based agroforestry systems (Ghana: Kyereh, 2017; Abdulai et al., 2018; Côte-d'Ivoire: Dumont et al., 2014; Kpangui et al., 2015).

In Togo, coffee is grown in the subhumid zone that is characterized by the presence of semi-deciduous forests. Indeed, the first test to introduce *C. arabica*, in the semi-deciduous forests by the German colonizer, was from 1895. New efforts, by the French administration from 1925 were a failure. Farmers will be interested in coffee, only after the establishment of cocoa farms, during the 1940s. It will then be *C. robusta*, less fragile than C. *arabica.* Currently, only *C. robusta* vulgarized by SRCC (Coffee and Cocoa Cropping Renovation Society) in the 1970s, is the most widespread and cultivated, *C. arabica* has disappeared. In this zone, many studies were conducted on forests (Akpagana, 1989; Guelly, 1994; Adjossou, 2004, 2009), but were not really focused on the CAFS. Guelly (2000) focused on the importance of *Albizia* spp. in some CAFS in forest reconstitution while Koda (2013) also showed the conservation of biodiversity in CAFS, but these works did not cover the whole area and therefore did not allow to have an overall knowledge on the actual floristic composition of these CAFS. Despite their ecological and socio-economic importance, the diversity and composition of these systems are not well known.

In this regard, the objective of this study was to contribute to the knowledge of the composition of the CAFS in the forest zone of Togo. Specifically, this work intended to assess the diversity of coffee farms, to establish the typology of CAFS and to characterize them.

MATERIAL AND METHODS

Study area

The study area represents the unique zone of Togo with semi-deciduous forests and favorable for coffee cultivation, as well as cocoa. It is one of the 5 ecological zones (ecological zone IV) of Togo (Ern, 1979). It extends between 6°15 and 8°20 latitude North and 0°30 and 1°20 longitude East (Figure 1). This zone is the meridional portion of the Atakora mountain chain. The total land mass of the study area is about 65,000 ha. Geologically, the main structural unit of the study area is the Atakorian, composed of epimetamorphic formation (Bessoles and Trompette, 1980). This zone is also composed of amphibolite epidote, amphibolitic gneiss, pyroxene gneiss and amphibole-pyroxenite (Kounétsron and Seddoh, 1978). The pedology is dominated by slightly evolved soils, ferrallitic soils, and leached ferruginous tropical soils. The zone benefits from transitional subequatorial climate (Papadakis, 1966; Trochain, 1980) characterized by annual rainfall and temperatures varying between 1390 mm and 1700 mm, and 22.5°C and 26°C, respectively. Regarding the vegetation, Togo is located in the Dahomey corridor being the interruption of the West-African forest block by the savanna that covers up to the coastal zone. The study area appears as the continuation of the humid and semi-deciduous forests of Ghana (Hall and Swaine, 1981). According to Akpagana (1989), the vegetation of the sub-humid mountainous zone of Togo is constituted of the humid semi-deciduous forest. However, it has become the zone of forest remnants with the most important plant diversity found in remote areas with difficult access (Adjossou, 2009).

Data collection

To determine the typology of CAFS and their structural characteristics, forestry inventories were conducted in the coffee farms (coffee based farming systems) of the study area. Clearly, 163 sampling plots of 25 m × 25 m (625 m²) were established randomly in representative sites over the study area, taking into consideration the CAFS (Figure 1). The total surface area inventoried in this study, was 10.1875 ha for associated species.

The geographical locations of the sampling plots were recorded using a handheld GPS Garmin 64S. In each plot, all woody species,

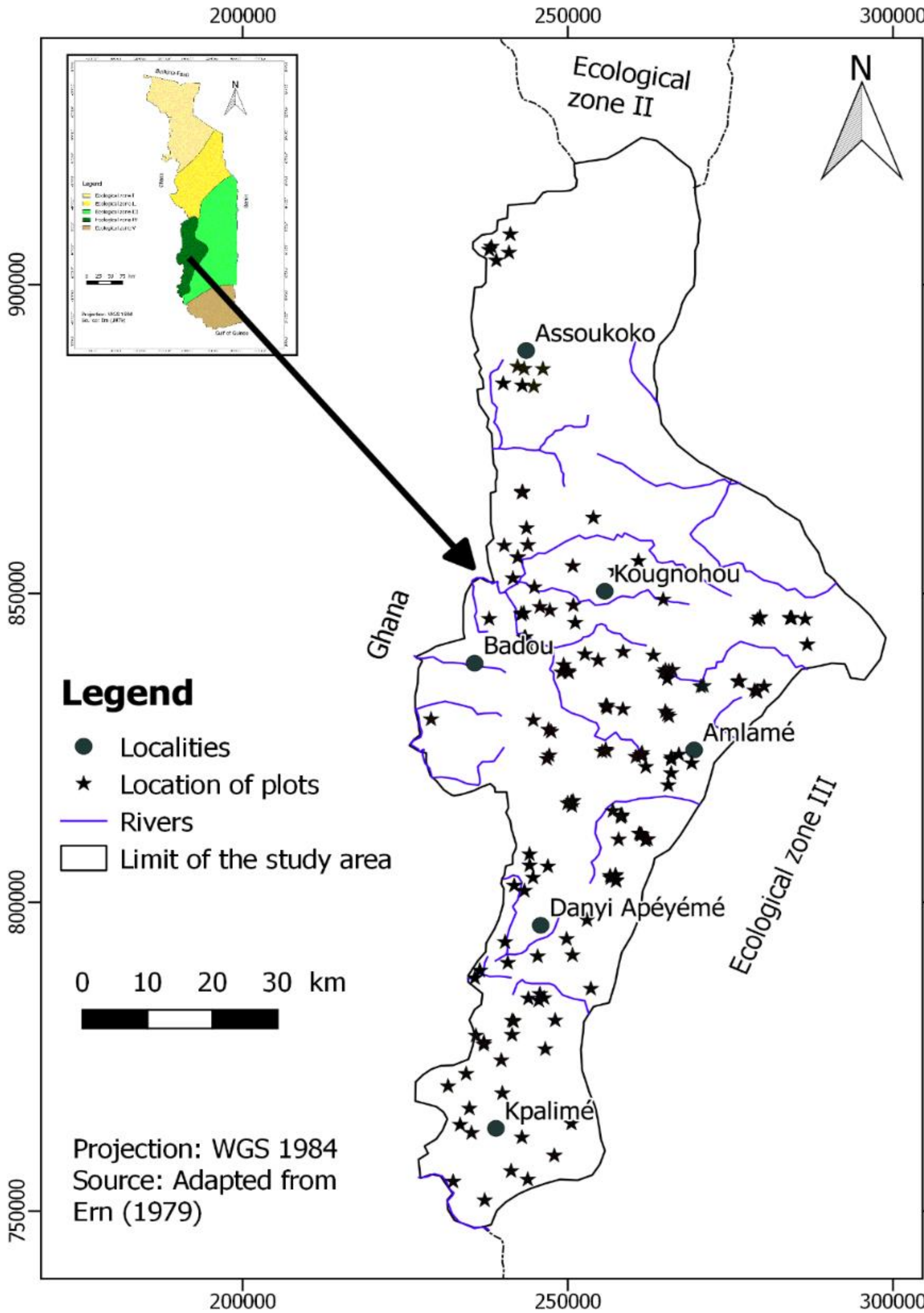


Figure 1. Location of sampling plots over the study area.

occurring in the CAFS, were recorded. The diameters at breast height (dbh) (1.3 m from the ground) of trees greater than, or equal to, 5 cm in diamter were recorded using a diameter measuring tape. The total height of these species, expressed as meters, was estimated with a "Suunto" clinometer. An abundance-dominance coefficient has been assigned to each species. Most of the species have been directly identified on the field. The unidentified species in the field were sampled and taken to the Laboratory of Botany and Plant Ecology (University of Lomé, Togo) for identification purposes. The species identification was based on the use of supporting documents of Brunel et al. (1984) and Akoegninou et al. (2006) as well as the Herbarium of the University of Lomé.

Regarding coffee plants measurement, sub-plots of 10 m × 10 m (100 m²) were installed within plots of 625 m². These measurements were made on the diameter (at 50 cm) aboveground, for plants that were greater than, or equal to, 3 cm in diameter; and additionally the total height of the coffee plants was assessed and expressed as meters. The total surface area surveyed was 1.6 ha.

Table 1. Formulas of different indices used in this study.

Indices	Equation
Shannon index (H)	$H = -\Sigma (Ni/N) Log_2(Ni/N)$
Piélou's evenness (E)	$E = H/Log_2N_0$
Rarefaction index (RI)	RI = [1-(Np/Ntp)]*100

Ni: Individuals number of a given species; N: Total individuals number; N_0: Total number of species recorded; Np: Number of plots where a given species is found; Ntp: Total number of plots.

Table 2. Formulas used to calculate the structural parameters and the IVI.

Indices	Equation
Density of trees (D) in trees/ha	D = Nt/S
Basal area (gi) in m^2/ha	$gi = (\pi \times d^2)/4$
Importance value index (IVI) in %	IVI = FREQsp + DENSsp + DOMsp
Relative frequency (FREQsp) in %	FREQsp = (Np/Ntp) x 100
Relative density (DENSsp) in %	DENSsp = (Ni/Nt) x 100
Relative dominance (DOMsp) in %	DOMsp = (gi/Σgi) x 100

Nt: Total number of trees; S: area in hectare; d: Diameter of trees; Np: Number of plots where the species is found; Ntp: Total number of plots; Ni: number of trees of a given species; gi: Basal area.

Data analysis

Estimation of plant species richness, diversity, and frequency

The nomenclature used for species and families was the flora of Brunel et al. (1984) and Akoégninou et al. (2006), following the Angiosperm Phylogeny Group (APG) III (2009). Plant species richness of associated species was obtained by establishing the list of species occurring in the CAFS. The diversity was evaluated by computing the Shannon and Pielou's evenness (Magurran, 2004) indices and the frequency of species was determined using the rarefaction index (Rarity-weighted Richness Index), according to the equation of Géhu and Géhu (1980) (Table 1). The following thresholds have been set: rare species with RI > 80% and frequent species with RI < 80% (Adomou, 2005).

Life forms and chronological affinities

The life forms of associated species were determined according to Raunkiaer (1934), revised by several studies in tropical regions (Aké-Assi, 1984; Lebrun, 1981; Aké-Assi, 2001). They are phanerophytes and Geophytes. Chorological affinities were defined based on the chorological distribution of Africa Aké-Assi (1984), adapted to the classification of Evrard (1968) and White (1986).

Structural parameters

Using the formulas as in Table 2, basal area (gi) and densities (D) were calculated for associated plant species recorded in the CAFS. The importance value index (IVI) as described by Curtis and McIntosh (1950) was computed for each species. The distribution of CAFS trees by diameter and height classes-size has been done.

Analysis of the typology of plant communities in CAFS

Plots were submitted to a Hierarchical Clustering Analysis with R software, following the Euclidian distance and the Ward method using "Vegan" package. Groups from coffee-based agroforestry systems were discriminated according to Hierarchical Clustering Analysis and named taking into account the importance value index.

RESULTS

Richness, floristic diversity and species frequency of CAFS

In total, 2510 stems were recorded in coffee-based agroforestry systems. These stems belonged to 138 species, 110 genera, and 38 families. The most represented families were *Moraceae* (15 species), *Mimosaceae* (14 species), *Euphorbiaceae* (10 species), *Caesalpiniaceae* (7 species), *Meliaceae* (7 species) and *Sterculiaceae* (7 species). *M. excelsa*, *Albizia* spp. (*A. adianthifolia*, *A. zygia*), *A. africana*, *Persea americana*, *Citrus sinensis*, *Khaya grandifoliola*, *Aubrevillea kerstingii, Cola nitida* were the most frequent species in the investigated CAFS (Table 3). The rarefaction index (RI) revealed that all the species associated to CAFS were frequent (RI value < 80%), even though some species (*K. grandifoliola, A. kerstingii,* and *C. nitida*) had RI values close to the threshold.

In general, the analysis of the ecological characteristics showed that, the basal area and trees density of associated species were respectively, 27.99 m²/ha and 246.38 trees/ha. Details of these ecological parameters are provided for the different types of CAFS identified in this study. Concerning coffee plants, all the calculated

Table 3. Frequent species in coffee-based agroforestry systems.

Species	Family	Chorological affinities	Life forms	Rarefaction index (%)
Milicia excelsa (Welw.) C. C. Berg.	Moraceae	GC	MP	35.58
Albizia adianthifolia (Schumach.) W. Wight var. *adianthifolia*	Mimosaceae	GC	mP	48.47
Albizia zygia (DC.) J.F. Macbr	Mimosaceae	GC	mP	50.31
Antiaris africana var. *africana* (Engl.) C.C.Berg	Moraceae	GC-SZ	mP	58.90
Persea americana Mill.	Lauraceae	I	mp	69.94
Citrus sinensis (L.) Osbeck	Rutaceae	I	mp	76.07
Khaya grandifoliola C. DC.	Meliaceae	GC	mP	78.53
Aubrevillea kerstingii (Harms)	Mimosaceae	GC	MP	79.14
Cola nitida (Vent.) Scott. and Endl.	Sterculiaceae	GC	mP	79.75

Note: GC-SZ: Guineo-congolian_soudano-Zambezian; MP: Megaphanerophytes; mP: Mesophanerophytes; mp: Microphanerophytes; GC: Guineo-congolian; I: Introduced species.

Table 4. Calculated parameters for coffee trees.

Parameter	Value
Density (coffee plants/ha)	2670
Basal area (m²/ha)	7.85
Mean diameter (cm)	5.58 ± 2.5
Mean height (m)	3.89 ± 1.11
Total surface Area (ha)	1.6

parameters are summarized in Table 4.

Typology and characteristics of coffee-based agroforestry systems

Based on the hierarchical Clustering Analysis and at the threshold of 78.5%, 4 different groups of plots were identified according to their floristic composition, the abundance/dominance Importance Value Index (IVI) and observations made on the field (Figure 2).

Coffee-based agroforestry systems with *M. excelsa* and *P. americana* (G1)

This group is constituted of 44 plots. It was the CAFS with *M. excelsa* (IVI = 110.73%) and *P. americana* (IVI = 73.83%) as important species. The species richness was 79 species. The density of associated species was 198.18 trees/ha and the basal area had a value of 23.81 m²/ha. Shannon's index and Pielou's evenness index were 3.82 and 0.87, respectively. In this group, the Guineo-Congolian species were most represented with 54.67% of all individuals whereas Mesophanerophytes and Microphanerophytes were 41.83% and 29.35%, respectively (Figure 3).

Coffee-based agroforestry systems with *Albizia* spp (*A. zygia* and *A. adianthifolia*) and *C. sinensis* (G2)

Twenty-five (25) plots belonged to this CAFS. It represented coffee farms in association with *Albizia* spp (*A. zygia* and *A. adianthifolia*) with an IVI value of 223.01%, and *C. sinensis* (IVI=61.97%). The species richness, tree density, and the basal area were 62 species, 254.08 trees/ha 29.52 m²/ha, in the respective order. Shannon index was 3.58 and Pielou's evenness 0.86. Regarding the phytogeographical affinities, the Guineo-Congolian species were the most important with 56.67% of all individuals. The Mesophanerophytes were represented by 56.42% of individuals (Figure 3).

Coffee-based agroforestry systems with *A. adianthifolia* and *M. excelsa* (G3)

This group is composed of 30 plots. It is the CAFS with *A. adianthifolia* (IVI=122.27%) and *M. excelsa* (IVI=76.97%). The species richness was 73 species. The tree density had been 253.33 ind/ha whereas the basal area was evaluated to 28.18 m²/ha. The Shannon index and Pielou's evenness were respectively estimated to 3.73 and 0.86. Guineo-Congolian species were the most represented (68.63%) while the Mesophanerophytes (61.26%) were the predominant life form (Figure 3).

Coffee-based agroforestry systems with *M. excelsa* and *A. africana* (G4)

This cluster included the most important number of plots(64). It was the group of CAFS with *M. excelsa* (IVI = 104.47%) and *A. africana* (IVI = 82.69%) as important associated species. The Shannon index and Pielou's evenness were 4.06 and 0.86. The density was 273.25 ind/ha for species richness of 110 species and a basal

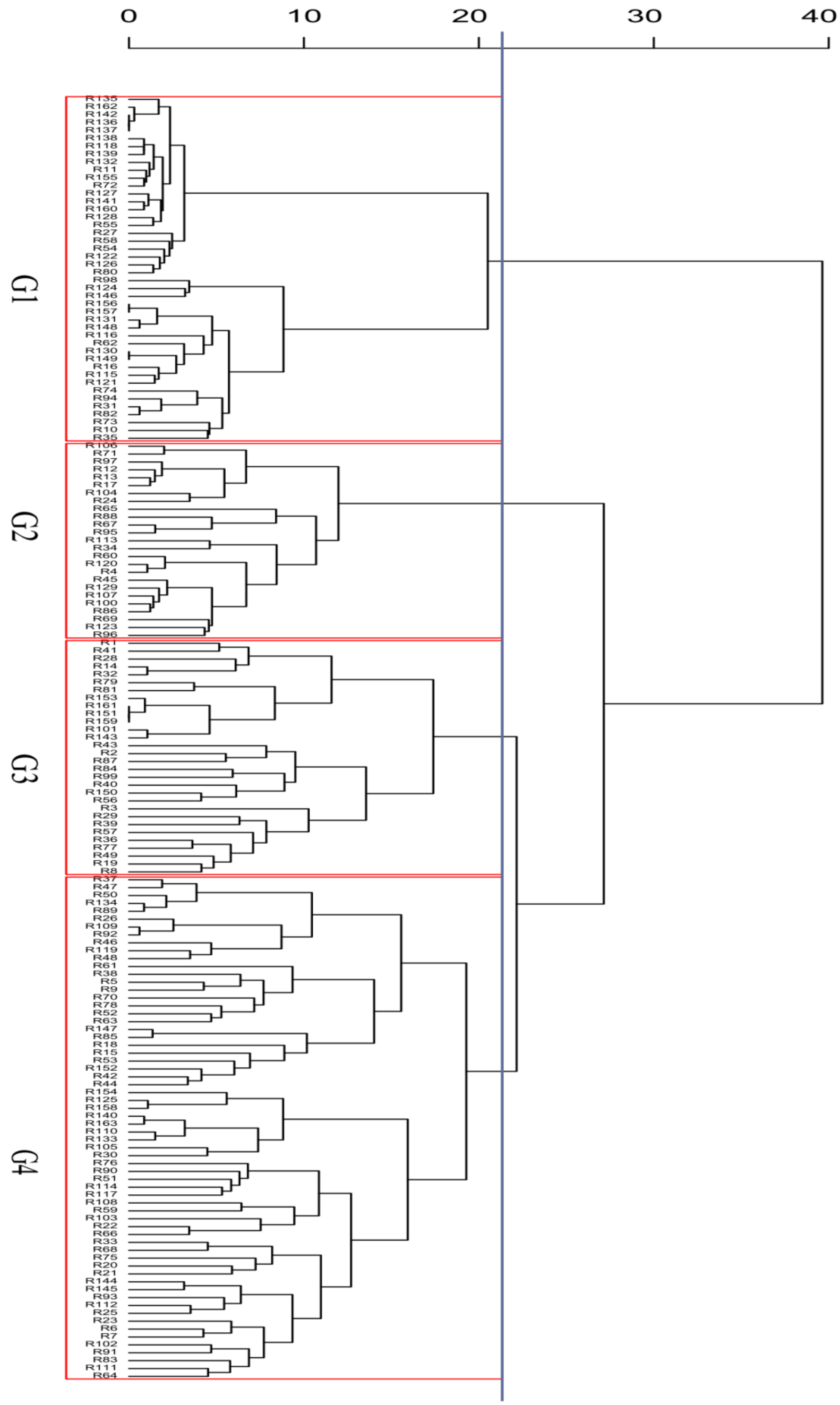


Figure 2. Hierarchical Clustering showing the discrimination of different variants of CAFS

area of 30.17 m²/ha. The Guineo-Congolian (GC and GC-SZ) were the most represented with 59.83% and 24.06% of the individuals. Mesophanerophytes were more important (50.77%), followed by Megaphanerophytes (23.97%) and Microphynerophytes (23.23%) (Figure 3). All the calculated values of the Importance Value Indices and the values of floristic and structural characteristics of identified types of CAFS are summarized respectively, in

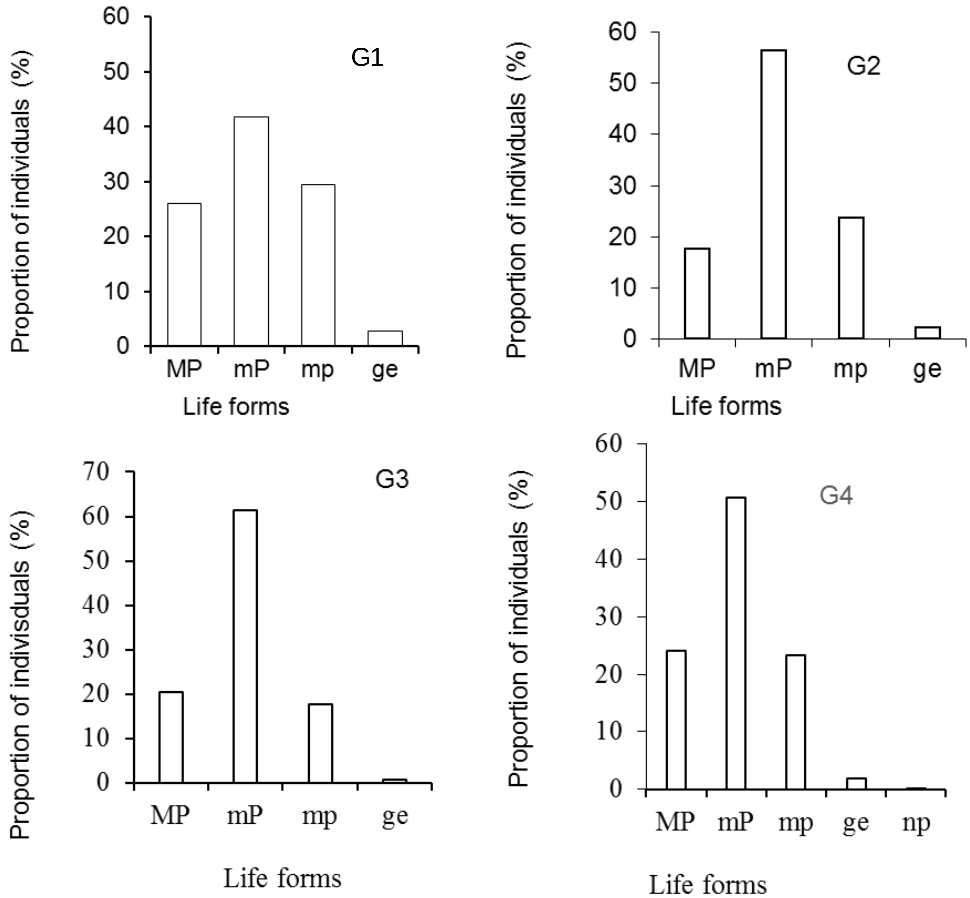


Figure 3. Spectrum of life forms. MP: Megaphanerophytes; mP: Mesophanerophytes; mp: Microphanerophytes; np: Nanophanerophytes; ge: Geophytes

Table 5 and Table 6.

Structures of coffee-based agroforestry systems

Diameter class distribution

The distribution of CAFS trees by diameter class-size showed a distribution whose appearance was similar to an "L"-shaped curve or inverted "J" type (Figure 4). This distribution characterized a structure with a predominance of individuals with small diameters (5 to 40 cm). The most represented diameters were comprised between 10 and 40 cm for all the CAFS types (*M. excelsa* and *P. americana, Albizia* spp. and *C. sinensis, A. adianthifolia* and *M. excelsa* and *A. africana*). Diameters from 50 to 100 cm are moderately represented in almost all groups. Trees with big diameters are scarce, except some among them that exceeded 200 cm observed in G4. The mean diameters of CAFS trees G1, G2, G3, and G4 are respectively 31.7 ± 19.36 cm, 31.26 ± 21.06 cm, 32.23 ± 19.38 cm and 33.96 ± 21.93 cm.

Height class distribution

CAFS trees present a bell-shaped structure (Figure 5). This structure reflected the dominance of trees with medium height. The height class from 8 to 10 m is the most represented in all CAFS types. Heights greater than 20 m are less represented except in the CAFS dominated by *M. excelsa* and *A. africana* (G4) where individuals are more present. It is in this group that individuals with heights up to 30 m are found. The mean height is 10.05 ± 4.92 m for the CAFS G1, 10.52 ± 4.44 m for G2, 10.96 ± 4.12 m and 11.65 ± 5.47 m for G3 and G4, respectively.

DISCUSSION

Floristic composition and species frequency

The study of agroforestry coffee systems enabled to have an idea about their floristic composition and the available species. The floristic structure analysis showed that *Moraceae* is the most represented family and species in

Table 5. Importance Value Indices of the different types of CAFS.

Group	Species	FREQsp %	DENSsp %	DOMsp %	IVI %
G1	*M. excelsa* (Welw.) C. C. Berg.	72.73	18.17	19.84	110.74
	P. americana Mill.	52.27	14.31	7.25	73.83
G2	*A. zygia (DC.) J.F. Macbr.*	92.00	19.40	21.18	132.58
	A.adianthifolia (Schumach.) W. Wight var. *adianthifolia*	68.00	12.85	9.59	90.44
	C. sinensis (L.) Osbeck	48.00	10.08	3.89	61.97
G3	*A. adianthifolia* (Schumach.) W. Wight var. *adianthifolia*	90.00	14.74	17.54	122.27
	M. excelsa (Welw.) C. C. Berg.	56.67	8.84	11.46	76.97
G4	*M. excelsa* (Welw.) C. C. Berg.	76.67	10.06	17.74	104.47
	A. africana var. *africana* (Engl.) C.C. Berg	61.67	8.69	12.33	82.69

FREQsp: Relative frequency; DENSsp: Relative density; DOMsp: Relative dominance; IVI: Importance value index.

Table 6. Values of floristic and structural characteristics of identified types of CAFS.

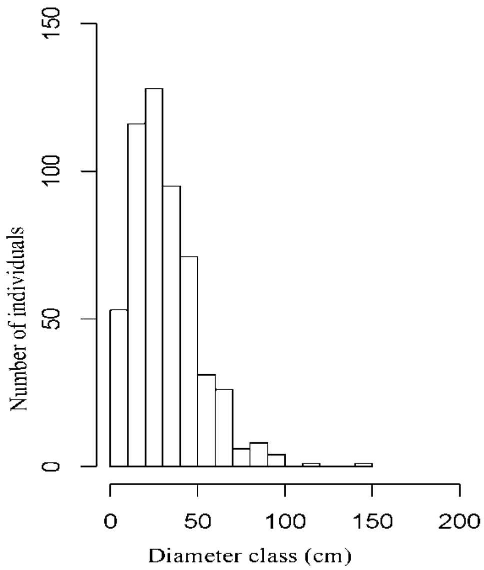
Floristic characteristics	G1	G2	G3	G4
Shannon index	3.82	3.58	3.73	4.06
Pielou's evenness	0.87	0.86	0.86	0.86
Species richness	79	62	73	110
Density (trees/ha)	198.18	254.08	253.33	273.25
Basal area (m²/ha)	23.81	29.52	28.18	34.32
Megaphanerophytes (%)	26.05	17.63	20.42	23.97
Mesophanerophytes (%)	41.83	56.42	61.26	50.77
Microphanerophytes (%)	29.35	23.67	17.68	23.23
Nanophanerophytes (%)	0	0	0	0.091
Geophytes (%)	2.75	2.26	0.63	1.92
Guineo-congolian species (GC) (%)	54.67	56.67	68.63	59.83
Introduced Species (I) (%)	26.23	16.87	8.42	15.37
Guineo-congolian_soudano-Zambezian (GC-SZ) (%)	19.08	26.19	22.94	24.06
Soudano-Zambezian (SZ) (%)	0	0.25	0	0.36

CAFS are in majority, semi-deciduous forest species (e.g., *M. excelsa*, *A. africana*, *Albizia* spp., etc.) and constitute the essential of secondary formations. These species were also the most represented and frequent in these agroforestry systems. Previous work of Akpagana (1989), Guelly (1994) and Adjossou (2009) have found similar results on the floristic composition of semi-deciduous forests in the study area (where CAFS are taking place). Likewise, the important representativeness of the *Moraceae* family has been highlighted by the work of Fouellefack Matsa Vougue (2015), in coffee-based agroforestry systems in Cameroon.

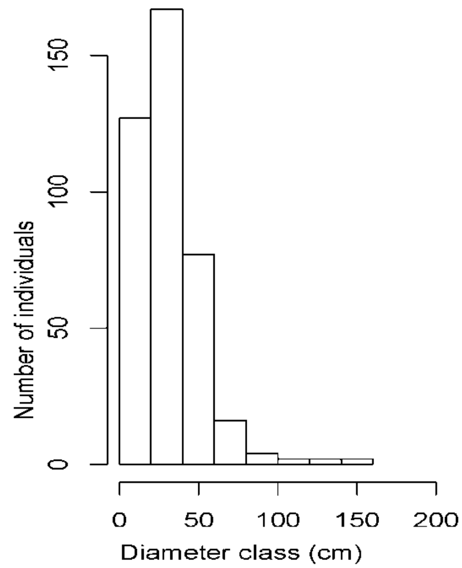
Tree density and phytogeographical affinities

The result showed that the overall tree density in CAFS was 246.38 ind/ha and varied between 198.1 in/ha and 273.25 ind/ha. Thus, these densities appear to be lower than results found by former works (Akpagana, 1989; Adjossou, 2004, 2009) in the forests of the same zone. In the meantime, the tree densities recorded in our study are higher than those reported (116 ind/ha) by Negawo and Beyene (2017) in Eastern Uganda, in a coffee-based agroforestry system. Nevertheless, our results are similar to values reported by other authors who have worked in coffee growing areas (Peeters et al., 2003; Lopez-Gomez et al., 2008; Correia et al., 2010). This situation can be explained by the fact that the coffee farms are more or less anthropized and are each time weeded, and therefore not as forest formations that are not always disturbed.

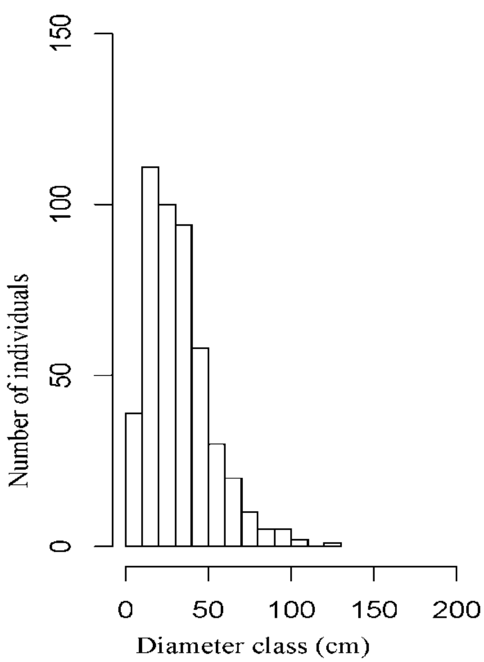
Coffee-based agroforestry systems are dominated by



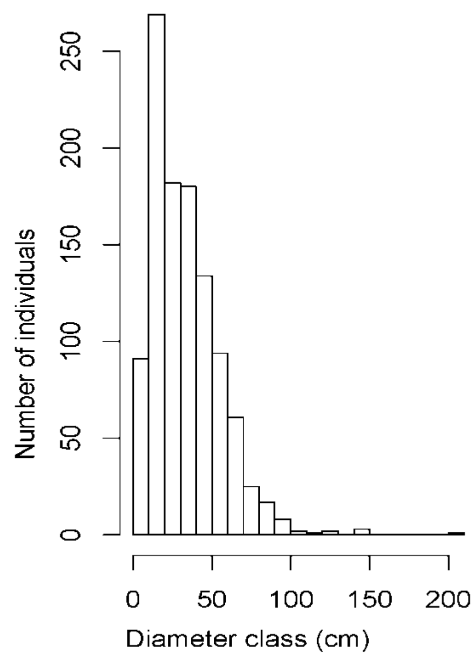
G1: CAFS with *Milicia excelsa* and *Persea americana*



G2: CAFS with *Albizia* spp. (*A. zygia* and *A. adianthifolia*) and *Citrus sinensis*



G3: CAFS with *Albizia adianthifolia* and *Milicia excelsa*



G4: CAFS with *Milicia excelsa* and *Antiaris africana*

Figure 4. Diameter class distribution within the four types of CAFS

species such as *M. excelsa*, *Albizia* spp., *A. africana*, etc., typical of the forest climatic zone of Togo. Thus, the species recorded in our study area are in majority Guineo-congolian. These results are similar to the works of Akpagana (1989); Guelly (1990); Guelly (1994); Adjossou (2009).

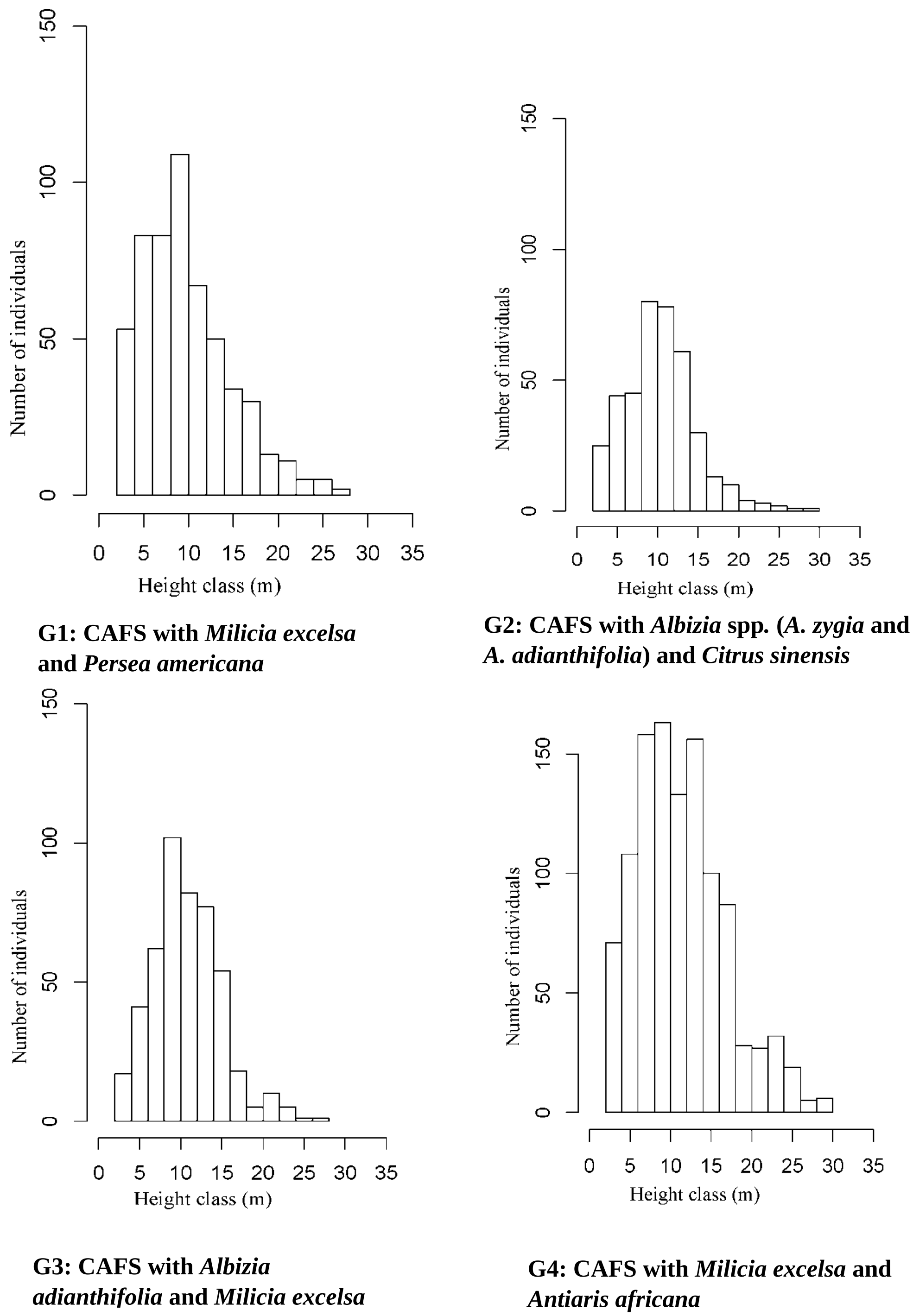


Figure 5. Height class distribution within the four types of CAFS.

Typology of coffee-based agroforestry systems

Four types of coffee-based agroforestry systems were identified on the basis of importance values indices, species richness, and ecological descriptors. Indeed, *Albizia* spp. are plants of semi-deciduous forests and constitute the essential of the secondary formations of the forest zone of Togo. They are heliophilous plants, having positive photosensitivity and are pioneer species that prepare the return back to the forest stage of these disturbed formations (Guelly, 2000). These CAFS with *Albizia* spp are the results of reforestation efforts introduced by the SRCC (Coffee and Cocoa Cropping Renovation Society). Similarly, Depommier (1988a), pointed out that in CAFS in Burundi, shade plants were usually *Albizia* spp. in light foliage and *Senna spectabilis* in denser foliage. In addition to the shading role, *Albizia* spp. is reported to as a key component for maintaining the soil fertility (Depommier 1988b). This role of fertilization of *Albizia* spp. was also highlighted by other works (Kalanzi and Nansereko, 2014), in Uganda. Equally, our findings are also similar to those obtained by Nigussie et al. (2014), Hundera et al. (2015) and Endale (2019), who showed that *Albizia* spp. contribute to the improvement of soil fertility, in coffee-based agroforestry systems in Ethiopia.

The CAFS dominated by forest species such as *M. excelsa* and *A. africana* (G4) constitute the most old coffee-based systems. These species were preserved by the farmer during the clearing of undergrowth vegetation for the establishment of coffee farms. This association of *M. excelsa* and *A. africana* was identified by Adjossou (2009) in forests of the study area. Likewise, the abundance and dominance of *M. excelsa* and *A. africana* in CAFS have been reported by several authors in coffee cropping regions (Herzog, 1994; Correia et al., 2010). These species, combined with other native species in CAFS, give to these systems, an appearance similar to dense forests.

Furthermore, other observed groups, especially *P. americana* and *C. sinensis* in association with other species in coffee farms, have also been reported by authors who have worked in CAFS (Gwali et al., 2015; Gonzalez-Zamora et al., 2016). These fruit species are associated with coffee trees, especially because of their high economic value (Davis et al., 2017).

When considering the four categories of CAFS, it should be noted that the species richness, density, basal area and Shannon index are higher in type G4 (*M. excelsa* and *A. africana*) than the three others. This case can be explained by the fact that this type is made up of more forest species and therefore, more diverse and denser. This group also refers to the abandoned CAFS undergoing natural recovery towards denser vegetation, especially forests.

Structure of CAFS

The distribution of CAFS trees by diameter class-size revealed an inverted "J" type. This distribution characterized a structure with a predominance of individuals with small diameters. This distribution seemed similar to that described in coffee-based agroforestry systems, in Ethiopia by (Mahmood, 2008) and in Guinea by Correia et al. (2010). This author pointed out that these patterns of diameter classes indicated the general trends of population dynamics and recruitment process. The abundance of young people individuals could be explained by germinations maintained by farmers. these CAFS are dynamic with a balanced structure and a constant renewal of big trees. The scarcity of the big can be explained by the fact that the farmers use to cut sometimes the big trees.

Conclusion

This study enabled to know the diversity and the different types of CAFS in the semi-deciduous zone of Togo, as well as the structural parameters that characterize them. In addition, this work revealed that CAFS can also conserve native trees. The investigations allowed to identify 138 ligneous species preserved by farmers for their different role on farms. Furthermore, coffee-based agroforestry systems have been allocated into four variants, according to the importance value indices of their species and ecological descriptors recorded during field work. These are CAFS with *Milicia excelsa* and *Persea americana*; CAFS in association with *Albizia* spp. and *C. sinensis;* CAFS with *A. adianthifolia* and *M. excelsa;* and CAFS in association with *M. excelsa* and *A. africana*. Among all these categories of CAFS, it should be indicated that the ones with *M. excelsa* and *A. africana* are the most species-rich and are therefore close to dense secondary humid forests.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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