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# Impact of cocoa farming on vegetation in an agricultural landscape in Ghana

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## Abstract

Cocoa production occurs almost wholly within areas identified as biodiversity hotspots in West Africa and it has been noted as a major contributor to deforestation at the forest-agriculture interface. This study investigated the impact of cocoa farming on vegetation in relation to three land-use types of increasing cocoa production intensity from remnant native forest through shaded to unshaded cocoa farmlands in Ghana. The study used transects and forty-two 25 m × 25 m vegetation plots. The overall noncocoa plant species richness decreased significantly (95% CI) from the remnant native forest through shaded to the unshaded cocoa farmlands. Significant differences ($P \leq 0.05$) were also found in the mean density and basal area of noncocoa plants per hectare with the remnant native forest recording the highest values and the unshaded cocoa farmlands the lowest. The relative density of about 44.7% out of the 41 most abundant plant species declined in cocoa farmlands. The results of this study showed that cocoa farming could result in a drastic forest plant species loss with subsequent recruitment of nonforest species, forest plant species population decline as well as changes in the structural characteristics of the vegetation. This impact increases with increasing cocoa production intensity.

*Key words:* biodiversity, cocoa, Ghana, management, vegetation

## Résumé

En Afrique de l'Ouest, le cacao est produit presque entièrement dans des zones identifiées comme des hauts-lieux de la biodiversité et l'on a noté qu'il contribue toujours de façon importante à la déforestation à l'interface entre forêts et terres agricoles. Cette étude a analysé l'impact de la culture de cacao sur la végétation pour une utilisation des terres de trois types caractérisés par des intensités de production de cacao croissantes, allant des restes de forêt native à des exploitations ombragées et non ombragées de cacao, au Ghana. Cette étude a utilisé des transects et 42 parcelles de végétation de 25 m × 25 m. La richesse globale en espèces végétales - hors cacao - diminuait significativement (IC 95%) en passant des restes de forêt native aux exploitations de cacao ombragées et ensuite à celles qui sont exposées au soleil. On a aussi trouvé des différences significatives ($P \leq 0{,}05$) de la densité moyenne et de la surface basale par hectare des plants hors cacao, la forêt native restante donnant les valeurs les plus hautes et les exploitations exposées de cacao, les plus basses. La densité relative de près de 44,7% des 41 espèces végétales les plus abondantes diminuait dans les exploitations de cacao. Les résultats de cette étude ont montré que la production de cacao pouvait entraîner une perte drastique des espèces végétales forestières suivie d'un recrutement d'espèces non forestières, un déclin des populations d'espèces végétales forestières et des changements des caractéristiques structurelles de la végétation. Cette impacts augmentaient avec l'intensification de la production de cacao.

## Introduction

Agricultural production is a major cause of deforestation in the world and the leading driver of biodiversity loss in the tropics (Primack & Corlett, 2005). It is argued that the fate of biodiversity is intimately linked to the use of land for agricultural production (Mattison & Norris, 2005). Recently, the impacts of some major agricultural crop commodities such as cocoa (*Theobroma cacao*), coffee (*Coffea arabica*) and oil palm (*Elaeis guineensis*) on biodiversity have

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become a major issue of international conservation interest (Donald, 2004).

Cocoa is the world's third most important agricultural export commodity, after coffee and sugar and a major earner of foreign income for countries such as Côte d'Ivoire and Ghana that dominate production. Despite being a plant of Amazonian origin, cocoa is the major agriculture commodity crop in lowland forests in West Africa where about 60% of the world's cocoa is produced (Rice & Greenberg, 2000). Cocoa production occurs almost wholly within areas identified as biodiversity hotspots in West Africa (Myers *et al.*, 2000) and it has been noted that cocoa production is likely to remain a major contributor to deforestation at the forest-agriculture interface particularly in West Africa (Donald, 2004).

In Ghana, the cocoa industry is a critically important component of the agricultural sector. It occupies a key position in terms of foreign exchange revenues and domestic incomes, as well as being the major source of revenue for the provision of socio-economic infrastructure (Asante, 2005). It is currently estimated that there are about 2,988,395 acres of land cultivated with cocoa in Ghana, with about 445,145 farmers in rural communities depending on cocoa farming for their livelihoods (Asante, 2005). Ghanaian cocoa exports account for about 40% of total exports, and in 2004, cocoa was the major export earner for the country (Asante, 2005). The government of Ghana has prioritized cocoa as a commodity crop and is aiming to increase cocoa production from current level of 745,000 MT to 1,000,000 MT by the year 2010.

However, one of the major problems facing sustainable cocoa production in Ghana is that to increase cocoa yield, some farms were established in clear cut forests providing poor habitats for a wide range of biodiversity (Asare, 2006). In such instances, there is increased cocoa yield, but this puts, significant ecological stress on the cocoa trees, which become susceptible to pests attack and productivity decline within a relatively few years (Rice & Greenberg, 2000). Efforts to adopt more sustainable ways of cocoa farming by farmers in Ghana in terms of long-term productivity and minimal impacts on biodiversity are being encouraged. Within the West Africa sub-region, the impact of cocoa farming on plant diversity has been studied largely from Cameroon (Zapfack *et al.*, 2002; Bisseleua, Hervé & Vidal, 2007; Schroth & Harvey, 2007; Sonwa *et al.*, 2007) with few studies from Nigeria (Oke & Odebiyi, 2007) and Ghana (Attua, 2003; Osei-Bonsu, Ameyaw & Tetteh, 2003; Ofori-Frimpong, Asase & Mason, 2005). Despite the above contributions, there are few studies that analyse differences between different types of cocoa production in relation to native forests, although this information has the potential to inform management practices.

This study investigated the impact of cocoa farming on vegetation in relation to three land-use types of increasing cocoa production intensity from remnant native forest through shaded cocoa farmland to unshaded cocoa farmland in a cocoa production landscape in Ghana. The study analysed this impact in terms of species diversity, vegetation structure and species population changes.

## Materials and methods

### *Study area*

This study was conducted in the Eastern Region of Ghana. The vegetation in the study area falls within the Upland Evergreen forest of Ghana (Hall & Swaine, 1981). The mean annual rainfall is between 1200 mm and 1800 mm and is characterized by a two-peak rainy season in April–June and October. A mild harmattan season occurs from November to March. Cocoa is the most economically important cash crop in the study area. Other common crops cultivated included plantain (*Musa paradisiaca*), banana (*Musa sapientum*), cassava (*Manihot esculenta*), maize (*Zea mays*) and cocoyam (*Xanthosoma sagittifotium*).

For this study, three broad land-use types, namely, remnant native forest, shaded cocoa farmland and unshaded cocoa farmland were identified. The density of cocoa trees in the three land-use types of increasing cocoa production intensity ranged from zero for the remnant native forest through an average of 76 trees $ha^{-1}$ for shaded cocoa farmland to 102 trees $ha^{-1}$ for unshaded cocoa farmlands (Ofori-Frimpong, Asase & Mason, 2005). The remnant native forest was used as the standard or control as all cocoa farms in our study area were originally derived from forests. The Atewa Range Forest Reserve in the Atewa District was selected as the control. There is very little primary forest left in Ghana and Atewa Range Forest Reserve is representative of remaining forest in the study area (Hawthorne & Abu-Juam, 1995). The reserve is located between latitudes 6° and 6°10′N and longitudes 0° and 0°36′W and about 232 $km^2$ in size. A total of 656 species of vascular plants have been recorded in the reserve.

The shaded cocoa farmlands were located at Adjeikrom in the Fanteakwa District. The area is located between latitudes 6° and 6°30′N and longitudes 0° and 0°30′W. The cocoa farmlands have shade provided mostly by native forest trees that had been left on the farms at the time of cultivation. The farmlands were cultivated with a mixture of hybrid and Amazon cocoa varieties (10–15 years) on a very steep to gentle slope and the farms were moderately maintained. Some of the farms were also cultivated with mixture of Amelonado (30–40 years) and Amazon (20–25 years) cocoa varieties on a gentle slope.

The unshaded cocoa farmlands were located about 10 km from Kwabeng in the Atewa District. The area is located between longitude 06° 20′ 037″N and 06° 20′ 750″N, and latitude 0° 34′ 806″ and 0° 34′ 786″W. The farmlands were mainly grown with hybrid cocoa variety (15–20 years) on a gentle slope and the farms were well maintained. To control pests, all the cocoa farmlands were sprayed with pesticides such as Kocide® (Griffin Corporation, Ontario, Canada) and Nordex® (Nordox AS, Oslo, Norway) twice a year from August to December.

### *Methods*

This study was conducted between April 2005 and October 2006. The transect method was used to study the vegetation in each land-use type. Transects spanned many farms in each land-use type, each farm being only a few hectares in size. There were twelve randomly located transects distributed across the three land-use types. The length of transects varied between 450 and 1000 m and were placed at least 200 m from each other in each land-use type. The position of each transect was determined using a handheld Global Positioning System (GPS) unit (Garmin GPS III plus; Garmin International, Olathe, KS, USA), delimited with a compass and cut with a cutlass. Total transect length was 3 km in remnant native forest distributed over three transects, 4.1 km in shaded cocoa farmland distributed over six transects and 1.2 km in unshaded cocoa farmland distributed over three transects.

Along each of the studied transects, vegetation plots of size 25 m × 25 m were demarcated without slope correction at 200 m intervals. All plants other than cocoa trees within the plots with a diameter-breast-height (DBH) ≥ 5 cm (1.3 m above ground) were identified and their DBH measured, and recorded in standard field data sheets.

The species of plants encountered were identified using the Flora of West Tropical Africa (Hutchinson & Dalziel, 1954–1972) and relevant literature (Hawthorne, 1990), and by comparison with voucher specimens at the Ghana Herbarium at the Department of Botany, University of Ghana at Legon. The authorities of the species were confirmed using the International Plant Names Index (IPNI) (http://www.ipni.org; accessed on 05 March 2008).

### *Data analyses*

The rarefaction method (Gotelli & Colwell, 2001) was used to estimate the expected number of species for the construction of species accumulation curves with 95% confidence intervals (CIs).

Species diversity was evaluated using two diversity indices: Shannon-Wiener index ($H' = \sum_{i=1}^{s}$ piInpi) and Simpson's index ($D = 1/\sum_{t=1}^{s}$ piInpi), where *s* is the total number of species and *p* is the relative abundance of the *i* species. In contrast to direct measures of species richness, these indices take into account the relative abundances of species (Legendre & Legendre, 1998).

Species compositional similarity among the three land-use types was estimated using the Jaccard similarity index. The Jaccard similarity index uses species presence/absence data for two sample sets (in this case land-use types) and is calculated as $J = M/(M+N)$, where $M$ is the number of species that occur in both land-use types and $N$ is the number of species that occur in only one of the two land-use types. We used the free statistical software EstimatesS version 8.0 (copyright 2008 by Robert K. Colwell, Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT, USA) (Colwell, 2006) for the species accumulation curves, and estimation of species diversity and compositional similarity.

The Kolmogorov–Smirnov test was used to determine if the DBH-size group distribution of individuals of plants between land-use types was significantly different after testing for normality. The basal area of the individual plants was calculated using the formula $\pi d^2/4$ where d is equal to the diameter of the plant. Statistically significant differences in mean DBH, density and basal area in the three different land-use types were analysed using ANOVA.

The data on most individual noncocoa plant species contained a high number of zero counts. Species population change could therefore be analysed for the most abundant noncocoa plants, that is, species with a total of ten or more individual plants recorded during the study. Generalized Linear Model (GLM) with logistic link function assuming Poisson distribution error followed by Maximum Likelihood (ML) method was used to test statistically significant differences in the relative abundance of species across the

**Table 1** Mean number of noncocoa plant species and diversity indices recorded for three land-use types in a cocoa production landscape in Ghana

| Parameters | Remnant native forest | Shaded cocoa farmland | Unshaded cocoa farmland |
|---|---|---|---|
| Mean number of noncocoa plant species recorded per plot | 11.23 ± 2.34 | 3.24 ± 1.56 | 2.00 ± 0.01 |
| Mean Shannon-Wiener diversity index [± standard deviation (SD)] | 4.09 ± 0.22 | 3.32 ± 0.31 | 1.44 ± 0.28 |
| Mean Simpson's diversity index [± standard deviation (SD)] | 36.43 ± 0.77 | 28.53 ± 6.64 | 4.34 ± 0.53 |

three different land-use types. Statistically significant levels are reported at $P \geq 0.05$. The free statistical software R version 2.6.0 (copyright 2008. The R Foundation for Statistical Computing, UK) (Crawley, 2007) was used.

## Results

### *Species richness, diversity and community similarity*

In total, 1306 individuals of noncocoa plants belonging to 194 species in 45 families were identified during the study. A majority (95.36%) of the species were forest plants, while nine of the species were exotic plants. The exotic plant species were *Anarcardium occidentalies*, *Cedrela odorata*, *Citrus sinensis*, *Chromolaena odorata*, *E. guineensis*, *Gliricidia sepium*, *Gmelina arborea*, *Mangifera indica* and *Persea americana*. With the exception of *E. guineensis*, which is indigenous to Africa but introduced to Ghana, all the exotics plants were recorded in the cocoa farmlands. Of the species of plants identified, only three (1.55%) species, namely, *E. guineensis*, *Funtumia elastica* and *Pycnanthus angolensis*, were found to be common to all the three land-use types. About 84.54% of the species identified were found in the remnant native forest, 35.05% in shaded cocoa farmlands and 6.19% in unshaded cocoa farmlands (Table 1). A majority of the noncocoa plants, 122 species representing 37.11% of the plants recorded were found only in the remnant native forest.

There were significant differences (95% CI) in species richness among the different land-use types. Plant species richness was found to be significantly higher (95% CI) for the remnant native forest followed by the shaded cocoa farmlands and least for the un-shaded cocoa farmlands (Fig. 1). Species diversity was also higher for the remnant native forest and the lowest for the shaded cocoa farmlands. For example, the mean Shannon-Wiener diversity index was 4.08 ± 0.22, 3.32 ± 0.31 and 1.44 ± 0.28 respectively for remnant native forest, shaded cocoa farmlands and unshaded cocoa farmlands.

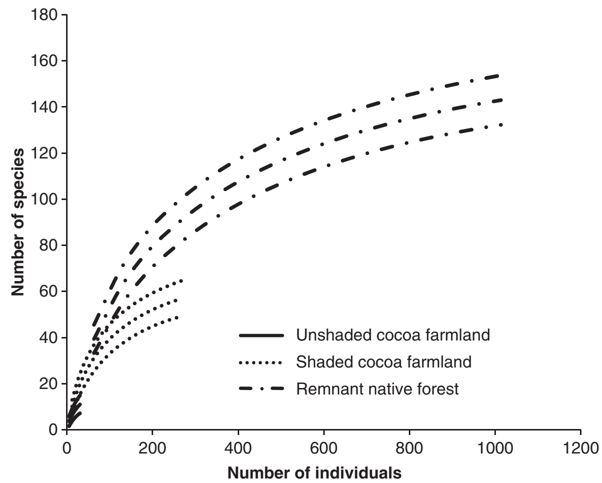


**Fig 1** Individual-based rarefaction curves (with upper and lower 95% confidence limits) for three land-use types in a cocoa production landscape in Ghana

Species compositional similarity statistics showed that the plant community in the remnant native forest was more similar to that of the shaded cocoa farmlands (Jaccard index = 0.226). The plant communities in the shaded cocoa farmlands and unshaded cocoa farmlands were found to be the next similar (Jaccard index = 0.096) while the least similarity was found between the remnant native forest and the unshaded cocoa farmlands (Jaccard index = 0.023).

### *Structural characteristics*

The DBH-size group distribution of the number of individuals of noncocoa plants in the three different land-use types is presented in Fig. 2. Significant differences in the distribution of noncocoa plants in the DBH-size groups were found between the remnant native forest and unshaded cocoa farmlands (Kolmogorov–Smirnov test, $P$-value <0.05), and between shaded cocoa farmlands and unshaded cocoa farmlands (Kolmogorov–Smirnov

 

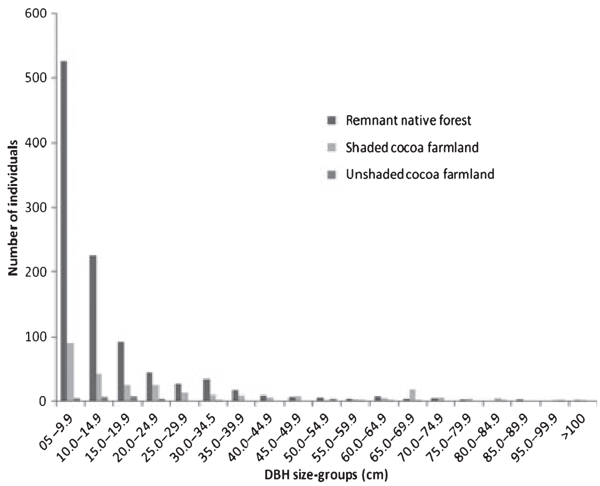


**Fig 2** DBH-size group distribution of individuals of noncocoa plants in three land-use types in a cocoa production landscape in Ghana

test, $P$-value <0.05). There was, however, no significant difference in the distribution of plants in the DBH-size groups between the remnant native forest and shaded cocoa farmlands.

The difference in the mean DBH-size of the individuals of noncocoa plants in the three land-use types was highly significant ($F_{2,1305} = 60.14$, $P \leq 0.001$). The largest mean DBH-size of 28.25 ± 2.81 cm [Standard Error (SE)] was recorded for the unshaded cocoa farmlands, while the smallest size 13.87 ± 0.49 cm (SE) was recorded for the remnant native forest. Mean DBH size for shaded cocoa farmlands was 24.56 ± 1.06 cm (SE). This means that most of the noncocoa plants found in the cocoa farmlands were larger trees.

Significant difference ($F_{2,41} = 97.26$, $P \leq 0.001$) was also found in the density of noncocoa plants among the three land-use types. The largest density of 505.00 ± 24.12 (SE) plants per hectare was recorded in the remnant native forest. Mean density for shaded cocoa farmlands was 97.09 ± 31.69 (SE) plants per hectare, while the smallest density of 41.33 ± 46.17 (SE) per hectare was recorded for the unshaded cocoa farmlands. Thus, the shaded and un-shaded cocoa farmlands contained about 19.23% and 8.18% respectively of the number of noncocoa plants per hectare found in the remnant native forest.

There was a significant difference ($F_{2,41} = 8.515$, $P = 0.00081$) in the mean basal area of noncocoa plants in the different land-use types. Mean basal area was 13.63 (SE = 1.29) $m^2\ ha^{-1}$ for the remnant native forest, 8.27 (SE = 1.70) $m^2\ ha^{-1}$ for the shaded cocoa farmlands and 4.49 (SE = 2.48) $m^2\ ha^{-1}$ for the unshaded cocoa farmlands. It thus follows that mean basal area for the remnant native forest was 1.6 times that of the shaded cocoa farmlands and three-times that of the unshaded cocoa farmlands.

### *Species population change*

Of the 194 recorded species of noncocoa plants, 41 were most abundant with a total of ten or more individual plants recorded during the study. Out of the 41 plant species, 29 species showed a statistically significant difference in relative density among the three land-use types ($P \leq 0.05$) whereas twelve species did not (Table 2). The relative density of about 41.7% of the most abundant plants declined in both shaded and unshaded cocoa farmlands. Eleven plant species representing 26.8% of the 41 abundant plants were more abundant in shaded cocoa farmlands than the remnant native forest and unshaded cocoa farmlands. The relative abundance of only one species of plant, *E. quineensis*, was significantly higher in unshaded cocoa farmlands compared with remnant native forest and shaded cocoa farmlands. Thus species population declined with increasing cocoa production intensity.

## Discussion

The results of this study showed that cocoa farming results in a drastic loss of forest plant species and that species richness and compositional similarity decreased in relation to increasing cocoa production intensity. Bisseleua *et al.* (2007) in a recent study of plant diversity and vegetation structure in traditional cocoa forest gardens under different management in southern Cameroon found that forest plant species numbers decreased from extensive cocoa gardens to intensive ones. Although tree diversity within cocoa production systems is variable, depending on management, cultural differences, location and farm history among other factors (Schroth & Harvey, 2007), a number of studies (Zapfack *et al.*, 2002; Oke & Odebiyi, 2007; Sonwa *et al.*, 2007) have shown that shaded cocoa farmlands have lower plant species diversity compared with the native forest as observed in this study.

This study also showed that cocoa farming results in recruitment of nonforest plants. Some of the recruited trees

**Table 2** Relative density of the most abundant noncocoa plant species in three land-use types in a cocoa production landscape in Ghana

| Species[1] | Relative density | | |
|---|---|---|---|
| | Remnant native forest | Shaded cocoa farmland | Unshaded cocoa farmland |
| *Albizia zygia* Macbride* | 0.0076 | 0.029 | – |
| *Alstonia boonei* de Wild* | 0.0031 | 0.046 | – |
| *Amphimas pterocarpoides* Harms | 0.012 | 0.023 | – |
| *Aulacocalyx jasminiflora* Hook.f.* | 0.047 | – | – |
| *Bussea occidentalis* Hutch.* | 0.042 | 0.0056 | – |
| *Carapa procera* DC | 0.023 | 0.011 | – |
| *Cedrela odorata* Blanco* | – | 0.16 | – |
| *Childlowia sanguine* Hoyle* | 0.057 | – | – |
| *Citrus sinensis* Osbeck* | – | – | 0.67 |
| *Dialium aubrevillei* Pellegr | 0.016 | – | 0.048 |
| *Diospyros kamerunensis* Gurke* | 0.025 | – | – |
| *Elaeis guineensis* Jacq.* | 0.0031 | 0.087 | 0.095 |
| *Entandroghragma angolensis* C.DC. | 0.013 | 0.0058 | – |
| *Ficus exasperata* Roxb.* | – | 0.098 | – |
| *Ficus sur* Forssk* | 0.0031 | 0.069 | – |
| *Funtumia africana* Stapf* | 0.060 | 0.0058 | 0.048 |
| *Funtumia elastica* Stapf | 0.017 | 0.0058 | 0.048 |
| *Greenwayodendron oliveri* (Engl.) Verdc.* | 0.019 | – | – |
| *Hannoa klaineana* Pierre & Engl.* | 0.025 | – | – |
| *Hymenostegia afzelli* Harms* | 0.031 | – | – |
| *Macaranga barteri* Mull. Arg. | 0.034 | 0.017 | – |
| *Macaranga hurifolia* Beille* | 0.019 | – | – |
| *Microdesmis puberula* Hook.f.* | 0.016 | – | – |
| *Myrianthus libericus* Rendel | 0.029 | 0.012 | – |
| *Napoleonaea vogelli* Hook & Planh | 0.034 | 0.017 | – |
| *Nesogordonia papaverifera* (A. Chev.) Capuron ex N. Halle | 0.019 | 0.012 | – |
| *Newbouldia laevis* Seem.* | – | 0.081 | 0.048 |
| *Piptadeniastrum africanum* P. Beauv* | 0.017 | – | – |
| *Pseudospondias microcarpa* Engl.* | – | 0.052 | – |
| *Pycnanthus angolensis* (Welw.) Warb | 0.014 | 0.017 | 0.048 |
| *Rauvolfia vomitoria* Afzel.* | 0.0078 | 0.10 | – |
| *Ricinodendroum heudolotii* Pierre ex Pax* | 0.017 | – | – |
| *Rinorea oblongifolia* C. Marquand* | 0.19 | – | – |
| *Sterculia tragacantha* Lindl.* | 0.0031 | 0.052 | – |
| *Strombosia glaucenses* Engl.* | 0.023 | 0.0058 | – |
| *Tabernaemontana africana* DC.* | 0.031 | – | – |
| *Tabernaemontana* sp.* | 0.078 | – | – |
| *Tetrochidium didymostemon* (Baill.) Pax & K. Hoffm | 0.022 | 0.012 | – |
| *Tricalysia discolor* Brenan* | 0.020 | – | – |
| *Trichilia monadelpha* (Thonn) J. de Wilde | 0.019 | 0.017 | – |
| *Voacanga africana* Stapf ex S. Elliot* | 0.0016 | 0.058 | – |

[1]Species with asterisks (*) are plants that showed a significant difference ($P \leq 0.05$) in their relative abundance among the three land-use types.

are exotic fruits trees such as orange (*Citrus sineesis*), mango (*M. indica*), oil palm (*E. guineensis*) and avocado pear (*P. americana*), while others are agroforestry trees such as *G. sepium*, *C. odorata* and *Gmelina* sp. These trees are often cultivated by farmers to provide edible fruits in addition to shade for cocoa, as also reported by Leakey & Tchoundjeu (2001), Duguma, Gockowski & Bakala (2001), Sonwa *et al.* (2007) and Asare (2006). The identification of nonforest plants in shaded cocoa farmlands is an indication of the level of alteration of the floristic composition and consequently, ecology of the native forest.

The mean density and basal area of noncocoa plants per hectare was found to decrease with increasing cocoa production intensity. Oke & Odebiyi (2007) reported that the density of noncocoa trees (≥10) found in shaded cocoa farmlands represented only 8.4% of nearby forest, lower than that found in this study. While the density of nonplants in the shaded cocoa farmlands has been found to be lower compared with native forest, a number of studies (Greenberg, 1998; Attua, 2003) have shown that shaded cocoa cultivation is much better compared with other crops and therefore could contribute better to biodiversity conservation. As there was no significant difference in the DBH-size group distribution of individuals of plants between the shaded cocoa farmlands and the remnant native forest, it suggests that shaded cocoa farmlands have at least some structural characteristics of the native forest compared to unshaded cocoa farmland and might therefore harbour significant levels of biodiversity (Reitsma, Parrish & Mclarney, 2001; Schroth & Harvey, 2007), although not as rich as the native forest (Ofori-Frimpong *et al.*, 2005).

The cocoa farmlands contained bigger size trees compared with the remnant native forest. This is because farmers will often not cut the bigger forest trees when establishing farms resulting in thinning of the forest canopy. Some of the trees retained in the cocoa farmlands are plants that are well known to be used for timber (for example, *Milicia excels*, *Triplochiton scleroxylon* and *Terminalia ivorensis*) medicine (for example, *Alstonei boonei*, *Carapa procera*, and *Voacanga africana*) and fuel wood (for example, *F. elastica*, *Celtis zenkerii* and *Sterculia tragacantha*) (Abbiw, 1990). These timber and nontimber forest products, together with the fruit trees planted on shaded cocoa, are sold on local markets providing farmers with additional sources of income and as such diversifying their source of livelihoods. There are also opportunities for exploring other environmental services such as carbon storage associated with shaded cocoa farming. Work to enable smallholding cocoa farmers to engage with the emerging carbon market is urgently needed. Economic factors have been found to affect the composition and structure of shaded cocoa farmlands in an attempt by farmers to diversify income sources (Sonwa *et al.*, 2007). There are, however, very little data on farmer's decisions about the species of plants they leave on cocoa farmlands.

While human factors are clearly important in the patterns observed, nonhuman factors such as plant dispersal combined with the likely decline of animal species could have contributed to the vegetation turnover and homogenization observed. For example, shaded cocoa farmlands provide corridors for the movement of animals and dispersal of plant propagules between forest fragments (Saatchi *et al.*, 2001). Thus, the observed vegetation patterns involve the interactions of both human factors and natural processes.

Although our study is of limited scope and additional research is needed as this study was restricted to a single tropical agricultural landscape and three broad land-use types in Ghana, it showed that cocoa farming could result in a drastic forest plant species loss with subsequent recruitment of nonforest plants, species population decline as well as changes in the structural characteristics of the vegetation. This impact increases with increasing cocoa production intensity. To manage plant resources effectively in cocoa producing landscapes, shade grown cocoa should be viewed as a better way of protecting forest plants while providing biological corridors for the movement of animals and sources of disseminules for forest patches compared with unshaded cocoa farming. Farmers should therefore be encouraged to protect forest trees or grow forest trees in farms to replace larger ones when they die. Interestingly, shaded farming has been found to be beneficial socially and economically, improving the livelihoods of local farmers (Gockowski & Dury, 1999; Degrande *et al.*, 2006).

There is a need for a similar research covering the entire cocoa growing region of Ghana including different biodiversity groups as well as the environmental goods and services associated with cocoa production landscapes. This information will assist in determining a more pragmatic approach for managing cocoa landscapes that reflects both needs and opportunities to protect remnant native forest (Green *et al.*, 2005).

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