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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 Froehn., 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 Ivorian’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; Garry, 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
25°C while monthly and annual potential evapotranspiration of Duekoüé 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 Duekoüé 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 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 Colic, 2006).

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

\[ H' = - \sum_{i=1}^{S} Pi \ln Pi \]

with \( Pi \) as relative average cover of species \( i \) in a community (Shannon and Wiener, 1949). \( H' \) varies from 0 (monospecific settlement) to \( \ln S \) (maximum diversity). This index is sensitive to the variation of importance for most rare species (Peet, 1974; Grall and Colic, 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       | 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 | PCOAD1          | 6° 42      | 7° 06       | PCAOS1           | 6° 31      | 7° 48      |
|                  | PCOAD2          | 6° 42      | 7° 06       | PCAOS2           | 6° 38      | 7° 51      |
|                  | PCOAD3          | 6° 42      | 7° 12       | PCAOS3           | 6° 39      | 7° 46      |
|                  | PCOAD4          | 6° 41      | 7° 14       | PCAOS4           | 6° 38      | 7° 51      |
|                  | PCOAD5          | 6° 42      | 7° 12       | PCAOS5           | 6° 38      | 7° 52      |
|                  | PCOAD6          | 6° 43      | 7° 12       | PCAOS6           | 6° 39      | 7° 46      |
|                  | PCOAD7          | 6° 42      | 7° 12       | PCAOS7           | 6° 38      | 7° 51      |
|                  | PCOAD8          | 6° 42      | 7° 12       | PCAOS8           | 6° 38      | 7° 51      |
|                  | PCOAD9          | 6° 43      | 7° 12       | PCAOS9           | 6° 39      | 7° 47      |
|                  | PCOAD10         | 6° 42      | 7° 12       | PCAOS10          | 6° 39      | 7° 47      |
| Rubber plantations | PHEVD1         | 6° 42      | 7° 06       | 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       | 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 \( H'_{\text{max}} \) (Pielou, 1966).

\[ J' = \frac{H'}{H'_{\text{max}}} \]

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
Hill varies from 1 (monospecific settlement) to $\alpha$ (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 $\alpha$-diversity in plots and biotopes whereas the undergrowth cleared forests (FDEFS) in Scio showed the second highest $\alpha$-diversity (Figure 2, Table 2). Both...
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 2. Richness and diversity indices in biotopes.

| Parameters    | FNBAS | FDEFS | PCAFD | PCAFS | PCAOD | PCAOS | PHEVD | PTECD |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 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-       |       |       |       |       |       |       |       |       |
| Weiner 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  |
| Pleiobr         |       |       |       |       |       |       |       |       |
| 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.
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     |
|-----------------|-----|-----|------|------|-------|
| 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    |

ANOVA

| Site andCulture | Duekoué Cocoa | Duekoué Coffee | Scio Cocoa | Scio Coffee |
|-----------------|---------------|----------------|------------|-------------|
| Duekoué Coffee  | ns            |               | ***        | ns          |
| Scio Cocoa      | *             | ***           | ***        | *           |
| Scio Coffee     | ns            | ns            | ns         | *           |

Bonferroni

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).
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    |       |

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 (FDEFS), as well as shrubs and trees, followed by burning (Donald, 2004; Beukema et al., 2007; Biselleu et al., 2008; Baatuuvie 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 plantation 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). Biselleu 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). Zapack 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, farmers 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.) W.F.Wright, *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 (Phlipott 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 Pioul’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 Baatuwije 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 monoculture 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 |
|-------|-----------|----------|----------|-------|-----------|----------|----------|
|       | FDEFS1    | -0.107   | -0.039   | 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    |          |
|       | FNBS1     | -0.123   | -0.081   | PCAFS4| 0.301     | 0.621    |          |
|       | FNBS2     | -0.175   | -0.185   | PCAFS5| 0.175     | 0.583    |          |
|       | FNBS3     | -0.155   | -0.130   | PCAFS6| 0.238     | 0.744    |          |
|       | FNBS4     | -0.120   | -0.153   | PCAFS7| 0.168     | 0.557    |          |
|       | FNBS5     | -0.118   | -0.146   | PCAFS8| 0.283     | 0.707    |          |
|       | FNBS6     | -0.072   | -0.078   | PCAFS10| 0.222    | 0.607    |          |
|       | FNBS7     | -0.157   | -0.128   | PHEVD2| 0.208     | 0.310    |          |
|       | FNBS8     | -0.154   | -0.151   | PHEVD2| 0.262     | 0.440    |          |
|       | FNBS9     | -0.159   | -0.170   | PHEVD3| 0.714     | 0.458    |          |
|       | FNBS10    | -0.154   | -0.139   | PHEVD9| 0.639     | 0.361    |          |
|       | PHEVD1    | -0.002   | 0.149    | PCAFD10| 0.659   | 0.506    |          |
|       | PHEVD3    | -0.002   | 0.149    | 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    | 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   |          |
|       | PTECD11   |          |          | PCAOS8| 0.885     | -0.384   |          |
|       | PTECD12   |          |          | PCAOS10| 0.885   | -0.384   |          |
|       | PTECD13   |          |          | PCAOS9| 0.885     | -0.384   |          |
|       | PTECD14   |          |          | PCAOS8| 0.885     | -0.384   |          |
|       | PTECD15   |          |          | PCAOS7| 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 adiantifolia* (Schum.) W.F.Wight | 4     |       |       |       |       |       |       |       | Natural  |            |
| *Albizia gluterrima* (Schum. and Thonn.) Benth. | 3     | 1     | 2     |       |       |       |       |       | Natural  | Wood       |
| *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       |
| *Antrocyon microstel* A.Chev. and Guill.  | 2     |       |       |       |       |       |       |       | Natural  |            |
| *Baphia nitida* Lodd.                    | 6     | 4     |       |       |       |       |       |       | Natural  |            |
| *Baphia pubescens* Hook.f.               | 9     | 8     |       |       |       |       |       |       | Natural  |            |
| *Belonophora hypoglaucua* (Welw. ex Hiern) A.Chev. | 2     |       |       |       |       |       |       |       | Natural  |            |
| *Bliigma unijugata* Bak.                 | 3     |       |       |       |       |       |       |       | Natural  |            |
| *Bliigia welwitschii* (Hiern) Radlk.      | 2     |       |       |       |       |       |       |       | Natural  |            |
| *Bombax brevicuspe* Sprague              | 4     |       |       |       |       |       |       |       | Natural  | Wood       |
| *Bombax buonopozense* P. Beauv.          | 4     |       |       |       |       |       |       |       | Natural  | Edible     |
| *Bussea occidentalis* Hutch.             | 2     |       |       |       |       |       |       |       | Natural  |            |
| *Caloncoba gigiana* (Sprague) Gilg       | 4     |       |       |       |       |       |       |       | Natural  |            |
| *Calpocalyx Aubrevillei* Pellegr.        | 5     |       |       |       |       |       |       |       | Natural  |            |
| *Calpocalyx brevibacteatus* 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 perpuschrum* Hutch. and Dalz. | 8     | 5     |       |       |       |       |       |       | Natural  |            |
| *Chrysophyllum taiense* Aubrév. and Pellegr. | 3     | 7     |       |       |       |       |       |       | Natural  |            |
| *Cleistopholis patens* (Benth.) Engl. and Diels | 4     |       |       |       |       |       |       |       | Natural  |            |
| *Coffee canephora* Froehn. (= 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.

| Common Name | Code | Natural/Exotic | Use |
|-------------|------|----------------|-----|
| *Cordia platythyrsa* Bak. | 3 | Natural | craft |
| *Corynanthe pachyceras* Schumann | 3 | Natural |
| *Dacryodes klaineana* (Pierre) Lam | 1 | Natural |
| *Desplatsia dewevrei* (De Wild. and Th.Dur.) Burret | 3 | 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 | Natural | Wood |
| *Drypetes chevalieri* Beille | 1 | Natural |
| *Elaeis guineensis* Jacq. | 3 | 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 | Natural |
| *Funtumia africana* (Benth.) Stapf | 5 | Natural | craft |
| *Funtumia elastica* (Preuss) Stapf | 9 | Natural | craft |
| *Glyphaea brevis* (Spreng.) Monachino | 6 | Natural |
| *Greenwayodendron oliveri* (Engl.) Verdc. | 4 | Natural | Medicine |
| *Guarea cedrata* (A.Chev.) Pellegr. | 3 | Natural |
| *Guibourtia ehie* (A.Chev.) J.Léonard | 1 | Natural | Wood |
| *Gymnostemon zaizou* Aubréd. and Pellegr. | 1 | Natural | Medicine |
| *Harungana madagascariensis* Lam. ex Poir. | 3 | Natural | Medicine |
| *Hevea brasiliensis* Müll.Arg. (= Rubber) | 1 | Exotic | Crop |
| *Holoptelea grandis* (Hutch.) Mildbr. | 2 | Natural |
| *Irvingia gabonensis* (O’ Rorke) Baill. | 3 | Natural | Edible |
| *Keayodendron bridelioides* (Hutch. and Dalz.) Léandri | 3 | Natural |
### Appendix 2. Contd.

| Species                                      | Quantity | Habitat  |
|----------------------------------------------|----------|----------|
| *Klainedoxa gabonensis* Pierre               | 4        | Natural  |
| *Lannea welwitschii* (Hiern) Engl.          | 3        | Natural  |
| *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 |
| *Milletia zechiana* Harms                   | 8 3 1    | Natural  |
| *Monodora tenuifolia* Benth.                | 2        | Natural  |
| *Musa paradisiaca* L.                       |          | Exotic Food |
| *Musanga cecropioides* R.Br.                | 2        | Natural  |
| *Myrianthus arbores* 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 hyloendron* 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.

| Species                                       | Code | Natural/Exotic | Wood/craft/Crop |
|-----------------------------------------------|------|----------------|-----------------|
| Rinorea convallarioides (Bak.f.) Eyles        | 1    | Natural        |                 |
| Rothmannia hispida (Schumann) Fagerl.         | 4    | Natural        |                 |
| Rothmannia urecelliformis (Hiern) Robyns      | 3    | Natural        |                 |
| Samanea dinklagei (Harms) Keay                | 3    | Natural        |                 |
| Scottellia klaineana Pierre var. mimfiensis Pellegr. | 4    | Natural Wood   |                 |
| Sterculia rhinopetala Schumann                | 5    | Natural        | Wood            |
| Sterculia tragacantha Lindl.                  | 1    | Natural        |                 |
| Stereospermum acuminatissimum Schumann        | 3    | Natural        |                 |
| Strombosia pustulata Oliv. var. pustulata     | 7    | 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 1          | Crop            |
| Tricalysia macrophylla Schumann               | 7    | Natural        |                 |
| Trichilia martineaui Aubrév. and Pellegr.     | 2    | Natural        |                 |
| Trichilia megalantha Harms                   | 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 Görke                         | 3    | Natural        |                 |
| Xyilia evansi Hutch.                          | 5    | Natural        | Wood            |
| Xylopia quintasii Engl. and Diels             | 3    | Natural        |                 |
| Xylopia villosa Chipp                         | 6    | 2             | Natural         |
| Zanthoxylum gilettii (Engl.) Waterman         | 3    | Natural        | Wood            |
| Zanthoxylum leprieurii Guill. and Perr.       | 5    | Natural        |                 |
| Total                                         | 58   | 85 12 13 7 4 4 12 |                |