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The Myth of Complex Cocoa Agroforests: The Case of Ghana

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Abstract Most researchers defend cocoa agroforests as a model, which guarantees sustainable cocoa production while protecting biodiversity. However, in most countries, farmers' strategies favour "full sun" cocoa farms, close to the concept of monoculture. Why this apparent paradox? Field surveys were conducted in 2005 and 2008 with 180 migrant and autochthon farmers in four districts of Ghana, including some measurements at the farm plot level and satellite images in a fifth district. An analytical grid shows how factors interact. Adoption of sun-loving hybrids; farmers' negative perception of ecological services in relation to hybrids; legislation excluding smallholders from the legal timber market; recent expansion of the timber industry; and the migratory phenomenon. Most smallholders consider complex cocoa agroforests as a thing of the past. They were designed at a time when land and forests were abundant. The future of cocoa and timber may lie in 'light commercial-oriented agroforests' or a kind of mosaic landscape.

Keywords Deforestation · Agroforest · Timber · Tree tenure · Migration · *Abunu* contract · Ghana

Introduction

Agroforests are often assumed to be the best strategy for governments and cocoa smallholders in terms of environmental protection and ecological services as a result of biodiversity and in terms of income diversification, especially in West and Central Africa (Herzog 1994; Greenberg 1998; Dury *et al*. 2000; Gockowski *et al*. 2004; Gockowski and Sonwa 2008; Schroth *et al*. 2004; Rice and Greenberg 2000; Asare 2005; Asare and Asley Asare 2009; Schroth and Harvey 2007; Sonwa *et al*. 2007; Sonwa and Weise 2008; Asare *et al*. 2008;). Yet, at least since the 1980s, in major cocoa producing countries such as Côte d'Ivoire, Ghana, and Indonesia, many cocoa smallholders have opted for full sun or very light shade strategies (de Row 1987; Ruf 1995, 2001; Hanak Freud *et al*. 2000; Kazianga and Sanders 2006). The debate about the future and possible decline of agroforests and their replacement by pure stands of tree crops, either rubber, oil palm or damar, is now underway in Indonesia (where the concept of agroforest was born) (Ruf *et al*. 1999; Belcher *et al*. 2005; Potter 2004; Kusters *et al*. 2008; Rist *et al*. 2009). Monoculture oil palm is clearly more profitable than jungle rubber, which it is rapidly replacing (Geisler and Penot 2000; Feintrenie *et al*. 2010). Using the case of damar in Indonesia, Kusters *et al*. (2008) showed that "developing new agroforests now often means destroying protected forest." More importantly, their response to the key question of whether agroforests will vanish is that while old damar agroforests may disappear, new ones will be established.

In the case of cocoa, with possible extrapolation to other commodity-based agroforests, I aim to demonstrate here that cocoa agroforests have already started to vanish in West Africa (Ruf *et al*. 2006), and will likely continue to do so. However, the case of the West African cocoa agroforests differs from the case of damar in one major way: in the first stage, complex agroforests are replaced by full sun plantations. In the second stage, new agroforestry systems may well emerge from full sun plantations but they will be much less complex than the old agroforests, In fact they will have little in common with the old complex cocoa agroforests.

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I first address the issue of why for the past 20–40 years the majority of West African cocoa smallholders are moving towards full sun plantations by examining the main determining factors of the choice of "full sun," which appears to be close to monoculture, and how this choice varies from country to country.

Different Disciplines, Different Explanations

Ecological Services at the Local Level Some agro-ecologists approach the question in terms of the ecological services provided, which should encourage farmers to keep shade trees, but this fails to explain why smallholders continue to remove trees. As a starting hypothesis, I suggest that most cocoa smallholders are less certain than some scientists about the ecological services to cocoa on the farm itself and possibly to neighbours' farms provided by "shade" and biodiversity in terms of controlling pests and diseases.

Environmental Services at the Regional Level Many economists and ecologists believe in the potential of eco-markets applied to the cocoa sector and also in the principle of paying for environmental services. In the cocoa sector, incentives such as eco-certification or a share of the carbon market may look promising (Hertel *et al*. 2009), but the carbon market is still in its infancy. Eco-certification experiments have not yet been evaluated, which means that cocoa farmers cannot rely on eco-markets for the time being.

Tree Tenure and Legislation Anthropologists and economists were among the first to suggest that the choice of deforestation and full sun options can be explained by existing laws that deny ownership of any timber tree to smallholders, even autochthons. This is the case in Côte d'Ivoire and Ghana (Ruf and Zadi 1998; Verdeaux and Alpha 2004; Amanor 2005; Boni 2005, 2006), and in many tropical countries. Decades of colonial and post-colonial legislation obviously play a role. Farmers, logically, tend to remove trees that provide them with little or no returns. However, cocoa agroforests were developed between the 1950s and 1980s, when farmers were already excluded from the timber market. Consequently legislation concerning ownership of timber trees cannot be the only factor responsible for complete forest clearing strategies.

Technological Change and Higher Returns From a technological point of view, many references can be found to hybrid varieties of coffee grown in a shade-free environment in Mexico (Nesten 1995) and Central America (Somarriba *et al*. 2004). The link between hybrids and shade-free environments has also been observed in the cocoa sector (Ruf *et al*. 2006). Gockowski and Sonwa (2008) showed that above and beyond agroforestry, West African cocoa cultivators seriously need to intensify existing cocoa farms and to start using hybrids.

The enormous potential yield of full sun cocoa has been known for decades. In the former Gold Coast (now Ghana), Cunningham and Smith (1961) tripled the yields of their experimental cocoa plots by removing shade trees. With the help of fertilizers, yields per hectare were even quadrupled. Unfortunately, as these trials were stopped after five years, the sustainability of such high yields is not known. More recently, a financial analysis of cocoa farming systems in Ghana estimated the returns of shaded and unshaded hybrid cocoa (Obiri *et al*. 2007). Over a period of 80 years, the shaded hybrid generated the highest net cash flow but, as acknowledged by the authors, such a long period is unrealistic. For a period of 20 to 25 years, the unshaded hybrid system is the most profitable, due to the earlier and higher peak yield (Obiri *et al*. 2007). In addition to the greater vigour of the hybrid, the use of moderate amounts of pesticides, fertilizers and herbicides (in that chronological order in Ghana and Côte d'Ivoire) helps maintain relatively good yields and good returns in 25–30-year old unshaded cocoa farms (Ruf 2007)

Migrant Effect In Côte d'Ivoire, geographers were among the first to show that migration plays a role in the intensity of deforestation. In the absence of a clear legal property framework, migrant farmers look for quick returns and plant cocoa as soon as possible to try to secure their property (Léna 1979; Schwartz 1979). Migrant labour plays a role in all cocoa economies in two main ways. First, migrants are the main stakeholders in most cocoa booms, including in Ghana (Hill 1963). Migrants are necessarily the main deforesters, regardless of the intensity of their forest clearing, which may be selective or complete. In addition, they are often the main users and promoters of radical forest clearing. The link between cocoa migration and full sun techniques has been observed in several countries including Côte d'Ivoire and Cameroon (De Row 1987; Ruf 1995; Kazianga and Sanders 2006). Migrants often opt for full sun while autochthons appear to be more faithful to shade.

An Evolutionary Path and a Boserupian Mechanism A good overview by a multidisciplinary team (Belcher *et al*. 2005) mentions a model evolutionary path that leads from low to high management, in agreement with Boserupian theory (when the population increases, less land is available, which, through automatic adjustment, leads to more intense labour consumption relative to the amount of arable land). Applied to agroforests, this would imply their replacement by "more intensive management" (Belcher *et al*. 2005).

These different approaches stress the need for an overview and bring me to my main hypothesis: In political contexts, where most farmers (at least in West Africa) are still excluded from the legal timber market (a situation that farmers cannot easily change, even if the official policies are supposed to have made some progress), full sun strategies are largely driven by technical breakthroughs in cocoa farming, especially the introduction of vigorous hybrids, and migrants' economic objectives based on their social and political situation. According to this hypothesis, the initial mechanism behind the decline of agroforests is not Boserupian but it progressively interacts with the other factors, for instance with the adoption of fertilizers, thus completing the rationality of full sun systems when the population increases and forest resources disappear.

As a result, (at least in West Africa), the existing or surviving complex cocoa agroforests are more likely to be remnants of the past than models for the future. There are a few exceptions, possibly related to autochthony and marginal ecotypes,[1] but most cocoa farmers will probably no longer be interested in complex agroforests. The latter are unable to compete with more intensive cocoa production in full sun, which generates income faster than shady plantations and complex agroforests. Consequently, if cocoa agroforests are to have a future in the twenty-first century, they probably need to be reinvented through dramatic technical, economic and institutional changes.

Method and Study Areas

I tested this hypothesis in the current situation in Ghana. After a brief discussion of the ambiguity related to the term 'agroforest,' I present the results of the first approach based on interviews with 140 farmers in three districts of Ghana: Kade in the Eastern Region (44 farmers), and Manso Amefi (55 farmers) and Enchi (41 farmers) in the Western Region. As most farmers correctly estimated the size of their own cocoa farms (checked by measuring 30% of the cocoa plots selected at random), and named the tree species and their number, I was able to make a preliminary evaluation of the densities of mature trees on the cocoa farms. The three main cocoa-producing regions in Ghana follow a geographical and historical gradient from east to west. The Kade district in the Eastern Region is the former cocoa cultivation showcase. At the other geographical and historical extreme, Enchi is located near the border with Côte d'Ivoire and is dominated by young cocoa farms. In many respects, Amenfi-East, which is located in the centre of the Western Region, lies between the two extremes. My primary objective was to ask farmers for their estimate of shade tree densities and about changes in density on their own farms in the last 10 years, which can be considered as the first stage in the decline of agroforests.

The second approach was to identify farmers' perceptions of agroforests and shade. In this case, my objective was to explain the decline of old agroforests. To complete the survey, a fourth district, Jasikan in the Volta Region, one of the oldest surviving cocoa regions in Ghana, was subsequently added to the sample (40 additional households, mostly autochthons) This brought the total number of farmers interviewed to 180. Taken together, the farmers cited a total of 288 reasons for the decline of agroforests.

Finally, I focused on the district of Enchi in the Western Region of Ghana using several research tools including interviews with farmers, satellite images, in-depth field observations and measurements at the farm plot level. The 41 smallholders interviewed included 22 autochthons and 19 migrants. Enchi is an agricultural frontier zone where migrants greatly outnumber autochthons. The sample thus over-represents the number of autochthons as I wanted to test the hypothesis of the important role of autochthony/migration in tree management. In addition to face-to-face interviews conducted with the 41 smallholders managing 84 cocoa plots, quadrats were established to evaluate the density of cocoa and forest trees to enable me to compare what farmers actually did with what they said they did. Cocoa trees and other trees were counted in 49 quadrats (20×20 m), which were randomly selected in 49 of the plantations in the sample. The tree density per hectare was thus extrapolated from the 400^2 m. The sample is too small for multivariate statistical analysis. However, it is sufficient for an empirical analysis of the factors that determine the choice between full sun and shade/agroforests

Ambiguity of the Term 'Agroforest' and Definitions

The concept of 'complex agroforest' was originally introduced and defined as "anthropogenic forests composed of numerous individually owned and managed plots, but which appear as a forest massif" (De Foresta and Michon 1997, quoted by Kusters *et al*. 2008). In contrast to a complex agroforest, 'simple agroforestry systems' can be composed of one tree species, for instance

[1] A few cases of recreating of cocoa agroforests in deforested regions exist, including savannahs in Africa, for instance in Cameroon (Glatard *et al*. 2007). On the Indonesian island of Flores, a case of reconversion of 'ladang' (land devoted to annual food crops) into cocoa highly commercial agroforests was observed.

coconut, mixed with one annual crop, for instance maize (De Foresta *et al*. 2000).

In this paper, I define a mature complex cocoa agroforest as "a cocoa farm which has more than 15 mature timber trees per hectare (and possibly as many as 60–80), usually giant trees more than 15 m tall, which are native to the natural tropical forest." These cocoa agroforests represent a wide range of biodiversity, including fruit trees, shrubs and other plants, generating at least three levels of canopy storage, one below that of cocoa and, more importantly, one or two above. Under this heavy shade, cocoa yields and revenues are low, whereas in a full sun (or zero-shade) mature cocoa farm yields are usually higher than those below a dense canopy, at least for some years.

The full sun system often has only one level of canopy storage: cocoa trees. Almost all the large natural forest trees have been felled or burned. However, it may include some limited yam moulds below the cocoa trees and a few banana and fruit trees, such as avocado (less than 10) isolated in an ocean of more than 1000 cocoa trees per hectare. This forms two levels of canopy storage in some parts of the cocoa farm, which can then be interpreted as a 'simple agrosystem.' A light-shade version may include up to 5–6 trees per hectare emerging above the cocoa. This may still be far from a complex agroforest but turns the system into what can be defined as a 'simple agroforest' or 'light agroforest.' However, biodiversity is poor and there is no real canopy above the cocoa. The landscape appears homogeneous and monotonous, like a monoculture system (Figs. 1 and 2).

Complex cocoa agroforests represent the old type. They underwent dramatic expansion from the 1940s until the 1970s in Côte d'Ivoire, and until the 1980s in Ghana. Cocoa trees were planted after selective clearing of the natural forest. The plantations thus conserved some of the large trees, which provided protective shade for the cocoa trees. This mode of clearing maintained a certain level of biodiversity in the cocoa plantations. Why are they rapidly declining? What can the case studies in Ghana tell us?

Results of Farmers' Interviews in Several Regions of Ghana

Remnants of the Natural Forest in Cocoa Farms Versus Tree Diversification

Farmers were asked to estimate the number of natural forest trees remaining in their cocoa farms (Table 1). The table can be read vertically and horizontally. It highlights the changes that have occurred over time and in space. In all the regions concerned, the number of mature trees is decreasing in the cocoa plantations. Then, from the oldest cocoa producing regions in the east (Kade in this case), towards the more recent ones in the far west (Enchi), there is a decrease in the density of shade trees. Taken together, density has decreased from 14 large trees per hectare in the 1990s in the Eastern Region to around one large tree per hectare in the mid-2000s in the extreme west of the Western region.

This trend does not mean that farmers are against tree diversification. On the contrary, a process of tree diversification accompanies the structural decline of trees on the cocoa farms. However, such trees are planted in separate farm plots which resemble monoculture. This is even the case for timber trees, such as teak (Table 2).

Fig. 1 Full Sun Cocoa farm planted after forest clearing in Jema, Western Region, Ghana, 2005

Fig. 2 Full Sun Cocoa farm planted after forest clearing in Enchi Western Region, Ghana, 2005

Farmers' Perceptions of the Decline of Agroforests

Cocoa planters in Ghana explicitly stated that technical progress is the main factor in the process of abandoning shade and in the almost systematic elimination of large forest trees. The introduction of hybrids is clearly perceived as the primary determining factor. All the farmers stated "Hybrids do not like shade" (Table 3). This was the case even in Jasikan district in the Volta Region, which was surveyed more recently. In this district, there are still a few surviving cocoa agroforests dating from the 1950s. Yet farmers are not interested in replicating this agroforest model on new cocoa farms. Smallholders mentioned the use of chemical treatments, fertiliser and other practices that improve full sun production with hybrid planting material. They consider that growing cocoa trees under shade is a thing of the past, which their experience caused them to abandon.

Technical Progress with Plant Hybrid Material (41%)

The smallholders were aware of a phenomenon that some ecologists had not taken into account: technical progress meant that planting material no longer goes hand-in-hand with the need for shade. Smallholders did not abandon shade through ignorance but through experience. Smallholders know that they will obtain higher yields more quickly with a vigorous hybrid in full sun than in the shade, at least for a period of 10–20 years.

This period may seem short and may be a far cry from the notion of sustainability, yet farmers are entrepreneurs who need rapid returns on their investment. In addition, in terms of research, I do not have any time series on the most recent hybrids and on the latest fertiliser to show that there will necessarily be a rapid drop in yield in full sun or very light shade after 25–30 years of cultivation.

Rather Negative Ecological Services (23%)

This is the second most important reason given by smallholders for felling trees. Smallholders in Ghana refuted several presumed ecological services provided by natural forest shade trees. On the contrary, they feared an increase in damage caused by insects and squirrels, which seek refuge in the upper strata of shade trees. Smallholders were also worried about the development of fungal diseases, particularly the dreaded form of black pod (*P. megackarya)*. In Enchi, farmers were very specific: given the abundant rainfall in Enchi "shade does not work" because it increases humidity and, as a result, leads to black pod. 'Abundant rainfall' is an important factor. As cocoa farms recently shifted to the southwest of Ghana, where rainfall is higher and more regular than in any other cocoa region, the risk of black pod is exacerbated by shade trees.

Last but not least, farmers stressed the negative effect of competition for light. Under heavy shade, cocoa trees tend to grow tall in search of light, which makes harvesting more difficult.

The Exclusion of Farmers from the Timber Market (9%)

The West African legislation supporting loggers against farmers is obviously a barrier to any farmer investing in

Table 1 Estimations by farmers of the number of natural forest trees remaining in their cocoa farms. Analysis according to the regions and the average age of cocoa farms in each region. 1994-2005

	Far west of the Western Region: Enchi (41 farmers)	Centre of the Western Region: Amenfi-East (55 farmers)	Eastern Region: Kade (44 farmers)
Characterisation of cocoa production	One of the most recent in Ghana, still an active agricultural frontier in the 2000s, but the sons of migrants are already leaving the region in search of new forests	The pioneer period is over but there are still many first generation migrants	Old cocoa producing region. Migrants are of the 3rd generation and consider themselves to be autochthons
Decade of the plantations' peak	1990–2000	1970–1980	1950[a]
Number of trees in the plantations (number of large trees/hectare of cocoa farm)			
Towards 1994	2.0	7.0	**14.3**
Felled between 1994 and 2004	1.0	2.5	3.4
Remaining in 2004/05	**1.0**	4.8	10.9

[a] A large part of this peak has now disappeared, especially due to the huge 1983 fires that devastated thousands of hectares in the country

timber trees. The value of timber is kept artificially low and has been for decades. In the 1990s and 2000s, the farmers' main reason for eliminating trees was the arrival of hybrid planting material. The associated emerging green revolution has convinced planters of the advantage of eradicating trees 'with no value' compared to that of mature hybrid cocoa trees.

In general, I agree with the analyses proposed by Amanor (2005) and S. Boni (2005, 2006) that by conserving some trees, farmers may face problems with legal and illegal forestry companies who come to fell and remove the trees. One farmer in Jasikan described the situation very clearly: "We are obliged to steal our own trees when the logger's back is turned." However, the extent of the problem remains difficult to establish. In our survey, this factor only comes in third place. It is not considered to be anything like as important as using hybrids or the farmers' perception of the rather negative ecological services provided by forest trees.

In Amenfi and Kade, 14% of the farmers mentioned that increasing logging activity is a general cause of the declining tree canopy. In Enchi, only one farmer suggested that he was afraid that a forestry company might go into his plantation, steal his trees and destroy his cocoa trees in the process. One reason that farmers in Enchi were virtually silent on this issue could be forestry companies' activity before the cocoa planters moved in. At least in the specific case of Enchi, the logging companies felled many trees in the natural forest before the migrants settled and started to plant cocoa. Secondly, farmers pre-empted the risk of the neighbouring sawmill (the biggest in Ghana) sending chainsaw teams and large tractors to their farms by removing all trees at the clearing stage. While old farmers in Kade still fear loggers' raids in their old shaded cocoa farms, recent migrant farmers in Enchi have no reason to worry. More generally, even in Kade and Amenfi, a third reason for the farmers' relative discretion may be "voluntary forgetfulness." The subject is politically sensitive and some planters consequently preferred not to talk about it.

Not all smallholders think they are totally excluded from the timber market. They believe that they are now 'aware' of their negotiation rights, which were theoretically granted by President Rawlings' government in the 1990s. In 2008–10, some planters obtained compensation amounting to \$50–100 for a high value tree, such as Iroko, after years of being paid a pittance (\$5–10 per tree). This is still a scandalously small sum compared to the value of timber to a sawmill. Asare *et al*. (2008) reported that the Ghanaian domestic market value for timber was \$109/ha compared to the world market value of \$1,460/ha. The gap may be even greater.

Table 2 Farm structure in three regions of Ghana in 2006

	Far west of the Western Region: Enchi (41 farms) (hectares)	Centre of the Western Region: Amenfi-East (55 farms) (hectares)	Eastern Region Kade (48 farms) (hectares)
Cocoa	5.6	3.7	2.2
Oil palm	0	1.2	2.8
Rubber	0	0.3	0
Citrus	0	0	0.3
Teak	0	0.1	0
Total	5.6	5.3	5.3

Timber Sales and Increasing Local Demand for Timber (7.6%)

Even if prices are very low, some farmers voluntarily sell trees to local chainsaw teams. As mentioned by one farmer in Kade, this is due to poverty and because of the seasonal nature of cocoa revenues (several lean months). The trees are increasingly being sold to illegal/unofficial chainsaw teams even more frequently than to legal/official timber companies, which are accused of destroying cocoa trees when they remove the trees with their forest tractors. The positive aspect of this is the beginning of management of timber trees according to their 'market' value. This illegal/local activity sends early market signals. There is more future for timber trees thanks to their intrinsic market value rather than to their role in protecting cocoa.

The more frequently cited reason was the personal use of timber for building houses in the village. With the spread of the chainsaw (see below) and local chainsaw teams, this opportunity is rapidly increasing. Some farmers said "we now have access to our own timber to build our houses or our sons' houses, we no longer need to buy wood." Against the

Table 3 The reasons for the rapid disappearance of shade in the cocoa plantations in four regions of Ghana, according to the smallholders (2005)[a]

Explanation given by the smallholders	Number of responses					
	Enchi Western Region	Amenfi Western Region	Kade Eastern Region	Jasikan Volta Region	Total	(%)
1. The cocoa hybrids do not like shade, unlike the old "Tetteh Quarshie" which needed shade.	23	26	33	36	118	41.0%
2. Negative ecological services: shade trees provide a sanctuary for mirids, squirrels and cause black pod.	13	10	13	29	65	22.6%
3. More and more loggers come and cut our trees+'we cut them down before loggers come'.	1	8	13	4	26	9.0%
4. Timber selling, and/or increasing personal and domestic use of planks for houses built in the village.	1	1	11	9	22	7.6%
5. New tools: chainsaws are now available.	2	0	10	1	13	4.5%
6. Generation change: new techniques adopted by young people.	3	1	9	1	14	4.9%
7. Large trees in the cocoa plantation represent a physical danger to people. Trees and branches can fall.	4	2	2	1	9	3.1%
8. The government encourages cocoa planting and extension services encourage cutting down all trees.	0	5	1	2	8	2.8%
9. New cocoa farms are no longer planted after forest but after fallow periods (especially by young people).	0	1	1	0	2	0.7%
10. Fires destroy old plantations and shade trees and/or diversification opportunity (oil palm and citrus).	0	1	5	1	7	2.4%
11. Other miscellaneous answers:	0	2	1	1	4	1.4%
- We cut the trees but they can re-grow afterwards						
- Trees die naturally during droughts						
- Farmers have learnt to select only the good trees						
- Family land, which would not be inherited by my children, hence a strategy to maximize returns.						
Total	47	57	99	85	288	100%

[a] : in 2008 in the case of Jasikan

background of the world crisis and the drop in international demand for timber, this domestic market is also encouraging for the future of timber management on cocoa farms.

New Tools for Timber: the Chainsaw (4.5%)

The introduction of the chainsaw partially accounts for the increasing pressure of loggers on cocoa farms. The chainsaw has primarily benefited logging companies and traditional chiefs who claim that they have some local authority. In Manso and Kade, chiefs are discretely accused of forming a kind of 'mafia' with certain loggers. This phenomenon was observed by Amanor (2005) and is consistent with the law that attributes 15% of the timber value to the 'holder of recognised traditional land rights,' the 'traditional chief,' and 0% to farmers.

Nevertheless, the chainsaw is another aspect of technical progress available to an increasing number of planters through the local activity of chainsaw teams. Chainsaws can be acquired by some farmers or by their sons and could trigger a positive development in that they enable direct small-scale management of the timber resource.

Change in Generation: New Cocoa Techniques and the Young (4%)

Smallholders—particularly young smallholders—insist that the change to new techniques and full sun farms is a 'natural development.' There is a connexion between the cocoa farm cycle and the family cycle: young farmers may inherit old farms but they usually aim to plant their own farm in order to reduce the risk of family interference in their business. As suggested above, there is also a connexion between the generational change, the introduction of chainsaws and the use of timber.

The Paradox: The Physical Risk Rather Than Protection Provided by Shade (3.1%)

"In an aside" planters suggested that large trees represent a real physical risk, a risk which is apparently ignored by experts. Particularly in the hilly landscapes of Enchi, where gradients can be as steep as 60% and winds are sometimes very strong, the likelihood of large trees being uprooted (remnants of the natural forest in an ocean of cocoa) is very high. They represent a real danger for people working in the plantations.

The Absence of Eco-Markets

None of the four district samples showed any signs of eco-certification or carbon market mechanisms. Farmers were not even aware that they existed, which simply confirms that their existence in the cocoa sector is merely incidental for the time being.

So far, the case of Ghana appears to fit our hypothesis satisfactorily. However, all the data were based on farmers' statements and perceptions. Let us now look at the cocoa farms themselves and compare what cocoa smallholders said with what they did. The example below is that of Enchi, where the tree cover has almost completely disappeared.

Results of Interviews and Quadrats in Enchi, Western Region

When the 41 smallholders in Enchi were asked about changes in the density of shade and timber trees in their region over the last few years, 39 replied without hesitation that shade was decreasing and being replaced by full sun techniques enabled by hybrids.

The Adoption of Hybrids and Technical Progress

The smallholders appear to be very discriminating in terms of the type of planting material they use and the plant population in the plantations, both for cocoa tree density and large residual forest trees. Agroforests are mostly made of the old 'amelonado' while hybrid and young cocoa plantations have a high density of cocoa trees and very little shade from large forest trees (Table 4).

The Demographic Component of the "Migration" Factor

Enchi is one of the current pioneer fronts in Ghana. Satellite images taken in 1990 and 2000 reveal the scale of

Table 4 Number of trees per hectare of cocoa farm observed per quadrate, according to the type of cocoa plant material (2005)

	Average number of trees per hectare		Average year of plantation
	Cocoa trees	Forest trees >10 m high	
Amelonado "Tetteh Quarshie"	992	50	1970
Amazonian	1095	4.7	1989
Hybrid and hybrid descendents	1493	3.4	1991
Probability of error	0.035	0.000	0.000

deforestation over a decade. There is a close correlation between the satellite images and the results of the survey on the age structure of the cocoa plantations. The rate of creation of cocoa plantations "exploded" in the 1990s (Figs. 3 and 4). The image, which is representative of Enchi's landscapes, provides further evidence of the link between deforestation and investment in cocoa (Fig. 2).

The determining role played by migration is also evidenced by the overlap between the curve showing the rate of creation of the first plantations and the rate of arrival of migrants, whereas the curve for *re-settled* autochthons lags behind (Fig. 4). When an autochthon returns to a village, a plantation is not created immediately, unlike when a migrant arrives. The correlation coefficient between the date of the farmer's arrival in the village and the first plantation is 0.81 in the case of the migrants versus 0.31 with autochthons. In fact, the difference between migrants and autochthons would have been more spectacular if we had chosen a representative sample showing the predominance of migrants.

Migration for cocoa production is thus clearly one of the main causal factors of deforestation and of the choice of full sun cocoa and, hence, of the decline in biodiversity in Enchi and in the wider Western Region. This is due to the number of migrants and the labour force they provide.

Migration and Autochthony: Now Less Important Than Expected?

I suggested above that there is a demographic—almost mechanical—dimension to migration that accentuates the process of deforestation. I also referred to an institutional dimension, with techniques that depend on the autochthon/migrant status and land/labour arrangements. Below I describe the situation in Enchi.

Smallholder Perception of Shade

Of the 84 plots sampled, the planters classified 74 in the full sun category, i.e., 87%. This perception appears to be coherent with the landscape (photo 2). Autochthons lag only slightly behind with 74% of full sun plots compared to 97% for the migrants (Table 5). Consequently, there is only a slight difference between autochthons and migrants. As a whole, planters are basically moving towards full sun.

Smallholder Perception of the Number of Timber Trees

When smallholders were asked for more details about the trees they conserved in their plots, they automatically thought in terms of large natural forest trees, which exceed 20 m in height and form a wide canopy over the cocoa trees. They were then asked to estimate the number of these large trees. First, all smallholders, whether autochthons or migrants, stated that there were very few large trees in their cocoa plantations. They are aware of their large-scale elimination. Second, the migrants estimated the number of large trees to be lower, although the values of standard deviation within each group are high (Table 6).

Confirmed by the Facts

In the field surveys, large trees were defined as being over 10 m tall. There were thus logically 'more' trees than there would have been if only trees of more than 20 m had been taken into account. In terms of relative value, the field counts

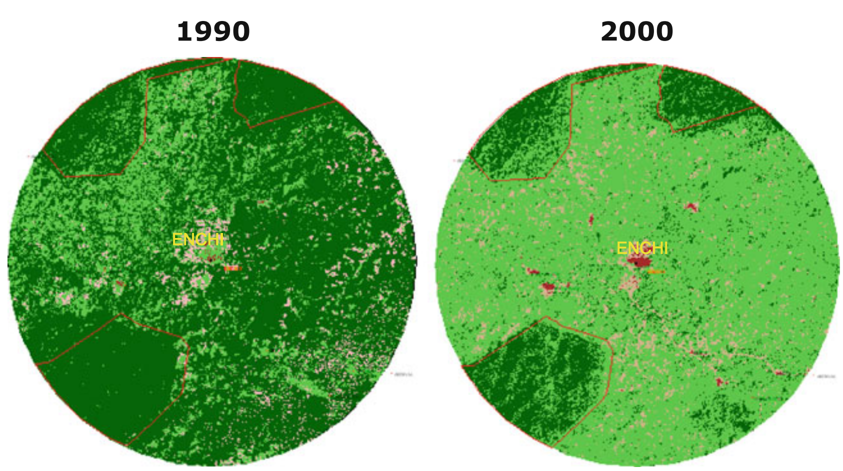

Fig. 3 Satellites images of Enchi in 1990 et 2000. *Enchi 1990*: Enchi is still a village and the encampments (in red) are almost non-existent, or invisible to say the least. The forest (*in dark green*) has already been eaten away in the east by "full sun" cocoa plantations (*in pale green*), but it represents the dominant plant cover. *Enchi 2000*: Enchi is becoming a town and the migrant encampments are developing. Apart from a few remaining scraps on the periphery, the forest has been "definitively" converted into "full sun" plantations in 10 years

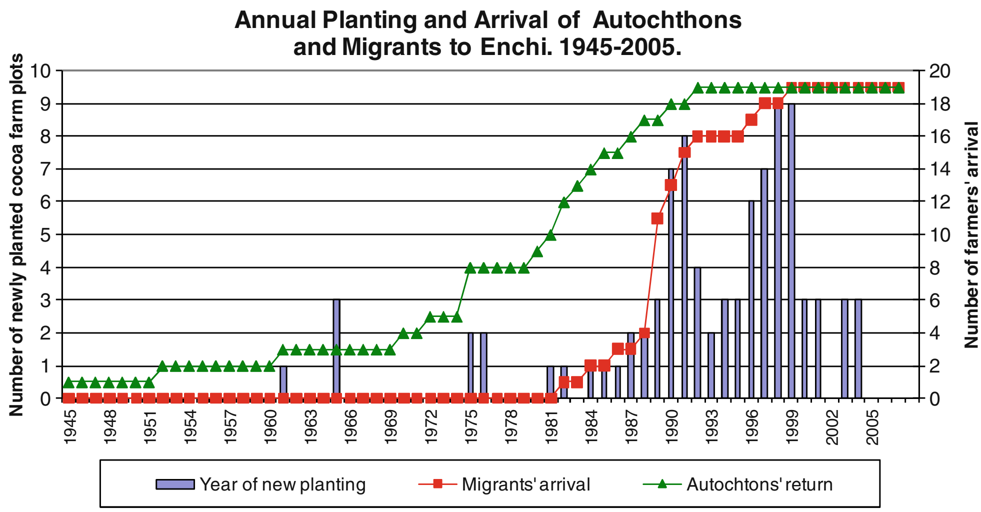

Fig. 4 Migration and investments in cocoa farms at Enchi. 1945–2005. Sources: Fig. 3: Amamoo-Otchere 2005. Figure 4 Author' survey, 2005

confirmed what the planters said. Here again, the number of large trees is the least well-defined variable in terms of the dualism between autochthons and migrants. There was an apparent difference, with ten large trees per hectare for autochthons compared to 4.3 for migrants. However, here again, variation within each group was high (Table 7).

At this stage, it is already possible to conclude that the link between the "autochthon/migrant" status and the "shade/full sun" choice is less important in Enchi in the 2000s than has been claimed in the literature and proposed in our hypothesis. How can this be explained?

A Key Institutional Factor: The Omnipresence of the 'Abunu/Domayenke' Arrangement

Contact with the migrants and their economic success has influenced indigenous smallholders in favour of 'full sun.' The influence of migrants is even more direct as a result of a number of institutional arrangements for land and labour, particularly the *Abunu* contract, also called *Yemayenkye*' or *Domayenkye*, which can be translated as 'Do and let's share' or 'Weed and let's share.'

A person with rights to land, a 'landowner,' who is generally an autochthon, 'concedes' (leases) a plot to a migrant on condition that the latter clears it, plants it entirely with cocoa trees, maintains it until it starts producing, at which point the plot is divided into two halves between the landowner and the *Abunu* (the name given to the lessee in the contract he/she makes).

Table 5 Smallholders' classification of their plots, by degree of shade (2005)

	Dense shade	Light shade	Full sun
Indigenous (42 plots)	4%	19%	77%
Migrants (44 plots)	3%	0%	97%

This land/labour exchange contract already existed in Ghana in the period 1930–1950 (Hill 1963). Since 1990 it has developed rapidly particularly in the Western Region. A total of 89% of the plots created by migrants in Enchi are declared under the *Abunu* contract.

A Time Factor and a Generational Change

All the autochthons claimed to have created their first plot themselves. This is possible, or at least logical, given that two thirds of the first plantations were created before 1990, which means before the arrival of most migrants. However, the autochthons recognised that the second and third plantations were created under *Abunu* contracts (Table 8). This is one of the indicators that the role of migrants has increased over the years. This phenomenon is characteristic of all cocoa booms.

The generational change has also played a role. Of the 41 autochthon smallholders interviewed, the seven youngest (under 40 years old) all opted for full sun and only declared 0.15 non-cocoa trees per hectare.

Discussion

The Rapid Decline of Complex Agroforests The results obtained in Enchi and in the four other cocoa producing

Table 6 Number of trees per hectare of cocoa plantation, according to the smallholders' statements (2005)

		Number of Forest trees >20 m high	
Indigenous (20)	Average	1.2	
	(St. dev).		(1.6)
Migrants (20)	Average	0.5	
	(St. dev).		(0.7)
Probability of error		0.13 (Not sign.)	

Table 7 Number of trees per hectare of cocoa farm, observed and counted per quadrate

		Cocoa trees	Palms and fruit trees	Forest trees >10 m tall
Autochthons (20)	Average	1119	7.5	10.0
	St dev	350	16.4	25.5
Migrants (20)	Average	1480	23	4.3
	St dev	629	37.1	11.6
Probability of error		0.02	0.08 (Not sign.)	0.27 (Not sign.)

regions of Ghana demonstrate that as a whole the smallholder population is increasingly making a deliberate choice in favour of full sun or very light shade. Complex cocoa agroforests are rapidly disappearing in Ghana (Tables 1, 3, 5; Figs. 1 to 3). And when old cocoa agroforests are replaced by rubber, oil palm, citrus, or teak, it is also in the form of monoculture plantations (Table 2). This process of tree diversification without tree intercropping but rather in the form of a mosaic of small farm plots is closer to the concept of polyculture than that of agroforest. It confirms that the decline of agroforests goes far beyond cocoa, as evidenced by a few case studies on rubber, oil palm and dammar, mostly in Indonesia (Belcher *et al*. 2005; Potter 2004; Kusters *et al*. 2008; Feintrenie *et al*. 2010).

Migration and Autochthony, Generational Changes, and Abunu Contracts The results of our survey also confirm the powerful effects of migration dynamics on deforestation and on migrants' preferences for full sun hybrid cocoa. The Ghanaian case studies had a slight impact on our hypothesis with respect to the institutional aspects of migration. The dichotomy between autochthons' agroforests and migrants' full sun farms is shrinking (Tables 5, 6 and 7). The fact is, in the 2000s, autochthons' agroforests are also rapidly disappearing. One reason is the generation change. Most young autochthons, at least those who do the planting themselves, tend to copy young migrants' practices because they share the same objective: quick returns (and possibly lack knowledge about their environment). The other factor is the 'labour/land' *Abunu/Domayenkye* contract, which is mostly drawn up between autochthons and migrants. When old autochthons do not see their sons and nephews coming back to ensure the future of their farm, the only option is to "give" their old Amelonado agroforests to young migrants for replanting under an *Abunu* contract. These young migrants opt for hybrids and full sun strategies. This is gradually erasing the differences between the two types of cocoa farming.

Table 8 Average year of creation of plantations belonging to autochthons and percentage of plots under *Abunu* contract

	Average year of plantation	Percentage of plots created under *Abunu* contract
1st plot created	1983	0%
2nd	1990	25%
3rd	1999	30%

In itself, *Abunu* is not responsible for deforestation and loss of biodiversity. However, against a background of inadequate legislation and relative uncertainty about land and tree tenure, it may accelerate the process.

Land Tenure, Productivity and Ecological Services Belcher *et al*. (2005) stated that further improvement in tenure security over land coupled with higher land value are likely to drive intensified land use. Better security of tenure could accelerate the move from agroforests to zero-shade farms. Sometimes the process is the reverse: the move to zero-shade farms improves security of tenure. For instance, in the case of rubber in Sumatra, because jungle rubber is not officially recognized as a real cropping system, smallholders replant clonal rubber as a way to protect their land rights (Ruf *et al*. 1999).

In our survey in Ghana, farmers did not mention problems of land tenure (Table 3). When migrant farmers started to abandon agroforests and to massively adopt full sun strategies in the mid 1970s in Côte d'Ivoire and in the mid-1980s in Ghana, tropical forest was still abundant. At the time, migrant farmers' objectives were to secure ownership of their land and obtain revenues, both as quickly as possible. Both objectives implied getting rid of natural forest trees. Firstly, a full sun strategy reduces the immature period from 5 years to 2–3 years. Secondly, a zero-shade cocoa farm is entirely made of planted trees, whereas giant trees left from the forest may reduce migrants' informal control over the land. The full sun technique is thus more often used as an attempt to improve land tenure than the other way around.

Land Tenure, Autochthony and Hybrids Land conflicts tend to increase among autochthons after the first generation change (Chauveau 2006). However, autochthons generally still enjoy more security of tenure than migrants and yet they are increasingly copying migrants' practices. In fact, all the smallholders are increasingly faced with a common environmental and technical reality, which goes beyond autochthon/migrant dualism. The most important factor that is destroying the relationship between 'indigenousness' and shade is the diffusion of technical progress, particularly planting material, mostly hybrids for the time being in the case of cocoa, possibly clones in the near future. The central role of hybrids "which do not like shade," and of technical progress in the decline of complex agroforest perfectly fits the hypothesis of this paper.

Agricultural Policies As underlined in the case of rubber and nutmeg in Indonesia, policies may have both an indirect and a direct impact in favour of intensification and abandonment of agroforests (Belcher *et al.* 2005). Regarding rubber, the showcase of Thailand is still more exemplary. In the 1960s, the government created the Office of the Rubber Replanting Aid Fund (ORRAF), which organized the replacement of all the jungle rubber by pure stands of clonal rubber. In West Africa, official policies also played a role in discouraging agroforests. Experimental trials of new hybrids were mostly performed without shade (Liabeuf 1979). Extension services often promoted zero shade systems. However, this was not explicitly mentioned by farmers (Table 3). They are partly right. Well before research institutions and extension services, migrants were the real inventors or re-inventors of full sun strategies (Ruf 2001).

Forest Policies and Timber Value The huge gap between the meagre compensation paid to farmers and the FOB export value of timber is a good indication of the potential gain for farmers if they were to obtain access to the legal timber market. Farmers are still not fully aware of the value of timber. While the traditional agroforest generates from $150 to $300/ha/year of net cocoa revenue, a mature full sun farm yields $450 to $700/ha/year. With timber currently worth around $100/ha, opting for new planting or replanting with full sun techniques is perfectly rational. If farmers had access to a market in which the value of timber was close to the world market price, they might consider a compromise between annual cocoa revenues and occasional financial gains from the sale of timber.

Over and above changes in policies and in legislation, the main aim should be to implement a widespread information campaign to raise awareness among farmers of the value of exported timber. This would encourage planters to reconsider the optimal balance between income from cocoa and timber.

An Evolutionary Path and a Kind of 'U Curve' Quoting Boserup (1965) and Homma (1992), Belcher *et al.* (2005) raised the principle of an evolutionary path of management intensity that increases with an increase in population density. As mentioned above, the zero shade system was adopted at the very beginning of the massive migration process in south-western Côte d'Ivoire and Ghana, and thus was itself an accelerator of migration and population density and deforestation. In terms of the smallholders' perceptions, old complex agroforests are extensive and based on an earlier model and were designed to deal with an earlier problem, neither of which is now pertinent.

Complex agroforests and their biodiversity relied on a low population density at a time when the limiting factors were labour and capital, not land. The planting material that was then available was slow to mature (around five years). Rather than weed for five years with no cocoa yield, the idea of leaving shade or encouraging regrowth of natural vegetation to provide soil cover, thereby considerably reducing the amount of maintenance work, was perfectly rational.

Massive migrations changed the rationale. Full sun strategies and systematic intercropping of annual crops were made possible by the tremendous increase in population density and labour. In terms of cocoa revenues, this type of complex agroforest, with its poorly productive cocoa trees, was no longer able to compete with full sun systems, especially with hybrids (Fig. 5). In terms of tree cover and biodiversity in the cocoa farms, this was the declining path of the U curve, close to the Malthusian theory that demographic growth is directly related to the environmental degradation. Are cocoa farmers ready to move to the next step of the U curve? This would reconcile the Malthusian and Boserupian approaches (Boissau *et al*. 1999).

In some regions of Ghana and Côte d'Ivoire, there are a few isolated case of renewed adoption of timber trees by cocoa farmers, possibly due to the recent rediscovery of some ecological value but more likely due to their anticipation of a timber market. Does that mean that the density of timber in cocoa farms may follow a kind of 'U curve'? Probably not. The few smallholders who decide to plant timber trees have a preference for separate pure stands of timber trees. In future, we may well have a kind of U curve in terms of timber production and the number of timber trees owned by cocoa farmers but it is likely that a high percentage of these trees will not be part of the cocoa farm plots. In any case, in terms of biodiversity, it may be more of a L curve.

Significance of Limited Data on Hybrids Grown Under Shade In the debate about the decline of agroforests and their comparative advantages and disadvantages, one of the difficulties is the lack of data concerning shaded hybrids. This can be explained by the historical shift in cocoa. Farmers used to abandon their old shaded cocoa farms (comprising *amelonado* or *amazons*) in their home region and create a

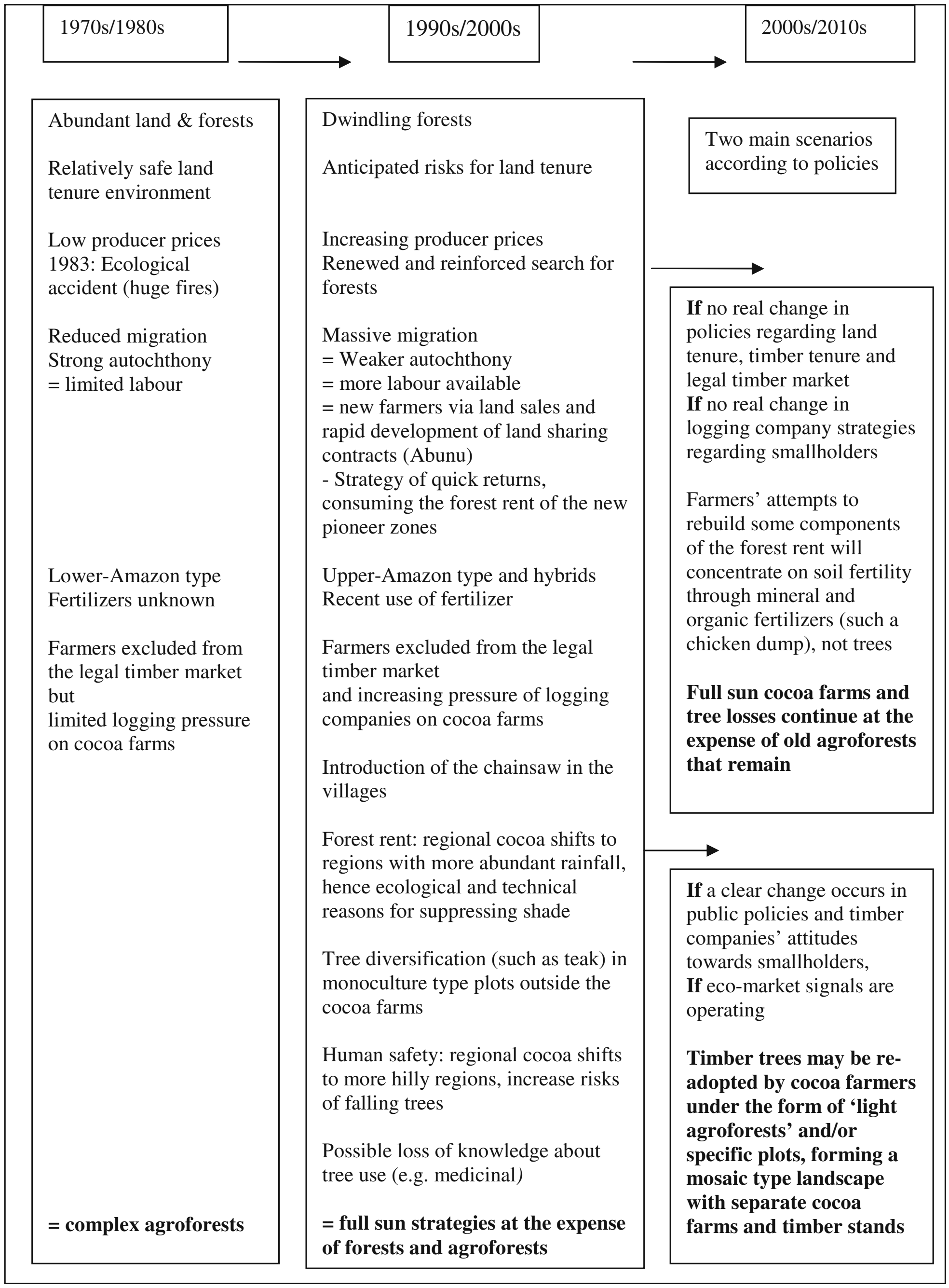

Fig. 5 Analysis grid explaining the shift from agroforests to full sun cocoa farms in the case of Ghana

zero-shade farm with hybrids (or descendants of hybrids) in a pioneer region where they went to look for good virgin soils and abundant rainfall. Subsequently, farmers started to cut down and burn the old shaded cocoa farm in their home region and plant hybrids without shade (Fig. 5).

Conclusion

Our examination of cocoa farmers' strategies in Ghana has shown that agroforests are now far from being complex. After forest clearing from the 1940s to 1970s/1980s, which led to the development of agroforests, farmers are now clearing the surviving forests and agroforests and replacing them with full sun farms, either of cocoa or rubber and oil palm, and possibly teak. The results of our surveys in Ghana helped build an analytical framework to explain these changes (Fig. 5). Overall, we validated our hypothesis based on four or five major factors that determine the choice of full sun and the vanishing of old agroforests, i.e., technical progress; legislation excluding smallholders from the legal timber market; recent expan-sion of the timber industry; and the migratory phenomenon, (in terms of its demographic implications and in its institutional dimension).

Technical progress, namely the adoption of vigorous hybrids complemented by the reasonable use of pesticides, fertilizers, and more recently herbicides, plays the most important role in the disappearance of cocoa agroforests, perhaps more than timber legislation.

Once they have started to use hybrids, farmers believe that the ecological services that complex agroforests could be expected provide are in fact limited. Shade and agroforests may even provide negative ecological services such as increased damage by pests (squirrels) and the spread of diseases, such as *P. megakarya*, the source of black pod. Other factors came to light, such as the physical and sometimes fatal risk involved in keeping isolated giant trees on a cocoa farm.

We also refer to the notion of time, notably the ongoing deforestation process, which is heightened with each plantation cycle, and thus follows a kind of evolutionary path. Maintaining biodiversity in cocoa plantations no longer involves reprieving or reproducing extensive systems developed at a time when forests were abundant. Complex cocoa agroforests are an anachronism, and are now in the process of becoming a myth.

However, after a period of approximately 30 to 40 years (from 1975 to 2005/10) when short/medium-term returns on cocoa, i.e., full sun strategies, were understandably a priority, there is a hint of the beginning of a return to timber trees. Above and beyond eco-certification, which has yet to prove its efficiency, the timber market appears to be the strongest factor in this potential U turn. As deforestation is complete and local populations are becoming aware of the shortage of timber for their own construction needs, a 'market call' is on the horizon in the form of a domestic/illegal market organized by the local chainsaw teams, who sometimes take over the timber business at the expense of legal companies.

More than a return to the use of timber trees, this will be the invention of new timber tree systems. If these trees are native species (like Iroko or Framire), the act of planting is essential to ensure tenure security. Nevertheless, a change in legislation and its implementation is necessary to accelerate this potential turnaround. Smallholders need full access to the timber market and to financial and institutional mechanisms to deal with the long period of investment.

More trees but which systems? Timber trees can be intercropped with cocoa or other tree crops such as oil palm. In that case, they would be part of new intensive 'light agroforestry systems' that are capable of generating a high income with good profitability per unit of land and labour. These modern simple agroforests or agroforestry systems will be made of cocoa and one or two timber tree species, based less on ecological services than on domestic and international markets, which are likely to be dominated by a limited number of timber species compatible with cocoa tree and with cocoa farmers' requirements. We may also see the development of 'box systems' with teak or other exotic timber species encircling a cocoa or oil palm farm and thus combining several functions, including improved control of land.

Alternatively, smallholders may plant timber trees in special plots. A lot of research remains to be done to evaluate the advantages and disadvantages of these different systems. Nevertheless, we believe more in the likelihood of special timber plots, because it will be easier for farmers to prove that the native Framire or Iroko trees did not result from natural regeneration but were planted. We also anticipate better management of land resources and reduced risks of log theft (for instance by planting timber trees close to the road and cocoa in more distant plots). In that case, the result of the 'U turn' will be a mosaic landscape with cocoa, timber, rubber and oil palm stands, with rotation of tree crops, such as rubber replacing timber and/or timber replacing cocoa, no longer based on complex or even simple agroforests but rather on a kind of polyculture based on rotation of tree crops: a tropical agroforestry model, nonetheless.

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