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Biodiversity and smallholder cocoa production systems in West Africa

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The Sustainable Tree Crops Program (STCP) is a joint public-private research for development partnership that aims to promote the sustainable development of the small holder tree crop sector in West and Central Africa. Research is focused on the introduction of production, marketing, institutional and policy innovations to achieve growth in rural income among tree crops farmers in an environmentally and socially responsible manner. For details on the program, please consult the STCP website <http://www.treecrops.org/>.

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Introduction

Tropical rainforests are estimated to account for more than half of the plant and animal species on earth with some estimates ranging up to 90 percent, although they only cover about seven percent of global land area. Rapid population growth in the 20th century, poverty and unregulated access to tropical forest resources are threatening globally critical tropical forest biomes that were until recent times protected by their inaccessibility. Worldwide, the coverage of closed canopy moist tropical rainforests has declined rapidly in recent years to roughly 20 million km^2 at the start of the 21st century. The destruction of approximately half of global tropical rainforest habitat in the last century has raised alarms from numerous quarters. Around the world, an estimated 27,000 species are lost each year due to the destruction of the rain forests (Wilson 2002). The single most important factor in species extinction is the destruction of habitat that occurs with forest conversion for agricultural purposes. In addition to biodiversity losses, deforestation due to land-use change is estimated to account for 17.4% of annual global greenhouse gas emissions (Nabuurs et al., 2007). The noted evolutionary biologist and conservationist, Edward O. Wilson (2002), believes the greatest and most urgent challenge facing the global environmental movement is to raise the poor of humanity to a decent standard of living without destroying most of life around us.

The focus of our analysis is cocoa production and deforestation in the Guinean moist forests of West Africa. Identified more than 30 years ago as a global priority ecosystem for biodiversity conservation (Myers, et al., 1988) these forests are home to more than a quarter of Africa's mammals, including more than 20 species of primates. However, rapid land-use change is threatening to consume the few remaining intact remnants of this ecosystem, which are home to an estimated 1,900 endemic plant and animal species (Conservation International, 2007). Once covering an estimated 600,000 km^2, only 10 to 15 percent of these forests remain. The West African cocoa industry which has been installed in this landscape by millions of small family farms, has done so in some places benignly and in other cases less benignly, and now accounts for more than 70 percent of global cocoa supply.

In its natural environment in the tropical forests of South America, the cocoa tree *Theobroma cacao* L. grows as an under-storey species, making it ideally suited for inclusion with other tree species in carbon-rich systems with relatively high levels of biodiversity (Schroth and Harvey 2007). At the same time research has focused on the development of shade-less mono-cultural production systems based on cocoa hybrids and fertility management. The environmental consequences and the landscape impacts of low productivity systems, versus intensified systems, versus agroforestry systems are often not considered by agricultural and environmental policy makers looking to improve the welfare of cocoa farmers while simultaneously conserving natural resources. In this paper we investigate when it makes economic and environmental sense to pursue an agroforestry approach versus cocoa intensification with the aim of shedding light on some of these issues.

We concentrate our analysis on Cameroon, Nigeria, Ghana, and Côte d'Ivoire because of their overriding importance to global cocoa commerce. We begin by examining changes in agricultural land use in the lowland forests of these countries over the last

10 years and the pressures placed on forests from land use conversions. The results of a long term (12 year) fertilizer + shade trial conducted on-station in the 1960s and 1970s in Ghana form the basis for pondering what today's landscape might have been like if these alternatives had been adopted by small holder cocoa farmers a generation earlier. We conclude with a discussion about cocoa production and biodiversity conservation strategies examining their overlap and interaction.

Data Sources

The data used to analyze these issues are drawn from several sources. National time series on crop production, area in cultivation and yields for some of the major crops grown in the humid lowlands were accessed on-line from FAOSTAT. While there are concerns about the quality of these data, we believe that they reflect the overall trends witnessed in the field. This is especially true for the four export crops for which fiscal receipts provide government an incentive for more closely monitoring their situation than is the case for food crops.

A set of published field studies focused on companion crops grown with cocoa in West Africa provides another leg of the analysis. Comparative ecological measures of biodiversity are compiled along with estimated use values.

The impact of new plantings of cocoa on biodiversity levels in the landscape depends on several factors. The type of land use prior to cocoa planting and its biodiversity level in conjunction with the type of cocoa production system determines the extent to which biodiversity is lost. The biodiversity of the cocoa production system depends on the type of system, increasing from monoculture, simple agro-silvacultural to complex agroforestry systems. Another major issue at the landscape level is the annual extent of new plantings.

These issues are examined by drawing upon the results of a cross-sectional household survey implemented in the major cocoa producing areas of Cameron, Ghana, Côte d'Ivoire, and Nigeria in 2001/2002. The objective of the survey was to establish a baseline of production and marketing parameters for the Sustainable Tree Crops Program (STCP). STCP is a public-private partnership that is implementing a research program on development-oriented actions targeting the rural transformation of the main cocoa growing regions of West Africa. The surveys began in Cameroon in July 2001 and finished in Côte D'Ivoire in May 2002. A two-stage balanced cluster sample design was implemented. In the first stage, cluster villages were randomly drawn from administrative lists with the number of villages proportional to the output of that administrative unit. In the second stage, after an initial visit to inform local authorities of the purpose of the survey, systematic sampling with a randomized starting point for the first household chosen was conducted. In total 337 villages were visited and interviews conducted with the heads of 4,426 households of whom 4,034 were producing cocoa.

The final data source upon which we draw are results obtained in the Ghana shade-no shade fertilizer experiment conducted at the Tafo experiment station of the Cocoa Research Institute of Ghana from 1958 to 1969 as reported in Are and Gwynne-Jones (1974). We use these data to consider what the impact on biodiversity might have been had these technologies been vigorously pursued in the intervening years.

Principal land uses and land use change in the moist tropics of West Africa

The humid lowland agro-ecological zone (AEZ) of our focal countries is characterized by a long growing period (+ 270 days) and annual precipitation ranging from 1,400 to 4,500 mm per annum. The principal tree crops largely exclusive to this AEZ are oil palm, robusta coffee, rubber and cocoa while plantain is the principal food crop. Acid soils are common especially in western Ghana, western Côte d'Ivoire, and southeastern Cameroon, posing major difficulties for agricultural use, but they can be productive if lime and nutrients are applied and appropriate soil management is practiced. Cocoa does not usually thrive on soils with pH < 5.5 whereas oil palm and rubber are more tolerant of low pH. Large-scale industrial plantations for rubber and oil palm are found in this AEZ along with family-operated mixed farms of cocoa, oil palm, robusta coffee and food crops. In the smallholder sector, credit constraints, underdeveloped human capital and the lack of robust soil fertility management practices, greatly limit the use of inorganic and organic fertilizers. Instead farmers rely upon nutrient accumulation in fallow biomass to rejuvenate soils. As population pressures have increased, and fallow periods have shortened, these stocks tend to decline leading to the depletion of nutrient stocks. The objective of agricultural research and extension is to address such biotic and abiotic constraints which limit the performance of the production technology.

Over time with well functioning research and extension services, a stream of new knowledge and material innovations can be expected to lead to increased productivity. Productivity growth is critical for slowing high deforestation rates that result when forests are converted to low productivity cropping systems and is therefore in our opinion a key to conserving biodiversity.

Although not a direct measure of economic productivity as conceptualized by economists, biophysical yields per ha provide an indication of agricultural intensification and are typically correlated with total factor productivity measures (Byerlee and Murgai, 2000). We define agricultural intensification as an increase in the quantity and/or quality of inputs used in conjunction with agricultural land (Gockowski et al., 2001). Inputs may be broadly defined to include planting material, scientific knowledge, management practices, labor, soil amendments, pesticides and capital (including human) investments. In general the intensification of production systems should result in improved yields. Growth in yields for the major crops of the moist lowlands over in the last 47 years has been mixed (Table 1). Overall, there was a statistically significant positive trend for slightly over half of the 20 sub-sector national yields considered, while one-quarter of the yields declined. A small but significant positive trend in cocoa yield occurred in every country.

Table 1. Annual growth in yields in major forest zone crops from 1961 to 2006.

	Cameroon	Côte d'Ivoire	Ghana	Nigeria
rubber	0.87%*	2.28%*	-1.16%*	-1.12%*
cocoa	1.10%*	1.58%*	0.92%*	0.62%*
plantain	0.23%	2.41%*	1.21%*	0.72%*
oil palm	1.10%*	-2.46%*	-1.41%	-0.08%
coffee	-1.01%*	-0.39%	-2.01%*	2.99%*

* indicates $P<0.05$

Source: FAOSTAT, accessed online November 9, 2007

Figure 1 presents the trends in closed canopy moist forest and the area cultivated for the five principal crops exclusive to the forest AEZ. Farming in the forest AEZ in Cameroon takes place in two tropical forest biomes--the lower Guinea Forest which extends from the country's western border to the Sanaga River and the Guinean-Congolian Forests to the southeast of the Sanaga. Of the two biomes, the Lower Guinean is under significantly more pressure due to the recent expansion of the Cameroonian cocoa sector in the Southwest Province. Because disaggregated statistics by forest biome are not available and as Cameroon with nearly 18,000 km^2 of closed tropical forest has nearly double the resource as the other three countries combined, we exclude it from the graphical analysis, while keeping in mind that the processes of agricultural expansion and deforestation in Côte d'Ivoire, Ghana, and Nigeria are nonetheless very similar to those in the Lower Guinean Forests of the Southwest Province of Cameroon.

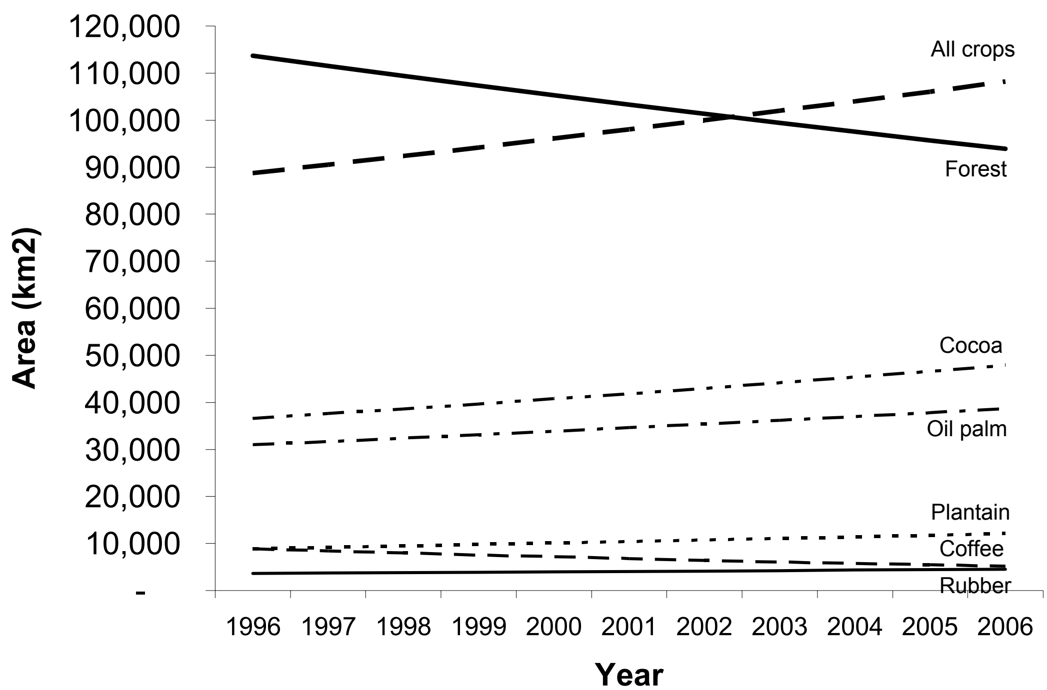

Figure 1. Area trends in major perennial tree crops, plantains and forest land uses for Côte d'Ivoire, Ghana, and Nigeria combined.
Source: authors' calculation using FAOSTAT 2007 and Mayeaux et al. 1997)

It is important to note that the estimated area in crops is confined to those whose agro-ecological requirements essentially restrict their cultivation to the forest AEZ. Because we restrict ourselves to a subset of the crops actually grown in the forest AEZ, the total area occupied by these crops underestimates the area under cultivation. Other important crops such as cassava, cocoyams and yams which are important for this AEZ are also grown in the moist savannah AEZ and the statistics available through FAOSTAT do not distinguish by AEZ. In conjunction with Mayaux's et al. (1997) remote sensing estimate of closed canopy forest area in the focal countries, an annual deforestation rate of 2.0% per annum is imputed from the annual change in area devoted to "forest" crops from 1996 to 2005.

Of the five monitored agricultural land uses, cocoa accounts for the greatest area and largest annual incremental change in area (table 2). Looking more closely at the cocoa sector, the combined annual production for Nigeria, Ghana and Côte d'Ivoire has been growing at nearly 5 percent since the mid 1980s (figure 2). Most of this growth in recent years is due to expansion of production in the Western region of Ghana and the Bas Sassandra region in south west Côte d'Ivoire. Cocoa production in both of these locales has grown by more than 15 percent per year since 2000 and now accounts for a combined output of 930,000 t, representing 57 percent and 30 percent respectively of national output in Ghana and Côte d'Ivoire. The recent planting activity in these two regions is also reflected in the age profiles of tree-stock investments—in Bas Sassandra 61 percent of the acreage had been planted in the last 20 years versus 45 percent for the rest of the country, while in the Western region it was 85 percent versus 46 percent in the rest of the country. The role of migrant farmers in the two sites was also significant. In Bas Sassandra, 83% of the hectares had been planted by migrants, mainly from other parts of Côte d'Ivoire but also from Sahelian countries. In the Western region, migrant farmers accounted for 29% of the hectares planted with the locals cultivating the remaining 71%.

Table 2. Predicted change in area harvested for forest zone crops, Nigeria, Ghana, and Côte d'Ivoire, 2005 to 2006.

Crop	Change in area
	ha per yr
cocoa	126,800
oil palm	84,800
plantain	36,800
coffee	-28,700
rubber	10,000
Total	229,700

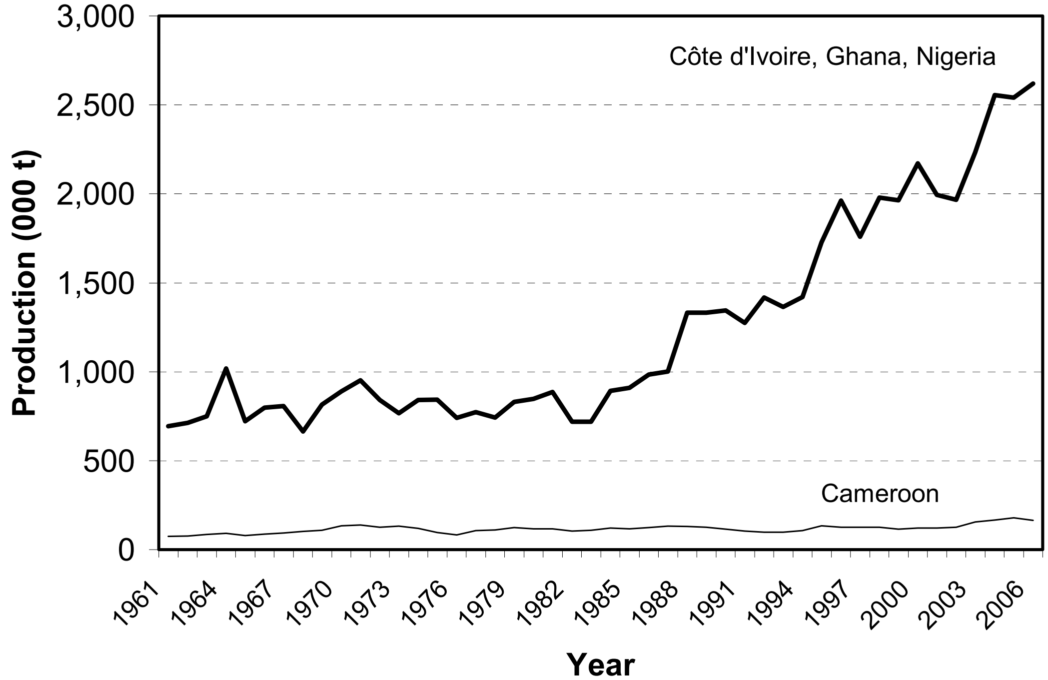

Figure 2. West African cocoa production, 1961 – 2006
Source: FAOSTAT, accessed online November 9, 2007.

It would appear that the increase in cocoa production over the last 20 years has come at a considerable cost in terms of biodiversity. However the impact of cocoa production on biodiversity also depends to a degree on the nature of the production system and the method in which it is established.

Shade and Cocoa Productivity in West Africa

Up until the 1970s most cocoa farmers in West Africa only had the option of growing unimproved Amelenado cocoa which was usually directly seeded. These systems often included numerous economic and non-economic tree species whose main purpose was the provision of shade as well as any secondary products that they may have generated. Then in the early 1970s, the reduction or often complete removal of shade in established cocoa farms along with the application of fertilizers and use of "F3" Upper Amazon varieties was increasingly recommended by research and extension especially to farmers in Côte d'Ivoire and Ghana (Are and Gwynne-Jones, 1974). The Cocoa Research Institute of Ghana's long running shade-fertilizer trial conducted in the 1960s at Tafo found that the removal of shade alone doubled yields while shade removal and application of fertilizers tripled yields (figure 3). This on-station experimental result gave a strong empirical basis for the development and extension of no shade cocoa systems. Today, cocoa systems in West Africa range from no-shade mono-specific systems using F3 Amazon to complex cocoa-fruit-timber-medicinal agroforestry systems with biodiversity values nearly equivalent to secondary forest (Sonwa, 2004, Gockowski et al., 2006, Sonwa, et al., 2007).

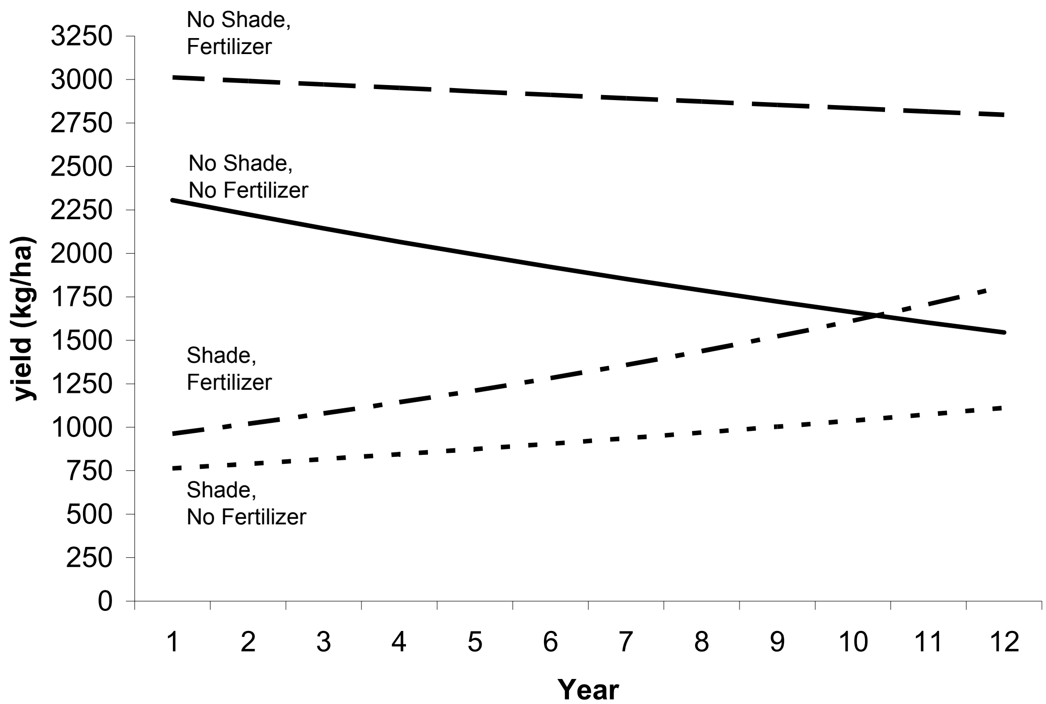

Figure 3. Ghana Shade—No Shade Fertilizer Trial, Tafo, Ghana
Source: Derived from data presented in Are and Gwynne-Jones (1974).

The degree of shade for each cocoa farm was solicited from farmers in the 2001/2002 STCP surveys along with farm size, output and year of establishment. In the Western region and Bas Sassandra, the spatial extent of systems with medium to heavy shade were in both cases below the national averages, while conversely systems with no shade or light shade were above the national average (table 3). The high instance of farms with medium to high levels of shade in Cameroon reflects in part still abundant forest resources and labor scarcities. Felling, slashing, and burning the 400 to 500 tons of biomass in a hectare of tropical forest is very labor demanding, especially in the absence of chainsaws. As a consequence, the majority of the cocoa farms in Cameroon have been established through the selective thinning of the forest, leaving tree species with local utility. In contrast in the Western region and Bas Sassandra, only 16 and 24 percent of the cocoa farms were established in this fashion. Here the predominant practice was to fell and slash the forest, burn the biomass and then cultivate food crops concurrent with cocoa for the first few years after establishment.

Table 3. Shade levels by country and region in the cocoa belt of West Africa

Country/Region	Amount of shade in cocoa farm: None	Light	Medium to Heavy
	-------of area planted---------		
Côte d'Ivoire			
Haut Sassandra	31.5%	41.5%	26.9%
Moyen Cavally	26.4%	46.9%	26.8%
Agneby	22.3%	63.8%	13.8%
Fromager	28.2%	37.5%	34.4%
Marahoue	33.6%	63.8%	2.6%
Lagunes	44.8%	34.8%	20.5%
Sud Badamana	26.8%	40.3%	32.9%
Bas Sassandra	20.6%	52.9%	26.5%
Moyen Comoe	27.2%	35.0%	37.8%
18 Montagnes	10.8%	25.7%	63.5%
Côte d'Ivoire subtotal	24.4%	48.1%	27.5%
Ghana			
Ashanti	13.4%	39.3%	47.3%
Brong Ahafo	14.1%	38.1%	47.8%
Eastern	7.4%	43.2%	49.4%
Western	26.7%	52.3%	21.1%
Ghana subtotal	22.6%	48.7%	28.7%
Cameroon	7.1%	31.6%	61.3%
Nigeria	2.0%	45.2%	52.7%

In the Bas Sassandra region and the Western region of Ghana, where on-farm shade levels most closely approach those of the no-shade treatment in the Tafo trial, the average yields reported by farmers were only 420 and 224 kg ha^{-1}, respectively. The poor performance of no-shade cocoa in the field relative to no-shade on-station results reported above likely relates to differences in management regimes, restricted access to production credit, and low utilization of inputs. In full sun systems, damage from capsid attacks tends to be higher than in shaded systems so that plant protection management becomes more critical (Padi and Owusu 1998; CABI 2007). Also if formation pruning of the jorquette is not properly attended to during the establishment period, canopy closure will not be satisfactory, leading to weedy conditions. In addition to pest management, fertility management is of great importance in these systems. In Bas-Sassandra, only 31 % of farmers were using fertilizers while in the Western region fewer than 3 percent applied any fertilizer in 2000. An average yield gain of 58% was achieved among the cocoa farmers in Bas Sassandra applying at least one 50 kg bag of compound fertilizer per ha (the average amount among these farmers was 2.6 bags per ha to produce 577 kg ha^{-1} versus only 365 kg ha^{-1} among those either not applying or applying less than one bag).

At the opposite end of the shade spectrum are the diverse cocoa agroforests of southern Cameroon and parts of Nigeria (Duguma and Gockowski, 1997; Gockowski and Dury 1998; Gockowski, et al., 2004; Sonwa, 2004; Gockowski et al., 2006; Oke and Odebiyi, 2007). Over the last 10 years, several investigations have been made characterizing the tree and botanical diversity of shade grown cocoa in West Africa. The findings from these studies more or less confirm an increasing gradient in shade levels as we move from West to East across the cocoa belt (table 4). Non-cocoa tree densities in Cameroon were between 5x and 25x greater than the densities reported elsewhere in West Africa.

Biodiversity of shaded cocoa systems

In southern Cameroon, two hundred eighty-six plant species were documented with the help of 46 cocoa farmers who described these species in terms of food, medicinal, construction and other values (Gockowski et al., 2006). The five most common tree species encountered were avocado, African plum, mango, oil palm and *Terminalia superba* (Engl. & Diels). The first three produce widely consumed fruits and the last is a timber species that is prized by carpenters and furniture makers for its workability. Oil palm and the African plum generated the most cash income followed by citrus (both oranges and mandarins), avocados, and timber. Total cash revenues from these non-cocoa species accounted for 23 percent of the total revenues from these production systems. The study which was conducted across a gradient of population pressure and market access found that farmers tended to intensify both cocoa, timber and associated fruit tree production when: (1) local markets were accessible and (2) population pressures were high. Intensification of the non cocoa component of the system, entailed a decline in biodiversity (as measured by a Shannon Weaver index) and an increase in the density of commercial fruit trees such as the African plum (*Dacryodes edulis*), avocadoes and citrus.

Farmers in southern Cameroon do not possess commercial timber rights to the trees on their land unless they can prove that they, or their predecessors, planted trees. Nonetheless, timber sales from cocoa agroforests were conducted in a parallel market, where presumably because of the risks associated with these transactions, the timber price was heavily discounted relative to FOB border prices. Excluding non-indigenous trees, eight different commercial timber species were of lead importance on at least one of the 46 inventoried farms. The majority were pioneer species characteristic of disturbed forest ecosystems, e.g. *Albizia spp., Alstonia boonei, Milicia excelsa, Terminalia superba,* and *Ficus* spp.

In the Eastern region of Ghana, avian, mammalian, plant and butterfly biodiversity were evaluated in shaded and full sun cocoa using identical protocols. The recorded mammalian and avian species richness of shaded systems was more than 3 times that of full sun systems, while butterfly and plant species richness were 4 and 30 times that of full sun systems (Ofori-Frimpong and Asase, 2005).

Table 4. Non-cocoa tree density and species richness in shaded cocoa systems across West Africa

Location	*Author/date*	*Land use*	*Tree Density* (Non-cocoa trees ha^{-1})	*Species richness* (No. of species)	Area Inventoried
Cam.—South and Center Provinces	Zapfack (2002)	Cocoa	120 [a]	116[e]	?? m^2
		Sec. forest	328 [a]	171[e]	?? m^2
		Pri. forest	296 [a]	160[e]	?? m^2
Cam.—South and Center Provinces	ASB (on-line)	Cocoa		71[f]	.16 ha
		Sec. forest		76[f]	.16 ha
Cam.—South and Center Province	Sonwa (2004)	Cocoa	256 [b]	206[g]	9.1 ha
Cam.—South and Center Province	Gockowski et al. (2006)	Cocoa	131 [c]	286[g] 176[f]	67 ha
Cam—Southwest Province	Laird et al. (2007)	Cocoa (migrants)	11	56 [f]	26 ha
		(indigenous)	22		
Nigeria—Ondo & Osun state	Oke and Odebiyi (2007)	Cocoa	23 [c]	45 [f]	21 ha
		Sec. Forest	256 [c]	62 [f]	0.56 ha
Ghana, Osino district, Eastern Region	Osei-Bonsu et al. 2004	Cocoa	33-111 [d]	116[f]	60 ha
CdI—Gagnoa	N'goran (1998)	Cocoa	28-36 [d]		
CdI—Gagnoa	Delerue (2003)	Cocoa	21-37 [d]		
CdI	Ruf and Schroth (2005)	Cocoa (migrants)	21 [d]		
		(indigenous)	37 [d]		
CdI—Southwest	De Roux (1987)	Cocoa	5-23 [d]		
CdI—Oume	Herzog (1994)	Cocoa	6 [d]		

[a] minimum tree diameter > 15 cm DBH; [b] minimum tree diameter > 2.5 cm DBH;
[c] minimum tree diameter > 10 cm DBH; [d] minimum tree diameter not specified
[e] all plant species; [f] only tree species; [g] timber and non-timber forest product (NTFP) species used by local population

Discussion

Over the last 50 years, rapid population growth combined with low productivity growth in smallholder agriculture, open access to land resources for migrant farmers, and the development of industrial plantations of oil palm and rubber have all combined to greatly reduce the extent of the West African Guinea Forest. According to FAOSTAT, from 1984 to 2006 cocoa production in Côte d'Ivoire, Ghana, and Nigeria increased by 1.7 million tons. The largest portion of this increase is attributable to an expansion in the area harvested of 2.3 million ha. As we have seen the most rapid growth has occurred in the Western Region of Ghana and the Bas Sassandra region of Côte d'Ivoire where the last remnants of the West African Guinea Forest are under siege.

The West African Guinea Forest is a global priority for conservation. Three protected areas in particular are under extreme pressure from cocoa farmers; they are Bia National Park and Resource Reserve and Krokosua Hills Forest Reserve in the Juabeso-Bia district of the Western Region of Ghana and Tai National Park in the Bas Sassandra region of Côte d'Ivoire (Oates, et al. 2000, Oates, 2006). In the Lower Guinean Forest of Nigeria and Cameroon, Cross Rivers National Park and Korup National Park (providing a home to the western-most population of lowland gorillas in Africa) are similarly under pressure from the rapid expansion of cocoa farming in these regions. When examined with satellite imagery these protected areas standout as islands in a fractured mosaic of agricultural land use (figure 4). In Ghana, these protected areas provide some of the last remaining habitat for two of the rarest and most endangered primates in Africa—the Roloway Guenon (*Cercopithecus diana roloway)* and the white-naped mangabey (*Cercocebus atys lunulatus*), both included among the 25 most endangered primates list of the IUCN (Oates 2006). Tai National Park in western Côte d'Ivoire is the single-largest tract of undisturbed tropical rainforest in West Africa and ranks among the highest priority tropical moist forest areas in Africa, according to action plans drawn up by IUCN's Species Survival Commission (WWF, 2007). It is the last refuge in Côte d'Ivoire for keystone forest species such as the forest elephant and the pygmy hippopotamus.

Figure 4. Satellite imagery showing encroachment of smallholders into Tai National Park (area in oval) in Bas Sassandra region of Côte d'Ivoire, 1988.
Source: UNEP, accessed at http://na.unep.net/digital_atlas2/webatlas.php?id=128

Cocoa production in West Africa has for the past 100 years been the leading agricultural export of the subregion. It is currently cultivated on over 5 million ha, most of which were once part of the West African Guinea Forest (Ruf and Schroth, 2004). Perhaps 200,000 ha of cocoa agroforests in the Centre and South Provinces of Cameroon still are. These cocoa forests conserve a considerable portion of the original forest biodiversity and interact in ecosystem functioning (Sonwa, 2004, Zapfack, et al., 2002). Around the Dja Reserve, the largest protected area in Cameroon and an IUCN Biosphere Reserve, there is gathering evidence of the importance of cocoa forests surrounding the reserve as a seasonal food resource for large hornbills in the genus *Ceratogymna* (Tom Smith, pers. comm.). Field studies suggest that the black-casqued hornbill, *C. atrata*, and the white-thighed hornbill, *C. cylindricus albotibialis*, are involved in the seed dispersion of at least 56 species of trees and lianas in this area (Whitney and Smith, 1998). Cocoa forests through their important food role help to ensure healthy populations of large hornbills which play a critical ecological role in the maintenance of wet forests in southern Cameroon. However the high biodiversity in the cocoa forests of southern Cameroon is the exception rather than the rule in most of West Africa. While farmers in the Lekie Division of the Center Province have successfully intensified both the cocoa and fruit elements of these systems, most farmers in southern Cameroon with these types of systems have very low cocoa productivity in terms of yield. The production systems in southern Cameroon are a reflection of the household's relative endowments of land and labor. As labor is scarcer relative to land, farmers choose extensive production systems which require relatively less labor input and more land input per unit of output. The result is a relatively biodiverse production system with low labor demand and low yields. The cocoa agroforests of southern Cameroon represent farmer's rational response to their economic and institutional setting. These systems are however not the solution to the issue of deforestation in West Africa. While they do have a much higher environmental value than full sun systems, it is still substantially less than intact forest (Zapfack et al., 2002, Schroth and Harvey, 2007) and with substantially lower land productivity, such biodiverse systems would require conversion of most of the remaining forest in Ghana, Nigeria, and Côte d'Ivoire in order to produce the current cocoa output. They are however capable of maintaining some of the important forest species needed to connect forest pockets. The utility of such highly biodiverse systems is especially pronounced when they are make up a significant component of the landscape bordering protected areas. There is definitely a need for such systems to create buffer zones and corridors of biodiversity linking important protected areas (e.g. Bia National Park and Krokosua Hills Forest Reserve in the Western Region of Ghana).

The lack of sustained productivity growth in the cocoa sector of West Africa has come at an enormous environmental cost. We illustrate with a "what if" scenario for Ghana. In 2006, the cocoa yield in Ghana was reported to be 400 kg ha^{-1}, which is less than 20% of the average yield in the full sun-fertilizer treatment of the CRIG shade-fertilizer trial conducted in the 1960s. Assume that Ghanaian farmers had at least partially adopted the no-shade plus fertilizer management system already available in the 1960s and that the average yield today was 1,000 kg ha^{-1} closing the yield gap to 50%. Under such a scenario, over 1.1 million ha of Ghanaian forest would have been spared and instead of 2.2 million ha (Mayaux et al, 1997), Ghana would have over 3 million ha of forest remaining. Thus the failure to translate research results into expected on-farm gains in productivity has cost Ghana about 50% of its forest endowment. There is a need to undertake immediately those actions, if any, that can still save the protected areas in the Bas Sassandra and Western Regions from further loss to cocoa production. This is a difficult balancing act for the

Ivoirian and Ghanaian governments, both of which depend on the cocoa sector for a significant portion of state revenues.

Recommendations for conserving the last remnants of the Upper Guinean Forests

Efforts to integrate sustainable economic development for populations bordering on protected areas and conservation efforts targeting critical biodiversity hotspots have not been very successful in West Africa (Oates, 1999). As an alternative, national governments in the region should strengthen activities that improve the effectiveness of forest conservation systems and protect remaining closed forest areas. These activities should include regular anti-smuggling, anti-farming and anti-poaching patrols, better communication systems in national parks and forest reserves, staff training, incentives and strengthening the enforcement of laws (UNEP, 2001).

The idea of creating conservation corridors between protected areas using cocoa agroforestry in order to increase ecological functioning and to ensure gene flows between genetic pools is relatively recent (Rice and Greenberg, 2000, Vaughan et al. 2007). Buffer zones and corridors incorporating biodiverse cocoa agroforests patterned after those of southern Cameroon should be designed with the input of wildlife managers and targeted to provide connectivity and habitat for endangered species (such as the Roloway Guenon) between critical protected areas in the Western Region of Ghana and the Bas Sassandra Region of Côte d'Ivoire. Conservation International (2006) has been a leader in promoting the idea of conservation corridors in the Upper Guinean Forests of Ghana-Côte d'Ivoire-Liberia. There is an urgent need to begin implementing projects to develop these corridors. While results from Cameroon show that high biodiversity and high profitability are not necessarily incongruous, this result is conditional on access to markets. As the biodiversity hotspot sites in Ghana and Côte d'Ivoire are rather remote from urban market centers it will be difficult for farmers to develop agroforestry systems that are as profitable as the full sun monocultures which currently dominate the landscape in both sites. As such, in order for conservation corridors to succeed, some level of subsidy/compensation payment to farmers to cover the opportunity costs of abatement may be required. Such mechanisms for reducing greenhouse gas emissions through avoided deforestation have recently been discussed at the UNFCC 2007 Bali meeting

Migration has been a prime factor in the expansion of production. In Ghana about 3 out of every four migrants to the Western region had migrated from a cocoa producing region (e.g. Ashanti, Brong Afaho, Eastern) presumably in response to declining productivity of cocoa farming practices. Given its importance in the recent expansion and deforestation episodes of both countries, special studies of these migrant communities should be commissioned to provide guidance on migration, environmental and agricultural policy.

There are no longer any frontier forests in West Africa for future generations to exploit. The best way to address simultaneously, the deforestation and development agenda is by extending to farmers' the knowledge and material inputs needed to sustainably intensify production. Achieving a target yield of 1000 kg in West Africa would take tremendous pressure off existing forest resources while helping to maintain Africa's competitive advantage in the world cocoa market. If yield growth were to jump from its current 1.7% p.a. rate to 6% p.a. then the one ton per ha target will be achieved in approximately 12 years. The scale of the effort required is not trivial—achieving this target would require doubling the yields on approximately 360,000 ha annually spread over the three countries over the next 12 years. To achieve this the size of the fertilizer market must also grow by approximately 50,000 t yearly, ultimately reaching an annual market of 600,000 tons. Attention will also have to be paid to the development of rural credit facilities to meet both the short and medium-term financing needs that intensification will engender. Medium –term financing (4 to 7 years) will be required to finance the uprooting and replacement of old tree stocks with the latest generation of cocoa hybrids. Extension efforts need to inculcate in farmers not only new technical skills concerning cultural practices to optimize the performance of Upper Amazon hybrids, but also the importance of farm management and record keeping. Research to support the intensification should address in an integrated effort the principal crop and resource management issues affecting West African productivity—namely, insect pests (capsids and stemborers), diseases (the *Phytophthora megakarya* variant of cocoa black pod disease and swollen shoot disease) and soil fertility research. Pest and disease problems are very much regional issues that warrant collaborative efforts between national and international research centers and advanced research institutes to develop promising approaches for the biocontrol of capsids and blackpod. With *P. megakarya* apparently now rapidly spreading across Côte d'Ivoire and Ghana, blackpod control is becoming much more of a constraint than in the past.

Concluding remarks

We have seen the environmental impact that the expansion of agriculture has had in the humid forest AEZ of West Africa. Over the course of the last 25 years the Upper Guinea and the Lower Guinea Forests of Côte d'Ivoire, Ghana, Nigeria, and Cameroon have been drastically reduced in size. Only the Guineo-Congolian forest ecosystem of southern Cameroon is not under threat. Cocoa farming has been a major factor in the deforestation of the Upper and Lower Guinea Forest with the extent of the impact amplified by low productivity growth in the sector. To save the remaining remnants of the forest, will require a transformation of cocoa farming technology in those areas that have already been deforested combined with enhanced protection efforts and the creation of conservation corridors and buffer zones linking protected areas using cocoa agroforestry. The Western Region of Ghana and the Bas Sassandra region of Côte d'Ivoire, are the principal sites of the expansion in recent years, and are also home to critical protected areas. Immediate investment in enhanced protection of these areas should be a priority. At the same time intensification of existing farms will require large scale and sustained public investment in research, extension, and production of improved planting materials in conjunction with significant private investment in fertilizer, agro-chemicals, capital goods, and replanting of tree stocks.

Fortunately, the cocoa industry of West Africa has many strengths to draw upon to help in achieving this effort, including world renowned cocoa research institutes, and organized marketing and processing capacity. The neglect of the sector has brought about a serious environmental crisis. Hopefully there is still time to address the matter, but coordinated urgent action is needed now.

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