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Full Length Research Paper

Structure of duekouué and scio protected forests under anthropogenic activvities in southwestern côôte d'ivoire

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This manuscript analyses the effects of anthropogenic disturbance on trees, shrubbs and lianas mean DBH, density and basal area in two protected rain forests in Southwestern Côte d'Ivvoire. These forests have been under timber harvesting since their protection in 1929. The Forestry Servvice had developed plantations of indigenous timber species and Teak since 1996 to increase their producctivities for timbers. Additionally, they host many plantatioons of cash crop among which Coffee, Cocoa and Rubber are the most important. To understand how thhese plantations affect the local vegetation structure, trees, shrubs and lianas with DBH ≥10 cm were analyzed through the mean DBH, density and basal area. Plots were of 20 m x 50 m size and a total of 10 per vegetation type. Highest mean DBH and basal areea in both plots and vegetation types were found in the nattural forests and the undergrowth cleared forests which had similar values of these parameters. Yet densitty showed both lowest and highest values in plantations. Density in plantations was influenced by the site location of the plantation and the nature of croop while mean DBH and basal area were influenced only byy the nature of crop.

Keywords: Forest protection, cash crops, agroforestry, vegetation structure, South-West Côtte d'Ivoire

INTRODUCTION

In the Upper Guinea sub-region (White, 1979, 1983) Côte d'Ivoire has the second largest West Africaan humid rain forest area after Liberia (Poorter *et al*., 20044; FAO, 2011) and is known to be among the countries that have the highest tropical deforestation rate (Sayer *et al*., 1992; Chatelain *et al*., 2004; FAO, 2011) due to hu man activities despite a century policy of forest protection. There are two main categories of protected areas in Côte d'Ivoire which are the national parks banned of any human activities except management and reseearch, and the classified (protected) forests whose purppose is management for sustainable logging (Kouamé, 1998). The definition and delimitation of these protected forests began in 1924 by their static conservation (de Konning, 1983; Ahimin, 2006). After the Ivorian freedom in 19960, their legal status has been created together with a national Forest Research

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Institute (IDEFOR) and a national Forest Service (SODEFOR). Forty years later, these proceedings couldn't stop the fast degradation of Ivorian forests (Dao, 1999; Chatelain *et al.,* 2004; Ahimin, 2006) that remain nowadays in some classified forests, national parks, biological reserves and in forest-fallow mosaics. Due to rarefaction of wastelands in the rain forest area, the farmers crossed the limits of protected forests within which they establish their crops and live. The politico-military crisis in Côte d'Ivoire since 2002 led to increasing the illegal occupation of its South-Western protected areas mainly the classified forests like Duekoué and Scio.

To understand the effects of the Forest Service's management and the farmers' activities on the structure trees, shrubs and lianas, eighty 20 m x 50 m plots were investigated in the classified forests of Duekoué and Scio. Woody plant individuals that had 10 cm DBH and above were sampled for their DBH in plots. The aim of this manuscript was to analyze woody plant structure in eight biotopes generated by human activities in two protected areas.

Hypothesis

As both Forest Service and farmers remove local vegetation during their activities in the study area, we hypothesized to find higher structural parameters in natural vegetation than in plantations.

MATERIAL 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 one long wet season from February to November and one 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 25 ºC while monthly and annual potential evapotranspiration of both areas show respectively 123.5 mm and 148.2 mm (Eldin, 1971). The soils belong to the remould ferrallitic group (Perraud and De La Souchère, 1970). The natural vegetation of Duekoué forest consists of a moist semi-deciduous forest (Kouamé, 2010; Kouamé and Zoro, 2010) defined as a tropical rain forest 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 (Trochain, 1957; ORSTOM and UNESCO, 1983) interrupted by savannas areas and inselbergs (Monnier, 1983). Original vegetation of Scio forest belongs to Ivorian South-Western evergreen forest type (Kouamé, 2010; Kouamé and Zoro, 2010) that spreads in the wettest forest area.

Field data collection was carried out in eighty 1000 m² (20 m x 50 m) plots established per 10 in 4 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 are the natural forest patches, the undergrowth cleared forest, 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 diameter at 1.3 m (DBH) at least 10 cm were assessed for their DBH.

Data analysis

The mean DBH that is the average of all individual DBH assessed in a plot was calculated and analyzed per plot and per biotope following Bonou *et al*. (2009) and Houéto *et al*. (2013). It expresses the wideness of trees, shrubs and lianas in the milieu. Additionally, distribution of individuals inside DBH classes was analyzed to improve the explanation the mean DBH values in plots.

The density which is the individuals' number in an area and the simple expression of the vegetation structure parameter (Fowler *et al*., 1999) was also calculated and compared per plot and vegetation type. The density is indicator of spacial occupation of an area by individuals.

The basal area that is the area covered by horizontal sections of plants at a level by individuals living in that area (CTFT, 1989) has several formulas among which one of the latest from Hédl *et al.* (2009) has been used in this paper.

$$\text{Basal area} = 0.00007854 \times DBH^2$$

Such as data in plots showed normal distribution, their statistical analyses had been performed with parametric tests as recommended Fowler et al. (1999) and Glèlè Kakai *et al*. (2006). Plot vegetation structural parameters were compared using paired samples *t test* of Student and their prospective correlations were analyzed throughout Pearson correlation with SPSS 18.0 software. Basal area and density in plots were analyzed using factorial analysis with with Statistica 7.1 software to clarify the relationships between plots by means of their spatial distribution. Structural parameters of Coffee plantations and Cocoa plantations that have been assessed in both research sites (Table 1) were analyzed with an ANOVA using Statistica 7.1 software for checking prospective impacts of site and/or crop nature on plot vegetation structure. 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 vegetation.

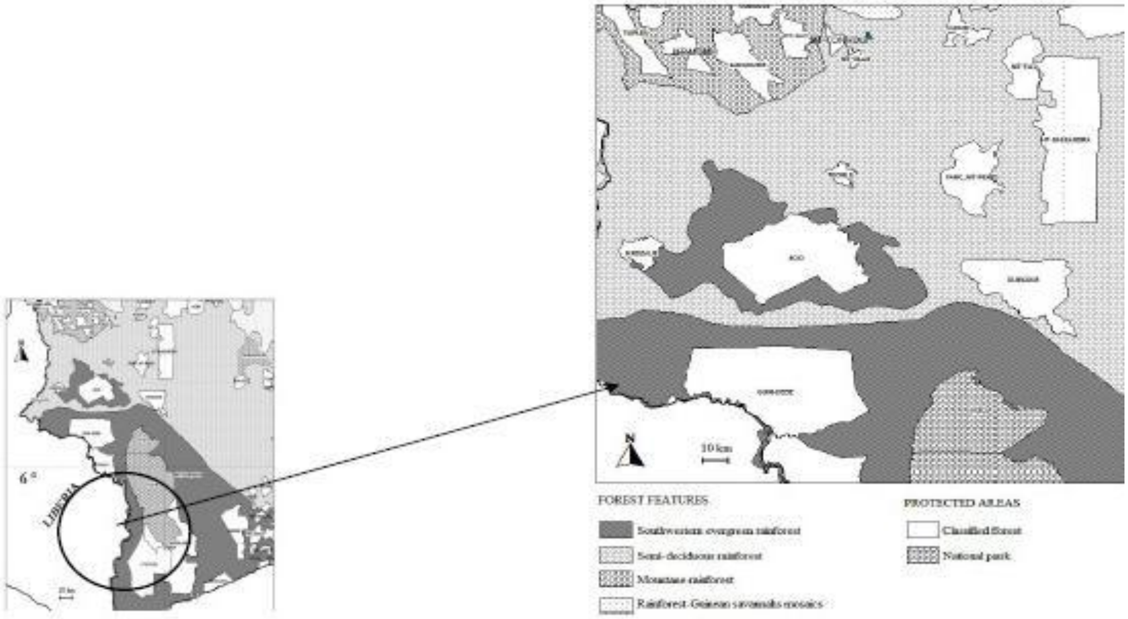

Figure 1. Localization with MapInfo 7.8 software of research sites on the map of protected areas and main floristic features distribution in Ivorian rain forest zone according to Kouamé and Zoro Bi (2010)

Table 1. Structure parameters in biotopes Duekoué forest biotopes: PCAFD (Coffee plantations), PCAOD (Cocoa plantations), PHEVD (Rubber plantations), PTECD (Teak plantations). Scio forest biotopes: FNBAS (natural forest), FDEFS (undergrowth cleared forest), PCAFS (Coffee plantations), PCAOS (Cocoa plantations).

Parameters		FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
Mean DBH	Minimum	17.19	17.88	11.60	11.03	12.35	13.13	12.34	12.95
	Maximum	26.70	23.57	27.17	25.57	15.31	13.65	17.89	22.23
	Total	212.32	204.80	168.57	155.35	138.55	134.95	153.80	175.23
	Mean	21.23	20.48	16.86	15.54	13.85	13.49	15.38	17.52
	Stand. Dev.	2.57	1.94	4.52	4.54	1.06	0.15	2.16	3.29
Density	Minimum	50	43	6	7	61	85	25	45
	Maximum	69	56	28	19	91	102	51	96
	Total	580	489	138	117	743	916	398	613
	Mean	58.00	48.90	13.80	11.70	74.30	91.60	39.80	61.30
	Stand. Dev.	7.09	4.70	6.76	4.69	9.21	5.64	8.39	15.01
Basal area	Minimum	2.05	1.72	0.11	0.08	0.79	1.24	0.35	0.75
	Maximum	5.72	3.21	0.89	0.65	2.04	1.49	1.31	2.31
	Total	33.31	22.76	4.24	2.95	14.28	13.45	8.04	15.90
	Mean	3.33	2.28	0.42	0.30	1.43	1.34	0.80	1.59
	Stand. Dev.	1.30	0.53	0.24	0.21	0.41	0.09	0.35	0.55

The total area of each biotope is a hectare (10 x 1000 m²). Thus for all parameters in table 1, total values correspond to hectare data while the others are research plot area (20m x 50 m) data.

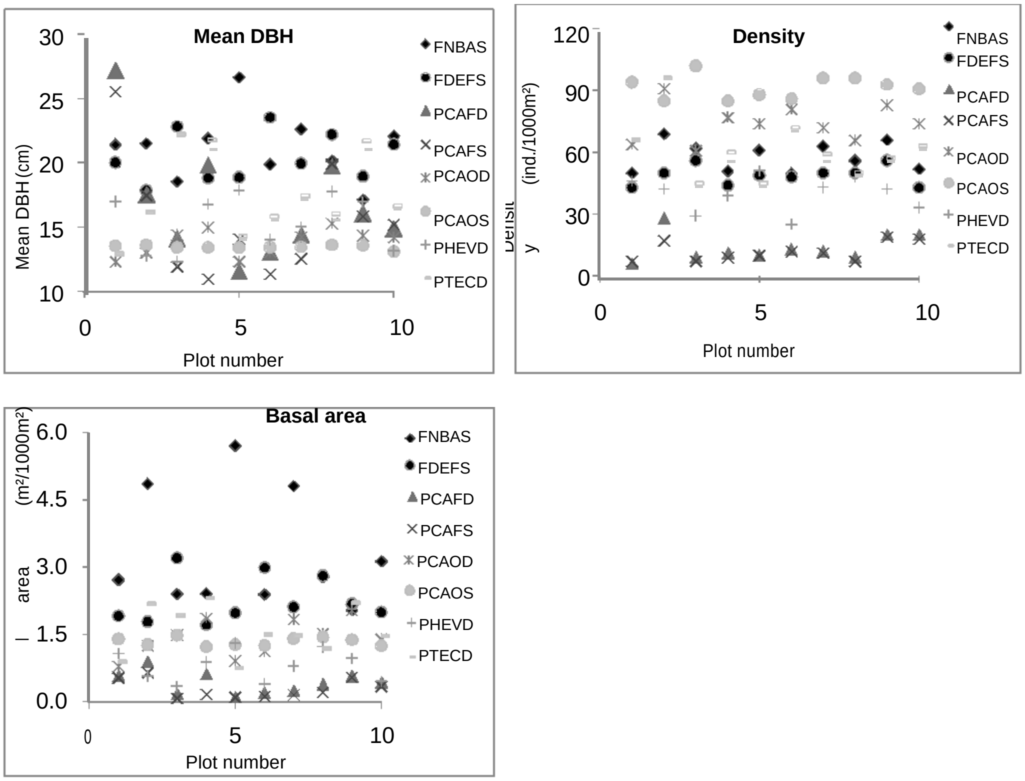

Figure 2. Variation of the vegetation structural parameters in plots

Table 2. Comparison matrix of mean DBH in biotopes

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		0.63	2.49	3.41	7.30	9.32	6.35	2.26
FDEFS	ns		2.18	3.00	10.54	11.15	4.85	2.46
PCAFD	*	ns		1.40	2.03	2.38	1.09	0.34
PCAFS	**	*	ns		1.07	1.44	0.11	0.90
PCAOD	***	***	ns	ns		1.06	2.01	4.35
PCAOS	***	***	*	ns	ns		2.82	3.88
PHEVD	***	**	ns	ns	ns	*		1.58
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.

RESULTS

Mean DBH and basal area showed highest (Figure 2, Table 1) and similar (Tables 2, 3) values in the natural forest patches (FNBAS) and the undergrowth cleared forest (FDEFS) at Scio site. Among plantations, the Teak (PTECD) showed higher values of these parameters while the lowest values were found in Scio Cocoa plantations (PCAOS) for the mean DBH and Scio Coffee plantations (PCAFS) for basal area (Figure 2, Table 1). But density showed highest values in the Cocoa plantations of both sites while its lowest values were found in Coffee plantations of both sites (Figure 2, Tables 1, 4). Density in Scio Cocoa plantations was almost twice higher than density in the natural forest patches and in the undergrowth cleared forest of the same forest area but

Table 3. Comparison matrix of basal area in biotopes

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		2.09	6.83	7.27	4.07	4.75	6.36	3.48
FDEFS	ns		8.31	9.43	3.98	6.01	6.37	2.74
PCAFD	***	***		3.06	7.10	10.30	2.81	7.77
PCAFS	***	***	*		7.58	14.04	4.05	7.56
PCAOD	**	**	***	***		0.65	3.51	1.29
PCAOS	**	***	**	***	ns		4.92	1.36
PHEVD	***	***	*	**	*	**		3.17
PTECD	**	*	***	***	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 4. Comparison matrix of density in biotopes

	FNBAS	FDEFS	PCAFD	PCAFS	PCAOD	PCAOS	PHEVD	PTECD
FNBAS		6.09	20.72	21.43	5.52	12.78	6.14	0.66
FDEFS	***		14.51	18.77	7.91	25.12	2.91	2.33
PCAFD	***	***		2.02	36.71	23.37	7.18	13.16
PCAFS	***	***	ns		30.94	29.40	8.50	11.72
PCAOD	***	***	***	***		3.90	7.69	3.85
PCAOS	***	***	***	***	**		16.08	5.08
PHEVD	***	*	***	***	***	***		3.71
PTECD	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.

belong to the [10-20 cm[DBH class exclusively (Figure 3). Among plantations, only Coffee and Rubber expressed lower density in comparison with the natural forest (Tables 1, 3). Individuals in Rubber and Teak plantations belong to the [10-30 cm[and the [10-40 cm[DBH classes, respectively while in the other plantations they could reach the [80-90 cm[DBH class (Figure 3). The natural forest patches expressed 90% of the BDH classes especially with some individuals of DBH ≥100 cm (Figure 3). Density in plots showed higher variability in Cocoa and Teak plantations when plot basal area expressed higher variability in both natural forest and Teak plantations (Figure 4).

A very highly significant and positive Pearson's correlation was found between plot density and plot basal area in both Scio Cocoa plantations and Duekoué Rubber plantations (Figure 5a) but no correlation was expressed between these two parameters in the other biotopes studies in this paper. Except the Duekoué Coffee plantations and the Scio Cocoa plantations, there was a positive and significant Pearson's correlation between plot mean DBH and plot basal area in all other biotopes. This correlation was significant in the Scio Coffee plantations (Figure 5b), highly significant in the Scio natural forest patches, in the Scio undergrowth cleared forest, and in the Duekoué Cocoa and Teak plantations and very highly significant in the Duekoué Rubber plantations (Figure 5b). A positive and significant Pearson's correlation was expressed between plot mean DBH and plot density in the Duekoué Rubber plantations (Figure 5c); in all other biotopes, this correlation wasn't significant and almost zero in the natural forest, the undergrowth cleared forest and the Cocoa plantations of Scio site but slightly negative in the remnant plantations (Figure 5c).

Distribution of trees in plantations was determined prior to the openness in vegetation and later by the nature of the target species (Figure 6). Thus, according to plot density plots were separated into three groups amongst which the biggest (group I Figure 6) gathered natural forest patches and undergrowth cleared forest from Scio site, and Teak plantations and Rubber plantations (Figure 6, Appendix 1) from Duekoué site. This group that was represented by

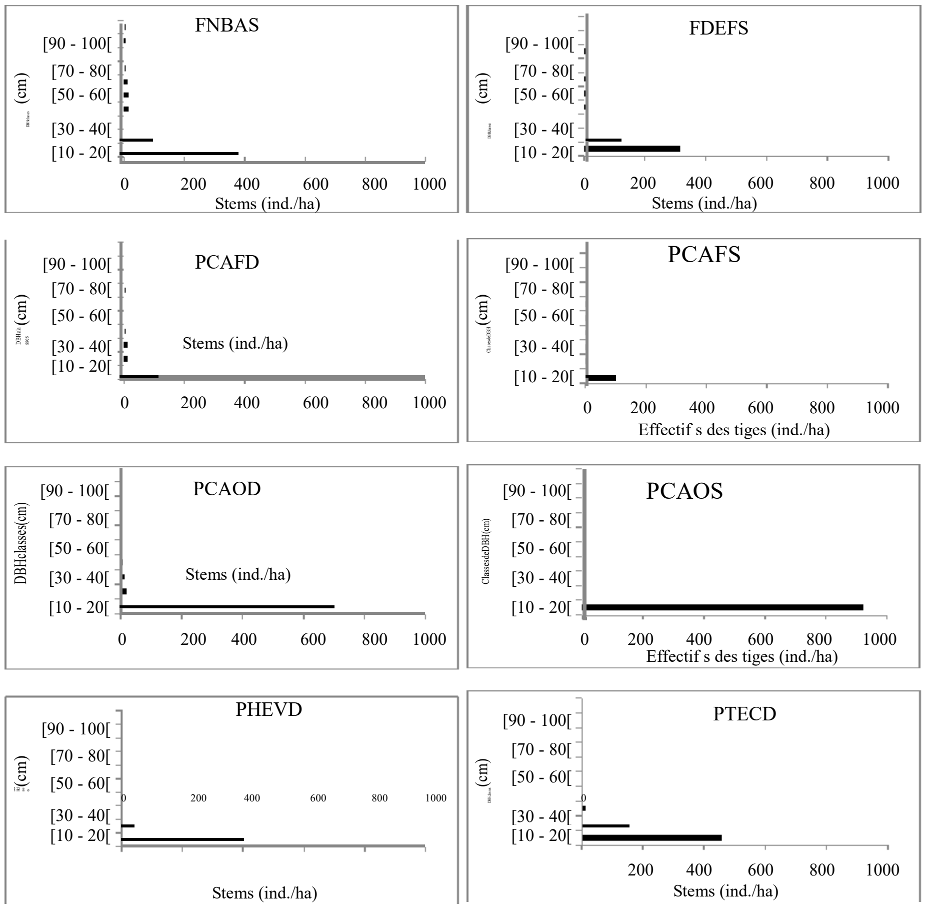

Figure 3. DBH classes distribution in plots

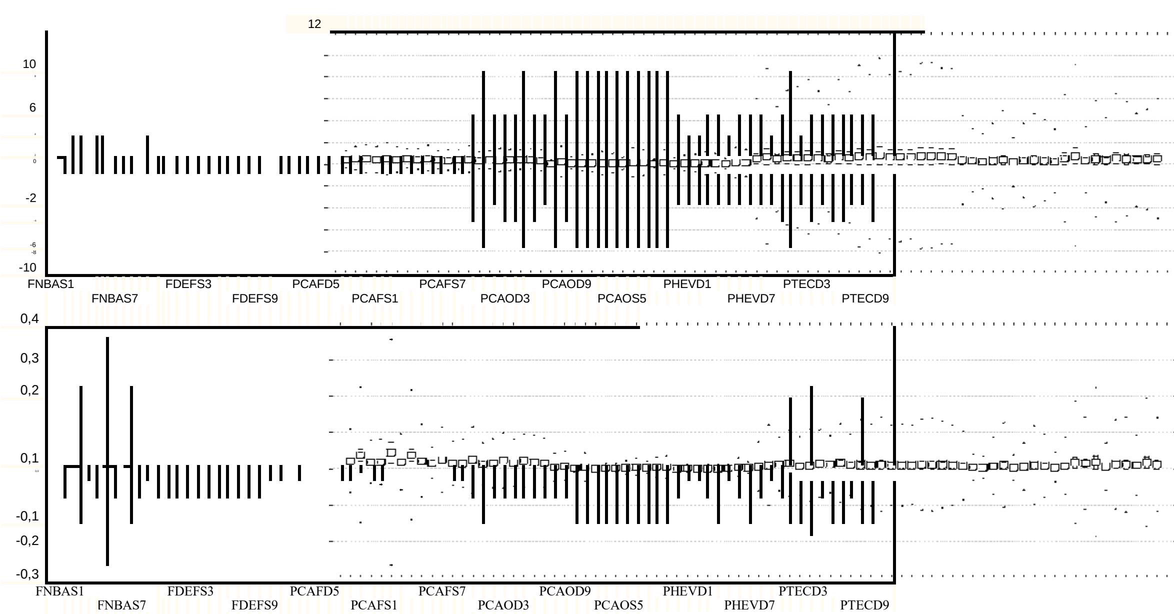

Figure 4. Boxplots of plot density (above) and basal area (below) using factorial analysis with Statistica 7.1 software. Mean values are in small central squares, error types are in small framing rectangles and standard deviation types are in vertical lines.

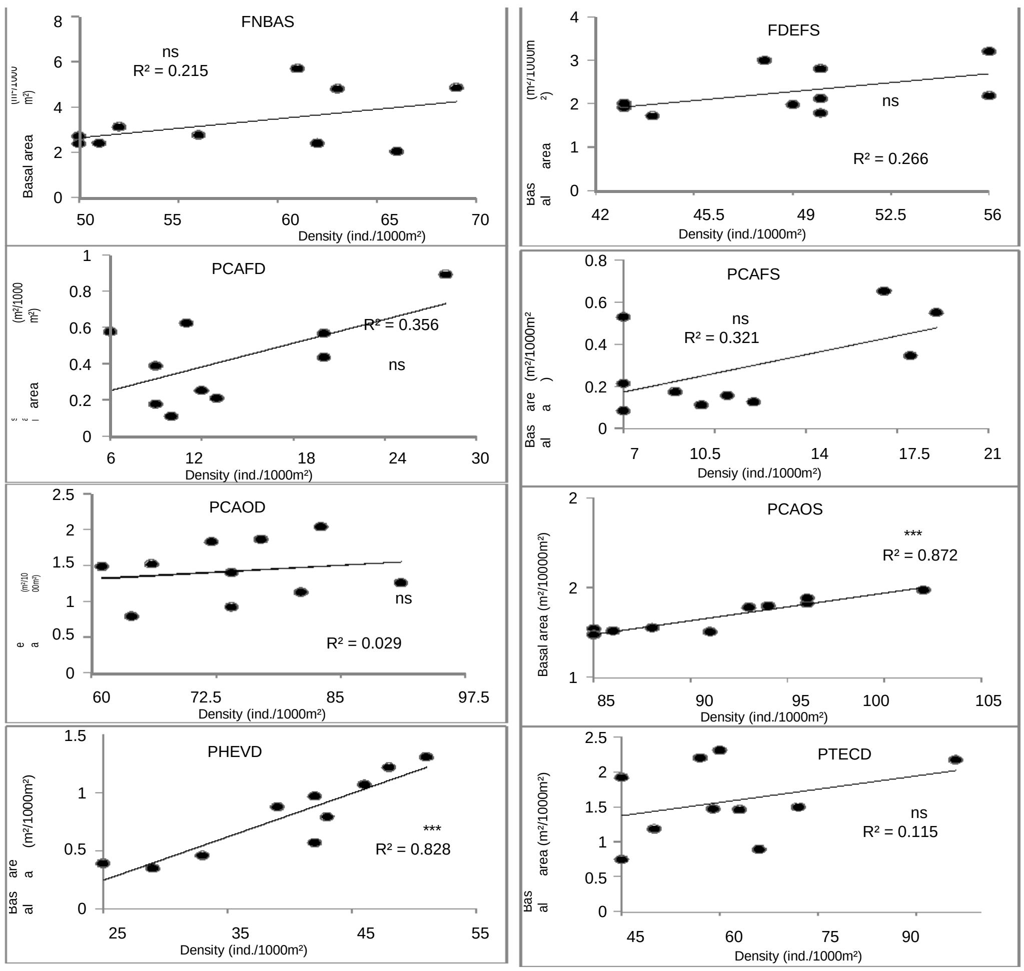

Figure 5a. Pearson correlation values between plot basal area and plot density ns: test non significant (P≥0.05); ***: test very highly significant (P<0.001). Plots' number (N) is 10 per biotope.

50% of plots appeared in low vegetation openness conditions. The two other groups were the Coffee plantations (group II Figure 6) from both sites in medium vegetation openness conditions and the Cocoa plantations (group III Figure 6) from both sites in higher vegetation openness conditions (Figure 6, Appendix 1). According to plot basal area, plots were separated into four groups of which three had similar coordinates on factor 1 expressing the vegetation openness (Figure 6, Appendix 2). Thus, the Rubber plantations were gathered into group I, the natural forest patches, and the undergrowth cleared forests and the Teak plantations belong to the same group II while the Coffee plantations of both sites constituted the group III in low vegetation openness conditions (Figure 6, Appendix 2). The fourth group was formed by Cocoa plantations of both sites.

A significant impact of the cash crop nature was found on mean DBH in Coffee and Cocoa plantations but no impact was found neither with the site of plantation location nor with the combination with cash crop nature and site location (Table 5). No impact was found with Bonferroni's Post Hoc test. Highly significant impacts of the site and very highly significant impacts of both the nature of the crop and the combination site and crop nature were found on the density in Coffee and Cocoa plantations (Table 5). Base on density, Bonferroni's test showed a very highly significant difference between Duekoué Coffee plantations and Scio Cocoa plantations, and between Cocoa plantations of both sites while Coffee plantations from both sites were similar (Table 6). A very highly significant impact of crop nature was found on basal area in Coffee and Cocoa plantations but no impact was found neither with the site of plantation location nor with the combination with cash crop nature and site location (Table 5). Base on basal area, Bonferroni's test showed no difference between Cocoa plantations of both sites, and between Coffee and Cocoa plantations from Scio forest area; but a very highly difference was between other pairs of biotopes (Table 6).

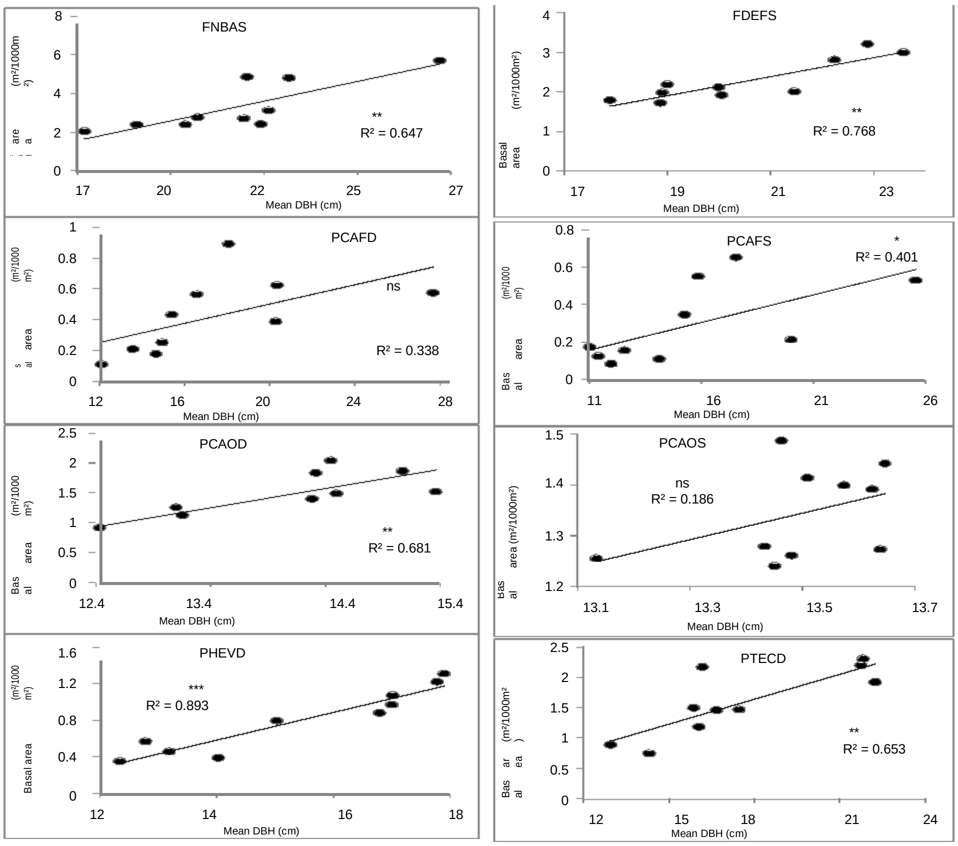

Figure 5b. Pearson correlation values between plot basal area and plot mean DBH ns: test non significant (P≥0,05); *: test significant (P<0.05); **: test highly significant (P<0.01); ***: test very highly significant (P<0.001). Plots' number (N) is 10 per biotope.

Table 5. Effects of the site and the cash crop nature on structure parameters in Coffee and Cocoa plantations from ANOVA with Statistica 7.1 software

Effect		SC	df	MF	F	P
Mean DBH	Ord origin	8922.52	1	8922.52	846.00	***
	Site	7.07	1	7.07	0.67	ns
	Crop	63.58	1	63.58	6.03	*
	Site*Crop	2.31	1	2.31	0.22	ns
	Error	379.68	36	10.55		
Density	Ord origin	91584.90	1	91584.90	1985.94	***
	Site	577.60	1	577.60	12.53	**
	Crop	49280.40	1	49280.40	1068.60	***
	Site*Crop	940.90	1	940.90	20.40	***
	Error	1660.20	36	46.12		
Basal area	Ord origin	30.50	1	30.50	432.15	***
	Site	0.11	1	0.11	1.605	ns
	Crop	10.54	1	10.54	149.35	***
	Site*Crop	0.01	1	0.01	0.07	ns
	Error	2.54	36	0.07		

ns: test non significant (P≥0.05); * : test significant (P<0.05); ** : test highly significant (P<0.01); *** : test very highly significant (P<0.001).

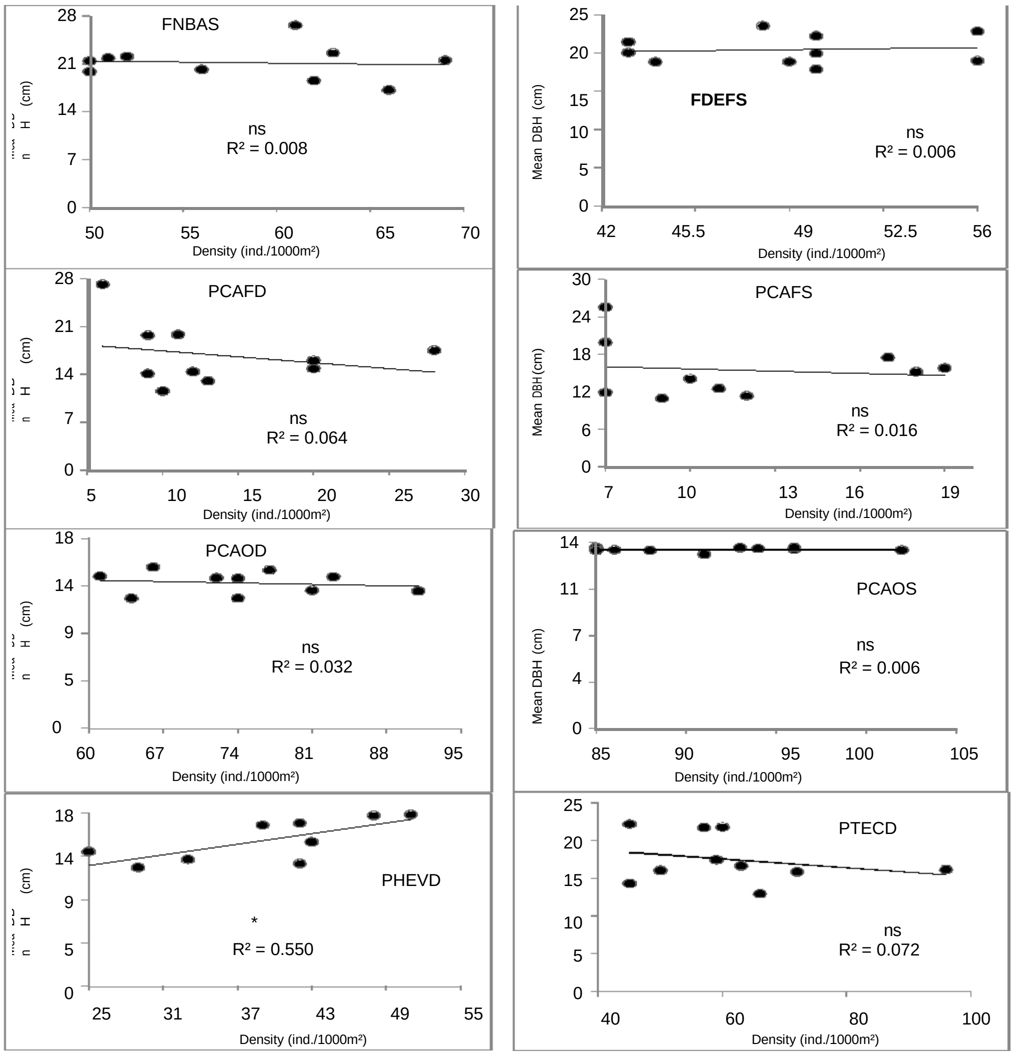

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Figure 5c. Pearson correlation values between plot mean DBH and plot density
ns: test non significant (P≥0.05); *: test significant (P<0.05). Plots' number (N) is 10 per biotope

Table 6. Bonferroni's Post Hoc test of effects of the site and the cash crop nature on structure parameters in Coffee and Cocoa plantations with Statistica 7.1 software

		Duekoué Cocoa	Duekoué Coffee	Scio Cocoa	Scio Coffee
Density	Duekoué Cocoa		***	***	***
	Duekoué Coffee	***		***	ns
	Scio Cocoa	***	***		***
	Scio Coffee	***	ns	***	
Basal area		Duekoué Cocoa	Duekoué Coffee	Scio Cocoa	Scio Coffee
	Duekoué Cocoa		***	ns	***
	Duekoué Coffee	***		***	ns
	Scio Cocoa	ns	***		***
	Scio Coffee		***	ns	***

This test is no significant for the mean DBH. df = 36. Error: MC Inter is 10.547 for mean DBH, 46.117 for density and 0.071 for basal area. ns: test non significant (P≥0.05); *** : test very highly significant (P<0.001).

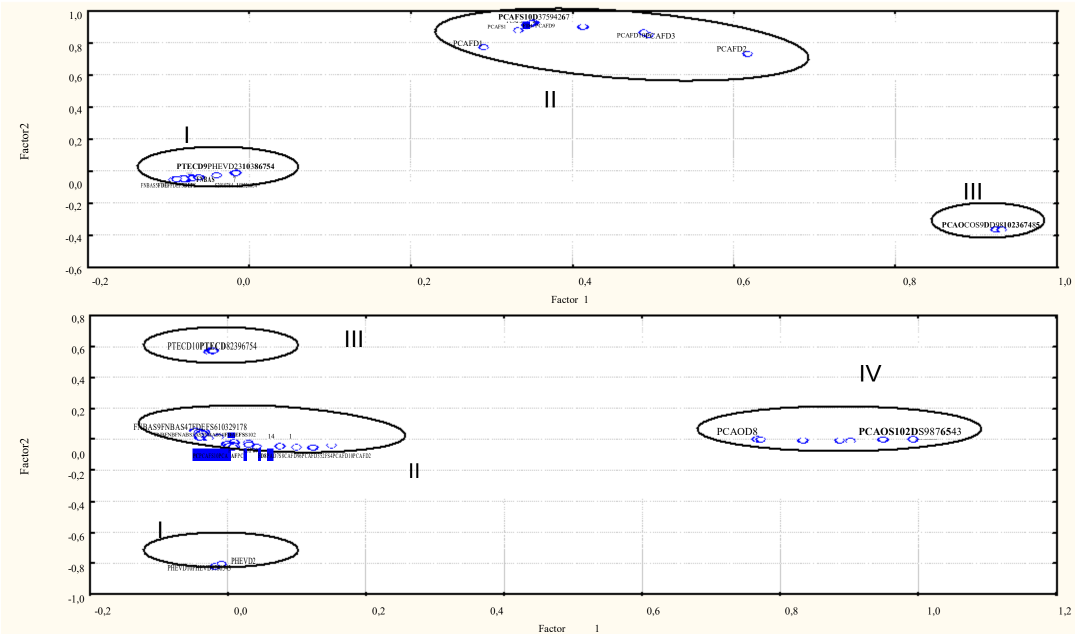

Figure 6. Projection of plots on the two first axes of the factorial analysis with Statistica 7.1 software according to their density (above) and basal area (below). For plot density, factor 1 on abscises explains 20. 63% while factor 2 on ordinates is responsible for 18.81% of total variation of the analysis. For plot basal area, factor expresses 18.23% and factor 2 explains 10% of total variation of the analysis. The factor 1 that segregates natural forests and plantations express the openness in vegetation while factor represents the nature of cash crop. See appendices for groups.

DISCUSSION

The general density of 580 individuals and basal area of 33.31 m² recorded in a hectare of the Scio natural forest patches site (Table 1) are higher than the 413 individuals and 30.82 m² found by Nusbaumer *et al.* (2005) in a hectare plot of the same forest. The general density of 489 individuals in the Scio undergrowth cleared forests is also higher while their basal area of 22.76 m² is lower in comparison to what Nusbaumer et al. (2005) obtained in Scio forest. Such differences of parameters can be assigned to the 10 years between both data collecting periods. Yet, since data collected by Nusbaumer *et al*. (2005), forest self regeneration led to the recruitment of numerous small trees that had less than 10 cm DBH and increased both density and basal area in the natural forest that should be diminished by the undergrowth clearance. These general density and basal area from both natural and undergrowth forests in Scio fall within the density of 339-649 individuals and the basal area of 23.7-40 m² of several Ivorian rain forests (Devineau, 1984; Corthay, 1996; Kouamé, 1998; Bakayoko, 1999, 2005) and African tropical rain forests (Ghazoul and Sheil, 2010). But these densities are poorer than Malagasy forests with 728 -739 individuals in hectare plots (Messmer, 1996; D'Amico and Gautier, 1999), and those of 702 individuals per hectare of the Pasoh forest in Peninsular Malaysia and of 875 individuals per hectare of the Luquillo forest in Puerto Rico (Ghazoul and Sheil, 2010). In comparison to non-tropical forest densities of 150-675 individuals and basal areas of 32.41-72.80 m² (Sharma and Raina, 2003), African tropical forest and especially the natural forest from our study area harbor thinner trees.

The decreasing of mean DBH and basal area in both biotopes and plots in all plantations compared to natural forest patches (Tables 1, 2 and 3) reveals the negative impacts of the cash crop production practices and agroforestry systems on local rain forest trees. The establishment of cash crop plantations involves prior clearing of forest undergrowth and lianas, as well as shrubs and trees, followed by burning. 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 crop is planted along with understory food crops (Isaac *et al.,* 2005). And the similarity of mean DBH and basal area between the undergrowth cleared forests (FDEFS) and the natural forest patches (FNBAS) at Scio site (Tables 1, 2 and 3; Figure 2) but the very highly significant higher density in the natural forests (Table 4, figure 2) show that numerous and thin lianas and shrubs of DBH ≥ 10 cm are removed in the study area during this first step of plantations establishment. Later, when crops are established, tall trees are removed from plantations where mean DBH and basal area that are closely linked to high DBH values (Figure 5b) fall sharply. But our results relative to the distribution of individuals inside DBH classes (Figure 3) show that some big native trees survive in all plantations except the Rubber's. Bisseleua et al. (2008) found an average of 62.25-135.85 cm mean DBH, 100-215 individuals and 10-45 m² of native trees in hectare plots of Cocoa plantations and confirmed the results of Zapfack *et al*. (2002) in Cameroon. Rolim and Chiarello (2004) obtained lower data in Brazil where Sambuichi and Haridasan (2007) found densities of 47-355 individuals and basal areas of 11.8-28.2 m² in hectare plots. According to Rice and Greenberg (2000), Cocoa production in West Africa follows both the Rustic system and the planted shade polyculture system but Steffan-Dewenter *et al.* (2007) advocated planting of Cocoa at low tree density and thinning for economical viability. Therefore higher density values in Cocoa plantations of both sites and Teak plantations (Table 1, Figure 2) are mainly due to Cocoa trees and Teak trees respectively. Density in Rubber and Coffee plantations should have also higher values in comparison to natural forest because farmers use similar density of crops during the establishment of their plantations. But Duekoué Rubber plantations are young and part of the crop trees still being thinner than 10 cm DBH; then they were not assessed yet during this study. And the Coffee tree is naturally thin and rarely reaches 10 cm DBH even in old plantations. Consequently in Coffee plantations, a part of Coffee trees that are the most abundant were not assessed too during this study due to their DBH< 10 cm and large DBH classes (Figure 3) belong to native trees. Méndez (2004) sheared these native trees in Coffee plantations into firewood group (77-96%), fruit group (40-100%), timber group (20-70%) and organic matter group (0-10%) in Western El Savador. In our study area, some exotic fruit trees like Mango (*Mangifera indica* L.) and Avocado (*Persea americana* Mill.) are introduced in Coffee plantations in addition to native non-Coffee trees. Thus, the Coffee plantations in our study area corresponds to the traditional polyculture system of Moguel and Toledo (1999) who distinguished 5 main systems of Coffee production in Mexico according to management level, and vegetational and structural complexity. The zero-shade Cocoa cultivation system (Rice and Greenberg, 2000) that corresponds to the unshaded monoculture Coffee cultivation system (Moguel and Toledo, 1999) is similar to the Rubber and Teak cultivation systems in our study area. All vegetation is removed before the planting of crops. Therefore, DBH classes, density and basal area obtained in these biotopes (Table 1, Figures 2, 3) belong mainly to the crop trees.

The membership of the Rubber plantations and the Teak plantations to the same group with the natural forest patches and the undergrowth cleared forests according to both density and basal area (Figure 6) shows that all these biotopes are similar for these parameters. Due to the presence of some big tree native or exotic non- crop trees in Coffee plantations, this biotope integrates the forest's group according to basal area whatever different according to density of which it has the lowest value (Figure 6). The higher variability of density in the Cocoa, Rubber and Teak plantations (Figure 4) can be explained by the differences in their ages and the cultivation systems. As these plantations were established in forbidden clearance area, we couldn't get real plantations' ages because farmers feared to be met. But plantations showed differences in the crop height and diameters that are generated by ages, the cultivation systems (Moguel and Toledo, 1999; Rice and Greenberg, 2000). The higher variability of basal area in the natural forest patches can be generated by the variation in logging intensity which is linked to local density of timber trees that can be logged (Kouamé, 1998). Thus, in the Scio natural forests and undergrowth cleared forests, basal area is more dependant ($P<0.01$) to mean DBH than to density while both mean DBH ($P<0.05$) and density ($P<0.001$) are important for basal area (Figure 5) in plantations.

The crop effect raised up by the ANOVA (Tables 5 and 6) was due to this difference in intensity of tree removed during the creation of Coffee and Cocoa plantations. In Coffee plots (PCAFD and PCAFS), Coffee trees always coexist with other native and/or exotic trees unlike Cocoa plantations where the Cocoa trees were found almost alone. The site effect (Table 3) could be explained by the difference in original vegetation types as both protected areas belong to two types of Ivorian rain forest (Kouamé, 2010; Kouamé and Zoro Bi, 2010).

CONCLUSION

Human activities in both Duekoué and Scio classified forests led to the decreasing of mean DBH and basal area of individuals with DBH ≥ 10 cm in accordance with the hypothesis of this paper. But Cocoa and Teak cultivation led to increase density for low and medium basal areas. When the forest undergrowth is just cleared for shrubs and lianas, mean DBH and basal area of individuals with DBH≥10 cm of African tropical forest still being similar to natural forest and its turnover should be faster if abandoned. In Duekoué and Scio forest areas, Coffee plantations where some natural trees survive and other exotic trees are introduced had similar importance with the natural forest and the undergrowth group despite their lower density.

Due to these results, we suggest to the Forestry Service to remove all the cash crop plantations from Ivorian classified forests and to circumscribe Teak and other wood plantations into some areas of these classified forests.

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REFERENCES

Ahimin AO (2006). *Détermination des aires abritant les formations végétales à haute valeur de conservation identifiées dans le Domaine guinéen de la Côte d'Ivoire*. Mém. DEA, UFR Biosciences, Université de Cocody-Abidjan, 71 pp.

Bakayoko A (1999). *Comparaison de la composition floristique et de la structure forestière de parcelles de la Forêt Classée de Bossématié, dans l'Est de la Côte d'Ivoire*. Mém. DEA, UFR Biosciences, Univ. Cocody-Abidjan, 72 pp.

Bakayoko A (2005). *Influence de la fragmentation forestière sur la composition floristique et la structure végétale dans le Sud-Ouest de la Côte d'Ivoire*. Thèse Doct., Labo. Bot., UFR Biosciences, Univ. Cocody-Abidjan, 229 pp.

Bisseleua D, Herve B, Vidal S (2008). Plant biodiversity and vegetation structure in traditional cocoa forest gardens in southern Cameroon under different management. *Biodivers. Conserv*. **17**: 1821-1835.

Bonou W, Glèlè Kakaï R, Assogbadjo AE, Fonton HN, Sinsin B (2009). Character-isation of *Afzelia africana* Sm. habitat in the Lama forest reserve of Benin. *Forest Ecology and Management* **258**:1084-1092.

Chatelain C, Dao H, Gautier L, Spichiger R (2004). Forest cover changes in Côte d'Ivoire and Upper Guinea. In: Poorter L, Bongers F, Kouamé FN, Hawthorne WD (eds) *Biodiversity of West African forests. An ecological Atlas of woody plant species*. CABI, UK, pp 15-32.

Corthay R (1996). *Analyse floristique de la forêt sempervirente de Yapo (Côte d'Ivoire)*. Mém. Diplôme, Univ. Genève, 152 pp.

CTFT (1989). *Memento du forestier*. Minist. Coopérat. Dével., Paris, 1266 pp.

D'Amico C, Gautier L (2000). Inventory of a 1-ha lowland rainforest plot in Manon-garivo (NW Madagascar). *Candollea* **55**: 319-340.

Dao H (1999). *Connaissance de l'environnement et systèmes d'information géogra-phiques : le cas de la déforestation en Côte d'Ivoire*. Thèse Doct. ès-Sc., Fac. Sc., Université Genève, 370 pp.

De Koning J (1983). *La forêt du Banco. I. La forêt. II. La flore*. Wageningen Agr. Univ. tome I, 156 pp., tome II, 921 pp.

Devineau J-L (1984). *Structure et dynamique de quelques forêts tropophiles de 'Ouest africain (Côte d'Ivoire)*. Thèse Doct. État, Univ. Paris VI, 294 pp.

Elidn M (1971). Le climat. In: Avenard JM, Eldin E, Girard G, Sircoulon J, Touche-beuf P, Guillaumet J-L, Adjanohoun E, Perraud A (eds) *Le milieu naturel de la Côte d'Ivoire*. ORSTOM, Paris, pp 73-108.

FAO (2011) *Global forest resources assessment 2011*. FAO. Rome, 176 pp.

Fowler J, Cohen L, Jarvis P (1999). *Practical statistics for field biology*. Wiley, 2e ed., 259 pp.

Ghazoul J, Sheil D (2010). *Tropical forest ecology, diversity and conservation*. OXFORD Press, 516 pp.

Glèlè Kakaï R, Sodjinou E, Fonton N (2006). *Conditions d'application des méthodes statistiques paramétriques. Applications sur ordinateur.* Cotonou, 94 pp.

Hédl R, Svátek M, Dancak M, Rodzay AWM, Salleh AB, Kamariah AS (2009). A new technique for inventory of permanent plots in tropical forests: a case study from lowland Dipterocarp forest in Kuala Belalong, Brunei Darussalam. *Blumea* **54**:124–130.

Houéto G, Fandohan B, Ouédraogo A, Ago EE, Salako VK, Assogbadjo, AE, Glèlè Kakaï R, Sinsin B (2013). Floristic and dendrometric analysis of woodlands in the Sudano-Guinean zone: a case study of Belléfoungou forest reserve in Benin. *Acta Botanica Gallica* **159**(**4**):387-394.

Isaac ME, Gordon AM, Thevathasan N, Oppong SK, Quashie-Sam J (2005). Temporal changes in soil carbon and nitrogen in West Africa multistrata agroforestry systems: a chronosequence of pools and fluxes. *Agroforest. Syst*. **65** : 23-31.

Kouamé FN (1998). *Influence de l'exploitation forestière sur la végétation et la flore de la Forêt Classée du Haut-Sassandra (Centre-Ouest de la Côte d'Ivoire).* Thèse Doct. 3e Cycle, UFR Biosciences, Université Cocody-Abidjan, 227 pp.

Kouamé FN (2010). Main environmental factors of Côte d'Ivoire. Phytogeographic territories. In: Konaté S, Kampmann D (eds) Atlas de la biodiversité de l'Afrique de l'Ouest. Vol. III. Côte d'Ivoire. Biota, Abidjan and Frankfurt/Main, pp 132-138.

Kouamé FN, Zoro Bi IA (2010). Nouveau découpage de la zone de forêt dense humide de la Côte d'Ivoire. *Sciences et Nature* vol. **7** (**2**) : 177-194.

Méndez VE (2004). Traditional Shade, Rural Livelihoods, and Conservation in Small Coffee Farms and Cooperatives of Western El Salvador. Ph.D. thesis, University of California, Santa Cruz.

Messmer N (1996). Etude d'une parcelle d'un hectare de forêt dense humide de basse altitude à Madagascar. Diplôme, Univ. Genève, 96 pp.

Moguel P, Toledo VM (1999). Review: Biodiversity conservation in traditional Coffee systems of Mexico. *Conservation Biology* **13**(**1**): 11-21.

Monnier Y (1983). Carte de la végétation de la Côte d'Ivoire. In: Vennetier P, Laclavère G (eds) *Atlas de Côte-d'Ivoire*. 2e éd., Jeune Afrique, Paris, 72 pp.

Nusbaumer L, Gautier L, Chatelain C, Spichiger R (2005). Structure et composition floristique de la Forêt Classée du Scio (Côte d'Ivoire). Etude descriptive et comparative. *Candollea* **60** (**2**) : 393-443.

ORSTOM, UNESCO (1983). Ecosystèmes forestiers tropicaux d'Afrique. *Coll. Recherches sur les ressources naturelles*, n° **19**, Paris, 473 pp.

Perraud A, de la Souchère P (1970). *Esquisse pédologique de la Côte d'Ivoire*. Ech. 1/500 000e. Feuille Sud-Ouest, ORSTOM, Adiopodoumé, Abidjan.

Poorter L, Bongers F, Kouamé FN, Hawthorne WD (2004). *Biodiversity of West African forests. An ecological Atlas of woody plant species*. CABI, UK, 521 pp.

Rice RA, Greenberg R (2000). Cocoa cultivation and the conservation of biological diversity. *Ambio* vol. **29**(**3**):167-173.

Rolim GS, Chiarello GA (2004). Slow-death of Atlantic forest trees in cocoa agroforest in southern Brazil. *Biodivers. conserv*. **13**:2679–2694.

Sambuichi RHR, Haridasan M (2007). Recovery of species richness and conservation of native Atlantic forest trees in the Cocoa plantations of southern Bahia in Brazil. Biodivers. conserv. 16:3681-3701.

Sayer JA, Harcourt CS, Collins NM (1992). *The conservation Atlas of Tropical forests*. Africa. IUCN, Singapore, 288 pp.

Sharma N, Raina AK (2003). Composition, structure and diversity of tree species along an altitudinal gradient in Jammu province of north-western Himalayas, Jammu and Kashmir, India. *Journal of Biodiversity and Ecological Sciences* **3**(**1**): 6-14.

Steffan-Dewenter I, Kessler M, Barkmann J, Bos M, Buchori D, Erasmi S, Faust H, Gerold G, Glenk K, Gradstein RS, Guhardja E, Harteveld M, Hertel D, Hohn P, Kappas M, Kohler S, Leuschner C, Maertens M, Marggraf R, Migge-Kleian S, Mogea J, Pitopang R, Schaefer M, Schwarze S, Sporn GS, Steingrebe A, Tjitrosoedirdjo SS, Tjitrosoemito S, Twele A, Weber R, Woltmann L, Zeller M, Tscharntke T (2007). Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *PNAS* **104**:4973–4978.

Trochain J-L (1957) Accord interafricain sur la définition des types de végétation de l'Afrique Tropicale. *Bulletin Institut Études Centrafricaines*. Nouv. Sér. **13/14** : 55-93.

White F (1979). The Guineo-Congolian Region and its relationships to other phytochoria. *Bull. Jard. Bot. Nat. Belg*. **49**: 11-55.

White F (1983). *The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. Natural resources research XX, UNESCO, Paris, 384 pp.

Zapfack L, Engwald S, Sonke B, Achoundong G, Birang M (2002). The impact of land conversion on plant biodiversity in the forest zone of Cameroon. *Biodivers. conserv*. **11**: 2047–2061.

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

	Plots	Factor 1	Factor 2		Plots	Factor 1	Factor 2
	FNBAS1	-0,083	-0,043		PCAFD1	0,290	0,775
	FNBAS2	-0,090	-0,053		PCAFD2	0,616	0,734
	FNBAS3	-0,071	-0,039		PCAFD3	0,494	0,852
	FNBAS4	-0,071	-0,042		PCAFD4	0,342	0,909
	FNBAS5	-0,063	-0,037		PCAFD5	0,350	0,927
	FNBAS6	-0,042	-0,024		PCAFD6	0,350	0,926
	FNBAS7	-0,095	-0,052		PCAFD7	0,352	0,929
	FNBAS8	-0,082	-0,046		PCAFD8	0,343	0,911
	FNBAS9	-0,081	-0,047		PCAFD9	0,412	0,903
	FNBAS10	-0,090	-0,049		PCAFD10	0,488	0,867
	FDEFS1	-0,068	-0,035		PCAFS1	0,332	0,880
	FDEFS2	-0,076	-0,045		PCAFS2	0,351	0,928
	FDEFS3	-0,077	-0,045		PCAFS3	0,348	0,922
	FDEFS4	-0,082	-0,043		PCAFS4	0,351	0,927
	FDEFS5	-0,083	-0,049		PCAFS5	0,350	0,924
	FDEFS6	-0,072	-0,041		PCAFS6	0,352	0,928
	FDEFS7	-0,081	-0,043		PCAFS7	0,350	0,924
	FDEFS8	-0,085	-0,050		PCAFS8	0,345	0,913
	FDEFS9	-0,094	-0,055		PCAFS9	0,350	0,925
	FDEFS10	-0,075	-0,040	Groupe II	PCAFS10	0,349	0,927
	PHEVD1	-0,016	-0,009		PCAOD1	0,931	-0,363
	PHEVD2	-0,014	-0,001		PCAOD2	0,931	-0,364
	PHEVD3	-0,016	-0,009		PCAOD3	0,929	-0,364
	PHEVD4	-0,016	-0,009		PCAOD4	0,931	-0,362
	PHEVD5	-0,016	-0,009		PCAOD5	0,931	-0,363
	PHEVD6	-0,016	-0,009		PCAOD6	0,931	-0,364
	PHEVD7	-0,017	-0,010		PCAOD7	0,931	-0,363
	PHEVD8	-0,016	-0,009		PCAOD8	0,923	-0,361
	PHEVD9	-0,016	-0,009		PCAOD9	0,931	-0,363
	PHEVD10	-0,016	-0,009		PCAOD10	0,930	-0,364
	PTECD1	-0,017	-0,010		PCAOS1	0,931	-0,364
	PTECD2	-0,017	-0,010		PCAOS2	0,931	-0,364
	PTECD3	-0,019	-0,010		PCAOS3	0,930	-0,364
	PTECD4	-0,017	-0,010		PCAOS4	0,931	-0,364
	PTECD5	-0,017	-0,010		PCAOS5	0,931	-0,364
	PTECD6	-0,017	-0,010		PCAOS6	0,930	-0,364
	PTECD7	-0,017	-0,010		PCAOS7	0,931	-0,364
	PTECD8	-0,017	-0,011		PCAOS8	0,931	-0,364
	PTECD9	-0,017	-0,010		PCAOS9	0,930	-0,364
Groupe I	PTECD10	-0,017	-0,010	Groupe III	PCAOS10	0,931	-0,364

Appendix 2. Plots coordinates on the two first axes of the factorial analysis of plot basal area with Statistica 7.1 software

	Plots	Factor 1	Factor 2		Plots	Factor 1	Factor 2
Groupe I	PHEVD1	-0,019	-0,819	Groupe III	PCAFD1	0,008	-0,012
	PHEVD3	-0,019	-0,819		PCAFD2	0,150	-0,037
	PHEVD2	-0,010	-0,802		PCAFD3	0,099	-0,048
	PHEVD4	-0,019	-0,819		PCAFD4	0,009	-0,017
	PHEVD5	-0,019	-0,819		PCAFD5	0,005	-0,046
	PHEVD6	-0,019	-0,819		PCAFD6	0,001	-0,041
	PHEVD7	-0,020	-0,817		PCAFD7	0,010	-0,047
	PHEVD8	-0,019	-0,819		PCAFD8	-0,001	-0,028
	PHEVD9	-0,019	-0,819		PCAFD9	0,075	-0,041
	PHEVD10	-0,019	-0,819		PCAFD10	0,123	-0,050
Groupe II	FNBAS1	-0,038	0,031		PCAFS1	0,029	-0,019
	FNBAS2	-0,038	0,046		PCAFS2	0,006	-0,033
	FNBAS3	-0,041	0,015		PCAFS3	0,004	-0,044
	FNBAS4	-0,044	0,037		PCAFS4	0,041	-0,045
	FNBAS5	-0,020	0,011		PCAFS5	0,004	-0,046
	FNBAS6	-0,028	0,011		PCAFS6	0,008	-0,048
	FNBAS7	-0,038	0,043		PCAFS7	0,002	-0,041
	FNBAS8	-0,037	0,035		PCAFS8	0,009	-0,039
	FNBAS9	-0,055	0,038		PCAFS9	0,030	-0,032
	FNBAS10	-0,042	0,030		PCAFS10	0,007	-0,048
	FDEFS1	-0,034	0,016	Groupe IV	PCAOD1	0,992	0,003
	FDEFS2	-0,013	0,018		PCAOD2	0,992	0,003
	FDEFS3	-0,047	0,056		PCAOD3	0,766	0,004
	FDEFS4	-0,013	0,017		PCAOD4	0,901	-0,008
	FDEFS5	-0,032	0,018		PCAOD5	0,992	0,003
	FDEFS6	-0,049	0,047		PCAOD6	0,992	0,003
	FDEFS7	-0,041	0,038		PCAOD7	0,833	-0,005
	FDEFS8	-0,034	0,049		PCAOD8	0,771	0,001
	FDEFS9	-0,037	0,036		PCAOD9	0,885	-0,004
	FDEFS10	-0,041	0,053		PCAOD10	0,949	0,002
	PTECD1	-0,022	0,574		PCAOS1	0,992	0,003
	PTECD2	-0,025	0,576		PCAOS2	0,992	0,003
	PTECD3	-0,025	0,569		PCAOS3	0,992	0,003
	PTECD4	-0,022	0,574		PCAOS4	0,992	0,003
	PTECD5	-0,022	0,574		PCAOS5	0,992	0,003
	PTECD6	-0,023	0,572		PCAOS6	0,991	0,003
	PTECD7	-0,022	0,574		PCAOS7	0,992	0,003
	PTECD8	-0,028	0,566		PCAOS8	0,992	0,003
	PTECD9	-0,023	0,573		PCAOS9	0,991	0,003
	PTECD10	-0,022	0,574		PCAOS10	0,992	0,003