



Biodiversity Management and Plant Dynamic in a Cocoa Agroforest (Cameroon)

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Authors' contributions

This work was carried out in collaboration between all authors. This work has led to a master degree; we thank author LZ for proposing and supervising the project. Author LFM has carried out the project for his master in the laboratory and author VNN has written and submitted the present manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate plant diversity and to show the structural variation of the vegetation in a cocoa agroforest of various ages.

Study Design: Slash and burn agriculture is one of the processes of deforestation and degradation of forests. Cocoa agrosystems that consist to plant cocoa for commercialisation by farmers are also the measures of attenuation and adaptation to climate changes. It is important to harvest the catalogue of species that can be found in a cocoa agrosystem.

Place and Duration: Pendiki subdivision from 10 September 2013 to 20 January 2014.

Methodology: Three types of cocoa were selected; young, adult and old cocoa agroforests. Sampling was done along plots of 625 m² (25 x 25 m²). A total of 36 plots were realized with 12 plots for each category of cocoa agroforest. Each plot was subdivided into sub-plots of 5 x 5 m². Floristic inventory concerned herbs, shrubs and trees with DBH superior or equal to 3.2 cm. A total surface of 2.25 ha was investigated.

Results: A total of 414 species including 109 timbers and 306 herbs and divided into 256 genera

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and 87 families were harvested. Young cocoa agroforests were more diversified than old cocoa plantations. Some big trees were scattered in the cocoa agroforests (*Ceiba pentandra*, *Albizia zygia*, *Canarium schweinfurthii*). Some species of the IUCN red data list were found in the study site (*Azelia bipindensis*, *Entandophragma cylindricum*, *Nesogordonia papaverifera*).

Conclusion: Although the conservation of biodiversity in the cocoa agroforests of Pendiki is not a priority for the cocoa farmers, the agricultural practices favour the preservation of biodiversity. Such agricultural practices could be considered as an attenuation measure to climate changes; the evaluation of the stock of carbon in such agrosystem is being carried out.

Keywords: Agricultural practices; biodiversity conservation; cocoa agroforest; regeneration.

1. INTRODUCTION

Agroforestry is defined as a dynamic and ecologic system of managing natural resources by integrating trees on arable land and pasture; which are diversified and permit the production of little exploitations leading to important social, economic and ecologic advantages [1]. Nowadays, faced with the destruction of tropical forest, agroforestry is proposed as one of the strategies of conservation of natural resources in the tropics [2]. Inspired with the definition of agroforestry, cocoa agroforests is a manner of making use of soil in which perennial trees (*Dacryodes edulis*, *Mangifera* spp., *Citrus* spp.) and crops are deliberately associated with cocoa in order to optimize their profits [3].

The cultivation of cocoa maintains a high proportion of trees in a diverse structure, progressively seen as a method of sustainable management that contributes to the conservation of biodiversity [2,4]. Cocoa is an object of interest particularly in REDD_S (Reduction of Emission due to Degradation and Deforestation) processes. Practice of agroforestry alongside with cocoa is carried out in Cameroon in the Southern west, Littoral, East, Center, West and South regions [5]. Several studies on the biodiversity conservation and techniques on the cultivation of cocoa were realized in agroforestry systems in the South West, Center and South [5-7]. Very little study has been done on the capacity of cocoa agroforests in order to evaluate floristic diversity in the Littoral Region. In order to have a global view on the biodiversity conservation in the cocoa farms of the Littoral Region, a study was carried out in the Division of Sanaga Maritime which is an area of average production of cocoa in Cameroon [8]. So, this study aims to evaluate floristic biodiversity and structural modification of the vegetation of cocoa agroforests in different classes of age in Pendiki village.

2. MATERIALS AND METHODS

2.1 Study Site

Located in the Littoral Region, Sanaga Maritime division covers 10,500 Km². Nyanon sub division is amongst the 11 subdivisions that compose the Sanaga Maritime division. Nyanon is made up four districts amongst which we have the Basso district. Pendiki, the study site is one of the 24 villages in the Basso district. Pendiki lies with Latitude 4°16 and 4°18 North and Longitude 10°56 and 10°58 East (Fig. 1). The village is bounded to the East by Logbikoy, North by Nyahendel, South by Nsinglibado and West by Hock. The average altitude is between 600 and 700 km.

The relief is very accidental in many places with the presence of many juxtaposed mountains. The climate of the Pendiki village varies from Equatorial Guinean to maritime type. There are two seasons: the rainy season that runs from March to November and the dry season that runs from December to February but presently undergoing fluctuations due to climate changes. Most of the soils are ironic, red or yellow clay soils characterized with iron oxides, often sandy. The vegetation of Pendiki village can be described as that of the semi-deciduous humid dense forest [9].

Agriculture is the principal activity of the Pendiki population. The agricultural tools are rudimentary. The population practices subsistence agriculture which provides them with cassava, maize, groundnuts, plantains, and banana. Classic agriculture is represented with the cultivation of cocoa. Cocoa plantations cover around 0.5 to 7 hectares.

2.2 Sampling

In this work, cocoa agroforests were partitioned in three classes of age: young cocoa agroforests

2.3.2 Simpson evenness

Simpson's index gives the probability of any two individuals drawn at random from an infinitely large community belonging to different species. It is expressed using the following formula: $D' = \sum (N_i/N)^2$ [15]. It is equally the inverse of diversity, increase in Simpson results to low diversity.

2.3.3 Pielou equitability EQ

$EQ = H'/\log_2 N$. It corresponds to the relationship between observed diversity and possible maximum diversity of the number of species (N). It should be noted that a weak evenness shows the significant present of some dominant species. A weak equitability indicates a significant presence of some dominant presence of some dominant species [16].

The density of timbers was calculated using the different types of cocoa agroforests. The surface area of timbers was calculated using the following relationship: $ST = \sum d^2 (\pi/4)$ (d=stems diameter; $\pi=3.14$ and ST in m^2/ha).

In order to outline the horizontal structure of timber population, histograms of distribution in different classes of diameter were realized. Moreover, 11 classes of diameter were noted and used to analyse the general distribution of all the plants associated with cocoa. The limits of these classes were as follows: [3,2-10 cm], [10-20 cm], [20-30 cm], [30-40 cm], [40-50 cm], [50-60 cm], [60-70 cm], [70-80 cm], [80-90 cm], [90-100 cm], ≥ 100 cm.

In order to outline the vertical structure of timber population, histograms of distribution in different classes of height were realized. The vertical stratification effectuated in cocoa agroforestry by Sonwa [17] and Konan [18] were used. It consisted of classes of height: [≥ 4 cm]; [4-8 cm]; [8-12 cm]; [12-20 cm] and >20 cm.

3. RESULTS

3.1 Floristic Diversity

A floristic list of 414 species was realized on the 36 plots amongst which we had 12 exotic species. These species were subdivided into 256 genera and 87 families. In young cocoa farms we had a total of 312 species; 251 species in adult cocoa farms and 246 species in old cocoa farms. The most represented families were *Fabaceae* (23 species), *Acanthaceae* (19 species),

Euphorbiaceae (16 species) and *Rubiaceae* (14 species).

Shannon's index reduces with increase in the ages of cocoa farms. An elevated Shannon's index indicates that most species are not highly represented. Pielou's equitability is almost the same in the three types of cocoa farms. A high equitability indicates that most of the species are uniformly represented thus having the same number of species. The highest value of Simpson's index was noted in old cocoa agroforest. For this index the values are similar in young cocoa farms (Table 1).

3.2 Horizontal Structure

The density of plant association is highly elevated in young cocoa farms on the one hand (Table 2). On the other hand, the density of wooden species is higher in adult cocoa farms (1477) and less in young cocoa farms (1251). The number of individuals is lower in young cocoa farms because only individuals with DBH ≥ 3.2 cm were counted.

The wooden species in the young cocoa farms occupies a surface area of (21.58 m^2/ha) which is inferior to that occupied by wooden species of old cocoa farms (Table 2). This result can be explained based on the fact that we have a less number of individuals with DBH ≥ 3.2 cm in young cocoa agroforest.

The distribution of stems in different diameter classes in the cocoa agroforests of different classes of age gave evidence on the structural divergence (Fig. 2). This repartition of individuals in different classes of diameter brings about two types of structure. In the Young cocoa agroforest farms, the distribution of wooden species, in different classes of diameter indicates the decreasing exponential rate indicating that the lower classes of diameter are highly represented in individuals than the higher classes of diameter. In adult cocoa farms, the distribution of associated wooden species show a bell form (indicating that intermediate classes of diameter are better represented than extremes). Old cocoa agroforests equally have a bell structure with less young stems as compared to adult cocoa farms.

3.3 Vertical Structure

The stratification of trees in the different types of cocoa agroforests shows an important density of wooden species inside young cocoa agroforests

in the first three classes of height (Fig. 3). Whereas adult cocoa agroforest have a higher density of wooden species in the two last classes.

4. DISCUSSION

4.1 Specific Diversity

87 families subdivided into 256 genera and 414 species were identified. *Fabaceae* was the most diversified family follow by *Acanthaceae*, *Euphorbiaceae* and *Apocynaceae*. This result was observed in cocoa plantations in Mbalmayo [11]. The specific richness of young cocoa plantations (312) is almost similar to 313 species obtained in Nkolenyeng's cocoa plantations [19].

Shannon's diversity index decreases with the age of cocoa plantations. This high diversity (5.63) in the young cocoa plantation may be due to the fact that the conditions of the site are favourable for the development of the numerous species. All values of Shannon indexes obtained are closer to 6; 6 and 5 obtained respectively in previous studies in Ebolowa, Mbalmayo and Yaounde cocoa plantations [17]. Pielou evenness is 0.75 in young cocoa plantations and 0.78 in old cocoa plantations. These high values indicate a uniform repartition of species thus having the same number of individuals. These results corroborate those of Sonwa [17] and Kengne [19] in South, respectively 0.67 and 0.65.

4.2 Structure of Cocoa Agroforest

Young cocoa plantation shows a decreasing exponential structure in classes of diameter indicating a rapid regeneration within the site. This structure in classes of diameter is in conformity with the results obtained in previous

studies [17, 20-22]. The diametric structure of old cocoa farm shows a rate that is almost similar to adult cocoa agroforest. Such a structure can be a result of farming taking place within the cocoa plantation by the farmers in the course of which young stems regenerated within the plantations are eliminated because competition for light and minerals in the soil reduces cocoa production.

The density of associated plants more elevated in young cocoa plantations decreases with age of the plantation. This evolution of density in relation to the age of cocoa plantation is in conformity with many studies [8,23]. The surface area (21.58 m²/ha) of all the wooden species in the young cocoa plantations are inferior to those of older cocoa plantations. These results can be explained based on the lower density of wooden species with DBH ≥3.2 cm) in young cocoa agroforests. All the surface areas of Pendiki cocoa plantations are inferior to 36 m²/ha and 46 m²/ha obtained respectively by Sonwa [17] and Bisseleua et al. [24] in the cocoa agroforests in South Cameroon.

The analysis of the vertical structure shows that height class [12-20 m] is the most represented of the total number of plant associated stems (28,83%) followed by class >20 m with 19,97% of wooden species in all cocoa agroforests. Density increase of stems in class height [12- 20 m] and more than 20 m is remarkable in old cocoa agroforests, average trees and big isolated trees (since the installation of the cocoa agroforests) and introduce cocoa plants during development. This agricultural practice is contrary to that practiced in Ivory Coast in old cocoa plantations where most of the wooden species were destroyed leading to a lower number of wooden species with higher classes of height [18].

Table 1. Diversity index of different categories of cocoa systems

Cocoa agroforests	Specific richness	Shannon index	Pielou equitability	Simpson evenness
Young (< 10 years)	77	5.63	0.71	0.03
Adult ([10-40 years])	61	5.47	0.75	0.03
Old (≥40 years)	45	4.98	0.78	0.04

Table 2. Density (steams /ha) and area (m²/ha) of timbers in different types of cocoa agroforests

Cocoa agroforests	Number of steams		Associated plants		Total	
	Density	Surface area	Density	Surface area	Density	Surface area
Young (< 10 years)	923	2.36	328	19.93	1251	21.57
Adult ([10-40 years])	1250	5.16	227	22.20	1477	27.36
Old (≥40 years)	1115	7.35	159	20.00	1274	27.35

4.3 Conservation Value of Species

In Pendiki cocoa farms, farmers conserve protected species for a sustainable exploitation over national and international scale. *Azelia bipindensis*, *Entandrophragma cylindricum*, *Quassia sanguinea* are represented by very low densities (0.44 stems/ha). These species are frequently used by the local population for shelter and feeding. It is necessary to promote education

and sensitise peasants to protect and valorise endangered species by reducing the cutting down trees and promoting the growth of young plants. Six endangered plant species in Cameroon red list were found in the cocoa plantations [12]: *Azelia bipindensis*, *Entandrophragma cylindricum*, *Leptoderris ledermannii*, *Mansonia altissima*, *Nesogordonia papaverifera*, *Quassia sanguinea* (Table 3).

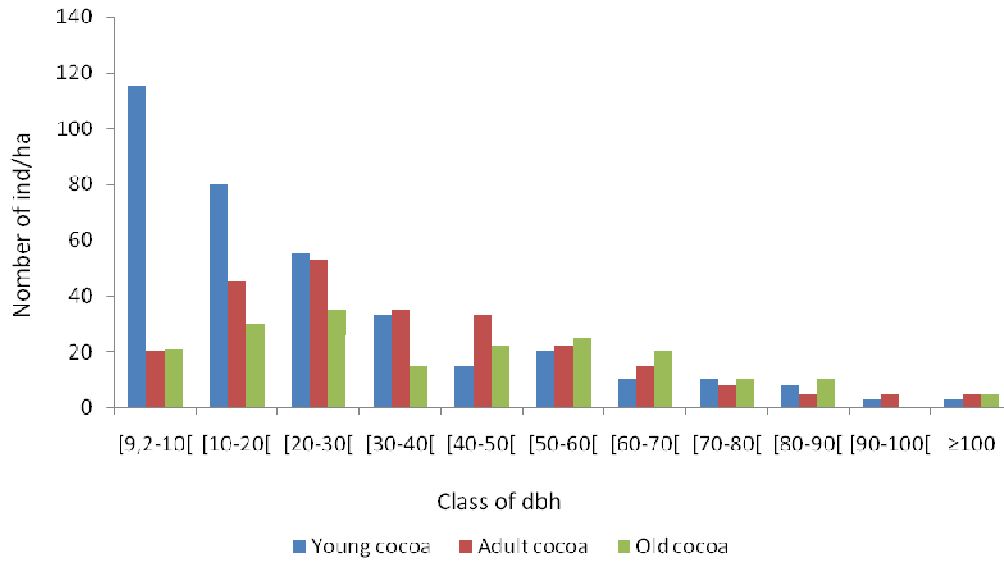


Fig. 2. Distribution of density of associated plants according to the diameters in different cocoa plantation

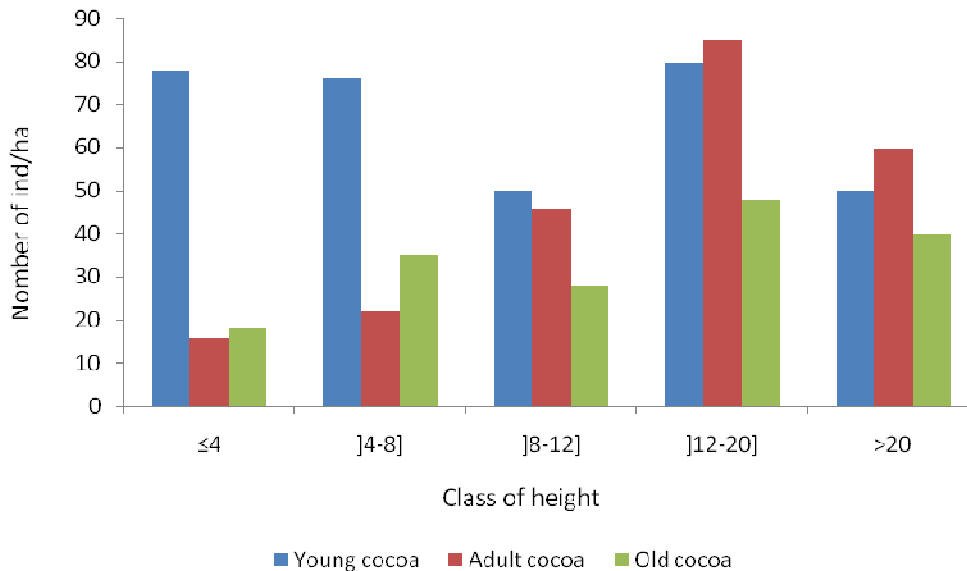


Fig. 3. Distribution of density of associated plants according to the height

Table 3. Endangered species of IUCN (EN: in danger; VU: vulnerable)

Species	IUCN criteria
<i>Afzelia bipindensis</i>	EN
<i>Entandrophragma cylindricum</i>	VU
<i>Leptoderris ledermannii</i>	EN
<i>Mansonia altissima</i>	EN
<i>Nesogordonia papaverifera</i>	VU
<i>Quassia sanguinea</i>	VU

5. CONCLUSION

In the course of this study, the results indicate that Pendiki cocoa agroforest are diversified. The botanic inventory in the different types of cocoa plantations had a total of 414 plant species with 109 wooden species and 305 herbaceous species partitioned into 256 genera and 87 families. Specific diversity and the regeneration of wooden species reduce with aging of the cocoa plantation. The vertical structure indicates the presence of many species within the cocoa plantation whose principal role is to shed the Cocoa plant. Agricultural practice effectuated in Pendiki highly conserves the biodiversity in cocoa agroforests thus protected species or species with durable exploitation at the national and international scale at present.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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