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Conserving woody species in cocoa agroforestry systems in the peri-urban area of Daloa, Center-West Côte d'Ivoire: Diversity, status and perspectives

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Abstract

Often overlooked, agroforestry systems play a central role in the conservation of woody biodiversity, particularly in peri-urban areas subject to high anthropogenic pressures. This study aimed to assess the diversity and conservation status of woody species in cocoa plantations in the peri-urban area of Daloa. The floristic inventory was carried out on 2,400 m^2 plots (60 m × 40 m) distributed across four rural localities: Briboua, Toroguhé, Zakoua and Zépréguhé. A total of 82 woody species, belonging to 60 genera and 27 families, were recorded. The most represented families were Fabaceae (16 species), Malvaceae (9 species), Moraceae (7 species), and Euphorbiaceae (6 species). The Shannon index ranged from 2.16 to 3.93, reflecting moderate to high species diversity. Pielou's equitability (0.59 to 0.91) indicated a relatively homogeneous distribution of species across sites. Analysis of the horizontal structure of the stands revealed an "inverted J" distribution, showing the predominance of young individuals (≤ 10 cm in diameter), while large-diameter trees (> 50 cm) were poorly represented. The relative importance value index showed that only a few species, including *Terminalia ivorensis*, *Petersianthus africanus* and *Mangifera indica*, constitute the main framework of the stands. The results confirm that cocoa agroforestry systems in peri-urban areas contribute significantly to the conservation of woody biodiversity, with dynamics strongly influenced by local agricultural practices. For sustainable management, it is necessary to integrate farmers' knowledge into conservation strategies, promote cocoa agroforestry, and enhance the value of woody species with high ecological utility.

Keywords: Agroforestry; Cocoa Farming; Woody Biodiversity; Diversity Index; Daloa; Côte d'Ivoire

1. Introduction

The tropical forests of West Africa are among the most biodiverse ecosystems in the world [19]. However, they are also among the most threatened, due to rapid and persistent deforestation [1]. According to [8], nearly 13 million hectares of forest disappear each year worldwide. In Côte d'Ivoire, this degradation has accelerated in recent decades, leading to a considerable loss of forest cover: from 16 million hectares at the beginning of the 20th century, only 6.38 million hectares remained in 2000 [5]. Several studies highlight that agricultural expansion, dominated by cocoa farming, has been one of the main drivers of this deforestation [4, 20]. The "Ivorian miracle" of the two decades following independence was largely based on the extensive exploitation of forests for the benefit of this export crop, of which the country remains the world's leading producer [6]. The gradual expansion of plantations from east to west has contributed significantly to the degradation of the forest landscape, with an estimated annual deforestation rate of 3.8% [4, 5]. Despite its role in reducing forest cover, cocoa cultivation is often associated with other tree species, thus forming agroforestry systems [9]. These systems are characterized by the presence of a dominant crop (cocoa, coffee, rubber, etc.) supplemented by forest or exotic species, vines, and shrubs. In some cases, they can maintain a level of biodiversity close to that of a secondary forest [18]. However, in recent decades, the diversity of trees and shrubs preserved by

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producers has tended to decline, mainly due to increasing anthropogenic pressures, such as rapid urbanization and demographic pressure in peri-urban areas [15]. This trend raises questions about the real potential for conserving plant diversity in cocoa agroforestry systems, particularly in heavily anthropized peri-urban areas [17]. In Daloa, a major cocoa-producing area, few studies have focused on the composition and ecological value of the woody species present in these agrosystems. This lack of documentation justifies the interest of the present study, which aims to assess the diversity and conservation status of woody species in cocoa plantations in the peri-urban area of Daloa. More specifically, the aim is to characterize the woody flora present in these agrosystems and to determine the importance of woody species conserved and/or associated with farmers.

2. Materials and methods

2.1. Study area

The study was conducted in the Haut-Sassandra region, in the peri-urban areas (Bribua, Toroguhé, Zakoua and Zépréguhé) of Daloa, located in the central-western part of Côte d'Ivoire (Figure 1).

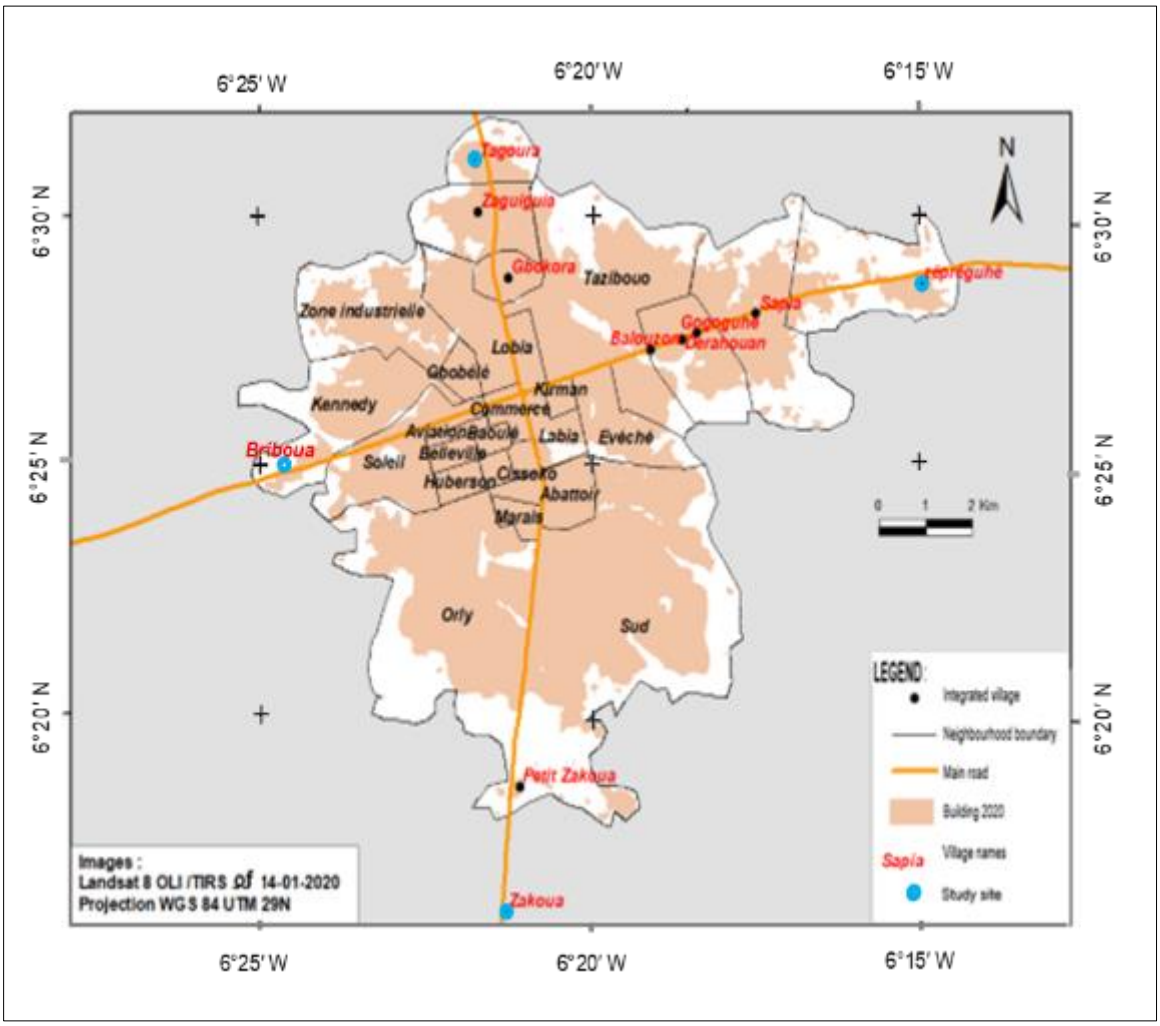

Figure 1 Map showing the location of the study area and sites

It lies between 6°52′ and 6.87′ north latitude and between 6°27′ and 6.45′ west longitude, approximately 141 km from Yamoussoukro, the political capital [3].

The climate is equatorial Guinean, characterized by two dry seasons, from November to February, and two rainy seasons, from March to October, with peak rainfall in June. Annual rainfall varies between 1,200 mm and 1,300 mm, while the average annual temperature is 25.6°C. The vegetation in the area was originally dense semi-deciduous rainforest dominated by *Triplochiton scleroxylon* and mesophilic savannahs [10]. However, under the effect of

anthropogenic pressures, these formations have declined significantly, giving way to degraded forests, fallow land, and cultivated areas.

2.2. Data collection

The study was conducted between 2023 and 2024 in four rural peri-urban localities selected for their accessibility: Zépréguhé (06°54′ N, 06°21′ W) on the Bouaflé-Daloa axis, Toroguhé (06°56′ N, 06°27′ W) on the Vavoua-Daloa axis, Zakoua (06°48′ N, 06°27′ W) on the Issia-Daloa axis, and Briboua (06°52′ N, 06°30′ W) on the Man-Daloa axis. In each of these locations, five cocoa plantations were selected at random. On each plantation, two 60 m x 40 m quadrats were randomly arranged, resulting in a total of 40 tree and shrub surveys. For each tree observed in the quadrats, the diameter at breast height (dbh measured at 1.37 m above the ground) was recorded and registered individually.

2.3. Data analysis

Taxonomic identification of species was carried out with reference to the classification in [16]. The specimens collected were compared with reference samples stored in the herbarium of the National Center for Floristics (CNF) at Félix Houphouët-Boigny University in Abidjan. The validity of scientific names, including specific genus and family levels as well as authors, was verified using recognized botanical databases, notably the International Plant Names Index (IPNI) and Plants of the World Online (POWO). The phytosociological parameters calculated include species richness, absolute frequency (AFr) and relative frequency (RFr). The floristic diversity of cocoa plantations was assessed using the Shannon-Wiener index [22], defined by the following formula:

$$H' = - \Sigma (p_i \times \ln(p_i))$$

Where p_i is (Ni/N), Ni - Number of individuals of species i and N - Total number of individuals of all species.

Pielou's equitability index [20] was calculated as follows:

$$E = H' / \ln (S)$$

With: H’ - Shannon-Weiner diversity index; S - Total number of species.

In addition, the structural parameters of the stands within the cocoa plantations were assessed using relative density, basal area, and dominance.

Relative density (RD) was obtained using the following formula:

$$RD = (n / N) \times 100$$

Where n - Number of individuals of a species and N - Number of individuals counted.

The basal area (S), calculated from the diameter of the stems measured at breast height, was determined using the formula:

$$S = \sum (\pi D^2) / 4$$

With: B - Base area; D - Stem diameter; π = 3.1416.

Relative dominance (RDo) was deduced from the ratio between the basal area of a species and the total basal area of the cocoa plot. The importance value index (IVI) was calculated by combining relative density (RD), relative frequency (RFr) and relative dominance according to the following relationship:

$$IVI = RD + RFr + RD$$

In addition to these parameters, the horizontal structure of the tree population in the cocoa plantations surveyed was analyzed by dividing the trees into diameter classes with 5 cm intervals [8]. Ten diameter classes were thus selected: 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm, 40-45 cm, 45-50 cm, and > 50 cm.

2.4. Statistical analysis of data

The data were processed using Statistica 7.1 software. Specific richness parameters and diversity indices were subjected to analysis of variance (ANOVA). In cases of significant differences, the means were compared using the Newman-Keuls test at a 5% threshold. In addition, one-factor ANOVA and Kruskal-Wallis tests were applied to floristic parameters (richness, diversity indices) and structural parameters (density and basal area).

3. Results

3.1. Specific richness and diversity of cocoa plantations

The floristic inventory of the cocoa plantations surveyed identified 82 species (Table 1).

Table 1 Taxonomic diversity, dendrometric characteristics, and indices of importance of woody species in cocoa plantations

Species	Family	AFr	ni	Average diameter (cm)	Basal area species (m^2 /ha)	RD (%)	RFr (%)	RDo (%)	IVI
Acacia hamiltoniana Maiden	Fabaceae	26.05	128	18.95	3.60	0.88	1.36	2.38	4.62
Acacia mangium Willd.	Fabaceae	33.04	72	21.19	2.54	0.62	1.72	1.34	3.68
Adansonia digitata L.	Malvaceae	28.32	87	44.75	13.68	3.34	1.48	1.62	6.44
Afzelia africana Sm. ex Pers.	Fabaceae	25.89	51	44.7	8	1.96	1.35	0.95	4.26
Afzelia bipindensis Harms	Fabaceae	20.79	104	12.16	1.20	0.29	1.08	1.93	3.30
Albizia adianthifolia (Schumach.) W.F. Wright	Fabaceae	30.13	25	7.88	0.12	0.03	1.57	0.46	2.06
Albizia ferruginea (Guill. and Perr.) Benth.	Fabaceae	21.38	86	8.83	0.52	0.13	1.11	1.60	2.84
Albizia glaberrima (Schum. and Thonn.) Benth.	Fabaceae	40.45	55	12.49	0.68	0.17	2.11	1.02	3.30
Albizia lebbeck (L.) Benth.	Fabaceae	43.47	32	13.78	0.48	0.12	2.27	0.60	2.99
Albizia zygia (DC.) J. F. Macbr.	Fabaceae	19.10	19	6.03	0.05	0.01	1	0.35	1.36
Alchornea cordifolia (Schumach. and Thonn.) Müll.Arg.	Euphorbiaceae	36.25	46	15.92	0.91	0.22	1.89	0.86	2.97
Alstonia boonei De Wild.	Apocynaceae	25.21	63	43.54	9.38	2.29	1.31	1.17	4.77
Anacardium occidentale L.	Anacardiaceae	26.86	70	10.52	0.60	0.15	1.4	1.30	2.85
Annona muricata L.	Annonaceae	41.88	41	40.34	5.24	1.28	2.18	0.76	4.22
Annona squarnosa L.	Annonaceae	5.98	15	49.69	2.90	0.71	0.31	0.28	1.30

Anthocleista nobilis G. Don	Loganiaceae	6.67	91	43.21	13.34	3.26	0.35	1.69	5.30
Antiaris toxicaria var. *africana* Scott Elliot ex A.Chev.	Moraceae	3.85	48	7.21	0.19	0.05	0.20	0.89	1.14
Azadirachta indica A. Juss.	Meliaceae	37.97	109	41.41	14.68	3.59	1.98	2.03	7.60
Baphia bancoensis Aubrév.	Fabaceae	35.68	16	5.97	0.04	0.01	1.86	0.30	2.17
Baphia nitida Lodd.	Fabaceae	39.40	7	14.84	0.12	0.03	2.06	0.13	2.22
Bauhinia rufescens Lam	Fabaceae	44.10	56	7.60	0.25	0.06	2.30	1.04	3.4
Blighia sapida K. D. Koenig	Sapindaceae	36.56	85	10.37	0.71	0.17	1.91	1.58	3.66
Bombax buenopozense P. Beauv.	Malvaceae	22.38	37	9.48	0.26	0.06	1.17	0.69	1.92
Bombax costatum Pellegr. and Vuillet	Malvaceae	35.78	59	6	0.16	0.04	1.86	1.10	3
Bridelia ferruginea Benth.	Phyllanthaceae	7.97	5	8.52	0.02	0.01	0.42	0.09	0.52
Bridelia grandis Pierre ex Hutch.	Phyllanthaceae	29.88	43	9.69	0.31	0.08	1.56	0.80	2.44
Calotropis procera (Ait.) W.T. Ait	Apocynaceae	9.02	24	13.41	0.33	0.08	0.47	0.45	1
Carapa procera DC.	Meliaceae	42.68	51	49.05	9.63	2.36	2,22	0.95	5.53
Cassia javanica L.	Fabaceae	24.92	47	5.38	0.10	0.03	1.30	0.87	2.20
Cecropia peltata L.	Urticaceae	20.42	120	45.08	19.15	4.68	1.06	2.23	7.97
Ceiba pentandra (L.) Gaerth.	Malvaceae	14.11	61	41.67	8.32	2.03	0.74	1.13	3.90
Chrysophyllum cainito L.	Sapotaceae	35.52	65	12.79	0.83	0.20	1.85	1.21	3.26
Citrus aurantium L.	Rutaceae	22.16	109	48.65	20.26	4.95	1.16	2.03	8.14
Citrus grandis (L.) Osbeck	Rutaceae	26.87	82	9.11	0.53	0.13	1.40	1.53	3.06
Citrus limon (L.) Osbeck	Rutaceae	3.79	35	6.40	0.11	0.03	0.20	0.65	0.88
Citrus maxima (Burm.) Merr.	Rutaceae	28.94	29	5.33	0.06	0.02	1.51	0.54	2.07
Citrus sinensis (L.) Osbeck	Rutaceae	28.71	7	49.83	1.36	0.33	1.50	0.13	1.96
Coffea arabica L.	Rubiaceae	28.91	8	8.73	0.04	0.01	1.51	0.15	1.67
Coffea canephora Pierre ex A. Froehner	Rubiaceae	42.64	99	9.20	0.65	0.16	2.22	1.84	4.22

Cola nitida (Vent.) Schott and Endl.	Malvaceae	31.64	103	5.51	0.24	0.06	1.65	1.92	3.63
Eugenia malaccensis L.	Myrtaceae	18.10	112	8.65	0.66	0.16	0.94	2.08	3.18
Ficus capensis Thunb.	Moraceae	21.36	18	5.17	0.04	0.01	1.11	0.33	1.45
Ficus exasperata Vahl	Moraceae	32.30	117	7.31	0.49	0.12	1.68	2.18	3.98
Ficus lutea Vahl	Moraceae	5.53	45	12.65	0.56	0.14	0.29	0.84	1.27
Ficus sur Forsk.	Moraceae	31	77	14.44	1.26	0.31	1.62	1.43	336
Funtumia elastica (Preuss) Stapf	Apocynaceae	31.17	24	12.5	0.29	0.07	1.62	0.45	2.14
Garcinia kola Heckel	Clusiaceae	11.84	100	8.39	0.55	0.13	0.62	1.86	2.61
Gmelina arborea Roxb.	Lamiaceae	8.41	77	44.90	12.18	2.98	0.44	1.43	4.85
Gossypium barbadense L.	Malvaceae	16.25	31	8.39	0.17	0.04	0.85	0.58	1.47
Hevea brasiliensis (Will. ex A. Juss.) Müll.Arg.	Euphorbiaceae	18.28	71	41.79	9.74	2.38	0.95	1.20	4.65
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	Irvingiaceae	26.95	125	41.71	17.07	4.17	1.40	2.32	7.89
Jatropha curcas L.	Euphorbiaceae	21.42	57	9.63	0.41	0.10	1.12	1.06	2.28
Macaranga heudelotii Baill.	Euphorbiaceae	44.51	72	13.75	1.06	0.26	2.32	1.34	3.92
Mangifera indica L.	Anacardiaceae	7.29	113	49.44	21.69	5.30	0.38	2.10	7.78
Margaritaria discoidea (Baill.) Webster	Euphorbiaceae	11.77	66	11.08	0.63	0.15	0.61	1.23	1.99
Milicia excelsa (Welw.) C.C. Berg	Moraceae	9.77	19	45.97	3.15	0.77	0.51	0.35	1.63
Milicia regia (A. Chev.) C.C. Berg	Moraceae	30.43	101	47.84	18.16	4.44	1.59	1.88	7.91
Morinda lucida Benth.	Rubiaceae	13.64	9	10	0.07	0.02	0.71	0.17	0.90
Musanga cecropioides R. Br. ex Tedlie	Cecropiaceae	22.59	72	5.50	0.17	0.04	1.18	1.34	2.56
Myrianthus arboreus P. Beauv.	Urticaceae	13.27	114	46.99	19.76	4.83	0.69	2.12	7,64
Newbouldia laevis (P. Beauv.) Seem ex Bureau	Bignoniaceae	9.68	16	14.92	0.28	0.07	0.50	0.30	0.87
Parkia bicolor A. Chev.	Fabaceae	7.64	129	7.67	0.59	0.14	0.40	2.40	2.94

Pentaclethra macrophylla Benth.	Fabaceae	30.57	91	11.79	0.99	0.24	1.59	1.69	3.52
Persea americana Mill.	Lauraceae	8.80	82	48.64	15.23	3.72	0.46	1.53	5.71
Petersianthus africanus (Welw. ex Benth. and Hook. f.) Merr.	Lecythidaceae	11.26	126	47.51	22.34	5.46	0.59	2.34	8.39
Picralima nitida (Stapf) T. Durand and H. Durand	Apocynaceae	18.49	114	14.64	1.9152	0.47	0.96	2.12	3.55
Pinus caribaea Morelet	Pinaceae	37.48	80	45.54	13.03	3.18	1.95	1.49	6.62
Psidium guajava L.	Myrtaceae	7.08	61	7.12	0.24	0.06	0.37	1.13	1.56
Pterygota macrocarpa K. Schum.	Malvaceae	38.19	21	7.22	0.08	0.02	1.99	0.39	2.40
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	7.04	29	42.19	4.05	0.99	0.37	0.54	1.90
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	44.01	34	45.70	5.57	1.36	2.29	0.63	4.28
Spondias mombin L.	Anacardiaceae	22.68	26	44.52	4.04	0.99	1.18	0.48	2.65
Sterculia oblonga Mast.	Malvaceae	44.02	115	14.70	1.95	0.48	2.29	2.14	4.91
Tamarindus indica L.	Fabaceae	28.40	30	11.81	0.33	0.08	1.48	0.56	2.12
Tarrietia utilis (Sprague) Sprague	Malvaceae	34.05	85	40.85	11.14	2.72	1.77	1.58	6.07
Tectona grandis L. f.	Lamiaceae	4.65	65	5.56	0.15	0.04	0.24	1.21	1.49
Terminalia catappa L.	Combretaceae	14.88	126	44.88	19.93	4.87	0.78	2.34	7.99
Terminalia ivorensis A. Chev.	Combretaceae	8.05	123	48.81	23.01	5.62	0.42	2.29	8.33
Terminalia laxifolia Engl.	Combretaceae	15.44	122	14.76	2.08	0.51	0.80	2.27	3.58
Trema africanus (Planch.) Blume	Cannabaceae	7.99	66	46.18	1105	2.70	0.42	1.23	4.35
Voacanga africana Stapf	Apocynaceae	16.36	88	45.42	14.25	3.48	0.85	1.64	5.97
Xylopia aethiopica (Dunal) A. Rich.	Annonaceae	20.4	38	48.55	7.03	1.72	1.06	0.71	3.49

Abbreviations: AFr - Absolute Frequency; RD - Relative Density; RDo - Relative dominance; RFr - Relative Frequency; IVI - Importance Value Index

These species are divided into 27 families, the most important of which are (Figure 2):

- the Fabaceae family with 16 species, representing 19.51% of the total number of species recorded;

- the Malvaceae family with 9 species, representing 10.97% of the total number of species;
- the Moraceae family with 7 species, representing 8.53% of the total number of species;
- the Euphorbiaceae family with 6 species, representing 8.53% of the total number of species;
- the Apocynaceae and Rutaceae families, each represented by 5 identified species;
- the Anacardiaceae, Annonaceae, Combretaceae, and Rubiaceae families, each represented by 3 species (3.65% of species each);

the Meliaceae, Lamiaceae, Myrtaceae, and Pyllanthaceae families, each represented by 2 species (2.56% of species each).

The remaining 13 families, grouped under the term “others” and each represented by one species, constitute 15.85% of the total number of species.

Generic diversity remains notable, with a total of 60 genera recorded. The Fabaceae family includes nine genera, followed by the Malvaceae with eight genera, and then the Euphorbiaceae with six genera. The Apocynaceae family has five genera, followed by the Anacardiaceae and Moraceae, each represented by three genera, as well as the Annonaceae, Lamiaceae, Meliaceae, Myrtaceae, Rubiaceae, and Urticaceae, each represented by two genera. The other families have only one genus. In terms of number of species, *Albizia* and *Citrus* are the most represented with five species each, followed by *Ficus* with four species, *Terminalia* with three species, then *Acacia, Afzelia, Annona, Baphia, Bombax, Bridelia, Coffea* and *Milicia*, each with two species.

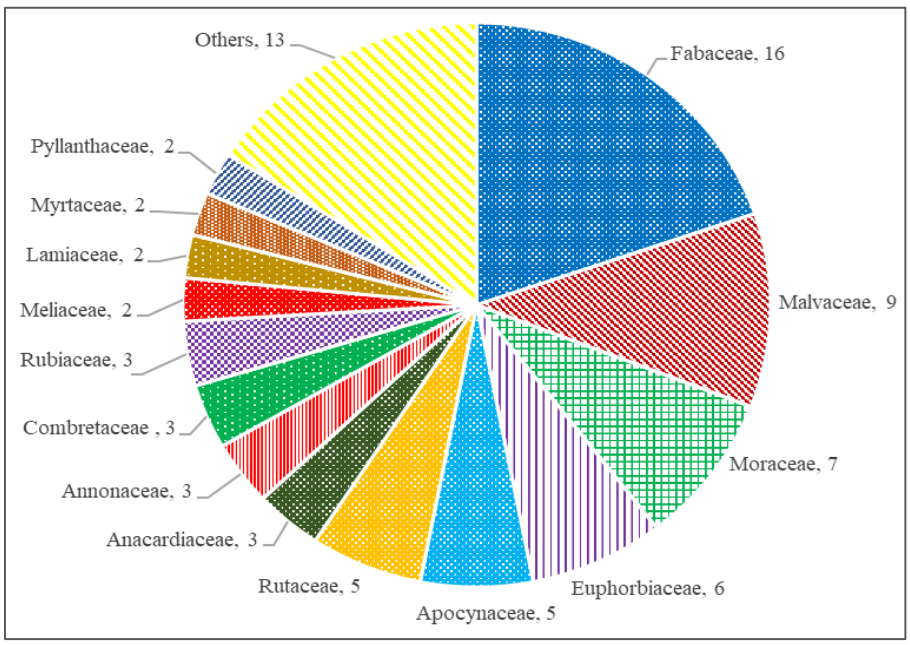

Figure 2 Proportion of families most represented in terms of number of species

Table 2 shows the species richness and diversity indices of woody species in the cocoa plantations at the four sites surveyed. The specific richness varies from 39 species in Toroguhé to 77 species in Zépréguhé. The greatest floristic richness was observed in the cocoa plantations of Zépréguhé (77 species), followed by those of Briboua (65 species) and Zakoua (48 species), while the lowest value was recorded in Toroguhé (39 species). Shannon diversity indices range from 2.16 in Toroguhé to 3.93 in Zépréguhé. The differences observed between sites are statistically significant ($F = 45.78$; $P < 0.0001$). Piélou's evenness varies from 0.59 to 0.91. The lowest value is observed in Toroguhé (0.59), reflecting a strong dominance of a few species. Conversely, the high values recorded in Zépréguhé (0.91) and Briboua (0.88) indicate a better distribution of individuals among species. Zakoua (0.82) occupies an intermediate position with a relatively homogeneous population. The differences observed between the average indices of cocoa plantations according to site are statistically significant ($F = 58.63$; $P < 0.003$).

Table 2 Species richness and diversity indices of the different cocoa plantations studied

Sites	Number of cocoa farms	Number of species	Shannon index	Piélou equitability
Briboua	5	65 ±20a	3,65±0,84a	0,88±0,12b
Toroguhé	5	39 ±7b	2,16±0,36b	0,59±0,04c
Zakoua	5	48 ±15b	3,19±0,04ab	0,82±0,09b
Zépréguhé	5	77 ±86a	3,93±0,92a	0,910,08a

Within the same column, values followed by the same letter are not significantly different at the 5% level.

3.2. Frequency and basal area of woody species in cocoa plantations

Table 1 also shows the floristic composition of cocoa plantations in the area. The most common species in the plots are *Albizia lebbeck* (43.47%), *Bauhinia rufescens* (44.1%), *Ricinodendron heudelotii* (44.01%), *Albizia glaberrima* (40.45%), *Baphia nitida* (39.54%), *Pterygota macrocarpa* (38.19%), *Alchornea cordifolia* (36.25%), *Blighia sapida* (36.56%) and *Azadirachta indica* (37.97%). They are followed by *Coffea canephora* (42.64%), *Annona muricata* (41.88%), *Macaranga heudelotii* (44.51%), *Sterculia oblonga* (44.02%), *Terminalia catappa* (14.88%), *Terminalia ivorensis* (8.05%), *Milicia regia* (30.43%), *Persea americana* (8.80%), *Petersianthus africanus* (11.26%), *Myrianthus arboreus* (13.27%) and *Mangifera indica* (7.29%). However, the other species had a specific frequency of less than 8%. Table 1 also shows the basal area of the species recorded in the cocoa p lantations. Ten species have the largest basal areas, notably *Terminalia ivorensis* (23.01 m^2), *Petersianthus africanus* (22.33 m^2/ha), *Mangifera indica* (21.69 m^2/ha*), Citrus aurantium (20.26 m^2/ha), Terminalia catappa (19.93 m^2/ha), Cecropia peltata (19.15 m^2/ha), Myrianthus arboreus* (19.76 m^2/ha), *Azadirachta indica* (14.68 m^2/ha), *Irvingia gabonensis* (17.07 m^2/ha), *Adansonia digitata* (13.68 m^2/ha*), Anthocleista nobilis* (13.34 m^2/ha), *Gmelina arborea* (12.18 m^2/ha). Twenty-one species have an intermediate basal area (between 1.5 and 12 m^2/ha) and play a significant role in the structure of cocoa plantations, including *Carapa procera* (9.63m^2/ha), *Hevea brasiliensis* (9.74 m^2/ha), *Ceiba pentandra* (8.32 m^2/ha), *Afzelia africana* (8 m^2/ha) and *Alstonia boonei* (9.38 m^2/ha). In addition, 28 species have a basal area of less than 1.5 m^2/ha, including *Albizia adiantifolia* (0.12 m^2/ha), *Citrus limon* (0.11 m^2/ha), *Albizia zygia* (0.05 m^2/ha) and *Coffea arabica* (0.04 m^2/ha). This distribution highlights the dominance of a few fast-growing trees and the presence of a group of intermediate and slow-growing species, contributing to the structural diversity of the cocoa plantations in the area.

3.3. Ecological importance of woody species in cocoa plantations

Table 1 also presents the importance value index (IVI) of the different woody species recorded in the cocoa plantations studied. This index, which combines relative frequency, density, and dominance, makes it possible to assess the ecological and structural role of species within stands. The results reveal marked floristic diversity, with highly variable levels of importance depending on the taxon. Among the 82 species inventoried, three stand out with a high IVI of over 6: *Adansonia digitata* (IVI = 6.44), *Azadirachta indica* (IVI = 7.60), *Cecropia peltata* (IVI = 7.97), *Citrus aurantium* (IVI = 8.14), *Irvingia gabonensis* (IVI = 7.89), *Mangifera indica* (IVI = 7.78), *Milicia regia* (IVI = 7.91), *Myrianthus arboreus* (IVI = 7.64), *Petersianthus africanus* (IVI = 8.39), *Pinus caribaea* (IVI = 6.62), *Tarrietia utilis* (IVI = 6.07), *Terminalia catappa* (IVI = 7.99), *Terminalia ivorensis* (IVI = 8.33). In contrast, more than 37 species have an IVI of less than 3, reflecting their low abundance and reduced dominance. Among these are *Bridelia ferruginea* (IVI = 0.52), *Newbouldia laevis* (IVI = 0.87), *Citrus limon* (IVI = 0.88), *Morinda lucida* (0.99), *Calotropis procera* (IVI = 1), *Antiaris toxicaria* var. *africana* (IVI = 1.14), *Annona squarnosa* (IVI = 1.3), *Albizia zygia* (IVI = 1.34), *Ficus lutea* (IVI = 1.47), *Bombax buenopozense* (IVI = 1.92) and *Jatropha curcas* (IVI = 2.28). This distribution highlights the coexistence of a small number of dominant species, essential to the structure and functioning of the cocoa plantations surveyed and a large number of secondary species which, although poorly represented, contribute to the floristic richness and ecological stability of these cocoa plantations in the face of disturbances caused by local agricultural practices.

3.4. Distribution of tree diameters in cocoa plantations

The diameter classes of trees in cocoa plantations provide a useful reference for understanding the structure of plant populations in these plantations. Figure 3 shows that the number of trees per diameter class within cocoa plantations, depending on the site, decreases as the diameter increases. The overall histogram has an inverted "J" shape, characterized by a high proportion of individuals with a small diameter (≤ 10 cm).

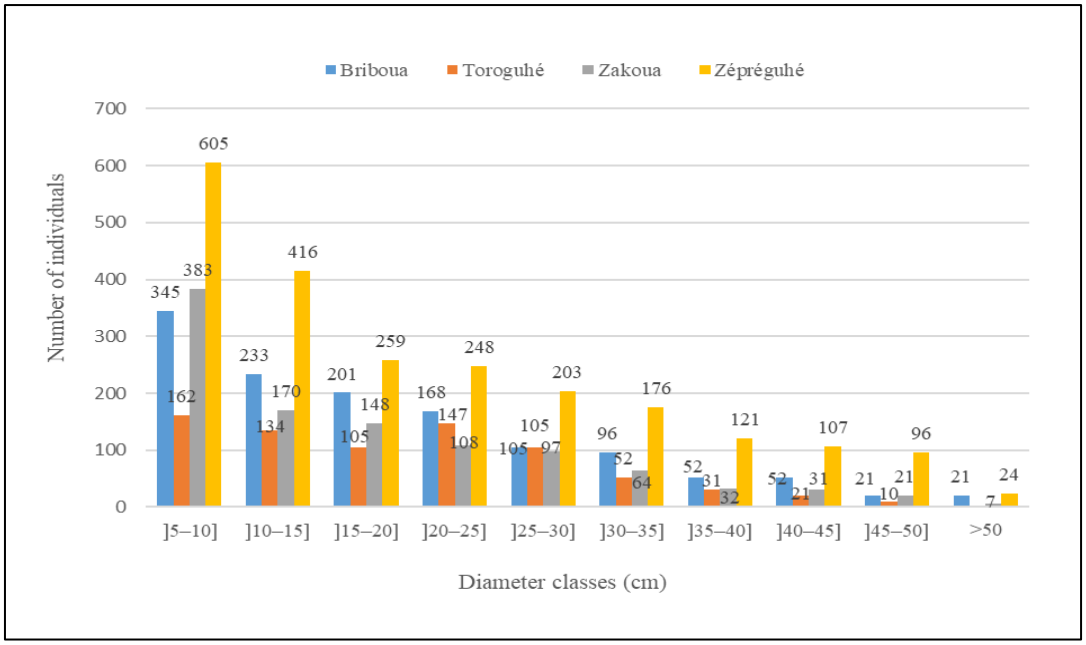

Figure 3 Distribution of woody individuals by diameter class and site

At the Briboua site, out of 1,294 individuals recorded, the 5-10 cm (345 individuals) and 10-15 cm (233 individuals) classes are predominant, while the > 50 cm class (21 individuals) is very poorly represented. At Toroguhé, out of 767 individuals, the 5-10 cm (162 individuals) and 20-25 cm (147 individuals) classes are the most abundant, while the > 50 cm class is not represented. At the Zakoua site, out of 1,061 individuals, the 5-10 cm (383 individuals) and 15-20 cm (148 individuals) classes are predominant, and the > 50 cm class (7 individuals) is very poorly represented. Finally, at Zépréguhé, out of 2,255 individuals, the 5-10 cm (605 individuals) and 10-15 cm (416 individuals) classes dominate, while the > 50 cm class (24 individuals) is poorly represented. The results indicate that the majority of individuals surveyed in the cocoa plantations have small or medium diameters, while large-diameter trees are few in number.

4. Discussion

The specific richness observed in our study is higher than that reported by [13] and [25], which were 64 and 72 species respectively in Zima in central Cameroon and Belabo in eastern Cameroon. This difference could be explained by the ecological characteristics and local agricultural practices within the cocoa plantations in our area, in particular the promotion of natural regeneration and the voluntary conservation of trees and shrubs by farmers. The complexity of traditional cocoa agroforestry structures and the management of species present in the plots also contribute to the maintenance and increase of woody diversity.

The results show a dominance of families such as Fabaceae (16 species), Malvaceae (9 species), Moraceae (7 species), and Euphorbiaceae (6 species). This array of families has already been reported as characteristic of Ivorian forests and especially of the agrosystems of Haut-Sassandra in the semi-deciduous forest zone [2].

Analysis of diversity indices enabled us to characterize the richness and distribution of woody individuals in the cocoa plantations studied. The Shannon index ranges from 2.16 to 3.93, reflecting moderate to high species diversity depending on the cocoa plantations at the sites. The highest values observed at Zépréguhé and Briboua indicate a relatively even distribution of individuals among species and suggest a more stable population structure. Conversely, Toroguhé, with lower values, is dominated by a few taxa, reflecting reduced diversity and marked species dominance. These results confirm the influence of cultivation practices on the diversity and structure of cocoa plantations, in line with the observations of [11]. Pielou's evenness indices, with values between 0.59 and 0.91, reflect the degree of uniformity in the distribution of individuals among species. Values close to 1 observed in the cocoa plantations of certain sites show that the species present within the plots are relatively well distributed, despite the anthropization of the systems. On the other hand, lower values reflect the dominance of certain taxa linked to the main crop and agricultural practices, which accentuates the impact of humans on the floristic composition and structure of cocoa plantations [14, 26].

Analysis of frequencies and basal areas reveals a structure dominated by a few species with strong growth, such as *Terminalia ivorensis*, *Petersianthus africanus*, and *Mangifera indica*, which form the main framework of cocoa plantations. Conversely, the majority of species are distributed in intermediate or low basal area classes, reflecting a more diffuse presence in the floristic composition. The relative importance value index confirms this trend: only about ten species exceed the threshold of 6, while more than 37 taxa have an IVI of less than 3. This structure reflects the anthropized nature of cocoa plantations, where farmers favor certain species for their ecological (shading, fertilization, soil protection) and utilitarian (food, medicinal, economic) functions. This pattern, already noted by [23] and [12], who estimate that cocoa agroforests have a structure similar to that of forests, enabling them to contribute, like forests, to the physical and chemical conservation of the soil in other tropical cocoa agroforestry systems, illustrates how human practices influence the composition and dynamics of woody stands, often to the detriment of uniformly represented diversity [12].

The diameter classes of trees in cocoa plantations are an essential indicator for understanding the structure and dynamics of plant populations. The results obtained reveal an inverted "J" distribution, reflecting a gradual decrease in the number of individuals as diameter increases. This configuration highlights the strong predominance of young trees (≤ 10 cm), indicating active regeneration within the plantations. Similarly, the cocoa plantations at the sites are mainly characterized by the presence of small and medium-diameter individuals, while large trees (> 50 cm) remain poorly represented. This structure reflects the particular dynamics of cocoa systems in the area, marked by management practices based on tree renewal and thinning. These results are consistent with the observations of [24] and [14] on cocoa-based agroforestry systems.

5. Conclusion

The objective of this study was to assess the diversity and conservation status of woody species in cocoa plantations in the peri-urban area of Daloa. The study was conducted in four rural locations: Briboua, Toroguhé, Zakoua and Zépréguhé. A total of 82 woody species, belonging to 60 genera and 27 families, were recorded. The cocoa plantations surveyed showed high species richness, with a significant proportion of trees and shrubs preserved. Significant differences were observed between the cocoa plantations at the four sites, both in terms of species richness and diversity indices and the structure of woody stands. The cocoa plantations in Briboua and Zépréguhé stood out for their floristic diversity, with varying levels of importance depending on the taxa. Among the 82 species inventoried, three had a relative importance value index greater than 6, reflecting their major ecological role in the structure of the stands. It also emerged that the cocoa plantations were characterized by individuals of small and medium diameter, while large trees (> 50 cm) remained poorly represented. In light of these results, it appears necessary for management structures to encourage farmers to associate more plant species with cocoa trees in order to restore soil fertility, preserve plant biodiversity and promote sustainable production in existing cocoa plantations.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest in this article.

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