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Recommendations for enhancing the biodiversity and spatial structure of Cacao plantations

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ABSTRACT

The study determined floristic composition in a Tropical Moist Rainforest and cacao plantation in Nigeria. This was with a view to understanding whether cacao plantations are capable of maintaining plant species biodiversity comparable to that of the natural forests they replaced.

The study was carried out in 0.0625 ha sample plots, three each in natural forests and cacao plantations, adjacent to each other, in Ile-Oluji, Ile-Oluji/Okeigbo Local Government Area of Ondo State, Nigeria. In each plot, all plant species (herbs, climbers and trees) were identified and girth sizes of all woody species measured at breast height. Herbaceous species composition was determined by randomly laying ten 1 m x 1m quadrats in each plot. The herbaceous species in each quadrat was identified and counted to determine the density. The data were analyzed using appropriate statistical methods.

The results showed that forest vegetation had higher species richness (90), basal area (20.06 $m^2\ ha^{-1}yr^{-1}$), and diversity (3.14) than those of cacao plantation (53; 15.54 and 1.93 respectively). This study concluded that the natural forests have higher plant species diversity than cacao plantations though the cacao plantations have reasonable plant species biodiversity. Thus clearing forests to establish cacao plantations should be reconsidered because of its adverse effect on plant species diversity biodiversity. However, effective management practices that focuses on diversity within plantation can help conserve biodiversity and sustain livelihood of local farmer.

KEYWORDS

Floristic composition; Forest; Cacao plantation; Ecosystem; Deforestation

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Introduction

A forest is a natural ecosystem in which trees are a significant component. Tropical rainforests are the most diverse ecosystems found in the world today [1]. They house high levels of biodiversity, maintain critical ecosystem services and exchange large quantities of carbon and water with the atmosphere [2-4]. They are home to thousands of plant and animal species, many of which are not found anywhere else. Notwithstanding the preponderance of species, it has been noted that so many of the trees found in the tropical rainforests are rare [5]. Despite this, humans continue to enjoy the forest resources directly or indirectly. Forests have an important role to play in human development. Throughout West Africa, forests form an integral part of the rural economy, providing subsistence goods and services as well as items of trade [6]. These forests are also threatened by widespread commercial logging, urbanization and rapid agricultural uses [7].

Human disturbance on forested ecosystems is posing a serious threat to local biodiversity [8]. In most areas of the world tropical deforestation has been attributed to timber extraction and agricultural expansion [9]. The highest rate of deforestation in Africa has been reported to have occurred in West Africa with the most rapid forest clearance occurred in Nigeria with an appreciable 21% clearance of its [10], making Nigeria one of the leading countries involved in deforestation.

Conversion of natural forests into farmland has mainly being brought about by commodity market expansion [11]. Important among commodities that enjoy global economic value and which involve a large-scale input-intensive farming system is cacao (*Theobroma cacao* L.) [12]. Despite being non- native cash crop in Nigeria, Cacao farms have become an important non-forest matrix within tropical moist forest landscape of Nigeria, covering about 750,000 ha of land [13].

The introduction of cacao plantations into tropical forest ecosystems has caused loss of forest land and has modified it with tremendous impact on important ecological functioning and structure that define the ecological integrity of forests. Although cacao production remains a major source of livelihood and foreign exchange in many tropical countries including Nigeria, conventional monoculture and low-shade production systems often reduce ecosystem complexity and compromise the ecological functions necessary for sustainable agricultural production [14]. As a result, protecting biodiversity within cacao plantation will help sustain ecosystem integrity and enhance agricultural productivity.

Cacao plantations with mixture of native shade tree species generally support higher levels of biodiversity than simplified production systems while maintaining competitive yields [15]. Clough et al also reported that cacao plantation that is rich in biodiversity provides several ecosystem services which include enhanced nutrient cycling dynamics, soil conservation, carbon sequestration and greater resilience to climate variability [16].

Recent studies advocate a transition from production systems focused solely on maximizing short-term yields toward ecologically sustainable management approaches that integrate biodiversity conservation with economic objectives. Such approaches include maintaining diverse shade-tree assemblages, conserving remnant forest patches and riparian buffers, reducing dependence on synthetic agrochemicals through integrated pest management, and promoting landscape connectivity to facilitate species movement and ecosystem functioning [17]. These strategies not only improve the spatial complexity of cacao plantations but also enhance their capacity to withstand environmental

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disturbances and contribute to long-term agricultural sustainability.

The aim of this study is to compare the floristic composition and structure between the forest and cacao plantation in a tropical moist rainforest to find out if cacao plantations harbor high biodiversity comparable to the natural tropical forests they replaced.

Materials and Methods

Study area

The study was undertaken in Ile-Oluji, Ondo State, Southwest, Nigeria, Ondo State lies between longitudes 4° 31' and 6° 00' E of the Greenwich Meridian and latitudes 5° 15' and 8° 15' N of the equator while Ile-Oluji lies between latitudes 6° 40' N and 7° 14' N, and longitudes 4° 38' E and 4° 53' E (Figure 1). The tropical climate of the State is broadly rainy season (between April and October) and dry season (between November and March). Temperature throughout the year ranges between 21°C to 29°C and humidity is relatively high. The annual rainfall varies from 2, 000 mm in the southern areas to 1,150 mm in the northern areas (Ondo State Ministry of Environment). The State enjoys luxuriant vegetation with rain forest in the south and sub-savanna vegetation in the northern fringe [18]. The major soil types found in Ondo State are alluvial, ferralsols and ferruginous tropical soils. The alluvial soil types are not important agriculturally. Areas with ferruginous soils are particularly suitable for cacao production. The soil has an exceptional clayey texture, combined with good drainage and aeration with good properties of moisture and nutrient retention. Ile-Oluji is underlain by the basement complex terrain of the crystalline rocks of Nigeria. The major rock is mainly the medium grained granite gneisses that are strongly foliated and commonly occurring as out crops. The surface of these outcrops is severely contorted with alternation of band of dark and light coloured minerals. The light coloured band contains minerals that are essentially feldspar and quartz while the dark well drained with a medium texture [19].

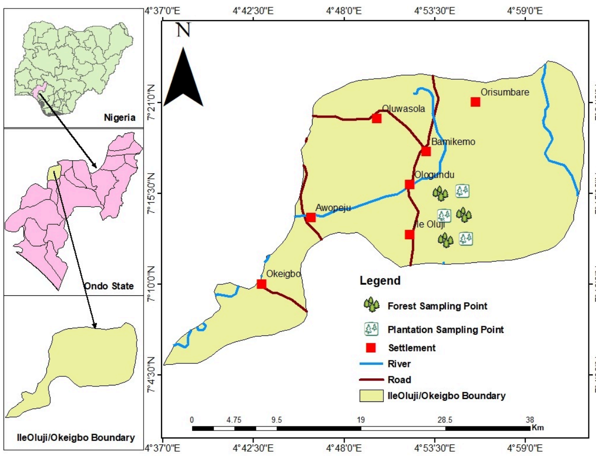

Figure 1. Map of the study area showing Nigeria, Ondo State, Ile-Oluji local government area and Ile-Oluji town with the sampling sites.

Sampling procedure

Three sample plots, 25 m x 25 m each were established in three different natural forests and three different cacao plantations adjacent to each other in the study area (Figure 1).

Vegetation sampling

All woody species within each sample plot were identified to species level. The species that could not be identified in the field were collected, pressed and identified in the IFE Harbarium (IH) in the Department of Botany of the Obafemi Awolowo University, Ile-Ife. The woody species were completely enumerated and their girths at breast height (gbh, 1.3 m) were measured with a measuring tape avoiding any intrusion on the trunk or lianas growing around it.

From the data obtained on the field, the following vegetation attributes were determined for each plot of cacao plantation and forest: tree species composition, density (ha^{-1}), basal area, Shannon-Weiner diversity index (H’), evenness of distribution of species and Sorenson’s index of similarity between adjacent cacao plantation and forest plots. The species composition of the plots was established by listing all the species encountered in each plot. Species similarity between forest and cacao plantation was calculated using the Sorenson index of similarity (SIS), calculated as [20]:

ISS = $\frac{2C}{A+B}$

C = number of species common to forest and cacao plantation

A = number of species in forest plot

B = number of species in cacao plantation plot

The girth measurements of the individual plants of each species was used to calculate the woody basal areas in cacao plantation and forest plots expressed in m^{2} ha^{-1} using the formula:

Basal area (m2ha-1) = $\frac{C^2}{4\pi}$

Where;

C is the girth size in meter

The basal areas of all individuals of each species were summed to get the species basal area for each plot. The plot basal area was calculated by summing all the species basal areas in the plot. The density of trees in the plots was calculated per hectare (ha^{-1}).

The cacao plantation or the forest woody basal area and density was calculated as the mean of the woody basal areas and densities of the plots of cacao plantation or forest ± 95 % confidence interval.

The species diversity index was calculated using the Shannon-Wiener index (Shannon and Weaver, 1949) using the formula:

$H^{I} = -\sum P_i \ln (P_i)$

Where;

H^{I} is the Shannon-Weiner diversity index

Pi = $\frac{ni}{N}$, the relative abundance of each species “i”

N = total number of individuals of all species

n_i = number of individuals of a species.

The evenness of distribution of species was calculated using Pielou’s evenness index, J [21];

J = $\frac{H'}{ln(S)}$

Where;

J is the Pielou’s evenness index

H^{I} is the Shannon-Wiener diversity index

S is the total number of species on each plot.

Results

Vegetation parameters of the natural forest and cacao plantation

Species composition of the forest and cacao plantation

In the forest and cacao plantation ecosystems, a total of 115 plant species were identified comprising 52 trees, 22 shrubs, 22 herbs and 19 climbers (Tables 1 and 2). In the forest ecosystem, a total of 90 species were identified, comprising 44 tree species, 20 shrubs, 7 herbs, and 19 climbers, while in the cacao plantation, a total of 53 species were identified, comprising 20 trees, 10 shrubs, 20 herbs, and 3 climbers (Tables 1 and 2). Thus, the forest had more tree, shrub, and climber species than the cacao plantation, while herbs were more in the cacao plantation than in the forest (Tables 1 and 2). The total

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genera in the two ecosystems were 93; the forest had 73, while the cacao plantation had 48 (Tables 1 and 2). The genus that most commonly occurred in the two ecosystems was *Cola* in the family Malvaceae (Table 1).

A total of 28 plant species were common to forest vegetation and cacao plantation and these are; *Albizia adianthifolia, Albizia zygia, Alchornea laxiflora, Allophylus africanus, Antiaris toxitoria*, *Baphia nitida, Carpolobia lutea, Cnestis ferruginea, Cola accumulata, Cola millenii, Elaeis guineensis, Icacina tracantha, Lecaniodiscus cupanioides, Lonchocarpus sericeus, Mallotus oppositifolus, Monodora myristica, Pycnanthus angolensis, Rineorea dentata*, *Spondias mombin and Terminalia ivorensis and herbs and climbers are Acanthus montanus*, *Adenia cissampeloides, Aspilia africana*, *Carphalea obovata, Chromolaena odorata, Culcasia scadens, Cyathula prostrata and Simicratea welwitchii* (Table1).

Table 1. Species composition, density and basal area in cacao plantation and natural forest (Mean ±Std).

				Species composition		**Basal area (m^2 ha^{-1})**		**Density (ha^{-1})**	
	Species	**Family**	**Life form**	**Cacao**	**Forest**	**Cacao**	**Forest**	**Cacao**	**Forest**
1	*A. ataxacantha*	Fabaceae	S	-	+	0 ± 0	0 ± 0	0 ± 0	48±67.88
2	*A. montanus*	Acanthaceae	H	+	+	0 ± 0	0 ± 0	266.67±301.4	192±271.53
3	*A. difformis*	Araceae	H	+	-	0 ± 0	0 ± 0	5.33±9.24	0 ± 0
4	*A. cissampeloides*	Passifloraceae	C	+	+	0 ± 0	0 ± 0	5.33±9.24	16±22.62
5	*A. lobata*	Passifloraceae	C	-	+	0 ± 0	0 ± 0	0 ± 0	26.67±37.71
6	*A. Africana*	Caesalpiniaceae	T	-	+	0 ± 0	1.072 ± 1.856	0 ± 0	21.33±30.17
7	*A. adianthifolia*	Mimosaceae	T	+	+	0 ± 0	0.527 ±0.665	5.33±9.24	16±13.06
8	*A. zygia*	Mimosaceae	T	+	+	0 ± 0	3.748 ±2.98	400±450.56	586.6±342.1
9	*A. ditormis*	Euphorbiaceae	T	+	-	0± 0	0 ± 0	16±27.712	0±0
10	*A. laxiflora*	Euphorbiaceae	T	+	+	0 ± 0	0.426 ± 0.416	101.33±175.51	592±520.18
11	*A. africanus*	Sapindaceae	T	+	+	0 ± 0	0.068 ± 0.712	10.67±18.48	138.6±226.4
12	*A. brasiliensis*	Amaranthaceae	H	+	-	0 ± 0	0 ± 0	357.33±618.91	0 ± 0
13	*Amorphophallus spp*	Araceae	H	+	-	0 ± 0	0 ± 0	10.67±18.48	0 ± 0
14	*A. vogelii*	Loganiaceae	T	-	+	0 ± 0	0.513 ± 0.889	0 ± 0	5.333±9.237
15	*A. macrophylla*	Euphorbiaceae	T	-	+	0 ± 0	0.102 ± 0.136	0 ± 0	42.66±60.57
16	*A. toxitoria*	Moraceae	T	+	+	0.168 ± 0.292	0.05 ± 0.09	58.67±56.19	16±27.71
17	*A. utilis*	Moraceae	T	+	-	0.183±239	0 ± 0	26.67±33.306	0 ± 0
18	*A. Africana*	Asteraceae	H	+	+	0 ± 0	0 ± 0	309.33±535.78	21.33±33.95
19	*A. gagantea*	Acantheceae	H	+	-	0 ± 0	0 ± 0	272±284.36	0 ± 0
20	*A. vogeliana*	Acantheceae	H	+	-	0 ± 0	0 ± 0	64±62.78	0 ± 0
21	*B. nitida*	Papilionaceae	T	+	+	0 ± 0	0.169 ± 0.213	42.67±73.900	197.3±78.92
22	*B. micrantha*	Euphorbiaceae	T	-	+	0 ± 0	0.675 ± 0.958	0 ± 0	64±73.32
23	*C. benthamianum*	Caesalpinaceae	C	-	+	0 ± 0	0 ± 0	0 ± 0	10.66±18.47
24	*C. obovata*	Rubiaceae	H	+	+	0 ± 0	0 ± 0	421.33±437.5	85.33±147.8

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Table 1 (continued)

				Species composition		Basal area (m^2 ha^{-1})		Density (ha^{-1})	
25	*C. lutea*	Polygalaceae	S	+	+	0 ± 0	0.0293 ± 0.051	144±249.41	10.66±18.47
26	*C. pentandra*	Sterculiaceae	T	-	+	0± 0	0.0627 ± 0.081	0 ± 0	10.66±9.237
27	*C. zenkeri*	Ulmaceae	T	-	+	0±0	0.105 ± 0.143	0 ± 0	106.6±133.2
28	*C. Canadensis*	Vitaceae	C	-	+	0±0	0 ± 0	0 ± 0	5.33±7.23
29	*C. sinensis*	Rutaceae	T	+	-	0.078 ± 0.136	0 ± 0	21.33±36.95	0±0
30	*C. kolly*	Rubiaceae	H	-	+	0±0	0 ± 0	0 ± 0	16±27.71
31	*C. odorata*	Asteraceae	H	+	+	0±0	0 ± 0	309.33±535.7	112±117.58
32	*C. ferruginea*	Connaraceae	C	+	+	0±0	0 ± 0	0 ± 0	394.6±258.6
33	*Cola accumulate*	Malvaceae	T	+	+	0.622 ± 1.077	0.0713 ± 0.124	42.67±73.900	5.333±9.237
34	*C. gigantia*	Malvaceae	T	-	+	0±0	0 ± 0	0 ± 0	48±83.13
35	*C. hispida*	Malvaceae	T	-	+	0±0	0.103 ± 0.178	0 ± 0	26.66±24.44
36	*C. millenii*	Malvaceae	T	+	+	0±0	0.769 ± 1.021	21.33±36.950	154.6±240.7
37	*C. nitida*	Malvaceae	T	+	-	0.194 ± 0.336	0 ± 0	10.66±9.237	0±0
38	*C. racemosssum*	Combretaceae	C	+	+	0 ± 0	0 ± 0	165.33±220.7	21.33±36.95
39	*Commelina difusa*	Commelinaceae	H	+	-	0 ± 0	0 ± 0	69.33± 72.01	0±0
40	*C. scadens*	Araceae	C	+	+	0 ± 0	0 ± 0	378.67 ± 655.86	464±803.67
41	*C. prostrata*	Amaranthaceae	H	+	+	0 ± 0	0 ± 0	810.67± 703.6	5.33 ±24.24
42	*D. pinnata*	Sapindaceae	S	+	-	0± 0	0 ± 0	26.67 ± 46.18	0 ± 0
43	*D. discolor*	Fabaceae	H	+	-	0±0	0 ± 0	378.67± 422.1	0±0
44	*D. guineensis*	Caesalpiniaceae	H	-	+	0±0	0 ± 0	0 ± 0	64±14.31
45	*D. madagascariensis*	Dichapetalaceae	T	+	-	0±0	0.304 ± 0.527	16±16	0±0
46	*D. arborescens*	Rubiaceae	T	-	+	0±0	0.106 ± 0.184	0 ± 0	64±156.76
47	*D. barteri*	Ebanaceae	S	-	+	0±0	0 ± 0	0 ± 0	106.6±171.0
48	*D. caloneura*	Euphorbiaceae	T	-	+	0±0	0.0383 ± 0.066	0 ± 0	5.333±9.237
49	*D. preusii*	Dioscoreaceae	C	-	+	0±0	0 ± 0	0 ± 0	64±97.32
50	*D. buettneri*	Sterculiaceae	T	-	+	0 ± 0	0 ± 0	0 ± 0	16±16
51	*D. mannii*	Asparagaceae	T	-	+	0 ± 0	0 ± 0	0 ± 0	112±193.98
52	*E. guineensis*	Arecaceae	T	+	+	0.115 ± 0.199	3.243 ± 1.897	37.3 ± 64.6	112±84.66
53	*F. exasperata*	Moraceae	T	-	+	0 ± 0	1.198 ± 1.188	0 ± 0	5.3±754
54	*F. sur*	Moraceae	T	-	+	0 ± 0	0.153 ± 0.266	0 ± 0	5.333±9.237
55	*F. elastic*	Apocynaceae	T	-	+	0 ± 0	1.897 ± 2.717	0 ± 0	678±222.16
56	*G. brevis*	Tiliaceae	T	-	+	0 ± 0	0 ± 0	0 ± 0	176±251.45
57	*H. madagascariensis*	Hypericaceae	S	-	+	0± 0	0 ± 0	0 ± 0	5.333±9.237

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Table 1 (continued)

				Species composition		Basal area (m^2 ha^{-1})		Density (ha^{-1})	
58	*Hollarhena floribunda*	Apocynaceae	S	-	+	0±0	0 ± 0	0 ± 0	10.67±24
59	*H. gabunense*	Combretaceae	T	-	+	0±0	0.0545 ± 0.095	0 ± 0	10.66±18.47
60	*I. tracantha*	Icacinaceae	S	+	+	0±0	0 ± 0	42.66± 57.83	32±55.42
61	*J. micratha*	Menispermaceae.	C	-	+	0±0	0 ± 0	74.67±79.54	37.33±64.66
62	*L. dulcis*	Apocynaceae	C	-	+	0±0	0 ± 0	0 ± 0	144±249.41
63	*L. aestuans*	Urticaceae	H	+	-	0±0	0 ± 0	144±249.41	0 ± 0
64	*L. cupanioides*	Sapindaceae	S	+	+	0±0	0.328 ± 0.362	5.333±9.237	522.6±464.3
65	*L. sericeus*	Papilionaceae	T	+	+	0 ± 0	0 ± 0	69.33±106.53	5.333±9.237
66	*M. barteri*	Euphorbiaceae	S	-	+	0 ± 0	0.342 ± 0.362	0 ± 0	32±26.12789
67	*M. oppositifolus*	Euphorbiaceae	S	+	+	0 ± 0	0 ± 0	421.3±729.77	202.6±148.6
68	*M. altissima*	Sterculiaceae	T	-	+	0 ± 0	0.038 ± 0.066	0 ± 0	26.67±30.28777
69	*M. indica*	Anacardiaceae	T	+	-	0± 0	0 ± 0	5.33±9.2376	0 ± 0
70	*M. discoidea*	Phyllanthaceae	S	-	+	0±0	5.011 ± 6.410	0 ± 0	32±38.08
71	*M. scadeus*	Asteraceae	H	+	-	0±0	0 ± 0	144±130.96	0 ± 0
72	*M. pinnata*	Convolvulaceae	C	-	+	0±0	0 ± 0	0 ± 0	16±23.19
73	*M. puberula*	Pandaceae	S	-	+	0±0	0 ± 0	0 ± 0	400±157.58
74	*M. excels*	Moraceae	T	-	+	0±0	0.511 ± 0.885	0 ± 0	10.66±18.47
75	*M. thonningii*	Papilionaceae	T	-	+	0±0	0.4 ± 0.693	0 ± 0	16±27.71
76	*M. myristica*	Annonaceae	T	+	+	0±0	0.188 ± 0.019	5.333±9.237	21.33±35.47
77	*M. tenuifolia*	Annonaceae	T	-	+	0 ± 0	0.028±0.024	0 ± 0	64±26.13
78	*M. guineensis*	Apocynaceae	C	-	+	0 ± 0	0±0	0 ± 0	96±117.34
79	*M. cecropioides*	Moraceae	T	-	+	0 ± 0	0.058 ± 0.100	0 ± 0	5.333±9.237
80	*M. arboreus*	Moraceae	T	-	+	0 ± 0	1.036 ± 1.367	0 ± 0	112±167.04
81	*N. imperialis*	Melastomataceae	T	-	+	0± 0	0 ± 0	0 ± 0	90.66±102.8
82	*N. laevis*	Bignoniaceae	T	+	-	0±0	0 ± 0	5.333±9.237	0±0
83	*O. subscorpioidea*	Olacaceae	T	-	+	0±0	0.011 ± 0.019	0 ± 0	37.33±46.18
84	*P. ambique*	Commelinaceae	H	+	-	0±0	0 ± 0	37.33±64.66	0 ± 0
85	*P. barteri*	Commelinaceae	H	+	-	0±0	0 ± 0	218. 67±304.84	0 ± 0
86	*P. hirsuta*	Commelinaceae	H	+	-	0±0	0 ± 0	16±27.71	0 ± 0
87	*P. nigrescen*	Asclepiadaceae	C	-	+	0±0	0 ± 0	0 ± 0	5.33±9.237
88	*P. pinnata*	Sapindaceae	C	-	+	0±0	0 ± 0	0 ± 0	16±27.71
89	*P. hirtella*	Rubiaceae	H	-	+	0 ± 0	0 ± 0	0 ± 0	10.66±18.47
90	*Phaulopsis pulchella*	Acanthaceae	H	+	-	0 ± 0	0 ± 0	58.67±101.13	0 ± 0

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Table 1 (continued)

				Species composition		Basal area (m^2 ha^{-1})		Density (ha^{-1})	
91	*P. guineensis*	Piperaceae	C	-	+	0 ± 0	0 ± 0	0 ± 0	5.333±9.237
92	*P. ebracteolatus*	Rubiaceae	T	-	+	0 ± 0	0 ± 0	0 ± 0	16±27.71
93	*P. osun*	Papilionaceae	T	+	-	0± 0	0 ± 0	5.333±9.237	0 ± 0
94	*P. angolensis*	Myristicaceae	T	+	+	0±0	0.0517 ± 0.063	5.333±9.237	16±16
95	*R. africanus*	Apocynaceae	S	-	+	0±0	0 ± 0	0 ± 0	21.33±37.69
96	*R. vomitoria*	Apocynaceae	S	-	+	0±0	0.346 ± 0.335	0 ± 0	96±84.66
97	*R. dentata*	Violaceae	S	+	+	0±0	0 ± 0	186.67±323.3	160±124.96
98	*R. longiflora*	Rubiaceae	T	-	+	0±0	0 ± 0	0 ± 0	5.333±9.237
99	*S. afzelia*	Asclepiadaceae	C	-	+	0±0	0 ± 0	0 ± 0	37.33±64.66
100	*S. biafrae*	Asteraceae	H	+	-	0±0	0 ± 0	42.67±73.900	0 ± 0
101	*S. welwitchii*	Celastraceae	C	+	+	0±0	0 ± 0	234.67 ± 406	42.66±73.90
102	*S. rotundifolia*	Smilacaceae	C	-	+	0±0	0 ± 0	. 0 ± 0	48±83.13
103	*Sphenocentrum jollyanum*	Menispermaceae	S	+	+	0±0	0 ± 0	16±27.71	437.3±64.66
104	*S. mombin*	Anacardiaceae	T	+	+	0.252 ± 0.437	0.107 ± 0.185	10.66±18.47	10.66±18.47
105	*S. oblonga*	Sterculiaceae	T	-	+	0±0	0.0937 ± 0.162	0 ± 0	5.333±9.237
106	*S. rhinopetala*	Sterculiaceae	T	-	+	0±0	0.050 ± 0.087	0 ± 0	5.333±9.237
107	*S. tragacantha*	Sterculiaceae	T	-	+	0±0	4.791 ± 3.612	0 ± 0	448±309.01
108	*S. pustulata*	Olacaceae	T	-	+	0±0b	0 ± 0	0 ± 0	5.333±9.237
109	*T. scandens*	Dilleniaceae	C	-	+	0±0	0 ± 0	0 ± 0	133.3±115.7
110	*T. ivorensis*	Combretaceae	T	+	+	0±0	0.095 ± 0.164	170.67 ± 295.60	10.66±18.47
111	*T. daniellii*	Marantaceae	H	-	+	0±0	0 ± 0	0 ± 0	90.66±157.0
112	*T. cacao*	Sterculiaceae	T	+	-	14.108 ± 5.324	0 ± 0	1690.67±363.56	0±0
113	*T. heudelotii*	Meliaceae	S	-	+	0±0	0.119 ± 0.207	0 ± 0	26.66±45.72
114	*T. subcordata*	Menispermaceae	C	-	+	0±0	0 ± 0	0 ± 0	53.33±130.6
115	*X. mafafa*	Araceae	H	+	-	0±0	0 ± 0	13.33±32.65	0 ± 0
	Total					15.537 ± 7.799	29.063 ± 32.189	9178.67 ± 6723.17	9724.67 ± 8391.32

S represents Shrub

T represents Tree

C represents Climbers

H represents Herbs

+ represents present

_ represents absent

Flora Used- Flora of West Tropical Africaby Hutchinson, J. and Dalziel, J.M. (1954-1972). (Revised by Keay, R.W.J and Hepper, F.M.)

The species that are peculiar to forested ecosystems are; *Acacia ataxacantha, Adenia lobata, Afzelia africana, Anthocleista vogelii, Anthonatha macrophylla, Bridelia micrantha, Caesalpinia benthamianum, Ceiba pentandra, Celtis zenkeri, Cissus Canadensis, Chassalia kolly, Cola gigantia, Cola hispida, Combretum racemosssum,*

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Dialium guineensis, Dictyandra arborescens, Diospyros barteri, Discoglyprema caloneura, Discorea preusii, Dombeya buettneri, Dracaena mannii, Ficus exasperata, Ficus sur, Funtumia elastica, Glyphaea brevis, Harungana madagascariensis, Hollarhena floribunda, Hylodendron gabunense, Jatorhiza micratha, Landophia dulcis, Macaranga barteri, Mansonia altissima, Margaritaria discoidea, Merremia pinnata, Microdesmis puberula, Milicia excelsa, Millettia thonningii, Monodora tenuifolia, Montandra guineensis, Musanga cecropioides, Myrianthus arboreus, Napoleonaea imperialis, Olax subscorpioidea, Parquestina nigrescen, Paullinia pinnata, Pauridiantha hirtella, Pier guineensis, Psilanthus ebracteolatus, Rauvolfia africanus, Rauvolfia vomitoria, Rothmannia longiflora, Secomone afzelia, Smilax rotundifolia, Sterculia oblonga, Sterculia rhinopetala, Sterculia tragacantha, Strombosia pustulata, Tetracera scandens, Thaumatoceous daniellii, Trichilia heudelotii, Triclisia subcordata (Table 1).

The species that are perculiar to the cacao plantation are*: Achomanes difformis, Alchornea ditormis, Alternanthera brasiliensis, Amorphophallus spp, Artocarpous utilis, Asystesia gagantea, Asystasia vogeliana, Citrus sinensis, Cola nitida, Deinbolia pinnata, Desmodium discolor, Dichapetala madagascariensis, Laportea aestuans, Mangifera indica, Melanthera scadeus, Newbouldia laevis, Palisota ambique, Palisota barteri, Palisota hirsuta, Pterocarpus osun, Senecio biafrae, T. cacao, Xanthosoma mafafa* (Table.1).

Basal area of woody species in the forest and cacao plantation

The total basal area (m^2/ha) in forest ecosystem was 29.05 and the species with highest basal area in this ecosystem is *M. discoidea* with the basal area of 5.01 m^2/ha (Tables 1 and 2). In cacao plantation, the highest basal was 15.54 m^2/ha and the species with highest basal areas in this ecosystem was *T. cacao* with basal area of 14.11m^2/ha (Tables 1 and 2)

Species density in forest and cacao plantation

The total density of the species (ha^{-1}) in the forest 9724.67±8391.32 was higher than of cacao plantation, 9178.67 ± 6723.17(Tables 1 and 2). The densities of the woody, herbs and climber species in forest ecosystem were 7101.33 ± 5601 ha^{-1}, 756.33 ± 309.07 ha^{-1} and 1866.67 ± 852.27 ha^{-1} respectively while in cacao they were 3909.33 ±2573.28 ha^{-1}, 3584 ± 3351.46ha^{-1} and 1685.33 ± 1978.59ha^{-1} respectively (Table 2). The density of woody species and climbers were higher in the forest than cacao plantation while herbs had higher density in cacao plantation than forest ecosystem (Table 2). The species with highest density in the forest ecosystem was *A. laxiflora* (woody), *A. montanus* (herb) and *C. scadens* (Climber) while in cacao plantation the species with highest density was *T. cacao* (woody), *C. prostrate* (herb) and *S. welwitchii* (Climber) (Table 2)

Species similarity, diversity and evenness indices in the forest and cacao plantation

There was low similarity in species composition between the two ecosystems, 0.42 (Table 2). The Shannon-Wiener diversity index in cacao ecosystem, 1.90±0.28 was lower than that of tropical moist forest, 3.14 ±0.09 (Table 2). There was lower Pielou's evenness of species distribution in cacao ecosystem (0.42 ± 0.05) than in the moist forest (0.72 ± 0.01) (Table 2)

Girth size for woody species in forest and cacao plantation

The girth size distribution of the woody species in the two ecosystem show that forest ecosystem had higher number of tree species at the girth size class of 0-20 cm, 61-80 cm, 81-100 cm and > 100 cm while cacao plantation had the higher girth size class of 21-40 cm and 41-60 cm (Figure 2).

Table 2. Summary of vegetation structural parameters in cacao plantation and natural forest.

Parameters	Cacao plantation	Forest
Species richness	53	90
Woody (tree and shrub)	20	64
Climbers	3	19
Herbs	30	7
Plant genera	48	73
Woody (tree and shrub)	26	50
Climbers	3	17
Herbs	9	6
Family	32	53
Woody (tree and shrub)	20	35
Climbers	3	12
Herbs	9	6
Basal area (m^2 ha^{-1})	15.54±7.79	29.06±32.19
Density (ha^{-1})	9178.67 ± 6723.17	9724.67± 8391.32
Woody (tree and shrub) (ha^{-1})	3909.33 ± 2573.28	7101.33 ± 601.78
Climbers (ha^{-1})	1685.33 ± 1978.59	1866.67 ± 852.27
Herbs (ha^{-1})	3584 ± 3351.46	756.33 ± 309.07
Diversity (H^1)	1.93 ± 0.28	3.14±0.09
Evenness (J)	0.42 ± 0.05	0.72±0.01
Similarity (SI)	0.42	

Discussion

In this study, the number of plant species in the forest ecosystem was higher than that of cacao plantation. Similar trend was reported by for cacao and forest ecosystems in southwestern Nigeria. The relative reduction in the number of species in the cacao plantation is due to the monocropping and management practices in the cacao plantation in term of weeding and, application of agro chemicals that might be injurious to the survival of some of these plant species. However, there were more herbaceous species in the cacao plantation than forest. The relative fewer number of the herbaceous species in the forest ecosystem is due to reduced light reaching forest floor as a result of closed canopy which inhibit the growth and survival of many herbaceous species against relative open canopy in cacao plantation allowing more light to reach the cacao plantation floor thereby encouraging more herbaceous growth and survival.

In this study, the forest tree basal area 29 m^2ha^{-1} reported is higher than the 8-17 m^2ha^{-1} for a number of lowland rain forests in Ondo State in southwest Nigeria and 21m^2ha^{-1} reported for lowland rain forest in Ile-Ife, Nigeria, but, the value falls within the range of 18-49 m^2ha-1 reported by Aigbe et al. for Ehor forest reserve, Edo State.

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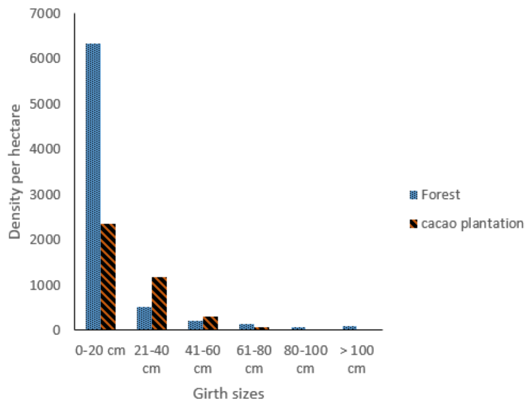

Figure 2. Girth size class distribution of woody species in the forest and cacao plantation.

Nigeria, and 28-33 m^2ha^{-1} reported by Sundarapandian and Swamy for western Ghat forest in India [22-24]. The differences in these tree basal areas of the different forests may be attributable to the difference in levels of disturbance in the forests. Also, in this study, tree basal area of 15.537 m^2ha^{-1} in cacao plantation was higher than 6.2 m^2ha^{-1} reported by Oke and Odebiyi for cacao plantation in Nigeria, the range of 2.14 – 10.26 m^2ha^{-1} reported for a number of cacao plantations in the south western Nigeria, 8.27 m^2ha^{-1} reported by Asase et al for cacao plantation in Ghana, 10.15 m^2ha^{-1} reported for cacao agroforests in Talamanca, Centra America but falls within the range 11.9 to 20.5 m^2ha^{-1} reported by Kessler et al and Merijin et al for cacao plantations in Indonesia and lower than 32.7 m^2ha^{-1} reported by Bobo et al. for cacao plantation in Cameroon [25-29]. These differences in tree basal areas of cacao plantations could be attributed to, locations of the plantations, age of the plantations and associated shade trees.

The basal area of the woody species in the forest was higher than that of cacao plantation studied (see Table 2). This trend was also reported for different forests and cacao plantations in southwestern Nigeria. This consistent trend in woody basal areas in cacao plantation and forest ecosystem is expected because cacao plantation is a monocrop ecosystem with few shade trees while forest is dominated by trees of different species with virtually no or little herbaceous growth. Management practices such as slashing and application of agrochemicals that might inhibit the establishment and growth of woody species in cacao plantations might contribute to this. The same trend in basal area in forest and cacao plantation was also observed for woody density between the two ecosystems. In this study, higher woody density was reported in forest than in cacao plantation.

The forest in this study had higher species diversity and evenness than those of cacao plantation. These results are similar to the results of Ogunleye, Hassan et al, Munoz-Reinoso, Pourbabaei and Roostami, Roberts, and Yirdaw who reported higher diversity and evenness in forests than plantations reported in other studies [30-35].

However, there have been studies which reported higher evenness for understory in plantations than that in forests [36]. This higher evenness distribution in the plantation understory than that of forests is due to the fact that trees are planted at defined spacing in plantations which created a micro-climate environment that favored the growth and regeneration of the understory species.

Conclusion

This study showed that cacao plantations are lower in plant species biodiversity and structural characteristics than tropical rain forest they replaced. Thus, the clearing of tropical rain forests for the establishment of cacao plantations should be reconsidered because of the adverse effects on plant species biodiversity and structural characteristics. However, Cacao production is likely to remain an important component of local livelihoods and the wider economy, most especially in the tropics. Conservation strategies that seek to restrict plantation development without considering these socioeconomic realities may have limited practical acceptance.

Recommendations

Greater emphasis is therefore recommended on management interventions capable of enhancing biodiversity and structural complexity within productive plantation systems. In particular, the retention and enrichment of native shade trees like *A. adianthifolia, A. zygia, A. laxiflora, A. africanus, A. toxitoria, B. nitida, C. lutea, C. accumulate, E. guineensis, L. cupanioides, L. sericeus, P. angolensis, R. dentata, S. jollyanum, T. ivorensis* as seen in the study and lots more could help maintain structurally diverse vegetation and increase the conservation value of cacao plantations without necessarily compromising their economic function. The adoption of such biodiversity-sensitive management practices would allow plantations to provide more heterogeneous habitats and support a greater diversity of organisms while continuing to contribute to agricultural production and local livelihoods.

The adoption of environmentally friendly agrochemicals in cacao plantations should be prioritized to sustain biodiversity. Unlike conventional chemical inputs, which can alter ecosystem integrity, eco-friendly alternatives help preserve ecological balance by minimizing adverse impacts on both flora and fauna. This approach supports the conservation of macro- and microfaunal communities, maintains plant diversity, and promotes the long-term ecological sustainability of cacao production systems.

Selective weeding of understory herbaceous species in cacao plantations should be considered as this would encourage more biodiversity within the agroforestry system. Planting distance should be considered in cacao plantations as it encourages the growth of understory within the ecosystem.

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