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Floristic diversity under anthropogenic activities in the protected forests of Duekoué and Scio in southwestern Côte d'Ivoire

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This study analyses the effects of anthropogenic disturbance on trees and shrubs floristic α-diversity in two protected rain forests in southwestern Côte d'Ivoire. These forests have been under timber harvesting since their protection in 1929. The forestry service had developed plantations of indigenous timber species and teak since 1996 to increase their productivities for timbers. Additionally, they host many plantations of cash crop among which coffee, cocoa and rubber are the most important. To understand how these plantations affect the local flora, the diversity of shrubs and trees with DBH ≥ 10 cm was analyzed through the species number and diversity indices. Plots were of 20 m x 50 m size and a total of 10 per vegetation type. Highest species numbers, Shannon-Wiener's index, Hill's index and Pielou's index, in both plots and vegetation types were found in natural forest and undergrowth cleared forest which had similar values of these parameters. Plot richness was ranked between 1 and 7 species whilst vegetation type richness varied from 4 to 12 species for all plantations. Yet Simpson's diversity index showed highest values in plantations. Richness in plantation was influenced by the location of plantation site and the nature of crop but no influence was found with the combination site and crop nature.

Key words: Forest protection, cash crops, agroforestry, flora and diversity, South-West Côte d'Ivoire.

INTRODUCTION

The tropical humid forests host higher vascular plant richness and diversity compared to European and North American forests (Richards, 1996; Myers et al., 2000; Blanc, 2002; Parmentier et al., 2007; Parmentier et al., 2011). Mixed mesophytic forests of China and Southeast America that are the richest among the non-tropical forests (Richards, 1996) harbor 20 to 30 species. These numbers are smaller than the richness of trees bigger than 10 cm DBH in a hectare of primary Tropical humid forest plot that is often estimated between 40 and 100

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species (ORSTOM and UNESCO, 1983; Kouamé, 1998) and can reach 251 species (Ghazoul and Sheil, 2010). These forests also harbor high abundance and diversity of lianas which constitute other fundamental characteristics of this vegetation type (Richards, 1996; Kouamé et al., 2007).

Agriculture has played an important role in the transformation of lowland tropical forest landscapes worldwide over the past centuries and continues to do so today (Lass, 2004; Schroth and Harvey, 2007). In many regions, cash crops have been a driver of deforestation, with plantations or agroforestry systems replacing the original forest ecosystems (Ruf and Schroth, 2004). In comparison to other land uses that replace intact forest, traditional Cocoa (*Theobroma cacao* L., Sterculiaceae) and Coffee (*Coffea canephora* Froenh., Rubiaceae) agroforests, with diverse and structurally complex shade canopies, are among the agricultural land uses that are most likely to conserve a significant portion of the original forest biodiversity (Perfecto et al., 1996; Moguel and Toledo, 1999; Rice and Greenberg, 2000; Schroth et al., 2004; Faria et al., 2006; Harvey et al., 2006). Although cocoa and coffee cultivation may represent a serious threat to biodiversity in certain countries such as Côte d'Ivoire, Ghana, and the Dominican Republic, where their agroforests make up a significant proportion of all woodland (Donald, 2004), there are a number of reasons for regarding their shaded cultivation as environmentally preferable to many other forms of agriculture in Tropical forest regions (Greenberg, 1998; Power and Flecker, 1998). Since economic prospects for Rubber (*Hevea brasiliensis* Müll.Arg., Euphorbiaceae) on the world market are positive (Smit and Vogelvang, 1997; Burger and Smit, 1998, 2000) and the production by smallholders is still profitable (Levang et al., 1999; Suyanto et al., 2001), large tropical forest areas have been converted into Rubber plantations responsible for drastic erosion of local trees richness (Beukema et al., 2007). For rubber cultivation, forest is fully cleared and crops are established as monoculture plantations on average replanted after about 40 years, but some plantations are maintained to an age of 70-80 years (Gouyon et al., 1993). In many Tropical countries, this loss of the natural forests has been counteracted by the rapid increase in degraded forestland allocated to plantation establishment and other policies (CTFT, 1989). Like many other tropical countries, the loss of Ivoirian's natural forests has been counteracted by comprehensive reform programmes in the forestry sector among which a key reform was the Government's initiative in plantation establishment in the country, not only to halt forest degradation but also to catalyze important native forest flora restoration after long period of anthropogenic and non-anthropogenic disturbances (Lemenih and Teketay, 2004; Baatuuwie et al., 2011). These programmes have increased plantations since 1992 of both native and exotic timber tree species amongst which Teak (*Tectona grandis* L.f., Verbenaceae) is predominant. Teak cultivation involves full local vegetation removal sometimes with mechanics.

In Côte d'Ivoire, there are two main categories of protected areas; the national parks exclude any human activities except management and research, and the classified (protected) forests whose purpose is management for sustainable logging (Kouamé, 1998). The definition and delimitation of these protected areas began in 1924 by their static conservation (de Koning, 1983; Ahimin, 2006). After the Ivorian independence in 1960, their legal status was created together with a national forest research institute (IDEFOR) and a national society for forest development (SODEFOR). Forty years later, anthropogenic activities in national parks, protected forests and biological reserves result in their degradation despite the promulgation of legal instruments/laws (Dao, 1999; Chatelain et al., 2004; Ahimin, 2006). Due to rarefaction of wastelands in the rainforest area, the farmers crossed the limits of protected forests within which they establish their crops. The politico-military crisis in Côte d'Ivoire since 2002 led to increase in the illegal occupation of its South-western protected areas, especially Duekoué and Scio forests. In areas undergoing rapid land use change such as the rainforest of Côte d'Ivoire, where undisturbed lowland forest has almost completely disappeared (Chatelain et al., 2004; BNETD, 2010), the question whether at least some of the native rainforest species can survive in disturbed forest types has become important. The potential significance of such agroforestry systems for biodiversity conservation is stressed by nature conservation agencies and the international research community (Siebert, 2002; Garrity, 2004; Schroth et al., 2004).

To understand the effects of Teak plantations created by the Forestry Service and the cash crops production by small farmers in the protected forests of Duekoué and Scio on the diversity of trees, shrubs and lianas, eighty 20 m x 50 m plots were investigated for their woody plant richness. We sampled woody plant individuals that had 10 cm DBH and above at the species level, with the aim of analyzing woody plant species composition and diversity in relation with the anthropogenic activities. Given that both the agroforestry systems of creating forestry plantations and farming cash crops aim to promote few targeted species at the expense of the local flora, we hypothesized to find higher plant species richness and diversity in natural vegetation than in plantations.

MATERIALS AND METHODS

Research site and data collection

Research was carried out in the classified forests of Duekoué (6° 30'- 6° 45' N, 7° 00'- 7° 15' W) and Scio (6° 30'-7° 00' N, 7° 30'- 8° 05'W) South-west of Côte d'Ivoire (Figure 1). Climate in both areas is sub-equatorial with a long wet season from February to November and a short dry season from November to January. Annual rainfall varies from 1600-1700 mm in Duekoué forest to 1700-1800 mm in Scio forest. The average monthly temperature is

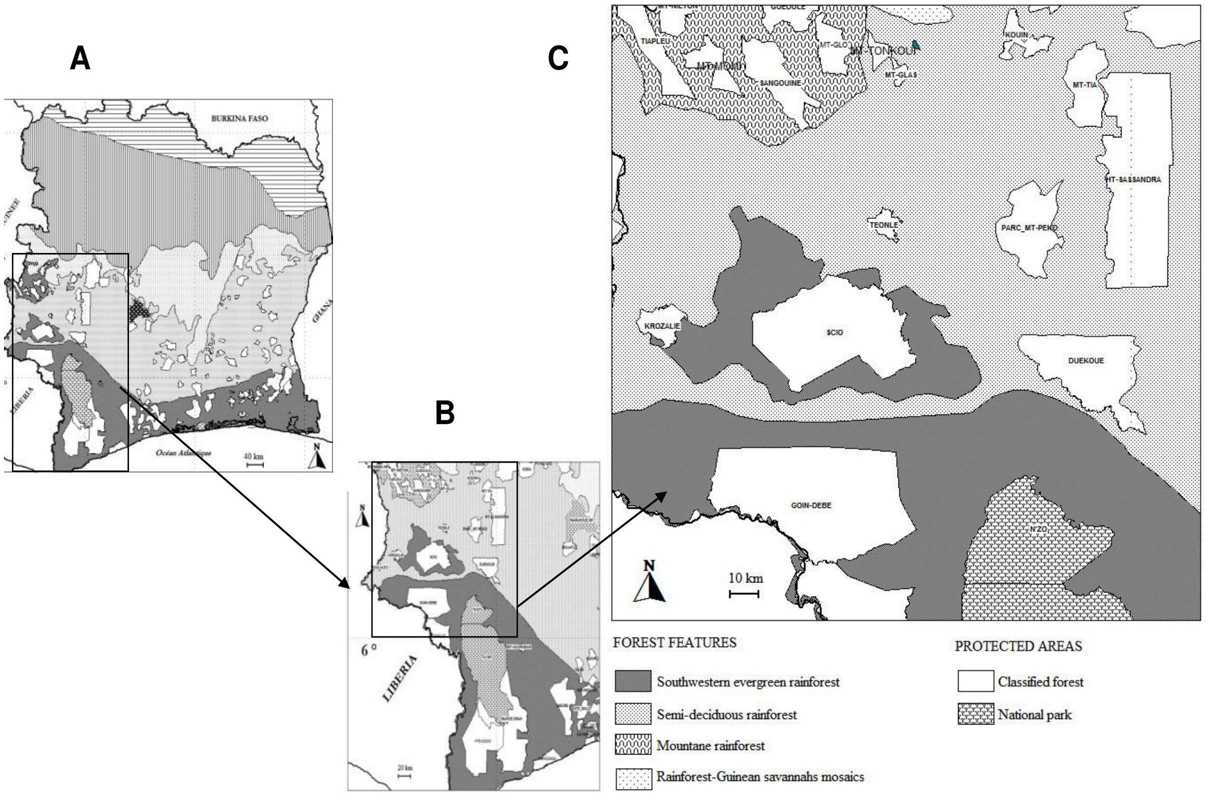

Figure 1. Localization with MapInfo 7.8 software of research sites on the map of protected areas and main floristic features distribution in Western Côte d'Ivoire rainforest zone (From Kouamé and Zoro Bi, 2010). A: General vegetation and protected areas map of Côte d'Ivoire, B: South-west region, C: research sites location.

25ºC while monthly and annual potential evapotranspiration of Duekoué and Scio are 123.5 and 1482 mm, respectively (Eldin, 1971). The soils of both forests belong to the remould ferrallitic group (Perraud and De La Souchère, 1970). The Duekoué forest, with an area of 53,600 ha (SODEFOR, 1994), consists of a moist semi-deciduous forest defined as a Tropical rainforest type in which part of the higher trees shed their leaves during the 3-4 months dry season in a region of 1350-1600 mm annual rainfall (ORSTOM and UNESCO, 1983) and interrupted by savannas areas and inselbergs (Monnier, 1983). The original vegetation of Scio forest, covering 88,200 ha (SODEFOR, 1996), belongs to South-western evergreen forest type of Côte d'Ivoire that spreads in the wettest forest area. (Kouamé, 2010; Kouamé and Zoro Bi, 2010)

Field data collection was carried out in eighty 1000 m² (20 m x 50 m) plots, as suggested by Thiombiano et al. (2010), established per 10 in four different vegetation types (biotopes) for each forest (Table 1). Homogeneity, local area, repetition, presence of plant individuals with DBH≥10 cm and availability were the criteria of these biotopes' selection. Thus, the biotopes plotted were the natural forest patches, the undergrowth cleared forests, the coffee plantations, the cocoa plantations, the rubber plantations and the teak plantations (Table 1). Each plot was sub-divided into ten 100 m² sub-plots where all plants with DBH≥10 cm were assessed for their scientific names and DBH.

Data analysis

Taxa identification followed Aubréville (1936), Lebrun and Stork (1991-1997), Aké Assi (2001, 2002) and Hawthorne and Jongkind (2006). Family and authors names have been updated with Mabberley (1997).

Floristic diversity was analyzed using the species number considered as the first diversity parameter (Gaston, 1996; Tuomisto, 2011) and the three commonest diversity indices (Shannon-Wiener, 1949; Simpson, 1949; Pielou, 1966). Simpson's diversity index (*D'*) checks the probability for 2 random individuals in a community to belong to the same species (Simpson, 1949).

$$D' = 1 - \sum Pi^2$$

Where, $Pi = ni/\sum ni$ with *ni* as average cover of a species *i* and $\sum ni$ the total cover of all species. *D'* varies from 0 (maximum diversity) to 1 (minimum diversity). This index is sensitive to the variation of importance for most abundant species (Peet, 1974; Grall and Coïc, 2006).

Shannon-Wiener's index (*H'*) which is the most recommended index to check richness diversity (Grall and Coïc, 2006) is below formulated:

$$H' = -\sum_{i=1}^{s} PiLnPi$$

with *Pi* as relative average cover of species *I* in a community (Shannon and Wiener, 1949). *H'* varies from 0 (monospecific settlement) to *LnS* (maximum diversity). This index is sensitive to the variation of importance for most rare species (Peet, 1974; Grall and Coïc, 2006).

Pielou's index (*J'*) measures the degree of a settlement diversity and corresponds to the average between the affective diversity

Table 1. Description and localization of plots.

Biotopes	Duekoué forest	Latitude N	Longitude W	Biotopes	Scio forest	Latitude N	Longitude W
Coffee plantations	PCAFD1	6° 42	7° 06	Coffee plantations	PCAFS1	6° 38	7° 52
	PCAFD2	6° 40	7° 06		PCAFS2	6° 38	7° 51
	PCAFD3	6° 41	7° 14		PCAFS3	6° 31	7° 48
	PCAFD4	6° 43	7° 12		PCAFS4	6° 39	7° 50
	PCAFD5	6° 41	7° 14		PCAFS5	6° 38	7° 52
	PCAFD6	6° 40	7° 06		PCAFS6	6° 38	7° 51
	PCAFD7	6° 42	7° 06		PCAFS7	6° 38	7° 53
	PCAFD8	6° 43	7° 02		PCAFS8	6° 38	7° 53
	PCAFD9	6° 40	7° 06		PCAFS9	6° 31	7° 48
	PCAFD10	6° 43	7° 12		PCAFS10	6° 39	7° 47
Cocoa plantations	PCAOD1	6° 42	7° 06	Cocoa plantations	PCAOS1	6° 31	7° 48
	PCAOD2	6° 42	7° 06		PCAOS2	6° 38	7° 51
	PCAOD3	6° 42	7° 12		PCAOS3	6° 39	7° 46
	PCAOD4	6° 41	7° 14		PCAOS4	6° 38	7° 51
	PCAOD5	6° 42	7° 12		PCAOS5	6° 38	7° 52
	PCAOD6	6° 43	7° 12		PCAOS6	6° 39	7° 46
	PCAOD7	6° 42	7° 12		PCAOS7	6° 38	7° 51
	PCAOD8	6° 42	7° 12		PCAOS8	6° 38	7° 51
	PCAOD9	6° 43	7° 12		PCAOS9	6° 39	7° 47
	PCAOD10	6° 42	7° 12		PCAOS10	6° 39	7° 47
Rubber plantations	PHEVD1	6° 42	7° 06	Undergrowth cleared forests	FDEFS1	6° 39	7° 46
	PHEVD2	6° 42	7° 06		FDEFS2	6° 38	7° 51
	PHEVD3	6° 42	7° 06		FDEFS3	6° 38	7° 51
	PHEVD4	6° 43	7° 06		FDEFS4	6° 39	7° 46
	PHEVD5	6° 43	7° 06		FDEFS5	6° 39	7° 51
	PHEVD6	6° 42	7° 14		FDEFS6	6° 39	7° 50
	PHEVD7	6° 42	7° 14		FDEFS7	6° 39	7° 50
	PHEVD8	6° 42	7° 12		FDEFS8	6° 38	7° 48
	PHEVD9	6° 43	7° 06		FDEFS9	6° 38	7° 52
	PHEVD10	6° 42	7° 06		FDEFS10	6° 38	7° 53
Teak plantations	PTECD1	6° 42	7° 12	Natural forests	FNBAS1	6° 39	7° 46
	PTECD2	6° 42	7° 12		FNBAS2	6° 38	7° 51
	PTECD3	6° 42	7° 12		FNBAS3	6° 39	7° 48
	PTECD4	6° 42	7° 13		FNBAS4	6° 38	7° 53
	PTECD5	6° 42	7° 01		FNBAS5	6° 39	7° 49
	PTECD6	6° 41	7° 14		FNBAS6	6° 31	7° 48
	PTECD7	6° 41	7° 14		FNBAS7	6° 34	7° 51
	PTECD8	6° 42	7° 12		FNBAS8	6° 39	7° 49
	PTECD9	6° 42	7° 13		FNBAS9	6° 30	7° 51
	PTECD10	6° 42	7° 12		FNBAS10	6° 39	7° 50

H' and the maximum theoretical diversity *H'max* (Pielou, 1966).

$$J' = H'/H'max$$

with *H'* as Shannon-Wiener index. *J'* varies from 0 (monospecific settlement) to 1 (similar distribution of all species).

Additionally to these commonest indices, Hill's index which is a combination of Simpson's diversity index and Shannon-Wiener's index (Hill, 1973; Grall and Coïc, 2006) was used to analyze the diversity in biotopes as recommended by Peet (1974) and

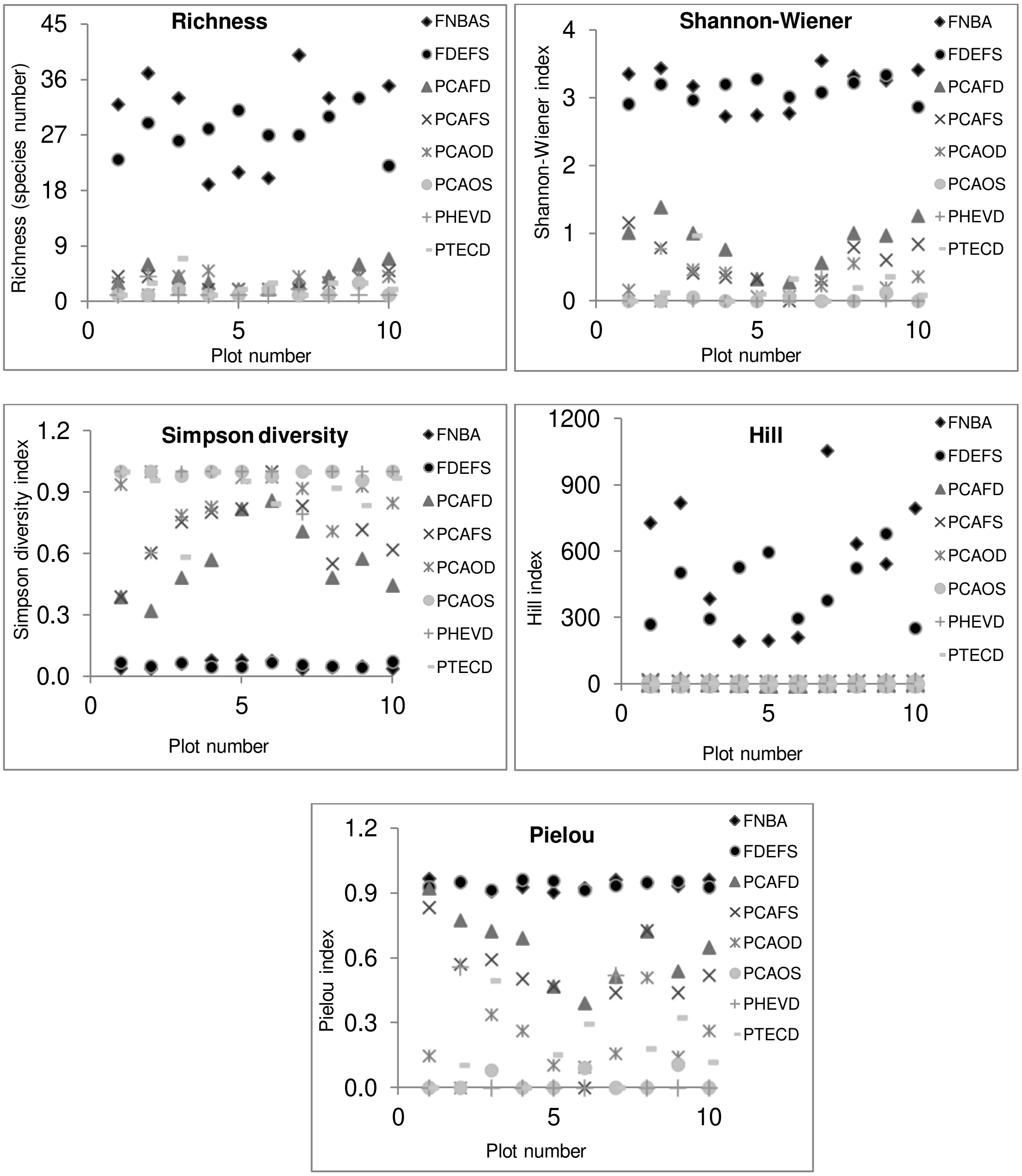

Figure 2. Richness and diversity indices in plots.

Routledge (1979).

$$Hill = (\sum Pi^2)^{-1} 1/exp[H']$$

Hill varies from 1 (monospecific settlement) to α (similar distribution of all species).

Such as data in plots showed normal distribution (Mead et al., 1993; Bar-Hen, 1998; Young and Young, 1998; Fowler et al., 1999), their statistical analyses were performed with parametric tests as recommended by Mead et al. (1993) and Fowler et al. (1999). Plot richness and diversity indices were compared using paired samples *t test* of Student (Student, 1908; Greig-Smith, 1983) with SPSS 18.0 software. Richness of coffee plantations and cocoa plantations that was assessed in both research sites (Table 1) was analyzed with ANOVA (Scherrer, 1984; Mead et al., 1993; Fowler et al., 1999) using Statistica 7.1 software for checking prospective impacts of site and/or crop nature on plot richness. Bonferroni's Post-Hoc test with Statistica 7.1 software led to segregate impacts of site and crop nature as the ANOVA showed their effects on plot richness.

RESULTS

The natural forest patches (FNBAS) in Scio site showed the highest α-diversity in plots and biotopes whereas the undergrowth cleared forests (FDEFS) in Scio showed the second highest α-diversity (Figure 2, Table 2). Both

Table 2. Richness and diversity indices in biotopes.

Parameters		FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
Richness	Minimum	19.00	22.00	2.00	2.00	1.00	1.00	1.00	1.00
	Maximum	40.00	33.00	7.00	5.00	5.00	3.00	4.00	7.00
	General	85.00	58.00	12.00	12.00	7.00	12.00	4.00	11.00
	Mean	30.30	27.60	4.00	4.00	3.20	4.00	1.60	2.60
	Std. dev.	7.50	3.41	1.76	1.76	1.23	1.76	1.07	1.78
Simpson diversity index	Minimum	0.03	0.04	0.32	0.39	0.71	0.96	0.60	0.58
	Maximum	0.08	0.07	0.86	1.00	1.00	1.00	1.00	1.00
	General	0.02	0.03	0.50	0.69	0.89	0.99	0.93	0.91
	Mean	0.05	0.06	0.56	0.71	0.89	0.99	0.94	0.91
	Std. dev.	0.02	0.01	0.18	0.17	0.09	0.01	0.13	0.13
Shannon-Wiener index	Minimum	2.73	2.87	0.27	0.00	0.00	0.00	0.00	0.00
	Maximum	3.55	3.34	1.39	1.15	0.56	0.12	0.77	0.97
	General	4.03	3.70	1.26	0.85	0.30	0.03	0.19	0.28
	Mean	3.18	3.11	0.86	0.56	0.25	0.02	0.11	0.21
	Std. dev.	0.31	0.16	0.37	0.34	0.19	0.04	0.26	0.29
Hill index	Minimum	195.19	252.40	1.53	1.00	1.00	1.00	1.00	1.00
	Maximum	1056.34	679.56	12.47	8.18	2.47	1.18	3.59	4.50
	General	2285.43	1191.98	7.10	3.38	1.51	1.04	1.31	1.45
	Mean	557.10	432.91	5.28	3.02	1.51	1.03	1.34	1.56
	Std. dev.	301.74	152.86	3.33	2.08	0.48	0.06	0.83	1.06
Pielou index	Minimum	0.90	0.91	0.39	0.00	0.00	0.00	0.00	0.00
	Maximum	0.97	0.96	0.92	0.83	0.51	0.11	0.56	0.50
	General	0.91	0.91	0.51	0.33	0.15	0.02	0.14	0.11
	Mean	0.94	0.94	0.64	0.51	0.20	0.03	0.11	0.17
	Std. dev.	0.02	0.02	0.16	0.22	0.15	0.05	0.23	0.16

The total area of each biotope is a hectare (10 x 1000 m²). Thus for all parameters in table 2, general values correspond to hectare data while the others are research plot area (20m x 50 m)data.

biotopes had similar plot richness which was very significantly higher than all plantations (Table 3) and showed also higher richness variability (Figures 2 and 3). Among plantations, the Rubber (PHEVD) cultivation led to the lowest plot richness (Figure 2, Tables 2 and 3) and variability (Figures 2 and 3). Distribution of trees in plantations was determined prior to the openness in vegetation and later by the nature of crop (Figure 4). Thus, plots were segregated into five groups amongst which the biggest (group I) gathered the natural forest patches and the undergrowth cleared forests from Scio site, and the Teak plantations (PTECD) and the Rubber plantations (Figure 4, Appendix 1) from Duekoué site. This group that was represented by 48.75% of plots appeared in low vegetation openness conditions. The second important group, in term of plots number (group II) that gathered 80% of Coffee plantations from both sites and a Rubber plantation (PHEVD2) from Duekoué, is found in medium vegetation openness conditions (Figure 4, Appendix 1). In slight higher vegetation openness, there were the smallest group (group III) made of four coffee plantations from Duekoué site and the group IV which gathered 90% of cocoa plantations from Duekoué site and 30% of cocoa plantations from Scio site (Figure 4, Appendix 1). The last group (group V) made of 70% of cocoa plantations from Scio site and a Cocoa plantation (PCAOD2) from Duekoué site appeared in highest vegetation openness conditions. Highly significant impacts of the site and of the nature of crop were found on the richness in coffee and Cocoa plantations but no impact was found with the combination site and crop nature (Table 4). Bonferroni's Post-Hoc test showed a very highly significant difference between Coffee plantations of Duekoué and Cocoa plantations of Scio, and a significant difference between Cocoa plantations of both sites while Coffee plantations from both sites were similar (Table 4).

Table 3. Matrix of biotopes mean richness comparison with SPSS 18.0 software.

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.97	12.63	12.35	11.35	12.08	12.86	11.70
FDEFS	ns		18.90	19.98	20.12	25.97	24.19	21.47
PCAFD	***	***		3.00	1.24	4.63	4.80	1.95
PCAFS	***	***	*		0.36	3.75	3.75	0.56
PCAOD	***	***	ns	ns		4.32	2.95	0.85
PCAOS	***	***	**	**	**		0.00	2.45
PHEVD	***	***	**	**	*	ns		1.86
PTECD	***	***	ns	ns	ns	*	ns	

Student *t* test values are above while significances are below. ns : test non-significant (P≥0.05); * : test significant (P<0.05) ; ** : test very significant (P<0.01) ; *** : test very highly significant (P<0.001). Degree of freedom of the test is 9.

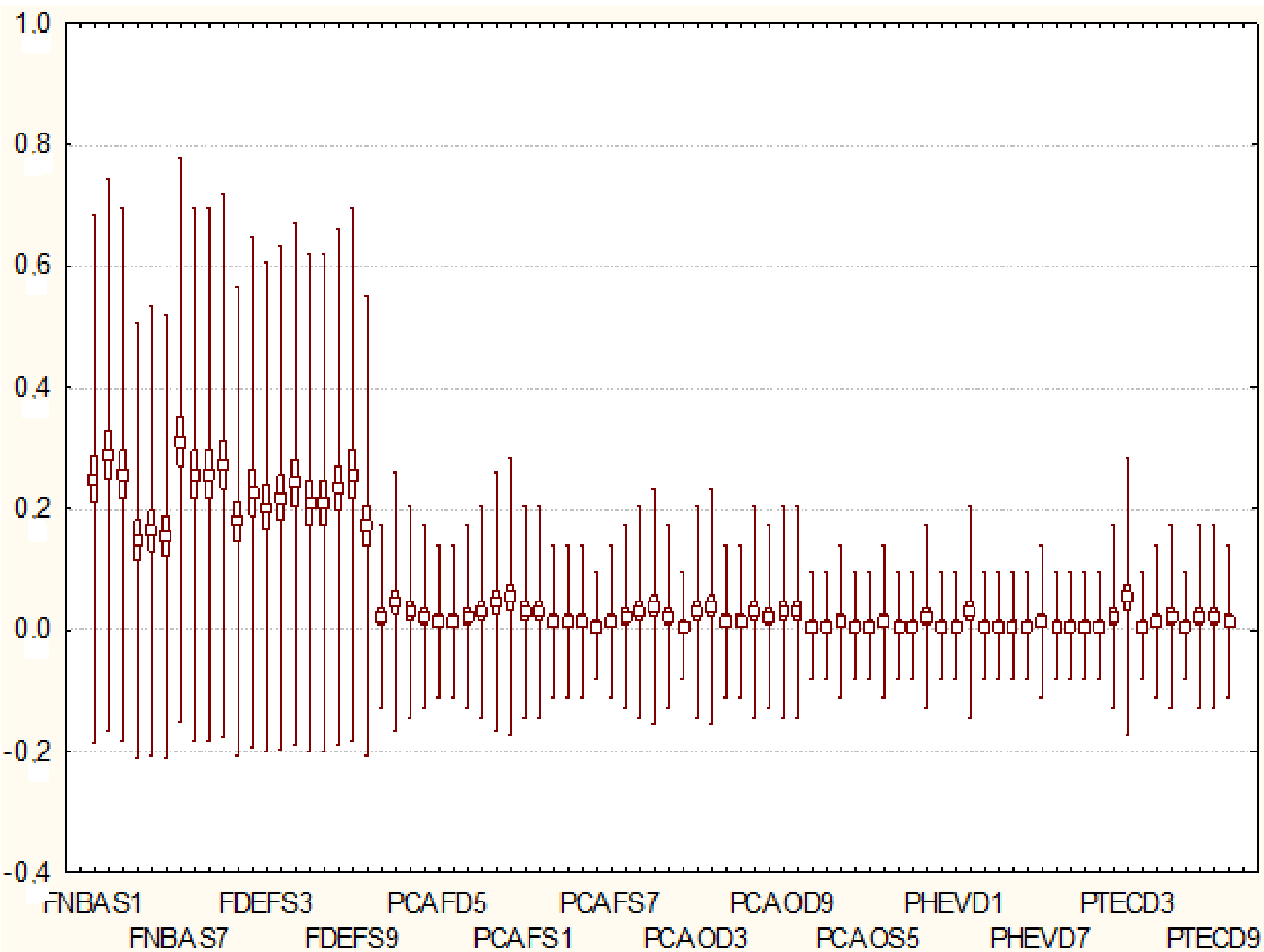

Figure 3. Boxplots of plot richness using factorial analysis with Statistica 7.1 software. Mean richness are in small central squares, error types are in small framing rectangles and standard deviation types are in vertical lines.

Shannon-Wiener's index showed highest (Figure 2) and similar (Tables 2 and 5) values in both natural forest patches and undergrowth cleared forests of Scio site. Despite the very significantly higher index value in coffee plantations of Duekoué site compared to value in coffee plantations in Scio site (Table 5), both biotopes showed

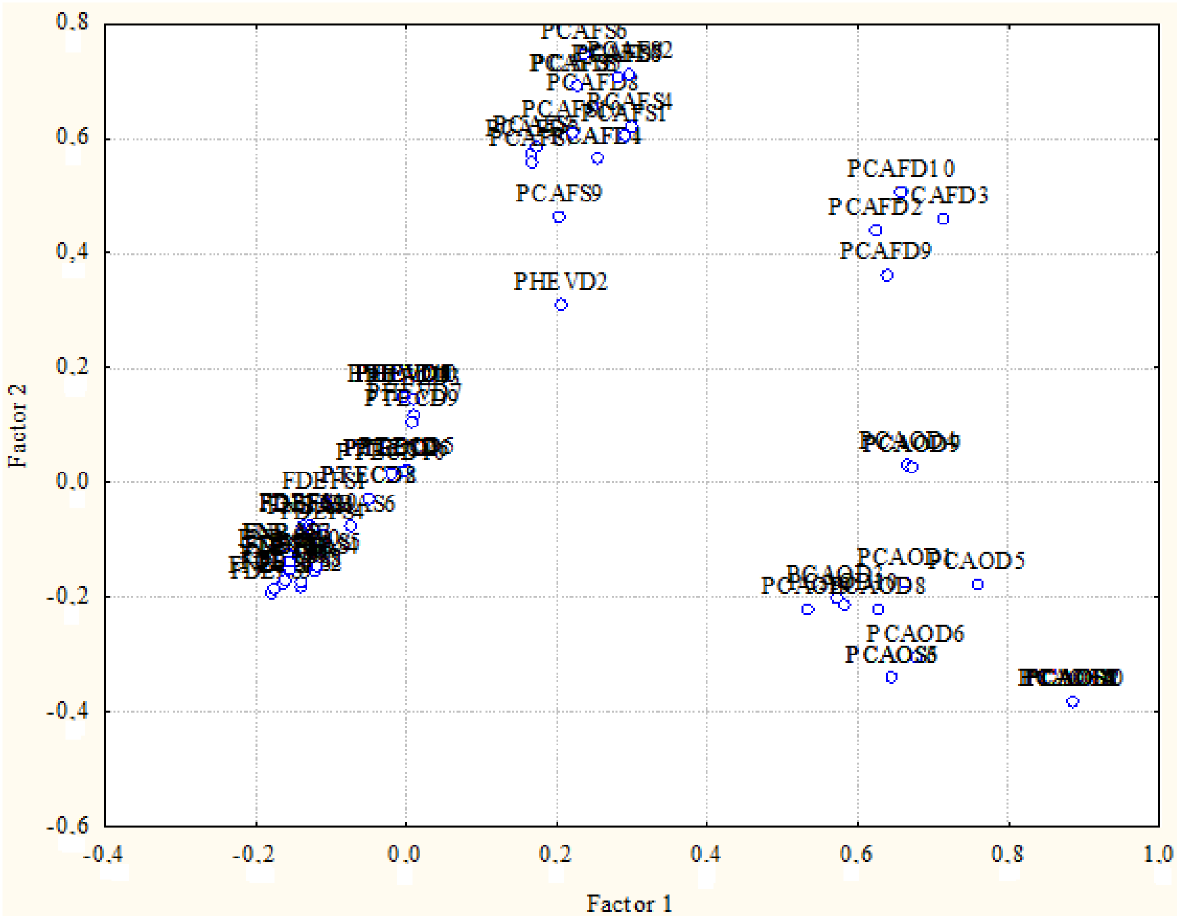

Figure 4. Projection of plots on the two first axes of the factorial analysis with Statistica 7.1 software according to their richness. Factor 1 on abscises explains 18.03% while factor 2 on ordinates is responsible for 12.06% of total variation of the analysis. The factor 1 that segregates natural forests and plantations expresses the openness in vegetation. The factor 2 distinguishes groups according the target species in plantations. Group I: Natural forest, undergrowth cleared forest, and Rubber and Teak plantations. Group II: Coffee plantations in both sites and one Rubber plantation (PHEVD2) except four Coffee plantations in Duekoué. Group III: the four remnant Coffee plantations in Duekoué site. Group IV: part of Cocoa plantations of both sites. Group V: remnant Cocoa plantations of both sites. Plots coordinates are given in Appendix 1.

Table 4. ANOVA and Bonferroni's Post Hoc test of effects of the site and the cash crop nature on richness in Coffee and Cocoa plantations.

	Parameter	**SC**	**df**	**MF**	**F**	**P**
ANOVA	Ord.of origin	336.4	1	336.4	208.8	***
	Site	19.6	1	19.6	12.2	**
	Crop	14.4	1	14.4	8.9	**
	Site*Crop	1.6	1	1.6	1.0	ns

	Site andCulture	Duekoué Cocoa	Duekoué Coffee	Scio Cocoa	Scio Coffee
Bonferroni	Duekoué Cocoa		ns	*	ns
	Duekoué Coffee	ns		***	ns
	Scio Cocoa	*	***		*
	Scio Coffee	ns	ns	*	

Error: MC Inter = 1.6111, df = 36 for Bonferroni Post Hoc test. ns, test non-significant (P≥0.05) ; *, test significant (P<0.05) ; *** : test very highly significant (P<0.001).

Table 5. Matrix of biotopes Shannon-Wiener's index comparison with SPSS 18.0 software.

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.55	25.83	29.30	26.49	31.22	32.57	21.02
FDEFS	ns		16.56	19.87	34.04	61.12	33.63	26.05
PCAFD	***	***		3.99	5.14	6.95	6.36	4.41
PCAFS	***	***	**		2.63	4.76	3.49	2.16
PCAOD	***	***	**	*		3.65	1.14	0.40
PCAOS	***	***	***	**	**		1.04	2.23
PHEVD	***	***	***	**	ns	ns		0.74
PTECD	***	***	**	ns	ns	ns	ns	

Student *t* test values are above while significances are below. ns : test non-significant ($P \geq 0.05$) ; * : test significant ($P<0.05$) ; ** : test very significant ($P<0.01$) ; *** : test very highly significant ($P<0.001$). Degree of freedom of the test is 9.

Table 6. Matrix of biotopes Simpson's diversity index comparison with SPSS 18.0 software.

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.33	9.58	12.78	27.95	115.56	22.08	20.10
FDEFS	ns		8.91	11.84	27.82	156.38	21.04	20.45
PCAFD	***	***		4.49	5.83	7.35	6.30	4.87
PCAFS	***	***	**		3.24	4.99	3.45	2.60
PCAOD	***	***	***	*		3.28	0.79	0.37
PCAOS	***	***	***	**	*		1.17	2.23
PHEVD	***	***	***	**	ns	ns		0.50
PTECD	***	***	**	*	ns	ns	ns	

Student *t* test values are above while significances are below. ns, test non-significant ($P \geq 0.05$) ; * , test significant ($P<0.05$) ; **, test very significant ($P<0.01$) ; ***, test very highly significant ($P<0.001$). Degree of freedom of the test is 9.

the highest values amongst plantations (Figure 2, Tables 2 and 5). Cocoa plantations of Scio site (PCAOS) expressed very significantly lower index value in comparison to those of Duekoué site but similar to values of rubber and teak plantations in Duekoué forest (Figure 2, Tables 2 and 5).

Simpson's diversity index showed its highest and similar values in Cocoa plantations of Scio site, Rubber and Teak plantations of Duekoué site (Figure 2, Tables 2 and 6). Cocoa plantations at Duekoué and Coffee plantations of both sites had medium index values, despite their variability, whereas natural forest patches and undergrowth cleared forests expressed the lowest and similar Simpson's diversity index values (Figure 2, Tables 2 and 6).

Highest and similar Hill's index values were found in both natural forest patches and undergrowth cleared forests of Scio site (Figure 2, Tables 2 and 7). Cocoa plantations at Duekoué and Coffee plantations of both sites had slight medium index values, despite their variability, when cocoa plantations of Scio site, rubber and teak plantations of Duekoué site showed lowest and similar values (Figure 2, Tables 2 and 7).

Pielou's index expressed highest and similar values in both natural forest patches and undergrowth cleared forests of Scio site and medium values in coffee plantations of both sites (Figure 2, Tables 2 and 8). Cocoa plantations of Duekoué showed similar Pielou's index values with both rubber and teak plantations (Table 8) while Cocoa plantations of Scio expressed similar values with the rubber plantations and lower value compared to teak plantations. Rubber and teak plantations shared the same Pielou's index values (Figure 2, Tables 2 and 8).

DISCUSSION

The decreasing of α-diversity in both biotopes and plots documented by this study in all plantations, in comparison to the natural forest patches (Tables 2 and 3), and reveals that the farmers' cash crop production systems and forestry service teak production system

Table 7. Matrix of biotopes Hill's index comparison with SPSS 18.0 software.

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.55	25.83	29.30	26.49	31.22	32.57	21.02
FDEFS	ns		16.59	19.87	34.03	61.12	33.63	26.05
PCAFD	***	***		3.99	5.14	6.95	6.36	4.41
PCAFS	***	***	**		2.63	4.76	3.49	2.16
PCAOD	***	***	**	*		3.65	1.14	0.40
PCAOS	***	***	***	**	**		1.04	2.23
PHEVD	***	***	***	**	ns	ns		0.74
PTECD	***	***	**	ns	ns	ns	ns	

Student *t* test values are above while significances are below. ns, test non-significant (P≥0.05) ; *, test significant (P<0.05) ; **, test very significant (P<0.01) ; ***, test very highly significant (P<0.001). Degree of freedom of the test is 9.

Table 8. Matrix of biotopes Pielou's index comparison with SPSS 18.0 software.

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.01	6.28	6.43	15.83	48.09	12.03	13.66
FDEFS	ns		5.90	6.31	15.80	52.83	11.66	14.25
PCAFD	***	***		3.61	7.39	10.54	6.15	5.83
PCAFS	***	***	**		4.63	6.18	4.01	3.51
PCAOD	***	***	***	**		3.51	0.93	0.55
PCAOS	***	***	***	***	**		1.03	3.43
PHEVD	***	***	***	**	ns	ns		0.58
PTECD	***	***	***	**	ns	**	ns	

Student *t* test values are above while significances are below. ns, test non-significant (P≥0.05); ** , test very significant (P<0.01) ; ***, test very highly significant (P<0.001). Degree of freedom of the test is 9.

affect local rainforest flora and diversity. Indeed, the establishment of all these plantations involves prior clearance of forest undergrowth and lianas (FDEFD), as well as shrubs and trees, followed by burning (Donald, 2004; Beukema et al., 2007; Bisseleua et al., 2008; Baatuuwie et al., 2011). For coffee and cocoa, farms are mostly established following a similar model referred to as short-term boom-and-bust cycles: primary or secondary forests are selectively cleared, burned and the crop is planted along with understory food crops (Isaac et al., 2005). Moguel and Toledo (1999) distinguished five main systems of coffee production in Mexico according to management level, and vegetational and structural complexity (Donald, 2004; Schroth and Harvey, 2007). In our study area like the most part in Côte d'Ivoire South forest region, cocoa planting can take place under thinned primary-forest canopy, regenerating forest after clear felling, or under the canopy of artificially planted trees as documented Greenberg (1998) and N'goran (1998). The shade trees are vital for cocoa saplings survival and growth but provide also farmers with a variety of products, including firewood, construction materials, pharmaceutical products and food (Herzog, 1994).

According to Rice and Greenberg (2000), cocoa production in West Africa follows both the rustic system and the planted shade polyculture system (Moguel and Toledo, 1999) but Steffan-Dewenter et al. (2007) advocated planting cocoa at low tree density and thinning for economic viability. In Cameroon where the impacts of cocoa cultivation on the local biodiversity still being the most assessed in Africa (Schroth and Harvey, 2007), agroforests such as traditional cocoa plantations are gradually receiving increasing interest since several years (Guyer, 1984; Ruf and Schroth, 2004; Laird et al., 2007; Sonwa et al., 2007). Bisseleua et al. (2008) reported that their management practices were influenced by their relationship to the other components of the land-use system and were oriented at using a combination of multiple forest resources (Sonwa et al., 2001; Schroth et al., 2004; Perfecto et al., 2005). And their adaptive nature offers options for combining biodiversity conservation and cocoa production for human benefits (Greenberg et al., 2000; Reitsma et al., 2001; Perfecto et al., 2004; MCNeely and Schroth, 2006; Gordon et al., 2007; Steffan-Dewenter et al., 2007). Zapfack et al. (2002) set the richness of vascular plants in the cocoa fields between of the natural forest areas and, of the fallows and non-Cocoa farms. They reported that many of the primary forest species were left standing in the course of burning, fruit trees were planted and other species (seedlings) were protected for further multiple uses (Zapfack et al., 2002). Schroth and Harvey (2007) reported that although both native and migrant farmers retain and plant useful species within their Cocoa farms, the native households retain and plant a higher density and diversity of non-Cocoa trees and use a wider range of non-tree species from their farms. In addition, the native farmers tend to have a greater number of local and wild species in their farms (Schroth and Harvey, 2007).

The lower richness in both cocoa and rubber plantations in Duekoué site documented by this study results from the near complete elimination of native trees species for their establishment than it is obtained in the cultivation of coffee plantations. Thus, medium values of diversity indices in Coffee plantations of both sites (Figure 2, Table 2-8) can be explained by the capacity of Coffee trees to grow and produce as well under the shade of many native or exotic tree species. Due to this capacity, famers preserve many useful tree species in their Coffee plantations for edible fruits and leaves, medicines, woods etc. on both sites of our study areas (Appendix 2). The crop effect shown by the ANOVA (Table 3) was due to this difference in intensity of tree species removed during Coffee and Cocoa plantations creating. Thus, the Coffee plantations in our study area correspond to the traditional polyculture system of Moguel and Toledo (1999) where several native and/or exotic species coexist with the crop. Hence, in both sites Legume tree species like *Albizia adianthifolia* (Schum.) WF.Wight, *A. glaberrima* (Schum. and Thonn.) Benth. *A. zygia* (DC.) JF.Macbr. and *Distemonanthus benthamianus* Baill. are especially preserved in both Coffee and Cocoa plantations (Appendix 2) in view of producing a mulch to supply organic matter for soil while exotic tree species as *Elaeis guineensis* Jacq. (Palm oil), *Mangifera indica* L. (Mango), *Musa paradisiaca* L. (Plantain Bananas) and *Persea americana* Mill. (Avocado) are introduced by farmers for their fruits (Appendix 2). Some natural and pioneer tree species like *Cordia guineensis* Schum. and Thonn. C. *platythyrsa* Bak., *Harungana madagascariensis* Lam. ex Poir., *Milicia excelsa* (Welw.) Berg and *Ricinodendron heudelotii* (Baill.) Pierre ex Heckel often survive as well in coffee and cocoa plantations for their products to the populations (Appendix 2) and their ability to promote quick shading of the Coffee and Cocoa trees, and to build refuges for Birds (Greenberg et al., 2000) which are benefic for Insects (Philpott and Armbrecht, 2006) and Mammals (Rolim and Chiarello, 2004). Thus, they lead to increase woody plant richness in such agrosystems. Rice and Greenberg (2000) suggested that the impact of cash crop production on biodiversity would be minimized if production was focused on already cleared lands, ensuring greater long-term stability of farms, and supporting greater levels of biodiversity. It is supported that the long-term incentives for promoting the management of a diverse shade canopy can be found in the ecological and agronomic services provided by the shade itself (Beer, 1987).

The similarity of the α-diversity and all diversity indices, between Rubber and Teak plantations shown by this study stems from the common practices of forest clearance, prior to the establishment of both types of plantations. Given that these sites are protected and managed for sustainable logging (SODEFOR, 1994, 1996; Kouamé, 1998), remnant timber species in these plantations increased their richness and diversity, especially in Teak plantations created by the SODEFOR. Higher and similar values of Shannon-Wiener, Hill and Pielou's indices and lower value of Simpson's diversity index in biotopes and plots of natural forest patches and undergrowth cleared forests compared to those in plantations (Tables 1-8, Figure 3) confirm the negative impacts of cash crop cultivation and Teak plantations on the flora of the study areas. Similar negative impact of Rubber cultivation on local natural plant species was also shown in Indonesia where plant richness decreased drastically from natural forests to Rubber plantations (Beukema et al., 2007). Except *E. guineensis* Jacq. and *M. indica* L. introduced in a young Rubber plantation at Duekoué site (PHEVD2), additional tree species in Rubber and Teak plantations were spontaneous and belonged to their undergrowth resproutings and remnant individuals (Appendix 2). And such introduction of exotic tree species explains the membership of PHEVD2 to the

Coffee plantation group II (Figure 4). The Teak's undergrowth self-regenerating capacity is shown by Baatuuwie et al. (2011) who pointed out no significant difference between the diversity of the socio-economic native tree saplings regenerating naturally under a Ghanaian's natural degraded forest, and a Teak mono-culture plantation and a mixed Teak-native tree species plantation.

The similarity of richness and all diversity indices found between the undergrowth cleared forests (FDEFS) and the natural forest patches (FNBAS) (Tables 1-8, Figure 2) shows that few big lianas and shrubs species were removed in our study area during this first step of cocoa plantations creating. The turnover of such biotope should be faster and very short if abandoned. Extinction of local tree species at the expense of cocoa starts with their destruction by felling or burning when cocoa trees become adults and need full sun for well fruiting. As the main features of the natural vegetation at Scio site, where such vegetation remains in our study areas, we assessed the same richness in the natural forest patches (Table 2) than Nusbaumer et al. (2005) despite differences in data collecting methods, plots' locations and ten years interval time between both studies. Scio's α-diversity is similar to those of Korup forest in Cameroon and, higher than the average 74±9 species per hectare documented by Kouamé (1998) in Haut-Sassandra protected semi-deciduous forest (Figure 1) and those 64 species of the Ituri forest in DR Congo (Ghazoul and Sheil, 2010). But it is as far poorer than Yasuni forest in Ecuador and Pasoh forest in Peninsular Malaysia where the richness of a hectare plot is set at 251 and 206 species respectively (Ghazoul and Sheil, 2010). A larger interval of 46-180 species of trees with DBH ≥ 10 cm in 3 ha plots was documented by Sambuichi and Haridasan (2007) in Southern region of Brazil. Parmentier et al. (2007) attributed the lower tree α-diversity of African rainforests in comparison to Amazonian forests to climate variation in both regions. Shannon-Wiener's index values in Scio natural forest patches and undergrowth cleared forest plots (Table 2) fall within the 3.73-4.36 values of surrounding forest patches (Bakayoko, 2005) and the 3.31-4.22 values of forest in Southern region of Brazil (Sambuichi and Haridasan, 2007) whereas they are higher than the 1.6-3.0 values of forest in Yapo region, Eastern Côte d'Ivoire (Vroh Bi, 2013). The site effect documented by the ANOVA (Table 3) could be explained by the difference in original flora as both protected areas belong to two types of Ivorian rainforest (Kouamé and Zoro Bi, 2010).

Conclusion

Teak plantations created by forestry service and cash crop plantations in both Duekoué and Scio classified forests led to the decreasing of richness and diversity of woody plant individuals with DBH≥10 cm in accordance with the hypothesis of this paper. These impacts vary with the cash crop nature and the site separately but they are invariably together. When the forest undergrowth is just cleared for shrubs and lianas, the richness and diversity of individuals with DBH≥10 cm of Scio forest still being similar to those of the natural forest and its turnover should be faster if abandoned. In both Duekoué and Scio forest areas, coffee plantations where some natural trees survive and other exotic trees are introduced had higher richness and diversity of woody plant individuals with DBH≥10 cm among plantations. The rubber and teak plantations where few natural trees survive had the lowest richness and diversity of such category of plants.

Due to these results, we suggest to the Forestry Service 1) to remove all the cash crop plantations from Ivorian classified forests, 2) to circumscribe Teak and other wood plantations into some areas of these forests and 3) to promote the turnover of the less degraded areas in view to increase both richness and diversity of the Ivorian classified forests.

Conflict of Interest

The authors have declared that there is no conflict of interest.

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Appendix 1. Plots coordinates on the two first axes of the factorial analysis with Statistica 7.1 software.

Group	Plots	Factor 1	Factor 2	Group	Plots	Factor 1	Factor 2
Group I	FDEFS1	-0. 107	-0. 039	Group II	PCAFS9	0. 206	0. 462
	FDEFS2	-0. 139	-0. 181		PCAFD1	0. 256	0. 563
	FDEFS3	-0. 158	-0. 151		PCAFD4	0. 256	0. 563
	FDEFS4	-0. 108	-0. 093		PCAFD5	0. 227	0. 689
	FDEFS5	-0. 161	-0. 179		PCAFD6	0. 168	0. 574
	FDEFS6	-0. 156	-0. 148		PCAFD7	0. 283	0. 707
	FDEFS7	-0. 136	-0. 077		PCAFD8	0. 250	0. 654
	FDEFS8	-0. 140	-0. 175		PCAFS1	0. 291	0. 603
	FDEFS9	-0. 176	-0. 196		PCAFS2	0. 298	0. 712
	FDEFS10	-0. 127	-0. 075		PCAFS3	0. 227	0. 689
	FNBAS1	-0. 123	-0. 081		PCAFS4	0. 301	0. 621
	FNBAS2	-0. 175	-0. 185		PCAFS5	0. 175	0. 583
	FNBAS3	-0. 155	-0. 130		PCAFS6	0. 238	0. 744
	FNBAS4	-0. 120	-0. 153		PCAFS7	0. 168	0. 557
	FNBAS5	-0. 118	-0. 146		PCAFS8	0. 283	0. 707
	FNBAS6	-0. 072	-0. 078		PCAFS10	0. 222	0. 607
	FNBAS7	-0. 157	-0. 128		PHEVD2	0. 208	0. 310
	FNBAS8	-0. 154	-0. 151	Group III	PCAFD2	0. 626	0. 440
	FNBAS9	-0. 159	-0. 170		PCAFD3	0. 714	0. 458
	FNBAS10	-0. 154	-0. 139		PCAFD9	0. 639	0. 361
	PHEVD1	-0. 002	0. 149		PCAFD10	0. 659	0. 506
	PHEVD3	-0. 002	0. 149	Group IV	PCAOD1	0. 665	-0. 173
	PHEVD4	-0. 002	0. 149		PCAOD3	0. 572	-0. 202
	PHEVD5	-0. 002	0. 149		PCAOD4	0. 668	0. 031
	PHEVD6	-0. 002	0. 149		PCAOD5	0. 760	-0. 179
	PHEVD7	0. 013	0. 115		PCAOD6	0. 679	-0. 304
	PHEVD8	-0. 002	0. 149		PCAOD7	0. 673	0. 024
	PHEVD9	-0. 002	0. 149		PCAOD8	0. 627	-0. 222
	PHEVD10	-0. 002	0. 149		PCAOD9	0. 673	0. 024
	PTECD1	-0. 017	0. 018		PCAOD10	0. 582	-0. 216
	PTECD2	-0. 048	-0. 028		PCAOS3	0. 647	-0. 341
	PTECD3	0. 012	0. 143		PCAOS6	0. 647	-0. 341
	PTECD4	-0. 017	0. 018		PCAOS9	0. 534	-0. 224
	PTECD5	0. 003	0. 022	Group V	PCAOD2	0. 885	-0. 384
	PTECD6	-0. 003	0. 019		PCAOS1	0. 885	-0. 384
	PTECD7	-0. 017	0. 018		PCAOS2	0. 885	-0. 384
	PTECD8	-0. 048	-0. 028		PCAOS4	0. 885	-0. 384
	PTECD9	0. 010	0. 106		PCAOS5	0. 885	-0. 384
	PTECD10	-0. 019	0. 013		PCAOS7	0. 885	-0. 384
					PCAOS8	0. 885	-0. 384
					PCAOS10	0. 885	-0. 384

Appendix 2. Frequencies, origins and uses of shrubs and trees with DBH≥10 cm assessed in biotopes of Duekoué and Scio forests.

Taxa	FDEFS	FNBAS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD	Origin	Uses
Aidia genipiflora (DC.) Dandy	3	1							Natural	
Albizia adianthifolia (Schum.) W.F.Wight		4		1					Natural	
Albizia glaberrima (Schum. and Thonn.) Benth.			3	1				2	Natural	
Albizia zygia (DC.) J.F.Macbr.		3	2	1					Natural	
Amphimas pterocarpoides Harms	3	5							Natural	Wood
Anthonotha fragrans (Bak.f.) Exell and Hillcoat		2							Natural	
Anthonotha macrophylla P.Beauv.	5								Natural	
Antiaris toxicaria Loes. var. *africana* C.C.Berg	3								Natural	Wood
Antrocaryon micraster A.Chev. and Guill.		2							Natural	
Baphia nitida Lodd.	6	4							Natural	
Baphia pubescens Hook.f.	9	8							Natural	
Belonophora hypoglauca (Welw. ex Hiern) A.Chev.		2							Natural	
Blighia unijugata Bak.		3							Natural	
Blighia welwitschii (Hiern) Radlk.		2							Natural	
Bombax brevicuspe Sprague		4							Natural	Wood
Bombax buonopozense P.Beauv.		4							Natural	Edible
Bussea occidentalis Hutch.		2							Natural	
Caloncoba gilgiana (Sprague) Gilg		4							Natural	
Calpocalyx aubrevillei Pellegr.	5								Natural	
Calpocalyx brevibracteatus Harms		4							Natural	
Ceiba pentandra (L.) Gaertn.				1					Natural	Wood, edible
Celtis adolfi-fridericii Engl.		8							Natural	
Celtis mildbraedii Engl.	9	9							Natural	
Celtis zenkeri Engl.	3	8							Natural	
Christiana africana DC.		1							Natural	
Chrysophyllum perpulchrum Hutch. and Dalz.	8	5							Natural	
Chrysophyllum taiense Aubrév. and Pellegr.	3	7							Natural	
Cleistopholis patens (Benth.) Engl. and Diels		4							Natural	
Coffea canephora Froenh. (= Coffee)			1	1					Exotic	Crop
Cola caricaefolia (G.Don) Schumann		2							Natural	
Cola lateritia Schumann	8	5							Natural	Edible
Cola nitida (Vent.) Schott and Endl.	5	5							Natural	
Cordia guineensis Schum. and Thonn.			2						Natural	Medicine

Appendix 2. Contd.

Cordia platythyrsa Bak.	3				3				Natural	craft
Corynanthe pachyceras Schumann	3	7							Natural	
Dacryodes klaineana (Pierre) Lam	1								Natural	
Desplatsia dewevrei (De Wild. and Th.Dur.) Burret	3	4							Natural	
Diospyros canaliculata De Wild.		3							Natural	
Diospyros ferrea (Willd.) Bakh.								1	Natural	
Diospyros vignei F.White								1	Natural	
Diospyros viridicans Hiern		1							Natural	
Discoglypremna caloneura (Pax) Prain		2							Natural	
Distemonanthus benthamianus Baill.	4		1	1					Natural	Wood
Drypetes chevalieri Beille		1							Natural	
Elaeis guineensis Jacq.			3	1	5		1		Exotic	Edible, cosmetic
Entandrophragma angolense (Welw.) C. DC.		1							Natural	Wood
Entandrophragma cylindricum (Sprague) Srague		7							Natural	Wood
Entandrophragma utile (Dawe and Sprague) Sprague	3								Natural	Wood
Eribroma oblongum (Mast.) Pierre ex Germain		6							Natural	Wood
Erythrophleum ivorense A.Chev.		2							Natural	craft
Erythroxylum mannii Oliv.		1							Natural	
Euadenia trifoliolata (Schum. and Thonn.) Oliv.		1							Natural	
Ficus exasperata Vahl						1	2	2	Natural	
Funtumia africana (Benth.) Stapf	5	2							Natural	craft
Funtumia elastica (Preuss) Stapf	9	7		1					Natural	craft
Glyphaea brevis (Spreng.) Monachino	6								Natural	Medicine
Greenwayodendron oliveri (Engl.) Verdc.	4	2							Natural	Medicine
Guarea cedrata (A.Chev.) Pellegr.	3								Natural	
Guibourtia ehie (A.Chev.) J.Léonard	3	1							Natural	Wood
Gymnostemon zaizou Aubrév. and Pellegr.		1							Natural	
Harungana madagascariensis Lam. ex Poir.			3	2					Natural	Medicine
Hevea brasiliensis Müll.Arg. (= Rubber)							1		Exotic	Crop
Holoptelea grandis (Hutch.) Mildbr.		2							Natural	
Irvingia gabonensis (O' Rorke) Baill.	3	2							Natural	Edible
Keayodendron bridelioides (Hutch. and Dalz.) Léandri		3							Natural	

Appendix 2. Contd.

Klainedoxa gabonensis Pierre	4								Natural	
Lannea welwitschii (Hiern) Engl.	3								Natural	craft
Lecaniodiscus cupanioides Planch.	6								Natural	
Maesobotrya barteri (Baill.) Hutch.	6								Natural	
Mangifera indica L.			6	4	3		1		Exotic	Edible
Mansonia altissima (A.Chev.) A.Chev.		2							Natural	Wood
Maranthes aubrevillei (Pellegr.) Prance		2							Natural	
Mareya micrantha (Benth.) Müll.Arg.		6						1	Natural	Medicine
Microdesmis keayana J.Léonard		4							Natural	
Milicia excelsa (Welw.) Berg	4	2	4	3				1	Natural	Wood
Millettia zechiana Harms	8	3						1	Natural	
Monodora tenuifolia Benth.		2							Natural	
Musa paradisiaca L.					3				Exotic	Food
Musanga cecropioides R.Br.		2							Natural	
Myrianthus arboreus P.Beauv.	8								Natural	Edible
Myrianthus libericus Rendle	3	4							Natural	Edible
Napoleonaea vogelii Hook. and Planch.	3								Natural	Edible, craft
Nauclea diderrichii (De Wild. and Th.Dur.) Merrill								2	Natural	Wood
Nesogordonia papaverifera (A.Chev.) Cap.	6	9							Natural	Wood
Newbouldia laevis (P.Beauv.) Seem. ex Bureau	3	5							Natural	Edible, craft
Ochthocosmus africanus Hook.f.	3								Natural	
Ongokea gore (Hua) Pierre		2							Natural	Medicine
Ophiobotrys zenkeri Gilg	3								Natural	
Panda oleosa Pierre	5	5							Natural	
Parkia bicolor A.Chev.	3	2							Natural	
Persea americana Mill.			1	2	4				Exotic	Edible
Petersianthus macrocarpus (P.Beauv.) Liben	9	8						2	Natural	Wood
Piptadeniastrum africanum (Hook.f.) Brenan	8	1							Natural	Wood
Placodiscus attenuatus J.B.Hall		1							Natural	
Pteleopsis hylodendron Mildbr.		2							Natural	
Pterygota macrocarpa Schumann		3							Natural	Wood
Pycnanthus angolensis (Welw.) Warb.		2						2	Natural	Wood
Raphia hookeri Mann and Wendl.					4				Natural	Edible
Ricinodendron heudelotii (Baill.) Pierre ex Heckel			1	1					Natural	Edible

Appendix 2. Contd.

Rinorea convallarioides (Bak.f.) Eyles		1							Natural	
Rothmannia hispida (Schumann) Fagerl.	4								Natural	
Rothmannia urcelliformis (Hiern) Robyns	3								Natural	
Samanea dinklagei (Harms) Keay	3	2							Natural	
Scottellia klaineana Pierre var. *mimfiensis* Pellegr.	4	4							Natural	Wood
Sterculia rhinopetala Schumann	5	9				2			Natural	Wood
Sterculia tragacantha Lindl.						1			Natural	
Stereospermum acuminatissimum Schumann		3							Natural	
Strombosia pustulata Oliv. var. *pustulata*	7	6							Natural	
Synsepalum afzelii (Engl.) Pennington	3								Natural	
Tectona grandis L.f. (= Teak)								1	Exotic	Wood
Terminalia ivorensis A.Chev.	3								Natural	Wood
Terminalia superba Engl. and Diels		3						1	Natural	Wood
Tetrapleura tetraptera (Schum. and Thonn.) Taub.		3							Natural	craft
Theobroma cacao L. (= Cocoa)			4		1	1			Crop	Crop
Tricalysia macrophylla Schumann	7								Natural	
Trichilia martineaui Aubrév. and Pellegr.		2							Natural	
Trichilia megalantha Harms	3	3							Natural	
Trichilia monadelpha (Thonn.) J.J.De Wild.		3							Natural	
Trichilia prieureana A.Juss.		7							Natural	
Triplochiton scleroxylon Schumann	3	4							Natural	Wood
Uapaca guineensis Müll.Arg.	5								Natural	
Vitex ferruginea Schum. and Thonn.		2							Natural	
Vitex micrantha Gürke	3								Natural	
Xylia evansii Hutch.		5							Natural	Wood
Xylopia quintasii Engl. and Diels		3							Natural	
Xylopia villosa Chipp	6	2							Natural	
Zanthoxylum gilettii (Engl.) Waterman	3	5							Natural	Wood
Zanthoxylum leprieurii Guill. and Perr.		5							Natural	
Total	58	85	12	13	7	4	4	12		