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The agroecological transition of agricultural systems in the Global South

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Chapter 3

Agroforestry: diversified practices for the agroecological transition of African cacao farming

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Since the 1960s, the cultivation of cacao (*Theobroma cacao* L.) in Africa has experienced unprecedented growth. The area under cacao cultivation in Africa, 3.3 million hectares in 1961, now stands at 6.5 million hectares. During the same period, African cocoa production has more than trebled, from 865,000 tonnes (Braudeau, 1969) to 3 million tonnes (FAOStat, 2017), confirming Africa's predominant position, and that of Côte d'Ivoire and Ghana in particular, in world cacao farming. Between them, these two West African countries account for 70% of the world cocoa supply (ICCO, 2017). In the coming years, world chocolate consumption is expected to increase sharply due to rising living standards in several very populated emerging countries (India, China and Brazil in particular). This trend could lead to problems for the global cocoa market arising from a possible supply-demand mismatch for this agricultural commodity (ICCO, 2017). Therefore, it is likely that the dynamics of cacao cultivation observed over the past 50 years, especially in Côte d'Ivoire and Ghana, will spread to other African countries in the humid tropics having soil and climate conditions favourable to cacao farming. Indeed, African family farming has already proven its ability to adjust its cocoa production to match demand.

In order to maintain or increase cocoa production, farmers have mainly taken the route of extension of cacao farms through repeated migrations into forest areas and clearing of forest lands (Ruf, 1995). Starting in the 1970s, a large number of farmers started cultivating cacao under the open sun, rather than under forest shade, as they had been doing until then. There are several reasons for this, technical as well as social and legal (Ruf, 2011). However, even though these full-sun cacao farming systems doubled the average yield of the African cacao farm from 250 kg/ha of marketable cocoa in the 1960s to 500 kg/ha in the 1990s (FAOStat, 2017), they have become extensive due to the withdrawal of technical and financial support resulting from the liberalization of the cocoa sector. Finally, the global phenomenon of climate change could lead

to a reduction in areas suitable for cacao farming in West Africa (Läderach *et al.*, 2013), and ultimately an increased vulnerability of farms whose existence depends on cultivating this cash crop.

At present, given the agronomic, social and ecological limitations of full-sun cacao farming and the challenges that confront it, an agroecological transition of African cacao farming is unavoidable, both for its own future and that of forest zones. Indeed, in Côte d'Ivoire and Ghana, the last remaining forest areas remain under threat. It is therefore urgent to protect them while supporting farmers in stabilizing existing cacao growing areas and improving their standards of living. In other countries that still have vast forest reserves and which may be tempted to embark on cacao cultivation to diversify their economies and provide income to rural populations, it is a question of limiting deforestation and reducing the negative environmental impact of cacao farming. This chapter analyses the relevance of agroforestry for an agroecological transition of African cacao farming.

The full-sun technical model called into question

Even though the cacao is believed to need shade to grow properly, it was shown in the 1960s that its productivity increases when it is fully exposed to sun light, provided with nutrients and protected from pests and diseases (Braudeau, 1969). The technical model proposed to farmers therefore focused on increasing yields through full-sun cultivation and the intensification of inputs and labour, based on the use of selected and vigorous varieties from hybrid seeds. This model also favoured the cultivation of cacaos as a monocrop or under a light and homogeneous shading, often reconstituted, with the use of synthetic inputs for phytosanitary protection and fertilization (Wood and Lass, 2001). At the same time, especially following the independence of the countries concerned, cacao cultivation became the subject of interventionism because of its economic potential, all the more pronounced due to high world cocoa prices. Farmers were aided and guided in particular through the availability of processing equipment and phytosanitary products.

In both countries, Côte d'Ivoire and Ghana, there is evidence that some farmers had practised full-sun cacao farming as far back as the 1920s and 1930s, well before the research community began recommending it. In Côte d'Ivoire, however, this practice increased sharply in the 1970s due to the massive flows of migrant farmers whose main objective was land appropriation (Ruf, 1995). These migrant farmers, who, incidentally, adopted widely distributed cocoa hybrids, were not interested in adopting intensive farm management practices once a farm was established, which would have required farm maintenance and recourse to inputs. They relied instead on 'forest rent' (soils rich in organic matter and nutrients left behind by the cleared forest cover) which, combined with rainfall quantities and patterns favourable for vigorous young cacaos, provided yields of 500-700 kg/ha (Ruf, 1995), yields which some farmers nevertheless boosted further by gradually adopting the use of pesticides recommended by agricultural extension services.

This technical model of full-sun cacao farming continues to be used by farmers as long as they continue to benefit from the high yields. However, in general, after 20 to

30 years of cultivation without sufficient mineral fertilization and adequate phytosanitary protection, the production conditions become degraded and cacao productivity collapses (Ahenkorah *et al.*, 1987; Hanak Freud *et al.*, 2000). Some farmers try to rehabilitate their cacao farms, but the technical difficulties and the additional costs to do so are prohibitive, forcing them to abandon their cacao farms to create new ones elsewhere, on new forest clearings. Other farmers convert their cacao farms to rubber or oil palm plantations, which are crops that are more easily cultivated than cacao on degraded soils (Ruf, 1995). By not providing the motivation for the rehabilitation of degraded cacao farms, the model of full-sun cacao farming therefore appears to be unsustainable. The farmers abandon their cacao plots and move to other places for planting new trees; thus, the system looks as if it is itinerant, even though cacao is a tree crop.

Forest areas have thus virtually disappeared from Côte d'Ivoire and Ghana; the Ivorian forest area decreased from 13 to 3 million hectares between 1960 and 1990 (Hanak-Freud *et al.*, 2000). The 2000s saw further acceleration of the disappearance of the remaining Ivorian classified forests and national parks (Higonnet *et al.*, 2017). The same is true in Ghana where it is estimated that 80% of forest areas have disappeared since the introduction of cacao cultivation to the country (Cleaver, 1992).

For cacao farmers – 95% of them have cacao acreages ranging from 1 to 10 ha (Rafflegeau *et al.*, 2015) –, the challenge is therefore to reinvent sustainable models of cacao farming that are also agronomically efficient. The objective is to guarantee them decent living conditions in a context that is uncertain in economic terms (fluctuation in world cocoa prices: between 2000 and 3500 US$/t over the last decade; high taxes; and/or weak public support) as well as in climatic terms (disrupted seasons, rising temperatures and shifting of areas suitable for cacao farming), with a minimum of environmental impacts.

In parallel with this dominant history of cacao farming, in some areas, farmers have been practising agroforestry cacao farming for a long time or have been moving towards more agroforestry-oriented practices.

Agroforestry systems: farmers' agroecological practices already in use

In fact, many African cacao farmers are developing and managing systems in which, unlike the full-sun model, the cacao is associated with other perennial, forest and fruit species with multiple uses. These systems are found in most cocoa producing countries, including Côte d'Ivoire, Ghana, Nigeria and Cameroon. These agroforestry systems, often called traditional, are highly diverse and demonstrate the farmers' capacity for adaptation and innovation. Recent studies have shown that these systems have several benefits, including for the farmers themselves. Five of these benefits can be mentioned.

Multiple productions help meet the cocoa producers' requirements

In comparison to full-sun monocrop cacao cultivation, the first advantage of agroforestry systems, whether they are simple (two or three components: cacao-rubber association,

cacao-fruit trees association or cacao-oil palm associations) or more complex, is the diversification of products. In Côte d'Ivoire (Herzog and Bachman, 1992; Adou Yao *et al.*, 2016), Ghana (Ruf *et al.*, 2006) and Cameroon (Jagoret *et al.*, 2014a), many species are associated with cocoa, such as *Persea americana* (avocado), *Elaeis guineensis* (oil palm), *Dacryodes edulis* (African plum), *Cola nitida* (kola) and *Ricinodendron heudelootii* (njansang), each of which provides an edible product: fruits, young leaves (sauce preparation), seeds (condiments, oil), and sap (palm wine). Other, mainly forest, species have a commercial value (*Terminalia superba* and *Milicia excelsa* for example for the supply of timber) and/or medicinal value because some of their organs (leaves, bark, root, wood) are used to treat various ailments (*Cola cordifolia*, *Alstonia boonei*, *Rauvolfia vomitoria* for example). These various species provide products that are both self-consumed and sold by rural households, two functions that can represent, as demonstrated in Cameroon, up to 56% of the usage value attributed by farmers to the various ligneous species present in their cacao farms (Jagoret *et al.*, 2014a).

By being more diversified than full-sun cacao farms, and by separating the species according to a spatial structuring (by surface and by height) that limits interspecific competitions, cocoa agroforestry systems are economically less risky. In Côte d'Ivoire, the association of rubber trees in cacao farms, still embryonic in the 2010s, can allow farmers to limit risks in an unstable context of high volatility of cocoa prices, while allowing them to derive value from their lands and make farming remunerative while awaiting the entry into production of rubber trees (Snoeck *et al.*, 2013). Jaza *et al.* (2015) have estimated that the introduction of three local fruit species into cacao farms in central Cameroon – African plum (*Dacryodes edulis*), the wild mango (*Irvingia gabonensis*) and the njansang (*Ricinodendron heudelotii*) – can generate substantial additional income compared to full-sun cacao cultivation. The different species associated with cacaos can also offer sequential productions that are spaced out over the year. Thus, in central Cameroon, the species of trees interplanted with cacaos allow farmers to harvest different fruits (avocados, mangos, kola nuts, African plums, palm nuts for oil production) in a staggered manner during periods when cacaos do not produce (Figure 3.1). At the same time, forest species and oil palms can provide farmers with timber and palm wine around the year, or even be host at certain times of the year to caterpillars that are consumed by local populations (Photo 3.1).

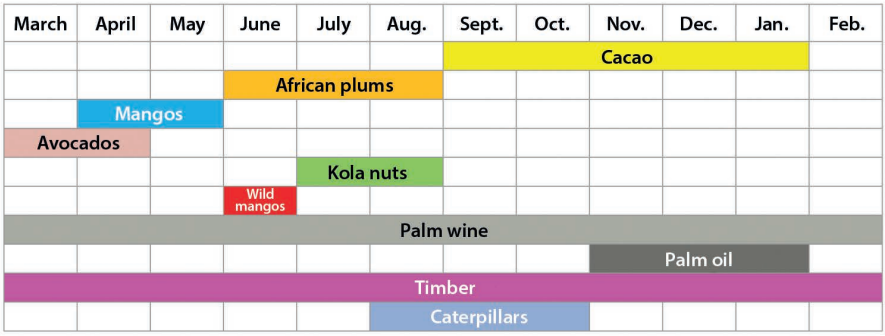

Figure 3.1. Periods of harvest of different products provided by the cocoa agroforestry systems of central Cameroon.

Photo 3.1. *Petersianthus macrocarpus* (Essia) is the host plant for *Imbrasia ertli*, a caterpillar species consumed by the populations of central Cameroon. © Patrick Jagoret.

Higher cocoa production than it appears

In cocoa agroforestry systems, marketable-cocoa yields can be similar to, or even higher than, those obtained in full-sun cacao farms when farmers are unable to apply the appropriate quantities of required pesticides and chemical fertilizers (Figure 3.2, green circle), even in older cacao farms that have significantly exceeded the threshold beyond which reconversion or rehabilitation is often recommended (Figure 3.2, blue circle). This is especially the case in central Cameroon, where the majority of the cocoa is produced from complex agroforestry systems. A study of observed yields, estimated from counts of pods made in dedicated studies, has shown that average yields are of 596 kg/ha, but they can reach up to 2 tonnes/ha in some areas (Bisseleua *et al.*, 2009; Jagoret *et al.*, 2017a; Saj *et al.*, 2017a). These yields were observed in plots in which an average of 1500 cacao trees per hectare are grown with 190 fruit or forest trees,

thus demonstrating that it is possible to grow cacao in such systems while achieving higher levels of yields than commonly believed. Saj *et al.* (2017a) further found that the cocoa yields in these complex systems depend on competition with associated trees. In particular below a certain level of presence of trees, long-term cocoa production, i.e. beyond 40 years, does not seem assured. A sufficient density of shade trees is thus necessary to maintain the long-term performance of cocoa agroforestry systems.

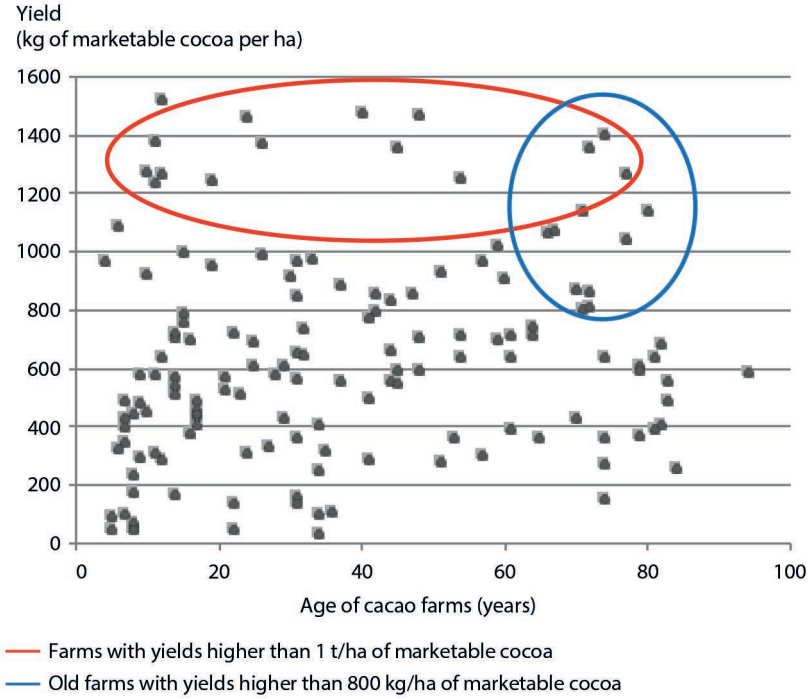

Figure 3.2. Yields of marketable cocoa observed in 144 agroforestry cacao farms in central Cameroon (Ngomedzap, Bokito and Zima areas).

Technical management without the use of synthetic fertilizers

Cocoa yields of complex agroforestry cacao farms can be maintained at satisfactory levels without recourse to fertilizers, provided that good agricultural practices are applied (Jagoret *et al.*, 2011). In central Cameroon, the soil organic matter content below cacaos is around 4.1 to 4.7% (Duguma *et al.*, 2001), whereas the level required for good cocoa growth is 3.5% (Braudeau, 1969). Snoeck *et al.* (2010) have shown that appropriate tree management in cacao farms allows farmers to correct the depressive effect due to the planting of cacaos on cleared forest plots, and to return after 25 years to a level of organic matter under cacao trees similar to that of the original forest. In the absence of fertilization, trees play an important role in restoring soil fertility by helping recycle organic matter and nutrients, which also improves the soil's cation exchange capacity. Also, in central Cameroon, the ability of agroforestry practices to maintain or even to restore soil fertility has also been observed by Jagoret *et al.* (2012) in agroforestry cacao farms installed on what was previously savannah, with

the soil organic matter content increasing significantly with age, from 1.7% in young cacao farms to 3.1% after 40 years. Over the long term, as far as fertility is concerned, the type of associated tree appears to be as important as the soil pedological origin (Snoeck and Dubos, 2018). Unlike for fruit trees, cacao fruiting is independent of the vegetative growth. Its nitrogen requirements are therefore low because nitrogen contributes more to its vegetative growth than to its fruiting. A nitrogen supply will favour long branches that bend easily. Consequently, to increase production, it is better to reduce the vegetative growth which will promote flowering (Snoeck *et al.*, 2016). The association with legumes is thus often sufficient to meet the cacao tree's nitrogen requirements (Nygren and Leblanc, 2009).

In cocoa agroforestry systems, the biological activity promotes water infiltration, the incorporation of organic matter into the soil, and the storage and release of surface nutrients. In addition, the permanent litter layer provides soil protection against runoff and erosion. Rousseau *et al.* (2012) have shown that the richness of the macrofauna of cocoa soils is not significantly different from that of the neighbouring forest and is greater than that of the neighbouring savannah or cultivated soils. This result confirms the observations made in Cameroon on the microbial activity of soils under young and adult cacaos in the forest and in the savannah (Snoeck *et al.*, 2010). In Ghana, favourable effects of shade trees on soil fertility and the nutritional status of cacaos (increased cation exchange capacity and higher nitrogen level) have also been demonstrated (Isaac *et al.*, 2007; Blaser *et al.*, 2017).

Higher carbon storage levels in agroforestry than in full-sun cacao

The more diversified and complex the cocoa agroforestry system, the more it seems to be able to store carbon, thanks in particular to the forest trees associated with the cacaos. In the agroforestry systems of central Cameroon, for example, the aboveground carbon stock of adult cacaos older than 15 years is, on the average, between 5 and 10 tonnes/ha (Saj *et al.*, 2013). In the most complex systems, cacaos thus represent less than 10% of the stock of the total tree biomass of these systems, whereas this stock can sometimes reach 20% in simplified agroforestry systems. Compared to neighbouring forest systems, however, the level of aboveground carbon storage of cocoa agroforestry systems remains 20 to 50% lower. It can however reach up to 180 tonnes/ha in certain areas (Saj *et al.*, 2013, 2017b). Also, in Cameroon, it has been shown that, in the cocoa agroforestry systems set up in savannah, the aboveground carbon stock can reach, after 60 years, the same level as that obtained in cocoa agroforestry systems created after clearing the forest (Nijmeijer *et al.*, 2018). These authors have estimated that the surface soil carbon content has increased from 6.5 to 9.5‰ per year for more than 60 years (Nijmeijer *et al.*, 2018).

In Ghana, in cacao farms established after forest clearing, significant decreases in surface soil carbon content (- 49%) have been observed, with no significant differences in tree cover levels at the plot scale. Nevertheless, localized positive effects of shade trees on soil carbon (+ 20%) were observed, in comparison with areas without tree cover (Blaser *et al.*, 2017).

Flexible and resilient cacao farming systems

For farmers confronted by the volatility of world cocoa prices and increasing climatic variability, agroforestry systems display significant adaptability and flexibility in farm management that full-sun cacao farms do not. A common argument in favour of full-sun cacao farming is that it is more profitable for a farmer to manage a mono-specific cocoa plot in a diversified farm, as such a configuration allows him to select crops for which investment in inputs and labour will be profitable. However, given the time lag between the completion of technical operations and their effects on the cocoa yield, farmers come to know the price that their cocoa will fetch too late to take advantage of this theoretical logic. Therefore, they have already invested in inputs and labour for their cocoa plots and in the post-harvest processing of cocoa when they learn what their exact remuneration will be, often calculated on the basis of fluctuating world prices. In contrast, the cacao agroforestry farms allow to reduce this kind of risk by ensuring a remuneration of the labour and the land through the other farm productions, contributing to, as already mentioned, enhanced food security through income from sales and self-consumed production.

In Cameroon, a reconstitution *a posteriori* of trajectories of former cacao agroforestry farms has shown that their technical management can be temporarily interrupted or modified without entirely destroying the system (Jagoret *et al.*, 2014b). This makes it possible to absorb shocks by returning to the initial situation after a semi-abandonment phase (Figure 3.3) or by transforming the cacao farms to initiate a different productive project by drastically reducing, for example, the density of cacao trees. In the case of abandonment following a fall in prices or family conflicts during, for example, the inter-generational transmission of the cacao farm, the presence of other trees in the cacao farms makes it possible to slow the degradation of the cocoa stands.

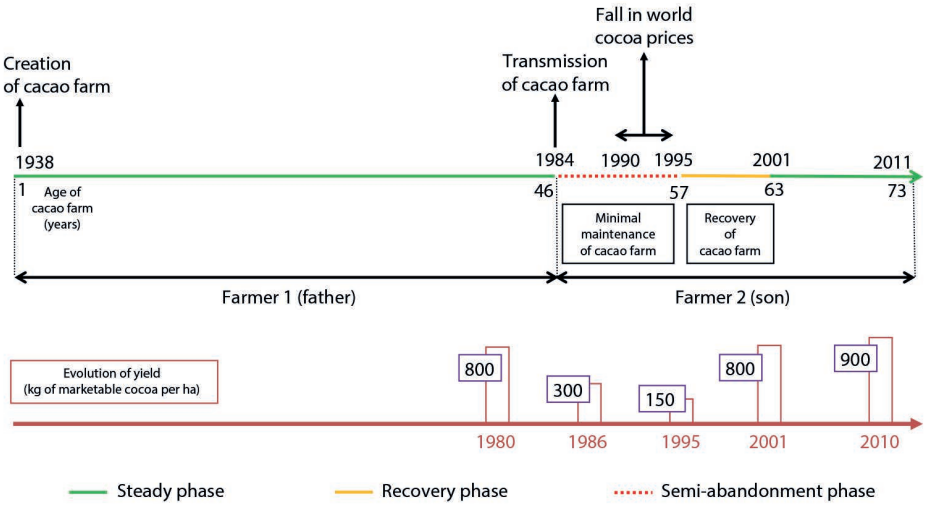

Figure 3.3. Example of the resilience of an agroforestry cacao farm in central Cameroon: the resumption by the farmer of cacao cultivation in his farm, after a management phase of at least eleven years, allowed him to restore it and return to an equivalent level of production (Jagoret *et al.*, 2014b).

Their restoration will be faster than in the case of degraded full-sun cacao plots overgrown with weeds. The biomass resulting from the growth of trees will also allow a favourable felling/replantation, by reconstitution of a 'forest rent'.

These different examples confirm that cocoa agroforestry systems can be a source of inspiration for researchers working on an agroecological transition of African cacao farming.

Modalities of supporting farmers

In Côte d'Ivoire, the trend towards agroforestry has gathered strength in recent years. Though initially not visible, spontaneous palms and fruit trees planted in full-sun cocoa plots eventually emerge above the cocoa layer. The agroforestry process is now becoming associated with the natural aging of cacaos (Schroth and Ruf, 2014). An increasing number of farmers are adopting innovative agroforestry practices to reintroduce trees into their full-sun cacao farms. Thus, Sanial (2015) showed that 30% of them plant *Ficus facensis* (*aloma* in the Baoulé language) because of its shading that is suitable for cacaos and its role in the maintenance of soil fertility. This is similar to the case of central Cameroon where many farmers retain *Ficus mucoso* and *Ceiba pentendra* (silk-cotton tree) for these same reasons (Jagoret *et al.*, 2014a).

In addition, under the pressure of environmental lobbies and rising international awareness of deforestation and climate change, official public and private sector discourses have gravitated significantly towards 'zero deforestation' and agroforestry, even though the latter concept is not always well understood or well defined. Looking beyond discourses, we can ask what public and private initiatives are likely to favour the adoption of agroforestry practices. In Côte d'Ivoire and Ghana, recent changes in forest regulations make it possible to assign the ownership of trees to cocoa producers and, theoretically at least, fulfil a condition necessary for the success of agroforestry cacao farms and thus conducive to their expansion. Other initiatives to promote the adoption of agroforestry practices can be mentioned.

The major cocoa certification programmes

The major cocoa certification programmes are usually based on the concept of sustainable development and combine environmental and ethical standards with the adoption of agricultural practices that are supposed to increase the cocoa yield of cacao farms (Lemeilleur *et al.*, 2015). Their goal is to ensure that a number of vendor and producer commitments are honoured in order to guide the choice of a buyer, regardless of whether the latter is the end consumer or a link in the supply chain. The certification thus attests to certain practices and compliance with these commitments by a producer, who derives a benefit from the sale of his product, for example in the form of a premium. The effectiveness of certification, however, is based on a demand for certified products and financial incentives that motivate the farmer to engage in this process. It also assumes that there are principles and indicators to demonstrate compliance with the commitments made and that the certification system is controlled by an independent third party.

By design, certification is based on a product differentiation strategy that all of the actors of the sector must voluntary embrace. These commitments may be motivated by restrictive regulations or the existence of a balance of power between consumers and suppliers. Cocoa is thus the subject of several certification schemes (UTZ, RA-SAN, Organic and Fairtrade, RainForest Alliance) representing around 30% of global production, with this percentage increasing steadily. Certified cocoa seems set to become the norm across the world in the future, with most importers committed to purchasing only certified cocoa by 2020. Standardization is therefore unavoidable. But we still see, in all agricultural sectors that take this path (including cocoa), that only part of certified production is sold as such at a premium price, the rest being sold at the same price as non-certified cocoa, reflecting in this way an inconsistency between the way of consuming and environmentalist demands.

Certification systems suffer from a number of limitations. The setting up of such a mechanism assumes that the market exists and that the consumer is ready to pay the price differential for certified products. It is possible to satisfy these two prerequisites for niche markets but much less so for generic markets. The system's reliability and reputation is based on a monitoring mechanism which often has the support of producer organizations, but the compliance cost remains high despite the extra premium (between 70 and 100 FCFA/kg of cocoa for example) offered to farmers. This premium barely compensates for the costs of meeting environmental and social standards. The certification system must also be able to provide the consumer with clear and precise information so that he or she can make a responsible choice and maintain confidence in the certification system. This assumes that the consumer is assured that the specifications of the certification standards are relevant and that the products on the market actually meet these criteria. The monitoring system must therefore be effective and subject to verification at short notice.

Finally, the certification of a product requires certification of its entire supply chain, which implies prior consultation of all the actors involved in the production process. Thus, although the certification systems of major international NGOs claim an environmental objective, in Côte d'Ivoire, for example, these systems have not deterred cocoa producers from massive infiltrations into classified forests and national parks, with cocoa from classified forest even being passed off as certified cocoa (Higonnet *et al.*, 2017). We also find certified cacao farms within classified forests, which can only call into question the value of the certification, obviously flawed currently as attested by such cases (Ruf and Varlet, 2017). As for programmes for the reintroduction of forest species in full-sun cacao farms via certified cooperatives, they have a limited impact, mainly because of the low involvement of farmers in the conception of these programmes and because the species to be reintroduced are chosen without consultation with them. Some NGOs and bilateral agencies have, however, adopted participatory approaches that are able to take the wishes and initiatives of cacao farmers more into account.

The REDD+ programme

In tropical countries, 20% of greenhouse gas emissions are linked to deforestation and forest degradation (Kurdej, 2015). Since cacao farms on forest lands are driving the expansion of cacao farming, the cultivation of this crop thus appears to be a factor of

deforestation, contributing significantly to greenhouse gas emissions. Conversely, it can also be an alternative to traditional slash-and-burn farming systems, contributing to a reduction of these same greenhouse gas emissions, provided that a number of preconditions are satisfied. The creation of cacao farms in areas with low carbon stocks, such as savannahs and fallows, should be favoured over the establishment of cacao farms after forest clearing, as should the maintenance of permanent forest cover or its restoration through the adoption of agroforestry practices. In doing so, it is possible to expect, in addition to any certification-related premiums, a specific derivation of value arising from the impact of this production on greenhouse gas emission levels and from its ability to contribute to their reduction. Payments for environmental services can thus contribute to the REDD+ programme (Karsenty, 2015). Such an initiative is currently being tested in northern Congo as part of a REDD+ programme that is being set up. In 2011, Côte d'Ivoire also initiated a REDD+ approach, leading to the validation of its national strategy to reduce greenhouse gas emissions. This strategy includes, *inter alia*, measures to promote sustainable cocoa production.

In Côte d'Ivoire, it is also possible to assume that the transition to agroforestry cacao farms could be based on the production of non-wood forest products mentioned above or on a better distribution of the value of wood of forest species introduced into full-sun cacao farms. This last point, however, needs clarity regarding the sharing of income from the sale of timber between sharecroppers and landowners because large-scale planting of forest trees will only take place if farmers find it very attractive. This implies moving from the extractive approach towards the 'natural' resource as practised by some loggers to a fair remuneration of the resource created by cacao farmers. Until very recently, the latter were excluded from the sharing of the value of timber: a major factor in the non-adoption of agroforestry techniques. Although the law has changed, it will take some time to become known and it remains to be seen whether this change in the legislative framework will facilitate a process of reintroduction of trees in cacao farms.

Rethinking plans for future development

It is necessary to propose new technical itineraries to farmers, adapted to the current situation of land scarcity and which offer better agronomic performance, especially in terms of cocoa production. It is matter also of promoting sustainable cacao farming systems that meet the requirements of environmental protection, biodiversity conservation, and economic and social development.

In Côte d'Ivoire, the 'Cocoa, Friend of the Forest' project, implemented in the region of Bianouan, is an operational translation of this strategy. It focuses, on the one hand, on the promotion of new technical intensification itineraries with the objective of increasing cocoa yields from 350 kg/ha of marketable cocoa to one tonne, and, on the other, on agroforestry approaches as environmental preservation techniques (maintenance of biodiversity, protection of water resources, protection of soils, prevention of pollution by pesticides and fertilizers). It also emphasizes the traceability of cocoa from the producer to the buyer through a reliable mechanism to ensure that the cocoa delivered by the cooperatives is indeed grown on cacao farms that satisfy the criteria of sustainability.

There are therefore several benefits of agroforestry, not only environmental but also economic and social. Cacao farmers have to choose, or even build, the agroforestry system that offers the best trade-offs to achieve their goals. If the farmer chooses the simplest form of agroforestry – the association of two perennial crops, such as the cocoa-rubber association in Côte d'Ivoire –, the benefit is clearly a certain economic security. If his choice is for more complex species association as in Cameroon, it is generally to respond as much to economic objectives as to environmental or even social constraints, such as the desire to build up and transmit a cocoa heritage in good condition to his heirs.

This diversity of cocoa situations poses a challenge in terms of training agricultural extension agents who provide support to cacao farmers. These agents can no longer disseminate a single technical message, be it the full-sun cacao farming model or a new agroforestry 'standard'. They have instead to consider the situation and circumstances of each farm and its plots, and find diverse and adapted technical solutions.

In fact, agronomists and agricultural extension agents have a lot to learn from – and should interact more with – cacao farmers in order to meet a number of challenges. The gradual conversion of a full-sun cacao farm or fallow into a simple or complex agroforestry cacao farm is a first challenge. The second challenge concerns the realization of the services expected by farmers from the species they choose for associating with cacaos in order to limit competition for water, light and nutrients. These choices vary widely depending on regions and communities (Jagoret *et al.*, 2014a; Sanial, 2015). The challenge of technical management is higher in the most complex cocoa agroforestry systems, which are necessarily more difficult to run and manage than simplified systems (Jagoret *et al.*, 2017b). The identification and dissemination of cocoa planting material adapted to agroforestry practices also remains a major technical challenge. Finally, the socio-technical challenge of managing trade-offs between ecosystem services in complex agroforestry systems requires the characterization of the services provided by the different species associated with cacaos.

These challenges will have to be overcome for agroforestry projects to contribute to an agroecological transition of full-sun cacao farming to agroforestry. Furthermore, this transition will likely be expensive. The State will not be able to generate the means necessary and a public-private partnership will become essential to meet these challenges of the transition to a predominantly agroforestry-based and more sustainable African cacao farming model.

Conclusion

It was family farming in Africa that turned the continent into the world's cocoa-producing powerhouse in the 20th century. However, this model of cacao cultivation has led to massive deforestation in some countries and the alternative of full-sun cacao farming has proven to be unsustainable. A true agroecological transition of African cacao farming based on agroforestry must therefore stand apart from the experiments of the introduction of imposed and poorly accepted species in cacao farms in order to meet a double challenge. On the one hand, in existing cacao farms, it is a matter of reducing the dependence on expensive chemical inputs and of rebuilding

a biodiversity that is useful at the plot and terroir scale. On the other hand, for the creation of new cacao farms, it is a matter of developing technical itineraries that favour the conservation of forest species to limit deforestation, or of setting up agroforestry cacao farms on fallows or savannahs, while aiming for the longest possible economic cycle, one that is renewable and requires little capital.

The examples presented here mainly pertain to complex agroforestry systems set up and managed by some African farmers, and for the most part on family farms. These systems have provided stable yields over time, even rectifying low fertility situations due to low organic matter levels in savannah soils, while facilitating pest control and reducing the need for chemical inputs. These systems thus appear to farmers to be more sustainable, flexible and resilient for many reasons. The simpler agroforestry systems, associating only two or three species, but where a forest layer is present above the cacaos, have been less studied here, but their continuing adoption suggests that such systems also provide solutions to the problems generated by full-sun systems. These simple agroforestry systems are usually preferred more by local, urban and rural investors, who generally have greater access to capital than do family farms.

Irrespective of the agroforestry systems, rethinking plans of future development also requires the mobilization of all stakeholders of the cocoa sector so that an agroecological transition of African cacao farming based on agroforestry can grow in scope in the coming years.

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