Biodivers Conserv (2007) 16:2385–2400
DOI 10.1007/s10531-007-9187-1

ORIGINAL PAPER

Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon

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Received: 24 March 2006 / Accepted: 28 March 2007 / Published online: 31 May 2007

Abstract In the humid forest zone of Southern Cameroon, farmers generally associate cocoa with native and exotic trees in complex agroforestry systems. Despite the socio-economic and ecological importance of these systems, few studies have investigated their plant composition. We investigated tree composition of cocoa agroforests along a gradient of market access, population density and resource use intensity in the humid forest zone of southern Cameroon, comprising (i) the sub-region of Yaoundé, (ii) the sub-region of Mbalmayo, and (iii) the sub-region of Ebolowa. Market access, population density and resource use intensity all decreased from the first to the third sub-region. We quantified the diversity of tree species associated with cocoa within individual agroforests, among agroforests in the same region, and among the three sub-regions, and classified the tree species according to their main uses. A total of 9.1 ha belonging to 60 cocoa agroforests were inventoried in 12 villages. We encountered a total of 206 tree species with an average of 21 tree species per agroforest. In the more urbanized area around Yaoundé, agroforests were less diverse than in the other sub-regions. In all of the agroforests, food producing tree species tended to be more frequent than other species. Two thirds of the food trees were native forest species and one third was introduced. From Ebolowa to Yaoundé, the

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density of food producing trees doubled and the density of exotic food-producing species increased relative to native species. Some local species producing high-value non-timber forest products were found in the agroforests, but their density was far lower than that of exotic tree species. The agroforests also provide medicine, charcoal and other products for household consumption and sale. We conclude that unless there are specific efforts to promote local forest tree species in cocoa agroforests, these will progressively lose importance with increasing market access, population pressure and land use intensity.

Keywords Cocoa agroforest · Congo Basin · Humid forest zone · Land use intensity · Market access · Plant diversity · Southern Cameroon

Introduction

Introduced in Cameroon in 1886 by the German colonial administration, cocoa production shifted from an enclave model of plantations owned by foreign planters to a system based on indigenous smallholders in the mid 1920s (Gockowski and Dury 1999). About 400,000 farmers are currently growing cocoa in Cameroon on about 400,000 ha of land. Farmers of Southern Cameroon have developed a system in which cocoa groves of about 0.7–2 ha are intimately associated with local and exotic tree species (Losch et al. 1991; Gockowski et al. 2004a, b). These cocoa agroforests, which in the past were considered ''indigenous'' or primitive (Champaud 1966), mimic to some extent forest structure and function (FAO 2002). Cocoa agroforests generally result from the clearing of some large forest trees in either secondary or primary forests and the thinning of part of the understory in order to introduce young cocoa plants. Other large trees are left during the establishment of the agroforest. Crops such as banana and plantain are used to shade the cocoa seedlings. As the plantation becomes older, the forest seed bank allows some native trees to regenerate, while some useful exotic and local tree species are planted by the farmers. Those trees gradually replace the temporary shade trees and crops as shade providers to the cocoa trees. The retention of forest trees and the introduction of native and exotic plants determine the composition and structure of the cocoa agroforests. The result is generally a multi-strata and multi-species agroforest whose species composition reflects the needs of the local people.

Growing cocoa under diversified native tree shade is increasingly being viewed as a means of contributing to biodiversity conservation within agricultural landscapes (Rice and Greenberg 2000; Schroth et al. 2004), complementing conservation in protected areas. Cocoa agroforests can play a role in conservation strategies in fragmented landscapes by providing habitat and resources for plant and animal species and by maintaining connectivity between forest areas (Schroth et al. 2004). Research, mainly in Latin America, has provided evidence for the ability of cocoa agroforests to conserve birds, bats, insects and other wildlife to a greater extent than alternative land uses such as cocoa with little or monospecific shade (Rice and Greenberg 2000; Faria et al. 2006; Harvey et al. 2006). Hence, cocoa agroforests will help maintain biodiversity in landscapes where forest habitat is decreasing due to human land use pressure.

Although not always recognized by agronomists (Braudeau 1969; Bidzanga 2005), trees in cocoa agroforests have many more uses for local farmers than just providing a suitable microclimate for cocoa trees. Farmers prefer trees that produce edible and market-oriented products (Franzel et al. 1996; Sonwa 2004). The low cocoa prices during the 1990s in

Cameroon have encouraged farmers to diversify their income by maintaining and introducing useful species (such as timber species, medicinal species and fruit trees) in their cocoa agroforests (Sonwa 2004). Economic factors thus affect the composition and structure of cocoa agroforests, and could potentially lead to their simplification and loss of biodiversity if market forces favor a small number of useful tree species, as is often the case (Ruiz-Pérez et al. 2004). Zapfack et al. (2002) and Bobo et al. (2006) recommended the reintroduction of selected forest tree species in cocoa agroforests to meet both household and conservation needs. Such efforts would need to be based on an understanding of current composition and dynamics of these agroforests.

The objective of this study was to characterize the tree diversity within and among cocoa agroforests in southern Cameroon and to determine patterns of tree species composition as related to market access, land use intensity and population density. We recorded tree species and their uses in cocoa agroforests on a gradient of population density and market access (ranging from the relatively remote villages around Ebolowa in the south to the more densely settled area around the capital Yaoundé in the north) in order to determine which species or use groups are likely to benefit from increasing market access and population density and which species tend to decrease and may require specific interventions for their conservation in the agricultural landscape.

Material and methods

Study site

In Cameroon, cocoa is mainly produced in the South West, Littoral, East, Central and South provinces (Losch et al. 1991). This study focused on the Central and South provinces. The southern part of Cameroon was originally largely covered by evergreen forest dominated by tree species such as *Gossweilerodendron joveri, Erythrophleum suaveolens, Detarium macrocarpum* and *Canarium schweinfurthii* (Zapfack et al. 1996). The climax vegetation in the study area includes dense semi-deciduous forest (mainly in the Yaoundé area), dense evergreen humid Congolese forest (mainly around Ebolowa), and mixed forests around Mbalmayo (Letouzey 1979, 1985). The whole area is characterized by high plant and animal diversity. Logging is very common and has already led to widespread forest degradation and subsequent deforestation (Essamah-Nsah and Gockowski 2000; Mbarga Bindzi 2005). Despite this degradation and deforestation, the country is among the top six countries in Africa in terms of total numbers of mammals, birds, and higher plants (GFW 2000). At the regional level, the forest of Cameroon still constitutes an important component of the Congo Basin (Kamdem-Toham et al. 2006). Cameroon has the highest number of plants per unit area in the region, with mammal and bird species counts surpassed only by Equatorial Guinea (GFW 2000). According to Okigbo (1994, cited by Essamah-Nsah and Gockowski 2000), the estimated over 10,000 plant species in Cameroon are only exceeded in number by the much larger Democratic Republic of Congo (formerly Zaire) in West and Central Africa. For the local population, forests are a source of construction materials, food, medicine and other non-timber forest products (NTFPs), and of land for farming.

As part of the Alternatives to Slash and Burn (ASB) program, the humid forest zone of Southern Cameroon was chosen as a model site to research and develop technologies and policies for natural resource management suitable for the Congo Basin (ASB 2000; CGIAR 2000). A benchmark research area (representing the Congolese rainforests of Africa) of

1.54 M ha was delineated, spanning a gradient of population density and market access, resource use intensity as well as significant spatial variation in soils and climate (Fig. 1; Tables 1 and 2). Average annual rainfall ranges from 1600 to 1820 mm and falls in a bimodal pattern. The soil of the benchmark falls mainly into the broad FAO soil class of Orthic Ferralsols. Primary forest still covers 3.7% of the area around Yaoundé, 5.3% of the area around Mbalmayo and 22% of the area around Ebolowa (Thenkbail 1999).

Across the benchmark area, 24.8% of the total surface area is estimated to be under agricultural use (including fallows). Cocoa occupies 48% of the total area under agricultural use. Over 100,000 ha of fallow land are cleared annually to create crop fields

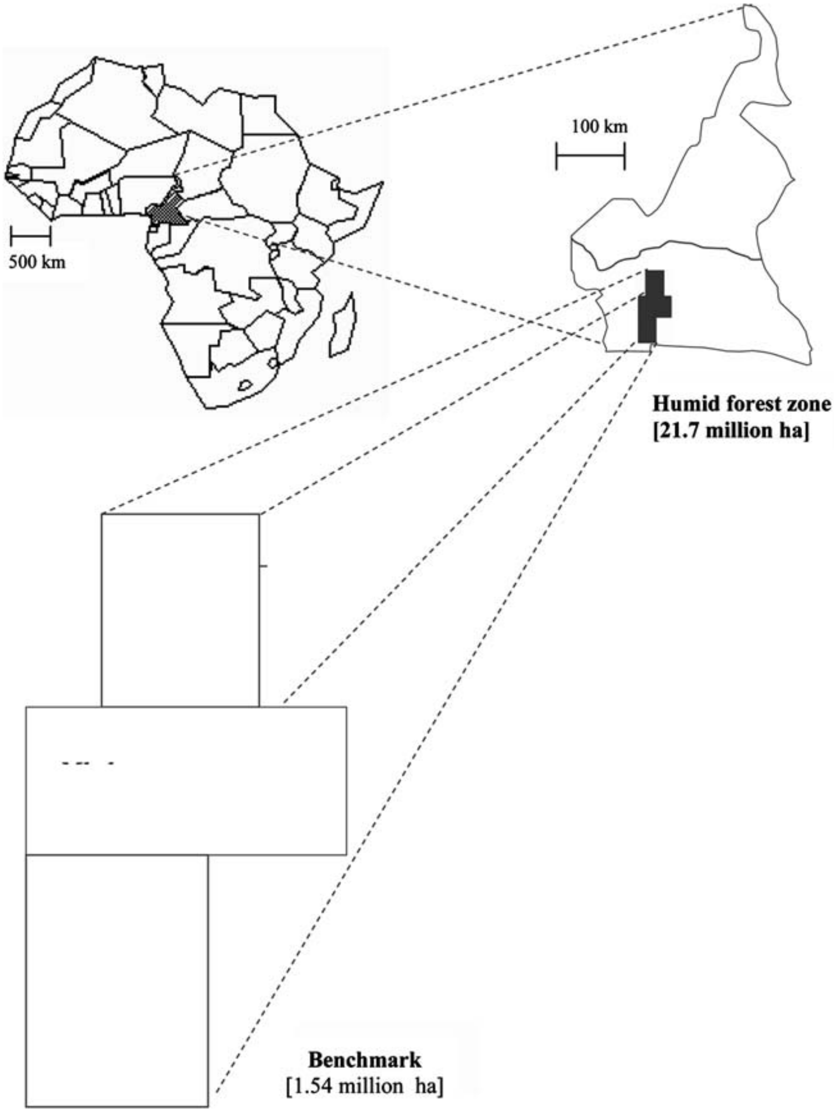

Fig. 1 The benchmark area of Southern Cameroon, consisting of the (from north to south) Yaoundé, Mbalmayo and Ebolowa sub-regions

Table 1 Biophysical and socioeconomic characteristics of the three study regions in Southern Cameroon

	Ebolowa	Mbalmayo	Yaoundé
Latitude	2°22–2°55′	3°16′–3°36′	3°46′–4°14′
Longitude	11°15′–11°25′	11°24′–11°47′	11°15′–11°33′
Surface area (M ha)	0.51	0.51	0.51
Primary and old secondary forest (% land)	22–58#	14.4	7.7
Young secondary forest† (% land)	10–35#	34.2	21.1
Secondary forest under-planted with cocoa†, (% land)	4–10#	2.39	1.21
Annual rainfall (mm)	1820	1600	1600
Distance from Yaoundé (km)	181–262	50–123	15–86
Villages on paved roads	7%	27%	67%
Habitants per km^2 (n = 15 villages)	2–15#	10–41	14–88
Fallow length of food crops (years)	7.5	5.4	3.9
Frequency of cocoa plantation (% households)	96	74	63
Household income contribution from cocoa or fruit trees (%)*	41–47 #	24–18	14 – 17
Household income contribution from cash crops (%)*	25–17	40–42	48–49
Household income contribution from gathering (%)*	11–13	16–14	13–9
Household income contribution from hunting (%)	53	27	0
Household income contribution from non agricultural work (%)*	23– 21	20–26	26 – 25
Household income contribution from remunerated work (%)	7	13	33
Average distance from villages to market (km)	21	20	17
Average cost of transport per person from villages to market (FCFA)	493	503	292

Sources: Gockowski (1996), Thenkabail (1999)

* Based on data from two main villages per subregion

† Data estimated from remote sensing

The lower value refers to the area around the town of Ebolowa and the higher value to the more forested area around Abam

1$ = 700 CFA (1990–1999)

representing 3.8% of the total land area. Mixed farming is common and is based on groundnut-cassava and squash-plantain systems. Food crops are mainly grown to meet subsistence needs, with any surplus sold on the market. Cocoa used to provide 50–75% of the household income in the 1980s (Leplaideur 1985) but this value has now fallen to 14–47% (ASB 2000). Forest products such as bush meat and the gathering of NTFPs in remaining forest, fallow and cocoa agroforests also make a small contribution to livelihood needs, with hunting being most important in Ebolowa (Table 1). Villages are mostly small, with most of them having only a few hundred inhabitants. About 10–42% of the households are headed by women (ASB 2000).

Tree inventories

Vegetation data were collected in 60 agroforests across 12 villages (4 per sub-region), with five representative cocoa agroforests selected randomly in each village. In each cocoa

Table 2 Villages in three sub-regions of Southern Cameroon where cocoa agroforests were inventoried

Sub-region	Villages	Distance from Yaoundé (km)	Coordinates	
			Latitude	Longitude
Yaoundé	Nkometou	22	4°05′25	11°33′15
	Nkongmesse	93	4° 14′40	11°15′30
	Nkoumadzap	28	3°46′00	11°25′10
	Minsoa	45	4°05′35	11°16′05
Mbalmayo	Awae	50	3°36′30	11°36′40
	Mvoutessi	123	3°16′30	11°47′45
	Ngat-Bane	68	3°25′00	11°34′00
	Evidinssi	80	3°26′00	11°24′00
Ebolowa	Akok	202	2°44′30	11°25′00
	Mengomo	215	2°35′15	11°18′00
	Mekomo	262	2°22′00	11°15′05
	Avam-Yevol	181	2°55′50	11°15′00

farm, 25% of the entire agroforest area was surveyed (a cocoa agroforest sample was 5534 m^2 on average, ranging from 1053 m^2 to 15051 m^2). This sample area was further divided into elementary plots of 25 m × 25 m which were randomly located in the agroforests. A total of 146 elementary plots were surveyed, representing a total area of 9.1 ha (52, 50 and 44 elementary plots, representing 3.25, 3.13 and 2.75 ha for Ebolowa, Mbalmayo and Yaoundé, respectively). In each of the elementary plots, all non-cocoa trees (including pseudo-trees such as bananas and palms) with a diameter at breast height (dbh) $\geq$ 2.5 cm were recorded. Species were identified following Vivien and Faure (1985, 1996) and Letouzey (1982) and by comparison with specimens in the National Herbarium, Yaoundé. The main uses of the plant species were identified through interviews with local cocoa farmers. The species were then grouped into one of the following classes: edible, medicinal, timber and others. Edible species comprise exotic fruits including bananas and plantains, as well as edible indigenous species including oil palm (*Elaeis guineensis*). Timber species were divided into those of high value (listed by the Office National de Developpement des Forêts, ONADEF as exported species) and low value (used mainly locally). Other species included pioneer trees that had re-grown since the cocoa farm was established.

Data analysis

For the analysis of the floristic composition of the agroforests, species richness, diversity and equitability were calculated for the non-cocoa trees in each of the 60 agroforests using information from the sample plots. Species richness was expressed as the number of non-cocoa tree species per agroforest by combining all the species recorded in all the sample plots inside the plantation. Diversity was calculated using the Shannon index, the Simpson index and the Piélou equitability index (Sonké 1998) at the level of each cocoa agroforest using the data of the individual plots. The Shannon index tends to be weighted slightly towards less abundant or rare species, while the Simpson index favours the more abundant or dominant species (Zapfack et al. 2002). The two indices together give a good description of the alpha (within site) diversity of the agroforest. The Pielou equitability index provides information on the distribution of individuals among the species; it is high if all species are about similarly abundant and low if some species dominate in number.

The average values for each of the three sub-regions and for the entire study region were calculated from data of the individual cocoa farms. Not all variables, at the sub-region level or the entire area study, had normal distributions according to the ''Goodness-of-Fit Test'' and ''test for normality''. The non parametric Kruskal–Wallis test was used to analyze data with non-normal distribution with the help of the statistical package STATGRAPHICS® (Centurion XV User Manual). All probabilities were evaluated at the 5% confidence level.

Species area curves showing the cumulative increase in species with increasing cocoa agroforest area inventoried were drawn for the entire study area and for the three sub-regions, using EstimateS 7.5 (Gotelli and Colwell 2001; Colwell et al. 2004). The Sorensen index (Sonké 1998; Zapfack et al. 2002) was calculated to determine similarities in species composition across pairs of sub-regions and across sites within the same sub-region.

Results

Species richness and diversity

A total of 206 tree species were found associated with cocoa in the 146 plots (9.1 ha) sampled. The total number of species per sub-region in Yaoundé, Ebolowa and Mbalmayo were 101, 138 and 125, respectively. The overall species accumulation curve (for the three sub-regions combined) tended to level off when approaching the total sample area of 9.1 ha, suggesting that the tree species composition of the cocoa agroforests in the region was satisfactorily sampled (Fig. 2).

On average, each agroforest had 21 tree species associated with cocoa (Table 3). The cocoa agroforests in the Yaoundé area were significantly poorer in tree species and had lower equitability indices than those in Ebolowa and Mbalmayo, indicating that they were more dominated by a subset of tree species. The Sorensen index was 0.44 between the 3 sub-regions, 0.59 between Ebolowa and Mbalmayo, 0.58 between Mbalmayo and Yaoundé, and 0.55 between Ebolowa and Yaoundé.

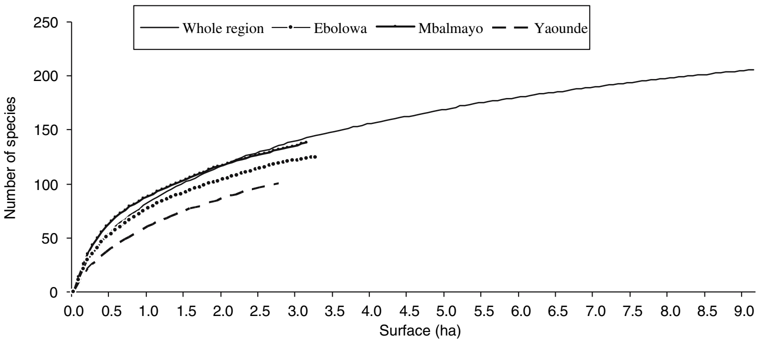

Fig. 2 Cumulative curve of plant species associated with cocoa plantations in southern Cameroon

Table 3 Average species richness and diversity (± standard error) of trees per cocoa agroforest in three sub-regions of Southern Cameroon

	Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)	P-Value
Species richness	21 (± 1.8) a	26 (±2.3) a	15 (±1.2) b	21(±1.1)	0.001
Shannon index	3.9 (± 0.13) a	4.2 (±0.12) a	3.1 (±0.16) b	3.7(±0.96)	<0.001
Piélou equitability	0.734 (± 0.022) a	0.753 (±0. 0.016) a	0.602 (±0.0.031) b	0.696 (±0.016)	<0.001
Simpson index	0.097 (± 0.010) a	0.076 (±0.006) a	0.188 (±0.234) b	0.12 (±0.011)	<0.001

P-values are the significance level of the Kruskal–Wallis test; n.s = not significant (p > 0.05). Sub-Regions not sharing a common letter in a row are significantly different at P = 0.05

Species frequency and abundance

The 10 most frequent tree species were found in half of the inventoried cocoa agroforests (Table 4). Oil palm, African pear (*Dacryodes edulis*) and (with the exception of

Table 4 The 10 most frequent tree species[#], with a diameter at breast height ≥ 2.5 cm, in cocoa agroforests in three regions of Southern Cameroon, and percent of inventoried agroforests where they were present

Species	Family	Main use	Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)
Elaeis guineensis	Arecaceae	CI	80	70	90	80
Dacryodes edulis	Burseraceae	CI	45	60	90	65
Persea americana	Lauraceae	CE	65	50	70	62
Ficus exasperata	Moraceae	O	50	70	30	50
Terminalia superba	Combretaceae	HVT	40	55	50	48
Ficus mucuso	Moraceae	O	40	75	30	48
Musa paradisiaca	Musaceae	CE	40	25	75	47
Spathodea campanulata	Bignoniaceae	O	35	50	55	47
Albizia adianthifolia	Mimosaceae	LVT	35	60	45	47
Margaritaria discoidea	Euphorbiaceae	O	60	60	65	47
Funtumia elastica	Apocynaceae	LVT	55	55	0	37
Pycnanthus angolensis	Myristicaceae	LVT	50	45	20	38
Petersianthus macrocarpus	Lecythidaceae	HVT	50	25	30	35
Hallea stipulosa	Rubiaceae	HVT	50	10	5	22
Mangifera indica	Anacardiaceae	CE	45	25	65	45
Rauvolfia vomitoria	Apocynaceae	M	0	70	40	37
Milicia excelsa	Moraceae	HVT	20	65	40	42
Grewia brevis	Tiliaceae	O	5	60	5	23

HVT: High Value Timber; LVT: Low Value Timber; CI: Native edible species; M: Medicinal; CE: Exotic edible species; O: Other species; [#] frequency here refers to the percent of the cocoa agroforests where the species occurred at least once

Mbalmayo) avocado (*Persea americana*) were the tree species that were most commonly found in cocoa agroforests across the study region. Oil palm occurred in at least 70% of the agroforests in all three regions.

Across all three sub-regions, the ten most abundant tree species accounted for 45% of all trees associated with cocoa. In Yaoundé, where the cocoa agroforests were less species-rich than in the other two areas, the ten most common species accounted for 68% of all trees associated with cocoa, with oil palm accounting for 17% and plantain for 23% of all trees associated with cocoa. In the Ebolowa and Mbalmayo sub-regions, the ten most frequent species accounted for 44% and 40% of all trees associated with cocoa, respectively. Apart from oil palm and plantain, no species accounted for more than 8% of the tree individuals in the agroforests.

Due to the relative dominance of plantain and oil palm, the *Musaceae* and *Arecaceae* were the most abundant families in the agroforests, followed by *Moraceae, Apocynaceae, Burseraceae* and *Mimosaceae*; each of these families represented at least 5% of the total number of plants associated with cocoa. The ten most abundant families accounted for 70% of the trees in the agroforests in the Ebolowa and Mbalmayo sub-regions and for 80% of the trees in the less diversified agroforests in the Yaoundé sub-region (data not shown).

Main uses of plants

For the study area as a whole, 17% of the tree species associated with cocoa had edible products, 11% produced low value timber, 11% produced high value timber, and 8% had mainly medicinal uses (Table 5). For 53% of the tree species associated with cocoa, farmers did not specify any important uses in the interviews. Among the 36 edible species, 11 were exotics. More indigenous edible species were found in Ebolowa and Mbalmayo than in Yaoundé. There were also more timber species of both high and low value in Ebolowa and Mbalmayo than in Yaoundé.

Individual cocoa agroforestry systems had an average of 6 species of food producing trees, 2 species of trees of medicinal value, and 7 timber species (Table 6). There were significantly more timber species in both Mbalmayo and Ebolowa than in Yaoundé, while

Table 5 Total number of tree species, with a diameter at breast height ≥ 2.5 cm, in cocoa agroforests in three regions of Southern Cameroon according to their main uses

Main use of plant		Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)
Edible*	Exotic	9	7	8	11
	Indigenous	18	24	15	24
	Subtotal edible	27	31	23	35
Timber	High value	15	19	14	23
	Low value	19	18	12	23
	Subtotal timber	34	37	26	46
Medicinal		12	10	8	17
Others (minor uses or unknown uses)		52	60	43	108
Total		125	139	101	206

* including oil palm, banana and plantain

Table 6 Average number of tree species (± standard error) in cocoa agroforests in three sub-regions of Southern Cameroon according to their main uses

Main uses	Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)	P-Value
Edible	6.65 (± 0.81)	6.0 (±0.74)	5.6 (±0.51)	6.08 (±0.40)	n.s
Medicinal	1.6 (± 0.27)	2.05 (± 0.32)	1.2 (±0.21)	1.61 (± 0.16)	n.s
Timber	7.0 (± 0.70) a	8.85 (± 0.89) a	3.9 (± 0.59) b	6.6 (± 0.49)	<0.001
Other (minor or no known uses)	5.8 (± 0.71) b	8.65 (± 0.96) a	4.2 (± 0.48) b	6.21 (± 0.48)	0.002
Total	21.1 (± 1.83) a	25.55 (± 2.33) a	14.95(± 1.23) b	20.51 (± 1.19)	0.001

P-values are for the Kruskal–Wallis test; n.s = not significant. Sub-Regions not sharing a common letter in a row are significantly different at P = 0.05

the number of food producing and medicinal species did not differ among sub-regions. From Ebolowa to Yaoundé, the number of trees (both native and exotic) with edible products per ha doubled, while the number of timber (high and low value), medicinal, and other (''mainly shade'') plants decreased (Table 7).

Among the 14 NTFP species for which, according to Wilkie (2000), market demand exceeds availability in Central Africa, six were present in the cocoa agroforests (Table 8), reflecting their potential economic role beyond producing cocoa. The average density of two of these species, *Irvingia gabonensis* and *Ricinodendron heudelotii*, tended to increase with increasing distance from Yaoundé, while the density of *Dacryodes edulis* tended to increase with decreasing distance from Yaoundé (Table 8). Of the 35 main species logged in Central Africa (CIFOR 2004), 16 were found inside cocoa agroforests albeit at low densities (data not shown).

Discussion

Plant diversity and landscape context of the cocoa agroforests

The cocoa agroforests of southern Cameroon harbour substantial tree diversity. A total of 206 tree species were recorded in 60 agroforests across the three sub-regions and an

Table 7 Density (± standard error) of different types of trees in cocoa agroforests in three sub-regions in Southern Cameroon (trees per ha)

Tree type	Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)	P-value
Exotic edible	45 (± 14.0) b	20 (±6.0) b	104 (±23.8) a	56 (±10.3)	<0.001
Native edible	61 (± 9.9)	73 (±10.9)	90 (±10.3)	75 (±6.1)	n.s.
High value timber	45 (± 5.5) a	55 (±8.0) a	26 (±5.7) b	37 (±4.0)	0.0096
Low value timber	58 (± 9.8) a	76 (±14.3) a	22 (± 4.8) b	52 (±6.6)	<0.001
Medicinal	20 (± 4.1) b	39 (± 9.4) a	14 (± 2.6) b	24 (±3.7)	n.s.
Other (minor uses or unknown uses)	71 (± 7.9) b	97 (± 9.1) a	53 (± 9.4) b	73 (±5.5)	0.001

P-value is the significance level of the Kruskal–Wallis test, n.s = not significant (P > 0.05). Sub-Regions not sharing a common letter in a row are significantly different at P = 0.05

Table 8 Density (± standard error) of tree species producing non timber forest products for which market demand exceeds availability in Central Africa in cocoa agroforests in three sub-regions of Southern Cameroon

Plant species	Family	Density (trees/ha)				
		Ebolowa (n = 20 agroforests)	Mbalmayo (n = 20 agroforests)	Yaoundé (n = 20 agroforests)	Whole region (n = 60 agroforests)	P-value
Cola acuminata	*Sterculiaceae*	0.3 (±0.3)	2.6 (± 1.5)	0.4 (±0.4)	1.1 (±0.5)	n.s.
Dacryodes edulis	*Burseraceae*	8.1 (±2.9) b	19.0 (± .4) a	23.1 (±4.5) a	16.7 (±3.1)	0.004
Garcinia mannii	*Clusiaceae*	0.1 (±0.1)	0.0 (±0.0)	0.0 (±0.0)	0.04 (±0.1)	n.s.
Irvingia gabonensis	*Irvingiaceae*	1.3 (±0.6)	0.9 (±0.6)	0.4 (±0.4)	0.9 (±0.3)	n.s.
Pausinystalia johimbe	*Rubiaceae*	1.5 (±0.9) a	0.0 (±0.0) b	0.0 (±0.0) b	0.5 (±0.0)	0.045
Ricinodendron heudelotii	*Euphorbiaceae*	1.2 (±0.6)	0.8 (±0.5)	0.2 (±0.2)	0.7 (±0.3)	n.s.

P-value is the significance level of the Kruskal–Wallis test, n.s. = not significant (p > 0.05). Sub-Regions not sharing a common letter in a row are significantly different at P = 0.05

average of 21 species occurred per agroforest. These cocoa agroforests have a high tree diversity compared to cocoa production systems in other parts of the tropics. For example, in an inventory of 60 traditional cocoa agroforestry systems of the Osino district of the Eastern Region of Ghana, Osei-Bonsu et al. (2003) found 116 species of trees on 79.1 ha inventoried. Rolim and Chiarello (2004) found 105 tree species, with a diameter at breast height $\geq$5 cm, on 4.8 ha of traditional cocoa agroforests in Southern Bahia, Brazil, compared to 167 species for the same sampling area in this study (see Fig. 2).

However, the high abundance of non-primary forest species like oil palm, African pear and avocado points to the degree of alteration of the cocoa agroforests compared to primary forest. Around Yaoundé, oil palm and plantain alone represented 40% of all trees in the agroforests. Other workers have shown that the plant species composition of cocoa agroforests in southern and south-western Cameroon is quite distinct from that of natural forest (Zapfack et al. 2002; Bobo et al. 2006). Zapfack et al. (2002) reported a Shannon–Weaver index of 4.39 in cocoa agroforests compared to 6.64 and 6.68, respectively, in primary and secondary forests, in southern Cameroon. The number of tree species in cocoa agroforests was 27.5% lower than that in primary forests in southern Cameron (Zapfack et al. 2002) and 62.1% lower in south-western Cameroon (Bobo et al. 2006). Floristic impoverishment relative to forest has also been shown for cocoa agroforests in Brazil, where natural succession and gap dynamics have been severely impaired and pioneers and early successional species are dominant (Rolim and Chiarello 2004).

The cocoa agroforests in the three sub-regions had many tree species in common, with 54 species shared across all three sub-regions and 60% of the species shared between Ebolowa and Mbalmayo and between Mbalmayo and Yaoundé, respectively. However, despite these similarities, there were also significant differences in species composition across sub-regions and individual villages. All of the diversity indices increased from cocoa agroforests located in villages which have good market access, high population density and consequently higher land use intensity around Yaoundé towards those in the more remote areas around Mbalmayo and Ebolowa, indicating that the socio-economic and ecological environment influences the species composition of the cocoa agroforests. It is already well established that market access drives forest peoples to specialize on the harvesting and cultivation of a sub-set of their local forest species (Ruiz-Pérez et al. 2004). This specialization process was reflected in a lower equitability index of the cocoa agroforests in the Yaoundé sub-region compared to Mbalmayo and Ebolowa.

These patterns of tree species richness of the cocoa agroforests in the different sub-regions parallel those of remaining forest cover in the landscape. In the Yaoundé sub-region, the cocoa agroforests that have the lowest tree diversity are located in a landscape mosaic with 7.7% of primary and old secondary forest and 21.1% of young secondary forest, while the more species rich agroforests in the south of the Ebolowa sub-region are located in a landscape with 22 to 58% of primary forest; Mbalmayo agroforests are intermediate in both cocoa tree diversity and remaining forest cover. The degree of fragmentation of the remaining forest also increases from Ebolowa to Yaoundé (Thenkabail 1999). The Ebolowa region is still characterized by relatively stable slash and burn agriculture at the fringe of the forest, and cocoa farmers reported occasional incursions of forest fauna such as gorillas and chimpanzees into their cocoa agroforests (which ate cocoa fruits and were hunted). The Yaoundé sub-region, in contrast, is a heterogeneous patchwork of land uses dominated by farmland.

Utility of trees associated with cocoa

The high percentage of useful (including exotic) tree species in cocoa agroforests and their increased abundance in the more intensely used landscape (Yaoundé) reflect the fact that farmers actively retain or introduce useful tree species into the cocoa agroforests. The preference for useful tree species is understandable in the context of Cameroon where 40% of the population lives below the poverty line of 1 dollar per day (UNDP 2004). The presence of trees in cocoa agroforests helps farmers achieve their basic needs of food, health, energy and housing. It is against this background that the potential of cocoa agroforests for the conservation of forest biodiversity needs to be analysed.

Trees with edible products were the most common tree species in the cocoa agroforests. Beside common crop species like oil palm, banana and plantain, they included local NTFP species such as the African pear (*D. edulis*), a tree of up to 20 m height that is common in agroforestry systems of West and Central Africa (Vivien and Faure 1996; Sonwa et al. 2002). The density of trees with edible products was highest in cocoa agroforests in the Yaoundé sub-region, where previous research had shown a stronger market orientation of agricultural activities compared to the more remote cocoa regions (Gockowski and Doumbe 1999). From Ebolowa to Yaoundé, the density of native tree species with edible products increased 1.5 fold, while that of exotic tree species of the same use category increased 2.3 fold (Table 7), showing a substitution of native by exotic species with increasing market access and land use intensity. In the village of Obala in the Yaoundé sub-region, the drop of cocoa prices around 1987 led to the development of a cocoa based agroforestry system with 189 trees with edible products (and 35 timber trees) per hectare, of which 77% were exotic species (Gockowski and Dury 1999). In comparison, of the tree species yielding edible products in the Ebolowa sub-region only 42% were exotic. The substitution of native by exotic tree species in areas with good market access is partly a consequence of the neglect of wild species by research, extension and marketing support. It should be mentioned that several of the tree species found in the agroforests, while not edible themselves, are known to be hosts of edible caterpillar species (Balinga et al. 2004; Mekembom 2005). The latter author also listed several vines with edible products that occur on cocoa or associated trees.

More than one in five tree species in the cocoa agroforests were timber species. Timber species occurred in lower densities in the Yaoundé area than in the Ebolowa sub-region, because timber trees in the Yaoundé area have been logged and replaced with (often exotic) fruit trees. Timber from cocoa agroforests is mostly sold in local urban markets, although 10% of Cameroon's timber exports are also derived from ''non forest land'', including cocoa agroforests (Eba'a Atyi 1998). Plouvier et al. (2002) found that the Yaoundé area is the main source of ''artisanal timber'' in Cameroon, suggesting that timber from cocoa agroforests could have an interesting market. However, cocoa farmers need a permit to legally sell timber trees from their farms, and the difficulty of obtaining these permits results in trees being sold illegally for very low prices compared to the international market value of the timber (Gockowski et al. 2004b). Besides being a potentially interesting source of income, timber trees such as *Terminalia superba* and *Ceiba pentandra* also contribute to the structural diversification of the agroforests, which is important for creating habitat for local fauna (e.g., birds) and flora (e.g., vines, epiphytes).

Farmers continue to rely on medicine from their agroforests. On average two tree species used mainly for medicine were found per cocoa agroforest and this number was not significantly different among the sub-regions. Tree species such as *Alstonia boonei* and *Enanthia chloranta* that are found in cocoa farms are commonly used against malaria. Ndoye et al. (1999) reported that from 1985 to 1998, the collection of various medicinal products from the wild increased 2 to 10 fold in Southern Cameroon. Since the collection of bark (the most commonly commercialized part) with medicinal properties can threaten the survival of the trees, several authors recommended the cultivation of such tree species in farm land and agroforests (Zapfack et al. 2002; Facheux et al. 2003; Bobo et al. 2006), complemented by sustainable harvesting techniques.

The density of the trees with minor (or no known) uses in the agroforests decreased from Ebolowa to Yaoundé, reflecting the increasing management intensity. In this category are species that were left over from the previous forest or regenerated spontaneously. Researchers working in Côte d'Ivoire found that many tree species in cocoa farms are retained because they are difficult to remove (Rouw 1987; Herzog 1994; N'goran, 2003). However, many of these tree species could provide fuel wood and charcoal. Of the 23 tree species listed by FAO (1999) as being used for charcoal in Cameroon, 17 were found in the cocoa agroforests, reflecting their potential contribution to meeting rural energy needs.

Conclusion

This study illustrates the multiple uses of native biodiversity in the cocoa agroforests of southern Cameroon. Income from trees associated with cocoa can complement that from the cocoa itself. We found many potentially valuable NTFP and timber species from the local forest flora that can grow well in cocoa agroforests. However, with increasing market access and land use intensity, native forest species were increasingly replaced with common and often exotic tree crops such as oil palm, banana, plantain and avocado. To counter this market pressure and maintain the potential of cocoa agroforests to conserve local forest tree species under increasing land use pressure, more efforts are needed to develop the markets for native forest species and provide rewards to farmers for their conservation efforts. Such efforts would have the benefit of helping to maintain access for poor people to forest products such as food, medicinal products and charcoal despite increasing land use pressure.

Acknowledgement This research was funded by International Institute of Tropical Agriculture, Sustainable Tree Crops Program, Deutscher Akademischer Austauschdienst and Mars Inc. We thank Goetz Schroth, Celia Harvey and Robert Nasi and an anonymous referee for their comments on earlier versions of the paper. Louis Zapfack and Bonaventure Sonke of the University of Yaoundé I, and Paul Mezili and Anacletus Koufani of the National Herbarium in Yaoundé helped in tree species identification.

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