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Farmers Influence on Plant Diversity Conservation in Traditional Cocoa Agroforestry Systems of Côte D'Ivoire

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Abstract: *Côte d'Ivoire keeps the leading place of cocoa production in the world because of the rapid expansion of cocoa cultivation areas at the expense of forests. In order to contribute to adapting the management of cocoa plantations to global change, our study focused on the population structure of associated woody vegetation with reference to utilization. In the Doboua region, a floristic survey on 90 plots of 400 m2 each and ethnobotanical interviews of 180 producers help to better analyze future conservation of cocoa agroforestry systems. Floristic variability was closely related to three distinct structural levels of frequency and ecosystem services, by the multiple factorial analysis. The group of the most frequent species denominates several fruit and food providing species, medicinal plants and business activities. The group of moderately frequent species comprises shade trees for young cocoa trees, and timber species. The less frequent species, generally spontaneous plants, contribute to firewood provision. Thus, the ecosystem services concern distinct species and reflect the diversity through peasant's management. Sustainable management for conservation of traditional cocoa agroforestry systems requires global change to be taken into account, ensuring the resilience of the agricultural areas and food security.*

Keywords: *Agrosystems, Daloa, Ecosystem services, Global Change, Phytodiversity, Sustainable agriculture, West Africa*

1. INTRODUCTION

Cultivation of trees in harmonious combination with crops is an old practice applied by farmers around the world. There are many examples of similar traditional practices in several parts of the world such as Central America (Wilken, 1977), Asia (Conklin, 1957), Finland (King, 1987) and Nigeria (Forde, 1937, Ojo, 1966). These examples are now referred to as "agroforestry" by Beer *et al*. (2003), AESA (2015) and Ngono *et al*. (2015). According to ICRAF (2013), agroforestry is the introduction of trees into cropping systems and their management to increase productivity, profitability, diversity and sustainability of the ecosystem. Agroforestry systems with cocoa (*Theobroma cacao* L.) are popular in West and Central Africa (Sonwa *et al*., 2003; Koulibaly, 2008) because they can reduce deforestation in the tropics (Dixon *et al*., 2001). In fact, during cocoa cultivation, cocoa trees are associated to many perennial woody forest and fruit species, which provide farmers with different products that they consume or sell to increase their income (Herzog & Gotsch, 1998, Duguma *et al*., 2001; Asare, 2005; Sonwa *et al*., 2007; Temgoua *et al*., 2018, Koulibaly *et al*., 2010a)

Since 1978, Côte d'Ivoire has become the world's leading producer and exporter of cocoa beans by providing over 42% of the world supply (Braudeau, 1969; Tano, 2012, MINEF, 2015; ICCO 2017, M'Bo *et al*., 2019,). Cocoa cultivation procures around 30% of the worldwide income from exports (MINEF 2015) and contributes to more than 15% of Côte d'Ivoire's Gross Domestic Product (ICCO, 2017). Cocoa production keeps over one million farmers occupied, standing for 15% of the rural

population, because 80% of cocoa are produced by smallholders (Jouvé and Milly, 1990; Koulibaly *et al*., 2010b; Assiri *et al*., 2012). However, the expansion of cocoa plantations leads to land conversion with drastic changes in vegetation cover and biodiversity (Chatelain *et al*., 1996; Koulibaly, 2008; Goetze *et al*., 2010; Aké-Assi and Dian (1990); FAO, 2005, 2009). The current land cover of Côte d'Ivoire indicates that more than 30% of the territory is occupied by cocoa plantations (FAO, 2009; REDD+ Strategy, 2018; Anonymous 2018; World Bank, 2019). In the context of global change, Côte d'Ivoire counteracts this forest loss by promoting agroforestry activities. The goal is to encourage farmers to maintain and introduce tree species in their cocoa plantations, while the effects of cocoa cultivation on plant diversity are hardly known.

This concern was met first with scientific investigations of forests in cocoa regions that have shown a severe reduction of the specific richness of forests by logging in the past (Koulibaly, 2008, Goetze *et al*., 2010). As a consequence, regeneration of forest species is compromised by an absence of adult or juvenile plants (Koulibaly *et al*., 2016). Concerning the cocoa plantations, floristic richness is highest in the early years in the South, Centre and West of Côte d'Ivoire (Adou Yao & N'guessan, 2006; Koulibaly, 2008; Konan *et al*., 2011). The most critical phase during the development of a cocoa plantation, which leads to a severe reduction in woody vegetation, is estimated to happen between the ages of 6 and 20 years of a plantation (Koulibaly, 2008). A decrease of important native plants in cocoa plantations was reported by several authors, being a result of influences from farmers regarding their origin, age and needs (Koulibaly, 2008, Piba *et al*., 2011; Kpangui *et al*., 2015: Koulibaly *et al*, 2015). However, most works studied only briefly the diversity of vegetation structure associated with cocoa trees although this information can help estimating the potential conservation of cocoa agroforestry systems (Deheuvels *et al*., 2007b; Veech *et al*., 2002; Crist *et al*., 2003).

As the presence of a species is linked to the preferences of the producers, we hypothesize that a species is encountered in the agrosystem once it is preferred, and that the species' frequency is high. It follows that the most adapted structural parameter is the specific frequency, allowing to estimate level of the peasants' conservation of species associated with cocoa plantations. In order to contribute to adapting the management of cocoa plantations to global change, our study focuses on the population structure of associated woody vegetation with reference to ecosystem services. Our study was carried out in the Doboua area (Figure 1)**,** located in the second largest cocoa production region of Côte d'Ivoire (Esso, 2009).

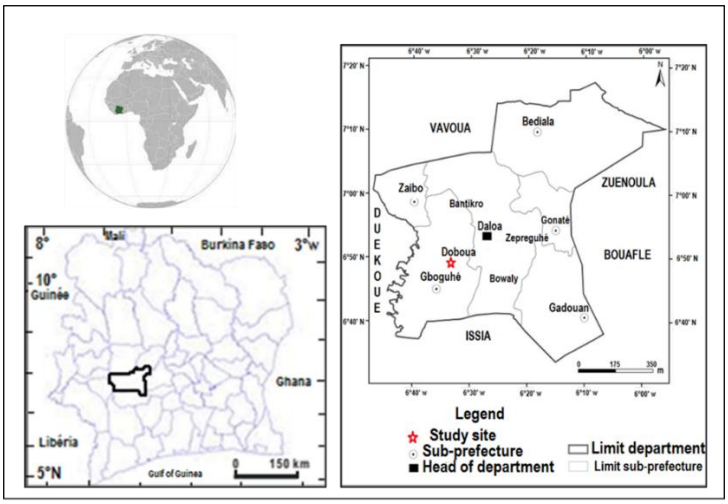

Figure 1: Location of the study site in Côte d'Ivoire.

2. Material and Methods

2.1. Description of the Study Site

The Doboua area is located in the western forest region of Côte d'Ivoire, dominated by semi-deciduous dense forests. Annual rainfall is around 1100 mm (Eldin, 1971; Declert, 1997, Anonyme, 2017). Temperatures range from 29 °C to 30.8 °C with an average of 29.67 °C. The landscape is formed by flat, slightly undulating areas bordering the Sassandra River (Koffié-bikpo & Kra 2013). Soils are

granitic and have a good ability for cultivating several crop types (Perraud, 1971; Lecomte, 1990). This situation has led to the development of perennial crops (cocoa, coffee, oil palm), food crops, and fallow lands, under anthropogenic pressure (Koffié-bikpo & Kra, 2013)

2.2. Data Collection and Analysis

The characteristics of associated woody vegetation were assessed in a floristic survey within 90 plots of 400 m^2 each. Diversity was determined through the number of species in floristic categories such as families, life forms and chorology. The generic coefficient of the flora was calculated according to Aké Assi (1984), which is the ratio between the total number of genera and the number of species belonging to them, as a percentage. High values of this coefficient indicate a diverse flora. Ethnobotanical interviews with 180 producers in the study area allowed for compiling the uses of woody species associated with cocoa plantations.

Firstly, structure was described by defining proportions of woody plants between floristic categories, which were assessed through the number (or mean) of individuals and the analysis of variance with one factor, testing the significance between categories. Secondly, the factorial correspondence analysis was used to describe the distribution of species frequency, and then its combination with an hierarchical linkage cluster analysis using Euclidean distance classified preferred species into different groups. Indicator species of each group was identified. Thirdly, multiple factorial analysis was used to describe floristic variability under ecosystem services in each group. All statistics were done with R 4.0 software.

3. RESULTS

3.1. Floristic Characteristics

3.1.1. Floristic Composition

The list of species found in the 90 plots shows 59 species assigned to 51 genera and 25 families. The generic coefficient of 0.86 indicates that the Doboua cocoa area contains a rich flora, and the most dominant (sub)families are Euphorbiaceae, Moraceae and Sterculiaceae with 10% of all species (Figure 2), followed by Anacardiaceae, Mimo”sac”eae, Rutaceae and Caesalpiniaceae, comprising 7% of the species. The species are grouped under four biological types dominated by microphanerophytes (83.68%, Figure 3A). Regarding the chorological distribution, 61.98% of all species belong to the transition zone between the Guinéo-Congolian and the Sudano-Zambezian domain (GC-SZ), and 16.24% are introduced species (Figure 4A).

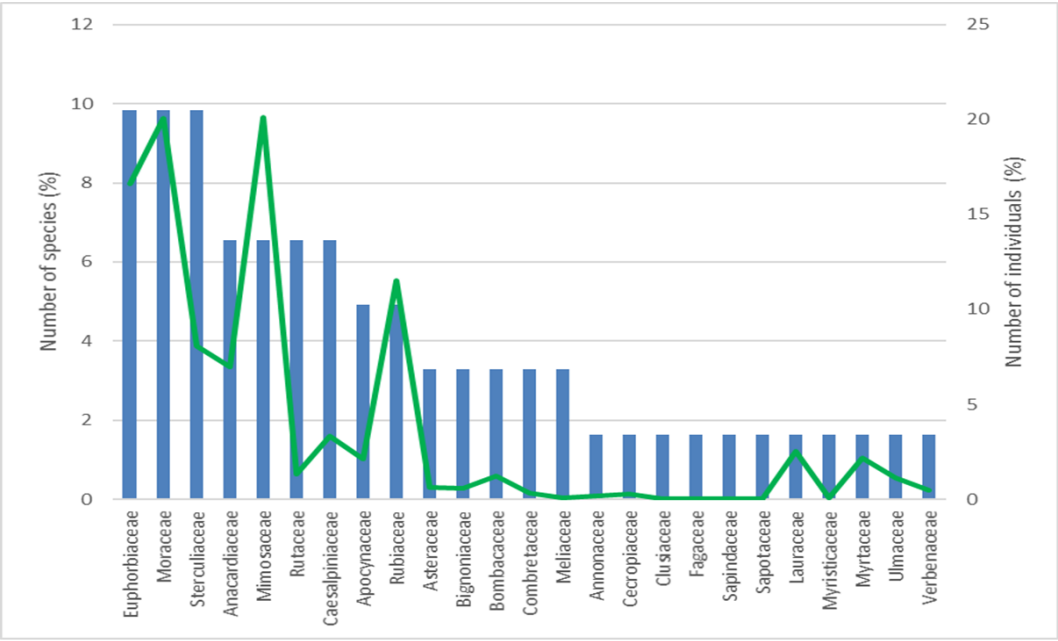

Figure 2: Proportionate numbers of species (blue) and individuals (green) in family taxa of 90 plots of cacao plantations.

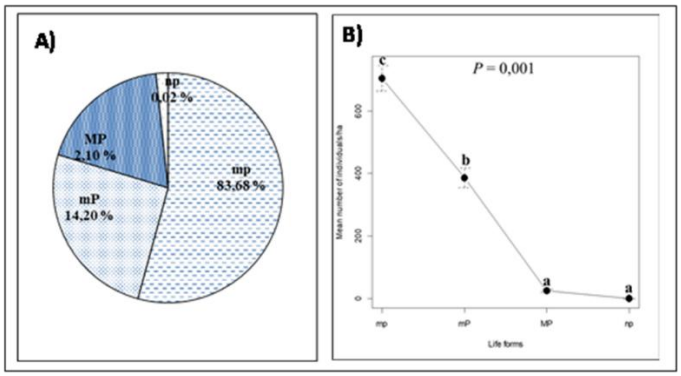

Figure 3: Life forms in 90 cacao plantations. A) Proportionate number of species; B) Mean number of individuals. mp= microphanerophytes, mP = mesophanerophytes, MP = mégaphanerophytes, np = nanophanerophytes.

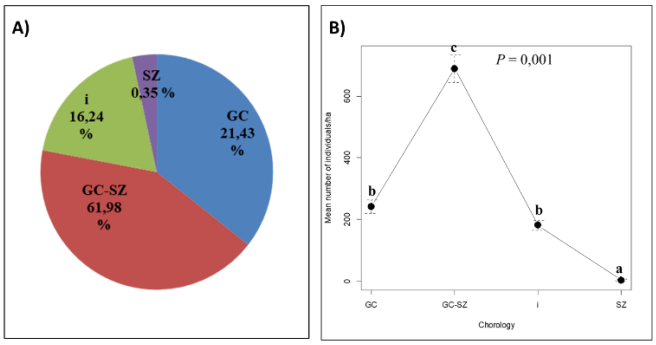

Figure 4: Chorology in 90 cacao plantations. A) Proportionate number of species; B) Mean number of individuals. GC = Guinéo-Congolian , GC-SZ = Guinéo-Congolian /Sudano-Zambezian transition, SZ = Sudano-Zambezian , i= introduced

3.1.2. Importance of Woody Vegetation for Farmers' Life

The interviews revealed that the species maintained in traditional cocoa agroforestry systems are useful in several domains of farmers' life (Figure 5). Most of them were used preferentially to produce shade at the young cocoa tree (44.1%), followed by the supply of firewood (37.3%) and medicinal use (35.6%). The smallest numbers of plants were used for farm delimitation (11.9%) and soil fertilization (6.8%).

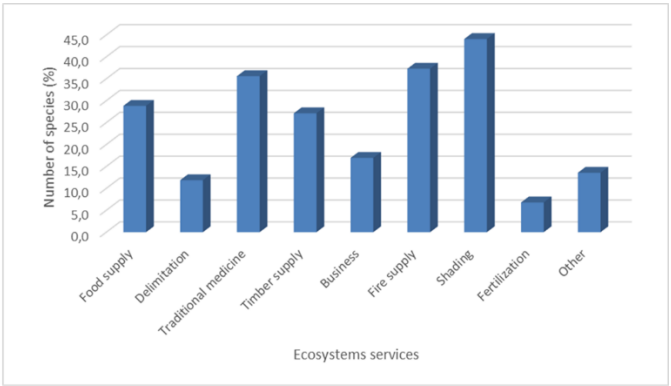

Figure 5: Importance of main ecosystem services of associated woody species in traditional cocoa agroforestry system of Doboua zone

3.2. Structural Components of Woody Vegetation

3.2.1. Proportions in Floristic Categories

The distribution of individuals across families shows that the families containing most species present also the largest number of individuals. These are, in decreasing order, Mimosaceae (20.11%), Moraceae (20.06%) and Euphorbiaceae (16.63%, Figure 2). Concerning life forms, the average number of individuals was highest for microphanerophytes. This number varies significantly between life forms (ANOVA test, F = 172.8; P = 0.001, Figure 3B). In terms of chorology distribution, individuals

belonging to species that have an affinity to the GC-SZ transition zone were most numerous. Also, a significant difference becomes obvious when passing from one chorological affinity to another (ANOVA test, F = 122.4; P = 0.001, Figure 4B).

3.2.2. Species Frequency in Cocoa Plantations

The factorial correspondence analysis (Figure 6) showed that the first and second axes account for 74.27% of variability of the analyzed database (Table 1). Following axis 2, species were grouped according to their frequency in traditional cocoa agroforestry systems. Three species groups were identified. This result illustrates the structure levels of species (groups) preserved in traditional cocoa agroforestry systems.

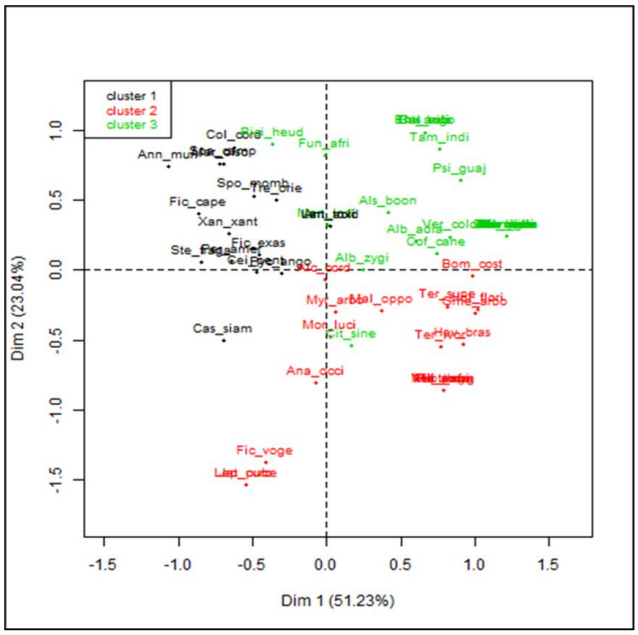

Figure 6: Factorial correspondence analysis of associated woody species individuals according to their frequency in 90 plots of cacao plantations.

Table1. *Summary of FCA of species in cocoa agroforestry systems of the Doboua area. Dim.1-Dim.4: FCA axes.*

Axes	Dim.1 (%)	Dim. 2 (%)	Dim. 3 (%)	Dim. 4 (%)	Total inertia (%)
Variance	0.307	0.138	0.099	0.055	
Floristic variability	51.231	23.040	16.558	9.172	0.599
Cumulative values of floristic variability	51.231	74.270	90.828	100	

These groups are each characterized by an indicator species finding by the Indval method: group (G1) with *Annona muricata*, group (G2) with *Ficus vogelii* and group (G3) with *Psidium guajava* (Figure 7).

Group (G1) with *Annona muricata* contains less frequent species that were mostly spontaneous fruit and forest species such as *Spondias mombin, Annona muricata, Lannea acida, Blighia welwitschii, Newbouldia laevis, Daniellia ogea, Sterculia tragacantha, Ficus exasperata,* and *Myrianthus arboreus.* This group also contains large trees such as *Ceiba pentandra, Cola cordifolia, Antiaris toxicaria and Entandrophragma angolense*.

In group (G2) with *Ficus vogelii*, there are moderately frequent species, including cultivated arborescent species such as *Anacardium occidentale, Hevea brasiliensis and Gmelina arborea*, and preserved forest species like *Terminalia ivorensis, Terminalia superba, Ficus vogelii, Mallotus oppositifolius, Morinda lucida, Bombax costatum*, *Nauclea diderrichii* and *Milicia excelsa.*

Group (G3) with *Psidium guajava* conains the most frequent species. These were mainly fruit cultivated species like *Psidium guajava, Citrus sinensis, Citrus maxima, Coffea canephora, Citrus limon, Citrus maxima, Jatropha curcas* and *Persea americana, Castanea sativa, Garcinia kola* and *Tamarindus indica*. There were also characteristic shrub species generally found in secondary formations, such as

Albizia adianthifolia, Albizia zygia, and large forest species like *Spathodea campanulata, Pycnanthus angolensis, Funtumia africana, Vernonia colorata, Vernonia amygdalina, Ricinodendron heudelotii, Alstonia boonei* and *Nesogordonia papaverifera*.

3.2.3. Plant Group Characteristics

Group G3 with *Psidium guajava* contains the highest number of species (55.14%), however, specific richness is not significantly different between groups (ANOVA test, F = 2.457; P = 0.0916, Table 2). Concerning the Shannon Diversity Index, groups G1, G2 and G3 appeared to be little diversified, with values H = 1.71 (±0.32); H = 1.57 (±0.3) and H = 1.69 (±0.33), respectively, also did not show significant differences (ANOVA test, F = 0.976; P = 0.381). The Pielou equitability index is relatively high in all groups, ranging from E = 0.84 to E = 0.88, and does not express any significant difference between the groups (ANOVA test, F = 1.705; P = 0.188).

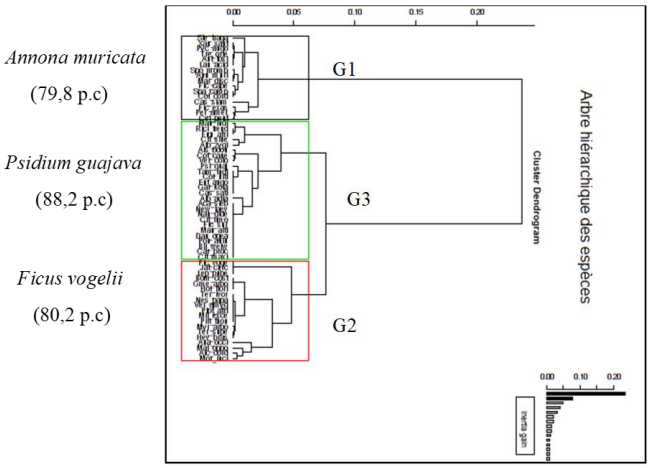

Figure 7 : Indicator species of each group of frequency level in a hierarchical classification of associated woody species individuals in 90 plots of cacao plantations.

Table2. *Floristic characteristics of groups of species frequency from different plant groups from cocoa plantations in the Doboua area; α = 0.05 ; H : Shannon index; E : Piélou equitability.*

Groups	Number of species	*H* (mean) value/ plot)	*E* (mean) value/ plot)	Indicator species (% value compared to other species)
G1	29	1.71±0.32[a]	0.86±0.074[a]	*Annona muricata* (79.8)
G2	19	1.57±0.3[a]	0.88±0.083[a]	*Ficus vogelii* (80.2)
G3	59	1.69±0.35[a]	0.84±0.079[a]	*Psidium guajava* (88.2)
Tests ANOVA		*F* = 0.976 ; *P* = 0.381	*F* = 1.705 ; *P* = 0.188	

3.3. Floristic Variability Related to Ecosystem Services

A multivariate factorial analysis in Figure 8 showed that the species and the ecosystem services are overlapping and distributed on the plot quadrants as vectors showing floristic variability among services for each frequency level of conservation. Each quadrant also indicated the association of frequency with the different ecosystem services. Most frequent species were used in the domains of business, food supply and traditional medicine. It was about the sale of numerous fruits from species like *Coffea canephora, Ricinodendron heudelotii, Cola nitida, Persea americana, Citrus* sp. and *Psidium guajava.* The plants from these species were concern by food supply, like *Castanea sativa* and *Tamarindus indica*, and medicine such as *Vernonia* sp., *Pycnanthus angolensis* and *Alstonia boonei*. Plant species used for shading of plantation were major timber supply. These plants were for example *Milicia excelsa, Terminalia ivoriensis, Terminalia superba* and *Piptadeniastrum africanum*. These species were moderately frequent in the agrosystems because they were the biggest forest species usually preserved directly after the cut of the forest. The less frequent species serve as firewood supply, such as *Mallotus oppositifolius* and *Holarrhena floribunda*; and other ecosystem services like fertilization with *Gmelina arborea* and for delimitation with *Hevea brasiliensis*.

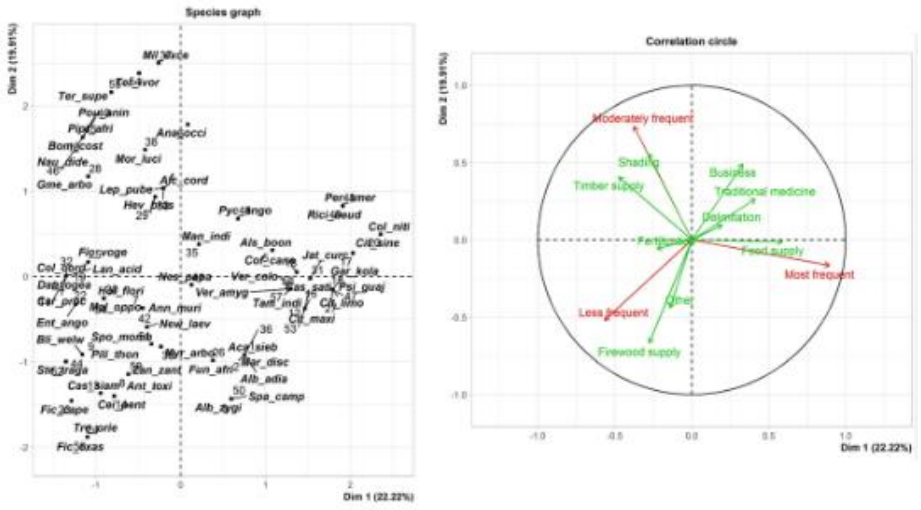

Figure 8: Main ecosystem services of associated woody species related to their frequency in 90 plots of traditional cacao plantations.

4. DISCUSSION

4.1. Phytodiversity of Traditional Cocoa Agroforestry Systems

Woody vegetation associated with cocoa trees had a rich flora, which contains 59 species belonging to 51 genera distributed among 25 families. The number of species obtained in the study area is much higher than in the M'Brimbo region, in a forest-savanna transition zone that only 14 woody species were associated to (Gala Bi *et al*., 2017). It is also higher than the associated flora in plantations of different ages in Cameroon with mean values ranging from 24 to 46 species (Temgoua *et al*., 2018). The average number of associated species is close to that obtained by Koulibaly (2008) in the Lamto region, Central-South of Côte d'Ivoire, being wetter than our study area. Introduction and preservation of more species in plantations has been reported by several authors including Tondoh *et al*. (2015) and Koulibaly (2008) in Côte d'Ivoire, (Asare, 2005) in Ghana, (Oke and Odebiyi, 2007) in Nigeria, (Zapfack *et al*., 2002; Sonwa *et al*., 2007) in Cameroon. Plant diversity analysis revealed that natural and exotic species were preserved in cocoa agrosystems. Seven most dominant families were Euphorbiaceae, Moraceae, Sterculiaceae, Anacardiaceae, Mimosaceae, Rutaceae and Caesalpiniaceae. In cocoa agrosystems, Euphorbiaceae and Moraceae were also found dominant by Konan *et al*. (2011) as well as Sterculiaceae in central-western Côte d'Ivoire by Kouadio (2018). Among the seven families identified to be dominant in cocoa agrosystems in Cameroon by Temgoua *et al*. (2018), the families of Sterculiaceae and Fabaceae (and Caesalpiniaceae) were cited. Dominant families were similar in the large band of traditional cocoa agroforestry systems in the West Africa. The most represented life forms in terms of species number were microphanerophytes (83.68%). This dominance of microphanerophytes is thought to be due to their perennial life form with vegetative resprouting, which constitutes the quantitatively important regeneration mode in the cocoa agrosystems as reported in the Lamto Reserve region and Oumé department (Piba, 2011; Koulibaly *et al*., 2016). This highest number of individuals in this life form could cause ecological disturbance and lead to a decrease of the number of chamaephyte and therophyte species (Kokou and Caballé, 2000; Vroh, 2013). The flora of the Doboua area had a pronounced affinity to the transition zone between the Guineo-Congolian and the Sudano-Zambezian domains (61,98%). This result is contrary to Koulibaly (2008) and Diomandé (2018) who also worked in the cocoa agrosystems in the Lamto Reserve region and Djêkro area in the Guineo-Congolian transition zone, where they reported a dominance of Guineo-Congolian species. This difference could be due to the fact that these areas were in a zone of pronounced humidity.

4.2. Diversity Conservation and Sustainable Cocoa Cultivation

The distribution of individuals across the floristic categories reflects the producer's preference for certain species which thus become more represented in number of individuals. Analysis of the structure of vegetation associated with cocoa trees in the cocoa agrosystems has shown that microphanerophytes are favoured both in terms of number of species and number of individuals. This is similar in species that have a strong affinity for the GC-SZ transition zone. The producer's preferences change the

structural characteristics of the studied agrosystems. The component factorial analysis has made a notable distinction between three levels of change. Through the frequency levels, associated species were grouped into: less frequent species, moderately frequent species and most frequent species. These groups have a weak index of Shannon diversity and are thus found to be little diversified, while the Pielou index indicates that individuals were distributed with equitability among the groups. Management of associated woody species is fragile even if a certain homogeneity of the environment reflects a reasonable arrangement by farmers with regard to the benefit of making maximum profits (Temgoua *et al*., 2018). This result is similar to those of Oke and Odebiyi (2007) in Nigeria, and Asare and Tetteh (2010) in Ghana in the cocoa agroforestry systems.

Traditional preservation was assessed using a multiple factorial analysis to describe the floristic variability according to the ecosystem services. The most frequent species are used for food supply, traditional medicine and provide marketable products including fruits that sell well on local and regional markets (Sonwa *et al*., 2007). Moderately frequent species play a protective role against sun radiation for young cocoa plants and thus contribute to their optimal growth (Cissé et al., 2016). Subsequently, they are eliminated for selling timber wood (Koulibaly et al., 2016). The less frequent species ensure the permanent supply of firewood and various other goods. These species were mostly spontaneous species that develop by sprouts or seeds left in the soil (Koulibaly, 2008). Other more or less frequent species are protected or introduced to serve as delimitation tree in the plantation such as *Hevea brasiliensis* and/or contribute to improve the fertility of the soil such as *Gmelina arborea* and *Ficus vogelii*. These latter species are used to protect the soil until sufficient cover is provided by the cocoa tree itself (Braudeau, 1969; Cissé *et al*. 2016). This method of plantation management applied in our study area is similar to that used in Cameroon where farmers keep the cocoa trees under woody trees of different age classes (Sonwa *et al*., 2000), and in Burkina Faso, where farmers use fallows as a method for restoring soil fertility to help managing agrosystems (Yaméogo, 2009). The results of this study show that each ecosystem service concern specific species, which ensures diversity achieved and supported by farmers.

Also, six species of particular status ranging from vulnerable to threatened by extinction have been noted in the studied cocoa agrosystems. It was *Entandrophragma angolense* reported among the less frequent species. In the group of moderately frequent species *Nauclea diderrichii* and *Terminalia ivorensis* were found. *Milicia excelsa*, an endemic species of Côte d'Ivoire, is threatened by extinction. *Garcinia kola* et *Nesogordonia papaverifera* were noted among most frequent species. To species of particular status, endemic or threatened by extinction, conservation efforts should be given priority (Myers *et al.*, 2000).

5. Conclusion

The cocoa farmer is the main actor in cocoa agrosystem creation. His contribution to conserving plant diversity is visible through the species frequency in the cocoa agrosystems. The three levels of species frequency contribute differently to the multiple gains, across different ecosystem services, and allow to understand the farmer's strategies to ensure the plant diversity conservation. Our study contributes to a better knowledge on the flora of woody species associated with cocoa trees, but above all allows us to evaluate the potential conservation of traditional cocoa agroforestry systems. In these systems, the flora is rich and contains mostly shrubs well adapted to the conditions. Vulnerable species have found a refuge and are generally frequent in cocoa agrosystems. The large trees preserved in the plantations for a long time contribute to the additional income of the farmer through the supply of timber and marketable products. In search for a compromise between cocoa production and plant diversity conservation, account must be taken of global change by ensuring the resilience of agricultural environments. In fact, in the cocoa regions of Côte d'Ivoire the majority of the species are rare in remnant forest formations, most of which are degraded.

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