Floristic Structure And Carbon Storage Capacity Of Cocoa Agrosystems In Bédiala (Daloa, West-Central Côte d'Ivoire)

Voui Bi Bianuvrin Noël Boué, Koulibaly Annick, Coulibaly Siendou, Djago Audrey, TapéBi Foua Alphonse

Abstract: A study on floristic characterization and carbon stock assessment of cocoa stands was carried out in Bédiala (Midwest, Côte d'Ivoire). From surface and itinerant surveys, the composition and floristic diversity were estimated in cocoa agrosystems of different ages (0-5; 5-10; 10-15; 15-20; ≥ 20 years). The stored carbon was determined from the biomass according to the non-destructive allometric method based on the diameter or height of the individuals. In total, 100 species belonging to 80 families and 45 genera were counted. The family of Sterculiaceae (9 percent) is the most represented. The most dominant biological types were Microphanerophytes (36%) and Mesophanerophytes (23%). The most important chorological types have been the taxa of the Guinean zone (53 percent). The values of the calculated indices being statistically the same from one agrosystem to another, there is however a floristic diversity and an equitable distribution of individuals within species. A total of 193.26 ton of carbon per hectare were determined across the plantations. We also note that age has not had a significant influence on the floristic diversity and the capacity of cocoa agrosystems to store carbon.

Keywords: Bédiala, carbon stock, cocoa agrosystems, floristic diversity

Introduction

In Côte d'Ivoire, cocoa farming has developed rapidly in the southern half of the country [25]. Thanks to the political will of successive governments, cocoa has become a strategic agricultural product in Côte d'Ivoire (5). Indeed, since 1978, Côte d'Ivoire has been the world's leading producer and exporter of cocoa beans [5]. Estimated at 410,000 tonnes between 1983 and 1984, production reached 2,100,473 tonnes between 2019 and 2020, i.e. nearly 40% of world supply, thus contributing 15% of GDP [35]. Cocoa farming employs more than one million farmers, i.e. 15% of rural population [19]. However, the economic success of cocoa farming in Côte d'Ivoire conceals a sad impact on forest areas [26]-[7]. Indeed, the expansion of cocoa plantations has been to the detriment of forests which have been severely decimated [16]. The forest, estimated in 1960 at 16 million hectares, has fallen to 2 million hectares today [13]. The current landscape of Côte d'Ivoire shows that more than 30% of the land area is occupied by cocoa plantations [38]. This dynamic expansion has amplified various environmental problems. These include the loss of biodiversity, erosion, contamination of drinking water, and the reduction of ecosystem services, including carbon sequestration, thus leading to an increase in greenhouse gases. In the current context of climate change, the association of cash crops (cocoa) with other plant species constituting agrosystems represents a credible alternative for biodiversity conservation and the mechanism for reducing emissions from deforestation and forest degradation [27]-[9]. To this end, several studies carried out in cocoa agrosystems have shown their diversity in plant and animal species (46). Furthermore, the work of [46] and [7] have also shown the importance of these cocoa agrosystems in carbon sequestration. However, in Haut Sassandra, particularly in Bédiala, no floristic and carbon storage studies have yet been conducted in juvenile, adult and old agroforests. Does the age of cocoa stands influence the species diversity of cocoa agrosystems? Does the capacity of these cocoa stands to store carbon vary from one agrosystem to another? In the present study, we hypothesize that cocoa agrosystems contain a remarkably rich flora and are capable of storing enough carbon. The general objective is to characterize cocoa agrosystems in order to implement sustainable biodiversity management strategies. Specifically, it is first to characterize the flora of the cocoa agrosystems of Bédiala and secondly to evaluate the quantity of carbon stored in the cocoa agrosystems of Bédiala.
1. Material and Methods

1.1 Characteristic of study area
The study was conducted in Bédiala, a sub-prefecture of the Haut-Sassandra region. It is located between 7.4°C and 7.11°C Latitude North and between 6.0°C and 6.20°C Longitude West (Figure 1). Rainfall varies between 1200 and 1600 mm per year. The climate is that of the Guinean domain, characterized by a humid tropical type with four alternating seasons: a long dry season from December to February, a short dry season from July to August, a long rainy season from March to July and a short rainy season from September to November. The average annual rainfall is between 1200 and 1600 mm per year. The average annual temperature is 26°C (25, 31). The forest vegetation, which occupies most of the region, is characterized by a semi-deciduous forest with Celtis spp. and Triplochiton scleroxylon in the mesophilic sector within Guinean domain [17]. The relief consists largely of a plateau with numerous valleys. The soil is of ferrallitic type of granite origin and is moderately and slightly denatured [23].

1.2 Study material
The plant material consisted mainly of the Theobroma cacao orchard and secondarily of the woody flora associated with it. This plant material came from village cocoa plantations, mostly installed on former fallow land.

1.3 Study methods
1.3.1. Surface and roving floristic inventory
In order to characterize the floristic composition of the stands, an area survey was carried out in cocoa agrosystems subdivided into five age classes: [0-5]; [5-10]; [10-15]; [15-20] and ≥ 20 years. The area survey method provided quantitative and comprehensive data on the general floristic composition (26). In each agrosystem of at least one hectare, nine square plots of 20 m x 20 m were randomly installed (Figure 2). Within each plot, all plant species other than cocoa trees were surveyed and identified. In order to contribute to a better knowledge of the flora, an itinerant inventory in addition to the first one was carried out according to the method of [2], [3] and [4]. The identification of species was done with the help of [28], [29], [30] and [3]-[4].

1.3.2. Carbon stock assessment
The carbon assessment was done according to the method described by [18]. The use of this method is justified since the larger the stand area, the more accurate the measurements will be. Thus, three main rectangular sub-plots of 40 m x 60 m were randomly installed within each cocoa stand. Within these sub-plots, all woody plants with a height of 2 m or more were measured. Within the main sub-plots, three sub-plots of 20 m x 40 m were delineated and randomly installed to measure cocoa trees (Figure 3). Data from these delimited plots were used to assess the carbon stock of the associated stand and the carbon stock of the cocoa stand only. The total height and circumference of each individual (cocoa tree and associated species) were measured. Carbon stock was estimated by calculating the plant biomass. The much more flexible allometric (non-destructive) method based on the diameter and height of woody individuals was used to estimate stand biomass. The method of [11] adapted to the climatic zone and to hardwoods served as basic allometric models. The estimation of the sequestered carbon rate was done in four steps: calculation of aboveground biomass, belowground biomass, total biomass and deduction of sequestered carbon.

1.4. Method of data analysis
1.4.1. Assessment of the quality of cocoa agrosystems
The quality of cocoa agrosystems was assessed on the basis of biological, chorological and morphological types. The classification method proposed by [37] served as a basis for organizing the different biological types. Referring to the work of [3]-[4], different biological types were sought: Chamephytes, Epiphytes, Geophytes, Hemicryptophytes,
Phanerophytes and Therophytes. Chamephytes (Ch) are plants whose buds or tips of persistent shoots are located above the soil surface, on creeping or erect branches. Epiphytes (Ep) are plants whose roots are anchored to the surface of other plants. Geophytes (G) are plants whose persistent shoots or buds are located in the soil during the bad season. Hemikryptophytes (H) are plants whose replacement shoots or buds are located at ground level. Therophytes (Th) are annual plants that multiply by seeds. Phanerophytes (Ph) are plants with persistent shoots or buds on persistent aerial axes. Phanerophytes have been subdivided into four height groups: Nanophanerophytes (sub-trees less than 2 m); Microphanerophytes (shrubs from 2 to 10 m), Mesophanerophytes (trees from 10 to 30 m) and Megaphanerophytes (trees over 30 m). The chorological type was established for the different species on the basis of the species lists made by [3]-[4] in order to get an overview of distribution of species in the dense rainforest zone. The main types of distribution that were retained are Guineo-congoles species (GC), Guineo-congoles species endemic to the West African forest block (GCW), Guineo-congoles species endemic to Côte d'Ivoire (GCI), sudanian species from the regional centre of sudanian endemism (SZ); species from the transitional zone between the Guineo-congoles and sudanian regions (GC-SZ) and introduced or cultivated species (i) in Côte d'Ivoire. Morphology is the shape and external structure of the plant and its organs. It allowed us to distinguish between arborescent, lianascent and herbaceous species.

1.4.2. Evaluation of quantitative parameters of cocoa agrosystems
Floristic richness refers to the number of taxa found in a given environment, without judging either their frequency or abundance, or the size and productivity of the species encountered [2]. For the present study, the species identified in each plot were used to draw up a floristic list. Subsequently, they were then grouped according to their genus, family, biological and chorological types in order to get a general idea of the floristic composition of the different agrosystems. The notion of floristic diversity also encompasses floristic richness, which corresponds to the total number of species, and regularity, which expresses the way in which the individuals encountered are distributed among the species inventoried [22]. Three indices were used to explain floristic diversity: Shannon-Weaver (H'), Pielou equitability (E) and similarity (Cs). The Shannon-Weaver index [41] evaluates the diversity of a stand by combining relative abundance of species and specific richness. This index has been used to quantify and compare floristic diversity of plant formations in different cocoa agrosystems. Its formula is as follows:

\[
H' = - \sum_{i=1}^{S} \frac{n_i}{N} \ln \frac{n_i}{N}
\]

With \(n_i\), number of individuals of species \(i\); \(N\), total number of individuals of all species in the environment. The values of \(H'\) vary between 0 and \(\ln S\) (maximum diversity, \(S\) being the total number of species in the environment). For environments containing only one species, \(H'\) is equal to zero, while for environments with a high number of species, \(H'\) is high and tends towards \(\ln S\). Pielou's equitability index [36] expresses the regularity and equitable distribution of individuals between species. Its formula is:

\[
E = \frac{H'}{\ln S}
\]  

With \(S\), total number of species recorded and \(H'\) Shannon-Weaver index. This index varies from 0 to 1. When it tends to 0, it describes a state of dominance of individuals of one species over the others. If \(E\) tends towards 1, then the distribution of individuals between species is regular. The floristic similarity index (Cs) is the degree of similarity between the flora of the different agrosystems inventoried. Similarity was defined through the Sørensen index [42]. This index varies from 0 to 100. The more species the floristic lists have in common, the more \(C_s\) tends towards 100. The more different the floristic lists are, the more \(C_s\) tends towards 0 (44). For two different agrosystems, the formula is as follows:

\[
C_s = \frac{2c}{(a + b)} \times 100
\]

With \(C_s\), similarity coefficient; \(a\), number of species in agrosystem A; \(b\), number of species in agrosystem B and \(c\), number of species common to both agrosystems A and B that are to be compared.

1.4.3. Assessment of the carbon stock of agrosystems
The estimation of the above ground biomass (AGB) of companion trees and cocoa trees was done using allometric equation of [11]. This is an equation specific to semi-deciduous dense rainforests. The basic mathematical model is as follows:

\[
AGB = 0,0673 \ (pD^2H)^{0.976}
\]

Where AGB is the above-ground biomass of the tree (in kg); \(D\), diameter of the tree (in cm); \(H\), total height of the tree (in meter) and \(p\), the specific density of the tree (in g.cm). The species specific densities given by (48) and (45) were used as reference. For trees with unknown specific density in this database, the standard density value is 0.58g/cm³ (10.39). The estimation of root or below ground biomass (BGB) of standing woody plants was done according to the guidelines established by [14]. According to the latter, the root biomass equivalence of standing woody plants is obtained by multiplying the value of above-ground biomass (AGB) by a coefficient \(R\) whose value is estimated to be 0.24.

\[
BGB = AGB \times 0,24
\]

Where BGB is the below-ground biomass (in kilogram); AGB, the above-ground biomass (in kilogram) and \(R\), the root/stem ratio. Once the above-ground and below-ground biomass of the different individuals were estimated using the general allometric equations, the total biomass was obtained by summing the above-ground and root biomass.

\[
BT = AGB + BGB
\]

With \(BT\), total biomass; AGB, above-ground biomass (in kilogram) and BGB, below-ground biomass (in kilogram). The total biomass estimated from the different equations was converted into the corresponding sequestered carbon stock by multiplying it by 0.5 (14). This parameter was calculated for each agrosystem using the mathematical formula below:

\[
C = BT \times 0,5
\]

Where \(BT\) is the total biomass and \(C\) is the total carbon stock.
1.5. Method of statistical analysis of the data
The statistical processing of the field data was carried out using Microsoft Excel 2016, pivot table option. The values generated were used to draw up the various graphs. The parameters of floristic richness, diversity indices and carbon stocks between agrosystems were submitted to the R software (version 4.0.1) for the one-factor analysis of variance test (ANOVA 1). Where differences were significant, means were separated by tests at the 5% level.

2. Results

2.1. Qualitative diversity of cocoa agrosystems
Floristic inventory has identified 100 species divided into 45 families and 80 genera. The most dominant family in terms of number of species was the Sterculiaceae (9%). The Fabaceae and Rubiaceae families, with 5% of species each, were the least represented (Figure 4A). In terms of biological type, Microphanerophytes with 36% and Mesophanerophytes with 23% were the most numerous in all cocoa agrosystems. Therophytes with 2% presence were the least represented (Figure 4B). Analysis of the chorological spectrum showed that taxa from the Guinean-Congolese (GC) region with 53% of species were the most represented. The least dominant were taxa from the Guineo-Congolian zone endemic to the West African forest block (GCW) and taxa from the Sudanian zone (SZ) with respectively 2% and 1% each (Figure 4C). Morphologically, arborescent species were 71% most prevalent in cocoa agrosystems. The lianescent species were the least represented with a rate of 14% (Figure 4D).

2.2. Quantitative diversity of cocoa agrosystems
Floristic diversity analysed from Table 1 reflected variability in the number of species from one agrosystem to another. On average 13.4 ± 1.75 species were inventoried for all cocoa agrosystems. The [0-5] year old cocoa agrosystem had the highest number of species (16). In contrast, the [5-10] year old agrosystem produced the fewest species (11). Significant differences existed between cocoa agrosystems for stand density (χ² =13.25; P=0.01). For all the cocoa agrosystems, the mean value of the Shannon-weaver index was 2.06 ± 0.23. This index varied from 1.06 ± 0.23 to 2.06 ± 0.23. This index varied from 1.94 (± 0.37) to 2.27 (± 0.26) from one agrosystem to another. The Shannon index of the [0-5] year old cocoa agrosystem had the highest value (2.27 ± 0.26), while the one older than 20 years had the lowest (1.94 ± 0.37). The difference between the values of these indices did not vary significantly within the different types of cocoa agrosystems (χ² = 4.91; P = 0.30). Concerning the Pielou Equitability Index, the mean value was 0.79 ± 0.08. This index varied from one agrosystem to another. The highest value (0.87 ± 0.05) was observed in the [0-5] year old cocoa agrosystem, while the lowest value (0.73 ± 0.12) was obtained in the cocoa agrosystem older than 20 years (≥ 20 years). There was no significant difference between the Pielou indices for the cocoa agrosystems of different age classes (χ² = 4.76; P = 0.31).
The values of Sørensen’s coefficients analysed from Table 2 show both similarities and dissimilarities between the cocoa agrosystems in pairs. The analysis showed dissimilarity between the [15-20] year old cocoa agrosystem and all the [0-5], [5-10] and [10-15] year old agrosystems; between the agrosystem of age ≥ 20 years and all the [10-15], [15-20] year old cocoa stands; and between the [5-10] and [10-15] year old agrosystem. On the other hand, there are similarities between the [0-5] year old cocoa agrosystem and all the [5-10] year old, [10-15] year old and ≥ 20 year old agrosystems on the one hand, and between the [5-10] year old and ≥ 20 year old cocoa agrosystem on the other.

Table 2: Comparison of the different cocoa agrosystems in Bédiala according to their Sørensen similarity coefficient

<table>
<thead>
<tr>
<th>Age of cocoa agrosystems(years)</th>
<th>[0-5]</th>
<th>[5-10]</th>
<th>[10-15]</th>
<th>[15-20]</th>
<th>≥ 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0-5]</td>
<td>-</td>
<td>69.56</td>
<td>54.16</td>
<td>49.41</td>
<td>59.94</td>
</tr>
<tr>
<td>[5-10]</td>
<td>-</td>
<td>45.65</td>
<td>44.44</td>
<td>52.94</td>
<td>-</td>
</tr>
<tr>
<td>[10-15]</td>
<td>-</td>
<td>44.7</td>
<td>45.28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>[15-20]</td>
<td>-</td>
<td>48.42</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

2.3. Biomass produced and carbon sequestered by species in cocoa agrosystems

Within the woody species associated with cocoa trees and with DBH ≤ 30 cm, the average biomass produced was obtained at the value of 16.98 T/ha. In the associated stand, the biomass produced and the carbon stored was 9 TC/ha. From one cocoa agrosystem to another, the difference between the biomass produced on the one hand and the carbon stored on the other hand are not significant (\(\chi^2=4.71; P=0.32\)) (Table 4). Finally, the total biomass produced in all the cocoa agrosystems was estimated at 386.52 T/ha, i.e. a carbon production of 193.26 T/ha. In the associated stand, the biomass produced and the amount of carbon sequestered exceeded twice as much as in the pure cocoa plantations (Figure 5).

Table 3: Total biomass and carbon stored in associated and pure cocoa tree stands in Bédiala

<table>
<thead>
<tr>
<th>Age of cocoa agrosystems (years)</th>
<th>BT (T/ha)</th>
<th>C (T/ha)</th>
<th>DBH ≥ 30 cm</th>
<th>BT (T/ha)</th>
<th>C (T/ha)</th>
<th>DBH ≤ 30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0-5]</td>
<td>7.12</td>
<td>3.37</td>
<td>18.14</td>
<td>0.67</td>
<td>4.55</td>
<td>2.27</td>
</tr>
<tr>
<td>[5-10]</td>
<td>6.96</td>
<td>3.53</td>
<td>16.02</td>
<td>0.55</td>
<td>4.15</td>
<td>2.18</td>
</tr>
<tr>
<td>≥ 20</td>
<td>10.66</td>
<td>5.33</td>
<td>22.59</td>
<td>1.19</td>
<td>6.56</td>
<td>3.27</td>
</tr>
</tbody>
</table>

| Paramaters of the test | P = 0.62 | P = 0.62 | P = 0.22 |

Means followed by the same letter are not significantly different according to Tukey’s HSD test of means comparison at α = 0.05; DBH- Diameter at breast height; BT- total biomass; CA-carbon; T/ha-tonne per hectare

DBH-Diameter at breast height; BT-total biomass; CA-carbon; T/ha-tonne per hectare

In associated stands of more than 30 cm in diameter, on average the biomass was evaluated at 39.67 T/ha equivalent to a carbon stock of 19.83 TC/ha (Table 3). The highest production was noted in agrosystems aged [0-5] years with 70.73 T/ha equivalent to a carbon stock of 35.37 TC/ha. The lowest biomass production was obtained in agrosystems older than 20 years with 11.05 T/ha equivalent to a carbon stock of 5.53 TC/ha. The analysis of variance showed no significant difference between the agrosystems (F = 1.86; P = 0.27) for biomass produced and carbon stored (Table 4). On average, the biomass produced for all pure cocoa stands was recorded at 20.66 T/ha corresponding to a carbon stock of 10.33 TC/ha (Table 4). This biomass varied from 14.32 T/ha (7.16 TC/ha) to 25.98 T/ha (12.99 TC/ha). In stands aged [0-5] years, the value of carbon sequestered (7.16 TC/ha) was the lowest, while that of agrosystems older than 20 years was the highest (12.99 TC/ha). From one agrosystem to another, the difference between the biomass produced on the one hand and the carbon stored on the other hand are not significant (\(\chi^2=4.71; P =0.32\)) (Table 4). Finally, the total biomass produced in all the cocoa agrosystems was estimated at 386.52 T/ha, i.e. a carbon production of 193.26 T/ha. In the associated stand, the biomass produced and the amount of carbon sequestered exceeded twice as much as in the pure cocoa plantations (Figure 5).

Table 4: Biomass and carbon stock (average) sequestered in the cocoa agrosystems of Bédiala

<table>
<thead>
<tr>
<th>Age of cocoa agrosystems (years)</th>
<th>DBH ≥ 30 cm</th>
<th>DBH ≤ 30 cm</th>
<th>Stand of pure cocoa tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT (T/ha)</td>
<td>CA (T/ha)</td>
<td>BT (T/ha)</td>
<td>CA (T/ha)</td>
</tr>
<tr>
<td>[5-10]</td>
<td>17.7</td>
<td>14.67</td>
<td>17.41</td>
</tr>
<tr>
<td>[15-20]</td>
<td>22.97</td>
<td>11.77</td>
<td>22.97</td>
</tr>
</tbody>
</table>

| Average (standard deviation)     | 14.98      | 14.43      | 14.67                   | 14.26      | 1.16 |

Means followed by the same letter are not significantly different according to Tukey’s HSD test of means comparison at α = 0.05; DBH- Diameter at breast height; BT-total biomass; CA-carbon; T/ha-tonne per hectare
Figure 5: Total biomass and total carbon stock of all cocoa agrosystems in Bédiala

BT- total biomass; TC-Carbon content; CA-carbon; T/ha-tonne per hectare

3. Discussion

The compilation of floristic lists from different cocoa agrosystems of Bédiala, allowed the identification of 100 plant species from 45 families and 80 genera. With little difference, the number of genera reached the number of species. This demonstrates the floristic diversity of cocoa agrosystems in Bédiala. Farmers in this area have acquired knowledge of the goods and services that plant species can provide both environmentally and socially. These species, most of which are native (others are exotic), are spontaneous and conserved and therefore benefit from protection because of their uses. These species in association with cocoa trees are either forest species (Milicia excelsa, Anttiaris toxicaria, Amphimas pterocarpoides, Khaya ivorensis, Ceiba pentandra, Blighia sapida, Cola cordifolia, Entandrophragma angolense, Khaya grandifoliola, Manosonia altissima, Milicia excelsa, etc.), or introduced species (Anttiaris toxicaria, Amphimas pterocarpoides), or introduced (Anacardu occidentale, Azadirachta indica, Dioscorea alata, Manihot esculenta, etc.) or fruit crops (Carica papaya, Citrus limon, Citrus reticulata, Citrus sinensis, Musa paradisiaca, Musa sapientum, etc.) and form typical agro-systems. These generally diverse agrosystems are able to create a microclimate favourable to cocoa cultivation. According to [15], diversity is higher in agroforestry systems than in full sun systems, which justifies the results obtained. The number of species obtained in Bédiala cocoa agrosystems (100 species) is higher than that obtained from the work of [46] in the traditional cocoa agroforests in the locality of LaKota (56 to 97 species) in Côte d'Ivoire. This number remains much higher than that obtained in Cameroon by [21] with 59 species. The dominance of certain families such as Sterculiaceae (9%), Apocynaceae and Moraceae with 7% each and Euphorbiaceae (6 %) in the agroforestry systems as a whole, accounts for the physiognomy of the plantations, which brings them closer to agroforests. Some of dominant families of plantations in Bédiala locality were cited by [26] in agroforestry systems in south-central Côte d'Ivoire, but also reported as characteristic of the african forest zone and ivorian forests by some authors, including [1]-[47] and [9]. This suggests that these families are well adapted to the ecological conditions that would be favourable to the regeneration of species present. A total of nine biological types dominated by Phanerophytes, among which Microphanerophytes (36%) and Mesophanerophytes (23%) were strongly represented. The predominance of these biological types is a farmer's choice that helps to reduce the shading of cocoa trees and to reduce competition between the main crop and companion species. Moreover, this predominance can also be explained by the strong regeneration by buds, which is an important mode of quantitative regeneration in this type of species. This is evidenced by the fact that some farmers keep a few trees or shrubs to protect young cocoa plants from solar radiation [26]. Our results are similar to those of [32]. Indeed, this author showed in the classified forest of Tos and Bouaflé that Phanerophytes, particularly Microphanerophytes and Mesophanerophytes were the dominant biological types. However, the low representation of Megaphanerophytes also illustrates their excessive use by farmers as timber and service wood. At the chorological level, the flora of cocoa agrosystems is dominated on the one hand by taxa from the Guinean-congoles zone [53%] and on the other hand by those from the Guinean-congoles and Sudano-Zambian zones with 27% representation. This dominance can be explained by the fact that producers keep forest species that are of particular interest to them (medicine, food and timber use) and their plantations (soil fertilization and shade). Furthermore, this result justifies the strong affinity of these species for this ecological zone and also accounts well for the type of vegetation that supported the plantations. This cultural precedent was also reported by [26] who obtained 48% of Guinean-congoles species in cocoa plantations in the Lamto Reserve (Côte d'Ivoire). Concerning morphological types, more than half of the species recorded are arborescent at a proportion of 71%. This confirms the exploited forest character of the study area. In fact, the specific characteristics of the forests favour the regeneration of arborescent types and the emergence of lianasce species. All of the different types of cocoa agrosystems in Bédiala showed Shannon indices close to 2. This reflects, on the one hand, a high floristic diversity and, on the other hand, a good reconstitution of the floristic diversity of the undergrowth, probably due to the favourable environmental conditions. Moreover, this diversity could also be due to the cultural practices adopted by Bédiala farmers, which consist in conserving and preserving different species. This result shows that cocoa agrosystems, although anthropised systems are likely to contribute to the preservation of biodiversity. According to [8], cocoa agrosystems can help to protect many forest species with potential for biodiversity conservation at both species and landscape level. The Piéou indices calculated in the different agrosystems of Bédiala approach unity. This highlights the phenomenon of a good distribution of individuals within plant species. These results corroborate those of [43] in Cameroon. This could be explained by the fact that farmer in managing cocoa plantations takes into account the spatial distribution of the territory in order to protect these plants. Indeed, when the plantation is created, the farmer leaves many species in place in order to provide shady cover for the young plants. Over time, cuts and selections are made to reduce humidity and thus favour the growth and development of the plants. With a Sorensen's coefficient above 50%, several agrosystems show similarities between them. The different combinations carried out make it possible to establish similarities between the following cocoa agrosystems: [5-10 year old], [10-15 year old] and [20-25 year old] cocoa agrosystems with [0-5 year old] cocoa agrosystems and [5-10 year old] cocoa...
agro-system with [10-15 year old] cocoa agro-system. These results show that the flora present is not exclusive to each of the cocoa agro-systems and that the differences in age classes do not influence this flora. These results also show that the ecological zone is favourable to all the flora common to these plantations. In addition to maintaining floristic diversity, the cocoa stands of Bédiala also contribute to climate preservation by participating in carbon sequestration. The results obtained show that the age of the cocoa stands did not have a significant impact on the amount of carbon stored by each agro-system, although the values differed between them. The carbon stock of the associated woody stand is differently distributed between trees with a diameter of 30 cm or more and those with a diameter of 30 cm or less. Indeed, the associated species with a diameter at breast height greater than or equal to 30 cm record high quantities of biomass (11.05 to 70.73 tonnes per hectare). In turn, they represent the species with the highest carbon sequestration per hectare (5.53 to 35.37 tonnes of carbon per hectare). This high sequestration is due to the presence of species such as Ceiba pentandra, Bombax buonoposense, Milicia excelsa, Ricinodendron heudelotii, which have large diameters. According to [12], biomass increases with tree size. These results justify the fact that the majority of carbon is stored by the large forest trees that are mainly conserved and associated with cocoa trees [40]. The trend remains the same when looking at the carbon sequestered by all associated woody species, which is 141.62 tonnes per hectare. This could be due to good diversity and especially to the presence of species with a high carbon storage capacity [6]. The carbon sequestered by all the associated woody species is slightly similar to that obtained by [33] in Cameroon at 135.5 tonnes of carbon per hectare but differs from those of [34] in Nigeria with 96 tonnes of carbon per hectare. These differences are probably due to the diversity of environments, age, previous crops and tree densities but also to the different allometric equations used. Furthermore, the carbon stored by cocoa trees and associated trees with a diameter at breast height less than or equal to 30 cm is minimal compared to the carbon stored by trees with DBH ≥ 30. The average value of carbon stored in cocoa trees (10.33 tonnes per hectare) is similar to that obtained by [20] in Ghana.

**Conclusion**

The aim of the study carried out in Bédiala was to characterize the flora of the Bédiala cocoa agro-systems and to evaluate the quantity of carbon stored in the Bédiala cocoa agro-systems. This study revealed a remarkably rich preserved flora with 100 species inventoried belonging to 80 genera and 45 families. In these cocoa agro-systems, the most important families in terms of number of species were Sterculiaceae, Apocynaceae, Moraceae and Euphorbiaceae. These species were strongly related to taxa from the Guinean-Congolese zone. All the species recorded in the cocoa agro-systems were presented under fairly varied biological types and dominated by Microphanerophytes and Mesophanerophytes. In all the agro-systems, species that were more than 50% arboreal dominated all morphological types. Despite their different ages, all types of cocoa agro-systems were equally diverse. Beyond plant diversity, estimates of the carbon stored in the different agro-systems showed that cocoa trees alone did not contribute to carbon storage. This storage was provided by the associated stand. Cocoa agro-systems thus have the capacity to limit the impacts of climate change by sequestering atmospheric carbon.

**4. References**


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