Chapter 12
Agroforestry-Based Diversification for Planting Cocoa in the Savannah of Central Cameroon

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Cocoa is a crop most often cultivated after clearing forests. This ensures, at least in the initial years, favourable conditions for good agricultural production: a relatively high level of soil organic matter, nutrient availability (from burning of standing vegetation), limited amount of weeds and reduced pest pressure (Ruf 1987, 1995). In order to establish cocoa plantations on forest land, large trees are either completely or partially cut down. In recent years, farming practices in several countries have evolved towards a requirement of complete clearing (Chap. 2).

However, in Cameroon, especially in its Centre and South regions, forest trees are usually preserved during clearing, both because of their economic value as well as to provide shade for young cocoa trees (Duguma et al. 2001). Native fruit trees, some with medicinal value, are also preserved. Farmers also adopt the practice of interplanting annual crops (maize, groundnut and cocoyam) with perennial crops (cassava and plantain) in the plots of young cocoa trees. At the same time, they also introduce other perennial species (oil palm, orange, African plum, kola, avocado, etc.) which grow in association with cocoa and the originally preserved forest trees (Tchatat 1996; Aulong et al. 1999; Temple et al. 2007; Chap. 2 of this book). These cultivation practices result, in a few years, in a highly diversified cocoa agroforestry system which dominates the cocoa production area of south-central Cameroon (Ruf and Schroth 2004; Zapfack et al. 2002; Bidzanga 2005; Sonwa et al. 2007).

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This development of cocoa cultivation, whether it is the agroforestry-based system prevalent in south-central Cameroon, or the more monospecific system found in other regions or countries, is very specific to humid tropical forests. Researchers and farmers consider savannahs to be unsuitable for cocoa cultivation because of their climatic constraints. While experts have classified Cameroon's Centre region as having suboptimal conditions for cocoa cultivation (Champaud 1966), farmers have succeeded in growing cocoa there.

In fact, for several decades now, this forest-savannah interface area has witnessed the development of cocoa. This has taken place, not on cleared strips of gallery forests, but well and truly on grassland covered by *Imperata cylindrica* and *Pennisetum purpureum*. The cropping system that is adopted follows a reconstituted agroforestry model. The existence of these multispecific cocoa plantations in the savannah invites us to take a closer look at the potential, characteristics and role of the dynamics of agroforestry-based diversification. The setting up of cocoa plantations on grassland soils is indeed a significant innovation in the history of cocoa cultivation, given that the crop has traditionally been dependent on tropical forests. What is the role of agroforestry-based diversification in this innovation?

12.1 Materials and Methods

12.1.1 Study Area

The study was conducted in the forest-savannah interface area of Cameroon's Centre region, in the villages of Bakoa, Begni, Yorro and Kedia in the Bokito sub-division (latitude 4°30′ north and longitude 11°10′ east, at an altitude ranging from 450 to 500 m) (Fig. 12.1). Most of the farmers are autochthons of Yambassa ethnicity (Jagoret et al. 2006a).

Several constraints render the forest-savannah interface area in central Cameroon a priori a suboptimal area for cocoa cultivation:

- Poor rainfall distribution. This zone has a hot and humid climate, with an annual average temperature of 25 °C. In addition to an average annual rainfall of about 1300 mm, which is considered to be the lower limit for the cocoa ecotype, the forest-savannah interface area of central Cameroon has a dry season of more than 3 months, during which rainfall is less than 70 mm (Champaud 1966). The annual rainfall deficit for cocoa cultivation is thus about 200 mm. When cocoa is grown as a monospecific crop, this deficit causes defoliation of the cocoa trees. When the defoliation is total, a very high mortality usually results (Braudeau 1969; Wood and Lass 1985);
- Poor soil quality. There are two types of dominant soils in the forest-savannah interface area of central Cameroon: ferric acrisols, which are found everywhere in the interfluvial area, and gleysols, which extend on either sides of the talweg (FAO 1998). In both cases, the surface horizon presents 60 % of sand, which is a

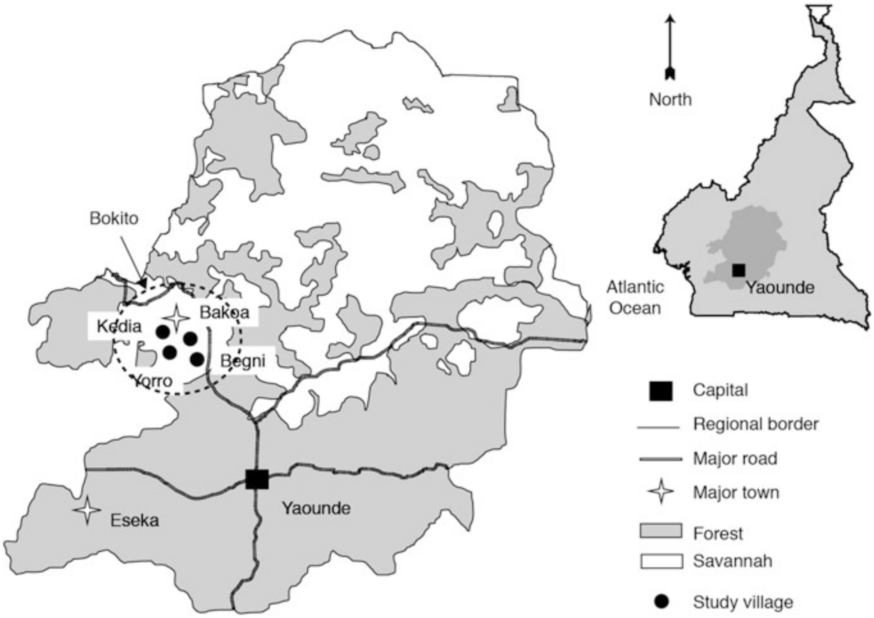

Fig. 12.1 Location of the centre region and the study area

clear handicap for cocoa cultivation. In addition, poor soil quality is not compensated by its levels of soil organic matter (less than 2 %), which can normally improve the soil's texture and its water-holding capacity (Braudeau 1969; Santoir and Bopda 1995);

- Scarcity of forest land. Much of the northern part of central Cameroon was once forested, but has now been subject to heavy clearing by human action. This deforestation has resulted in a forest-savannah mosaic characterized by gallery forests and groves which are normally used for cocoa cultivation (Kuété 1988). Most farmers can no longer benefit from the advantages of cleared forest lands, and forest rent is exhausted;
- The presence of *Imperata cylindrica*. Under human action, several types of savannahs have been developed for cultivation, especially grasslands characterized by *Imperata cylindrica* (Kuété 1988; Santoir and Bopda 1995). The development of these grasslands shows that farmers have been able to gain mastery over this weed. *Imperata cylindrica* is very heliophilous and tends to reappear when the cultivated plots are inadequately maintained. It competes with the crop for water and nutrients (Deuse and Lavabre 1979).

12.1.2 Method

In 2004, 339 cocoa plantations belonging to 282 farmers were randomly selected from lists of members of local cocoa producer organizations. The following information was obtained from each farmer: year of setting up of the cocoa plantation (age of the cocoa plantation in years), type of vegetation that existed before cocoa was planted (savannah or gallery forest), area covered and stated productions for three cropping seasons preceding the survey (2001, 2002 and 2003). The average yield of marketable cocoa for each cocoa plantation was calculated from data on area and production in order to arrive at an agronomic evaluation indicator for the cocoa cultivation system.

Data collected during this survey also helped obtain details about the different types of activities on the cocoa plantation (weeding, pruning, pesticide applications against mirids and black pod disease) and the human and material resources employed (type of labour, number of repetitions of each activity, number of working hours, quantity and cost of inputs).

The economic indicators used to evaluate cocoa systems in the savannah were:

- Gross value added per hectare. This indicator measures the income remaining with the farmer after deducting the cost of inputs used over the farming year;
- Gross value added per hour. This indicator may be interpreted as net labour productivity. It corresponds to the ratio of gross value added divided by the total hours of labour for a crop.

A typology of farmers was arrived at based on the criterion of homogeneity of elements in a class (Volle 1981) in order to compare the economic performance of classes of individuals predominantly having the same characteristics (age of the cocoa plantation, age of the farmer, level of intensification of labour and inputs in the technical itinerary) (Jagoret et al. 2006b).

We also interviewed village chiefs and elders regarding the historical stages of cocoa cultivation in the area.

At the end of the survey of 339 cocoa plantations, field visits revealed that farmers were using one of two strategies to remove *Imperata cylindrica* before planting cocoa in the savannah: the creation of dense shading or the cultivation of an annual crop. This is why, for each of these strategies, we selected five cocoa plantations that were being set up to study the modalities of growing cocoa in the savannah. We did so by conducting site visits, complemented by detailed interviews. These interviews focused on farmer practices and the main reasons behind the diversification of cocoa systems in order to reconstruct their evolution over time.

A change in the content of soil organic matter was observed in 16 cocoa plantations that were between three to 10 years old and which had been established in the savannah on gleysols (6 plots) and acrisols (6 plots), and on acrisols in gallery forests and groves (4 plots). The level of soil organic matter was estimated from the total carbon dosage (Walkley and Black 1934) in composite soil samples taken from depths of 20 and 40 cm.

The agrobiodiversity level of these cocoa systems was estimated from an inventory of forest and fruit species interplanted with cocoa (Messie 2007). These species were recognized on the basis of their local names. Their correlation with the common and scientific names was established with the help of identification guides (Vivien and Faure 1985; Eyog Matig et al. 2006). The agrobiodiversity level was assessed using the Shannon-Weaver index that took into account the proportion of each species present on the plot (Krebs 1985; Frontier and Pichod-Viale 1998).

12.2 Results and Discussion

12.2.1 Cocoa Cultivation in the Savannah, an Activity a Century Old

From our sample of 339 cocoa plantations, 157 were in the savannah and 182 in gallery forests or groves.

Despite the severe constraints that characterize the forest-savannah interface areas of central Cameroon, the distribution of cocoa plantations by age class and by preceding vegetation shows that cocoa cultivation was an old activity (Fig. 12.2). The first cocoa plantations were, in fact, established at the beginning of the 20th century. Interviews with village chiefs and elders helped to distinguish between three phases of development of cocoa cultivation.

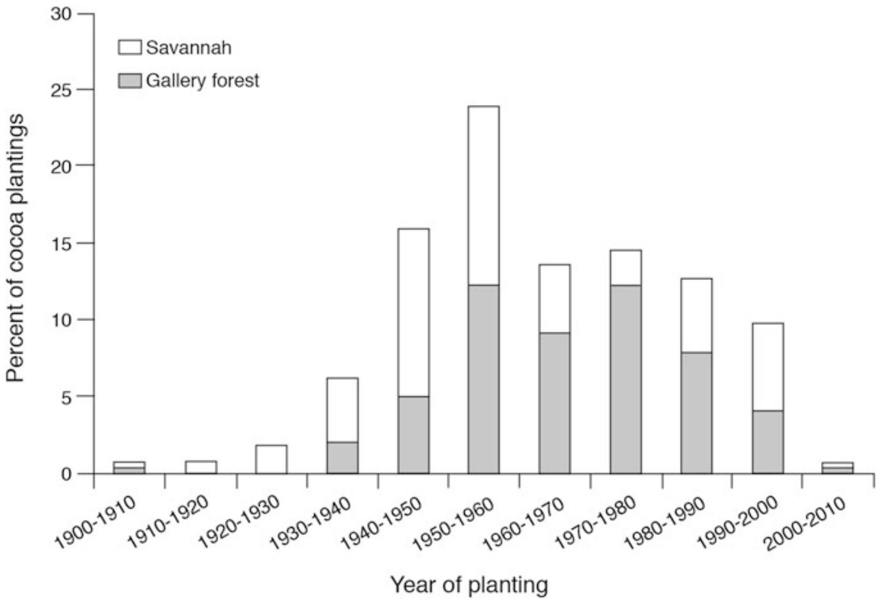

Fig. 12.2 Year-wise distribution of cocoa plantations in the initial establishment period in the Bokito sub-division for both the preceding vegetation types (savannah and gallery forests)

12.2.1.1 1900–1930: Establishment of the First Cocoa Plantations in the Savannah

Some pioneering farmers, convinced of the benefits of cocoa cultivation, smuggled out cocoa beans taken from the plantations of Eséka (Nyong and Kellé division) (Fig. 12.1). At the time, this city was the main centre for paying taxes in the region (Assoumou 1977). Two factors worked against the development of cocoa cultivation in the forest-savannah interface area: the lack of experience of these pioneers and local laws that forbade cultivation activities in gallery forests, which traditionally served as refuges during tribal wars. The first cocoa plantations were thus set up in the savannah. Thus, the social control exerted over gallery forests and groves explained to a large extent the appearance of cocoa cultivation in the savannah during this initial period.

12.2.1.2 1931–1960: Extending Cocoa Cultivation to Gallery Forests and Groves

The French colonial administration encouraged farmers and, in particular, traditional chiefs to grow cocoa on cleared forest lands. After the end of the Second World War, these chiefs lifted the bans that restricted the development of forest areas. They established their own cocoa plantations using cocoa pods distributed by the first German plantations established around Mount Cameroon and in the Kribi region (Michel 1970). They also encouraged their people to follow suit. This period was not only marked by the establishment of cocoa plantations in gallery forests and groves, but also by the onset of conflicts over allocation of forest areas. These areas, which were once collective resources, could now be appropriated by anyone growing cocoa.

12.2.1.3 1961–2000: Resurgence of Cocoa Cultivation in the Savannah

Cocoa cultivation continued to grow after independence, albeit at a smaller scale than in the earlier phase, with the support of agricultural services. The government intervened in the cocoa sector as a result of economic issues that largely resulted from skyrocketing global prices in the 1970s. Starting in the 1980s, the diseases and pests afflicting cocoa were proclaimed to be national scourges, and significant control measures were put in place. In addition to being provided subsidized treatment equipment and phytosanitary products, farmers were given selected planting material and support by the Cocoa Development Corporation (SODECAO) to establish their cocoa plantations (Assoumou-Mba 1981).

Most of the cocoa plantations established during the 1960s and 1970s were set up in gallery forests or groves. This trend reversed in 1980s; there was an increase once again in the number of cocoa plantations set up in the savannah. It became difficult to find fresh forest land, as much of it was already converted to cocoa plantations.

The slowdown experienced by cocoa cultivation starting in 1990 was largely due to the termination of SODECAO's activities following reforms announced by the government in 1989 as part of the structural adjustment programme. Liberalization and volatility in international prices also appeared to repeatedly undermine the profitability of cocoa cultivation in the production basin of south-central Cameroon (Alary et al. 1994; Janin 1999; Alary 2000).

However, despite these risks and economic disruptions, cocoa cultivation still occupied a dominant place on family farms in the forest-savannah interface area in central Cameroon. It represented, on an average, 60 % of their crop rotations, i.e., 2 ha for cocoa compared to 1.6 ha for annual and perennial crops. Cocoa cultivation also remained the farmers' main source of income, accounting for 67 % of their total income, i.e., 495,000 FCFA/year (739 €), whereas the income from other crops was, on an average, 181,000 FCFA/year (276 €) (Jagoret et al. 2006a).

These results were similar to those obtained in the forest areas of central Cameroon where cocoa cultivation accounted, on an average, for 57 % of the crop rotation of farms, and represented 69 % of the farmers' incomes (Jagoret et al. 2006a). They also confirm the values obtained by Weber (1977) and Santoir (1992) who had observed that cocoa represented 60 % of the crop rotation of farms. It was the same for household incomes: a survey conducted in 1954 showed that the sale of cocoa accounted for 70 % of the farmers' incomes (Binet 1956). Thirty years later, the sale of cocoa still covered 50–75 % of the budget of more than 90 % of the households (Leplaideur 1985).

12.2.2 Agroforestry-Based Diversification, an Essential Element of Savannah Cocoa Cultivation

The establishment of cocoa plantations in the savannah initially depends on mastering a key factor: the elimination and control of *Imperata cylindrica*—which is a limiting factor in any savannah area. After that, the success of savannah cocoa plantations depends on controlling two other major factors: shading and soil fertility levels.

Cropping practices used by farmers in the forest-savannah interface area in central Cameroon to establish and manage cocoa plantations in the savannah thus attempt to overcome these three major constraints. Since the reconstitution of an agroforestry system is the key to controlling the system, it becomes both a goal and a process.

Farmers thus developed two major strategies for controlling *Imperata cylindrica*: the establishment of dense shading by the planting of appropriate plant species (S1) or tillage to grow annual crops (S2).

12.2.2.1 Establishment of Dense Shading (S1)

The species most commonly used by farmers to control *Imperata cylindrica* before starting cocoa cultivation in the savannah is the oil palm (*Elaeis guineensis*). Palm seeds were sown through broadcasting in the area identified for the new cocoa plantation. Sometimes, young palm trees are interplanted with mango trees (*Mangifera indica*). The rapid growth and dense shade of these two species eliminates much of *Imperata cylindrica* within 4–5 years.

After this weed is eliminated for the most part, the high density of oil palm trees is gradually reduced. The felled palm trees are used to produce palm wine, thus increasing the farmer's income. At the same time, cocoa is introduced into the cultivation system. This is done either by direct seeding, where two to three pods are planted together in each hole, or by planting seedlings previously raised in nurseries or a germinator. These young plants can be combined with banana trees which add to the shade. The routine maintenance of cocoa trees and the progressive closure of their crown over the next 3–4 years help eliminate *Imperata cylindrica* from the plot.

12.2.2.2 Annual Crops (S2)

Before annual crops can be planted, the soil has to be broken by hand with a hoe. This deep ploughing operation pulls out the roots of *Imperata cylindrica* and exposes them to the sun so that they can be eliminated. Once the annual crop is planted, farmers introduce cocoa into the system, either by direct seeding before weeding (the pods are then sown during the hoeing) or by planting seedlings grown in nurseries or germinators. Young cocoa trees are thus interplanted with a mixture of annual and perennial crops: yam (*Dioscorea* sp.), cocoyam (*Xanthosoma sagittifolium*) and plantain (*Musa spp.*), followed by a succession of maize-groundnut (*Arachis hypogaea*-*Zea mays*) and pistachio-maize (*Cucumis mani*-*Zea mays*) associations which are renewed for 3–4 years. During this period, weeding is carried out with a hoe to remove and control any regrowth of *Imperata cylindrica* until the time the cocoa crowns are completely closed.

This technique to remove *Imperata cylindrica* based on tillage and cultivation of annual and perennial crops requires a greater amount of labour in comparison with the planting of dense shade trees. However, it allows farmers to establish their cocoa plantations faster in the savannah, in 5–6 years compared to eight to 9 years for the technique to remove *Imperata cylindrica* using oil palm trees.

12.2.2.3 Managing Interplanted Stands Over Time

Irrespective of the strategy adopted by farmers to control and eliminate *Imperata cylindrica* before establishing cocoa plantations in the savannah, several fruit and forest species are subsequently interplanted with the cocoa trees. The gradual

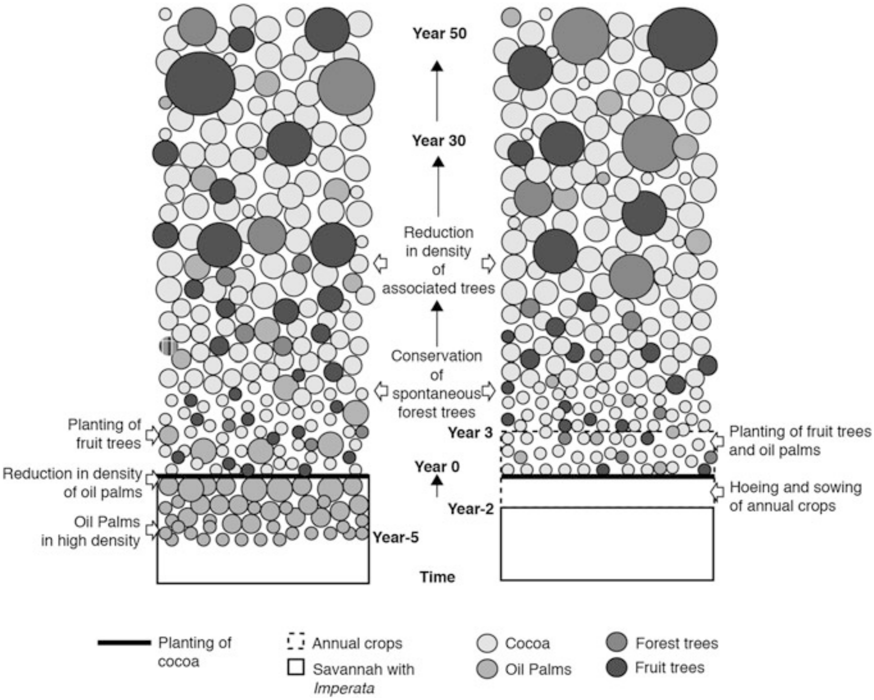

Fig. 12.3 Evolution over time of the savannah cocoa cultivation system based on the two strategies to control *Imperata cylindrica*. *S*1 Establishment of a dense shade; *S*2 Cultivation of annual crops

replacement of the initially planted dense shade trees or annual and perennial crops by fruit or forest species which provide light shading allows farmers to diversify their cocoa cultivation system (Fig. 12.3).

Farmers prefer a high density of fruit and forest trees in young cocoa plantations so that they can create an unbroken and dense ground cover to help control weeds in their plots, as well as to create a suitable shade for cocoa trees. To this end, farmers continue to plant various fruit trees in their cocoa plantations, including orange (*Citrus sinensis*), African plum (*Dacryodes edulis*), avocado (*Persea americana*) and kola (*Cola nitida*). Forest trees are also introduced into cocoa plantations through transplantation, or are preserved when they grow there naturally, like the kapok (*Ceiba pentandra*), iroko (*Milicia excelsa*), African border tree (*Newbouldia laevis*) and flat-crown (*Albizia adianthifolia*).

Subsequently, farmers vary their management practices according to the species but undertake a significant reduction in the density of fruit and forest trees. Farmers try to maintain a canopy cover over their plots which is favourable to cocoa development. They compensate for the growth of the several tree species interplanted with cocoa by regularly removing excess trees, mainly by girdling which causes their gradual demise. By using this technique, they avoid the damage that

Table 12.1 Main purpose of fruit or forest trees that are introduced—or retained—when a cocoa plantation is established in the savannahs of central Cameroon

Objectives	Answers (%) (sample size = 10)	
	Forest species	Fruit species
Home consumption of fruits	0	28.6
Soil fertilization	19	0
Sale of fruits or timber	19	52.4
Shading for cocoa	47.7	19
Utilization of timber	14.3	0

would be caused to cocoa in case these trees are felled. At the same time, the density of oil palm trees remains constant since farmers normally replace the trees that are felled for producing palm wine.

The strategy of reconstituting a diversified cocoa agroforestry cropping system serves several purposes (Table 12.1).

Trees of certain forest species that grow naturally in cocoa plantations are retained mainly to provide a favourable shade for cocoa trees. Some other species have a positive effect on soil fertility (Bidzanga et al. 2009). Farmers may also decide to retain some species which provide valuable timber for construction and for sale. On the other hand, the introduction of fruit species in the system is mainly for home consumption and for selling various products, with shading for cocoa being only a secondary objective.

12.2.3 Yield of Savannah Cocoa Plantations Equivalent to Those in Gallery Forests

12.2.3.1 Agronomic Performance

Table 12.2 provides a comparison by age group between the marketable yields of savannah cocoa plantations and those in gallery forests or groves. Regardless of the age class considered, there was no significant difference between these two situations of preceding vegetation. During the first years of cultivation, cocoa plantations on grasslands appeared to be as productive as those grown on forest land. After 20 years, however, not only was the yield of savannah cocoa greater than of cocoa from gallery forests and groves, but it remained relatively stable over time. Furthermore, the yield of marketable cocoa grown on the savannah is similar to that observed by Duguma et al. (2001) for cocoa plantations on cleared forest lands in central and southern Cameroon: between 264 and 500 kg/ha depending on the intensification level of the technical itinerary.

Table 12.2 Evolution in the yield of marketable cocoa in the forest-savannah interface area of central Cameroon for the two different preceding vegetation types (savannah and gallery forest)

Age classes	Average yield (kg of marketable cocoa per hectare)			
	N	Savannah (standard deviation)	N	Gallery forest (standard deviation)
<5 years	2	130 (±19.12)	4	20 (±5.03)
5–10 years	11	128 (±36.85)	6	136 (±23.80)
10–20 years	18	214 (±34.58)	22	223 (±28.11)
20–30 years	10	470 (±40.37)	39	444 (±35.96)
30–40 years	13	447 (±64.34)	38	324 (±21.49)
40–50 years	34	459 (±34.98)	40	383 (±31.12)
50–60 years	40	418 (±32.75)	24	353 (±54.21)
>60 years	29	406 (±37.76)	9	374 (±69.20)

N sample size

Table 12.3 Deriving value from the land for cocoa cultivation in the forest-savannah interface area of central Cameroon for the two preceding vegetation types (savannah and gallery forest)

Farmer class	Gross value added of land (FCFA/hectare)			
	N	Savannah (standard deviation)	N	Gallery forest (standard deviation)
A	33	125,236 (±74,879.51)	28	129,447 (±47,149.92)
B	107	214,910 (±114,180.22)	129	236,440 (±97,920.31)
C	17	386,845 (±136,228.07)	25	399,486 (±143,562.56)

N sample size

12.2.3.2 Economic Performance

The classification developed to group individuals with largely the same characteristics helped identify three categories of farmers: young farmers in the establishment stage (class A), farmers who had adopted an extensive itinerary (class B), and farmers with intensive farming practices (class C).

At the economic level, regardless of the farmers' categories, no significant difference was found between the two preceding vegetation types in terms of the gross value added per hectare in the productive phase (Table 12.3). It was the same for the gross value added per labour hour (Table 12.4).

Although the economic performance of cocoa plantations in gallery forest or groves remained higher than that of cocoa on the grasslands, the difference between the two preceding vegetation types was of the order of 10–15 % in the case of deriving value from the land, and from 3 to 9 % for deriving value from labour.

Table 12.4 Deriving value from labour for cocoa cultivation in the forest-savannah interface area of central Cameroon for the two preceding vegetation types (savannah and gallery forest)

Farmer class	Gross value added of labour (FCFA/h)			
	N	Savannah (standard deviation)	N	Gallery forest (standard deviation)
A	33	2,296 (±792.05)	28	2,600 (±860.39)
B	107	3,628 (±1,299.80)	129	4,223 (±1,430.59)
C	17	2,148 (±740.54)	25	2,496 (±852.01)

N sample size

Table 12.5 Number of species per hectare and the Shannon-Weaver index by type of preceding vegetation and soil type

Soil type	Preceding vegetation	Number of cocoa plantations	Number of species per hectare	Shannon-Weaver index
Acrisol	Forest	6	36	3.3
Acrisol	Savannah	6	77	3.0
Gleysol		4	58	2.9

12.2.3.3 Level of Agrobiodiversity

A total of 62 woody species belonging to 29 botanical families were recorded in the cocoa agroforestry system in the savannah. The average value of the Shannon-Weaver index—greater than 3—reflects the high diversity of this cropping system. This holds irrespective of the type of soil considered (Table 12.5).

The Shannon-Weaver index value of savannah cocoa agroforestry plantations is close to values obtained for cocoa plantations on forest lands in central Cameroon. These latter values were respectively 3.4 in the Lékié division and 3.8 in the Nyong and So'o division (Messie 2007). The level of agrobiodiversity of savannah cocoa was also the same as that obtained by Zapfack et al. in 2002 (4.3) and by Sonwa et al. in 2007 (3.1–3.9) for cocoa grown on forest lands in south-central Cameroon. However, it was greater than that observed for cocoa agroforestry in Nigeria (2.7) (Oke and Odebiyi 2007) and in Ghana (2.6) (Asare and Tetteh 2010).

We thus generally found that the process of a combined planting of woody species and cocoa to establish savannah cocoa agroforestry systems resulted in a high diversity akin to that observed for cocoa systems established on cleared forest lands.

The three dominant species of the savannah cocoa system are oil palm (*Elaeis guineensis*), orange (*Citrus sinensis*) and African plum (*Dacryodes edulis*) (Table 12.6). These fruit species, just like kola (*Cola nitida*) and avocado (*Persea americana*), are usually introduced at the time of establishing cocoa plantations. Their production (palm oil, palm wine, fruits) is meant for household consumption, while the surplus is sold.

The role of these fruit trees in providing shade for cocoa and improving soil fertility is limited. This function is normally provided by forest species, whose

Table 12.6 The main botanical species and families of savannah cocoa cultivation system in central Cameroon's forest-savannah interface area

Species			Family	
Common name	Scientific name	Presence (%)	Name	Presence (%)
Oil palm	*Elaeis guineensis*	17	Arecaceae	17
Orange tree	*Citrus sinensis*	12	Rutaceae	15.3
African plum	*Dacryodes edulis*	11.2	Burseraceae	12.3
Kola tree	*Cola nitida*	6.7	Sterculiaceae	10.7
Avocado	*Persea americana*	5.4	Moraceae	8.8
Mango tree	*Mangifera indica*	3.5	Anacardiaceae	5.9
Iroko	*Milicia excelsa*	3.5	Lauraceae	5.4
African border tree	*Newbouldia laevis*	2.9	Mimosaceae	4.6
Mandarin orange	*Citrus reticulata*	2.9	Bignoniaceae	3.1
Ayous	*Triplochyton scleroxylon*	2.4	Bombacaceae	2.1
Flat-crown	*Albizia adianthifolia*	2.2	Euphorbiaceae	2
Kapok tree	*Ceiba pentandra*	2.1		
Fig tree	*Ficus mucoso*	2		

importance to cocoa grown in the savannah appears to be less than that of fruit species. However, the role of forest species in the farmers' strategy to establish and cultivate cocoa in the savannah is crucial. This is the reason why several forest species are introduced in the cocoa cultivation system or are maintained if they grow there on their own: trees that provide shade to cocoa trees (*Albizia adianthifolia*, *Ceiba pentandra*, *Newbouldia laevis* and *Milicia excelsa*) and those that help improve soil fertility (*Ceiba pentandra* and *Ficus mucoso).*

Some forest species sometimes play a dual role: *Ceiba pentandra* (shading and improving soil fertility), *Newbouldia laevis* (shading and demarcation of plots) or *Milicia excelsa* (shading and timber production). The functions of different fruit and forest tree species in cocoa systems in the savannah thus appear to be complementary at the agronomic and economic levels.

12.2.3.4 Soil Fertility Level

The maintenance or regeneration of soil fertility is a key determinant of the agro-ecological sustainability of a cropping system. Monitoring changes in soil organic matter using a synchronic approach, as an indicator of the fertility and sustainability of cropping systems, helps highlight the performance of the savannah cocoa agroforestry system.

Levels of soil organic matter in cocoa plantations established in gallery forests or groves decrease in the initial years from 3.5 to 2.5 % compared to a control forest

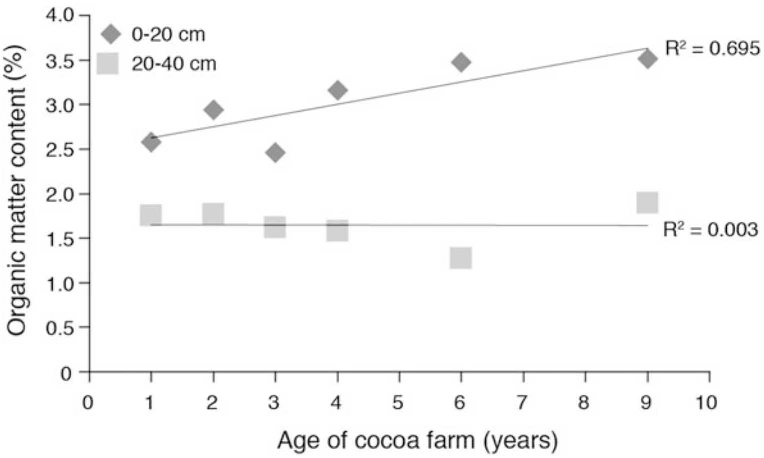

Fig. 12.4 Evolution over time of the level of soil organic matter in cocoa plantations set up on gleysols in the savannah

plot, and then stabilize after 25–35 years of cocoa cultivation (Glatard 2007). On the other hand, for savannah cocoa plantations set up on gleysols, the soil organic matter increases by 2.5–3.5 % over the control plot (uncultivated savannah) 9 years after the establishment of cocoa plantations (Fig. 12.4).

While it is known that soil organic matter of cleared forest land decreases following the establishment of cocoa plantations on it (Snoeck et al. 2010), the maintenance of—or even an increase in—the level of this indicator in the savannah cocoa agroforestry system is therefore a positive development, a result of the farmers' strategy of interplanting different woody tree species with cocoa over time. Such fruit and forest species, interplanted and organized in different strata, help in the process of biomass recycling and resource sharing which ensures a proper functioning of a natural ecosystem.

An increase in the organic matter content in the soils of cocoa plantations, from the low levels typical in grasslands with *Imperata cylindrica* or *Pennisetum*, thus becomes a criterion of sustainability for this relatively old and innovative multi-species cocoa cultivation system (Glatard et al. 2007).

12.3 Conclusion

Agroforestry-based diversification plays a central ecological and economic role in the establishment of cocoa plantations in the savannah. It is a key for the sustainable development of areas previously considered suboptimal for cocoa cultivation. At the agronomic level, the reconstitution of a multispecies cocoa cultivation system in forest lands by farmers in the forest-savannah interface area of central Cameroon helps overcome the main constraints presented by such areas for cocoa cultivation (uneven rainfall distribution, poor soil quality and presence of *Imperata cylindrica*). The spatio-temporal arrangement of several forest and fruit species interplanted with cocoa allows, firstly, the control and elimination of *Imperata cylindrica*. It also helps overcome of the lack of shading during the establishment of cocoa plantations in the savannah. Secondly, the reconstitution of a cocoa agroforestry cultivation system can significantly improve soil fertility in savannah cocoa plantations. Finally, the yield of marketable cocoa from cocoa plantations is similar to that from cocoa plantations in gallery forests and groves. The sustainability of cocoa plantations in the savannah is thus ensured.

At the economic level, the benefits of a cocoa agroforestry system in the savannah are also confirmed. The performance of cocoa agroforestry plantations in the savannah, evaluated in terms of gross margin per hectare and gross margin per labour hour, appears to be similar to those of cocoa agroforestry systems in gallery forests or groves, regardless of the intensification level of the technical itinerary adopted by the farmers. Finally, the positive environmental impact of the savannah cocoa agroforestry system on agrobiodiversity is also confirmed.

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