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Profitability and implications of cocoa intensification on carbon emissions in Southern Cameroun

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Abstract The present study evaluated profitability of some models of cocoa farms and analyzed the relationship between cocoa yield, income and carbon stored in traditional cocoa agroforests to discuss implications of cocoa intensification on carbon emissions in Cameroun. Surveys on establishment, management practices and marketing were conducted in 49 cocoa farms along a gradient of population density, forest cover and market access, and combined with data on carbon stock and trees species inventories. Traditional cocoa farms were stratified according to rehabilitation practices of farms (no rehabilitation, replacing dead/senescent cocoa plants in the farm or extending the farm by adding young plants around the old plots). Results showed that traditional cocoa agroforests are managed under high trees shade and present high carbon stock levels (average of 64 trees/ha of large tree diameter and about 94 tonC/ha). Management is based on an intensive use of family labor and there is little consistency in the use of inputs (as planting material, fertilizers and pesticides). Profitability analysis using net present value indicated that farms rehabilitated by replacement of cocoa trees were more profitable. Intensified systems are more profitable at the various discount rates considered, with up to 50 % cocoa yield increase but with less tree shade (about 40 trees/ha). Structural and productive parameters of the system showed a high variability and it was not possible to assess a clear relationship between carbon stock, yield, and incomes to clearly delineate tradeoffs. Under persistent poverty conditions and with no major intervention to support inputs purchase, suitable designs for intensification pathways should focus on good practices such as shade management, quality of associated trees, use of improved planting materials released by the research.

Keywords Profitability · Income · Cocoa intensification · Carbon emission

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Introduction

In southern Cameroon, cocoa is managed in complex agroforest systems (AFS) that includes annual crops, fruit and timber trees along with other remnant trees from the forest where the farm was first established. Traditional complex AFS are the outcome of an adaptation of local practices of trees resources management (Robiglio et al. 2013) to changing socio-economic household needs and marketing opportunities (Perfecto et al. 2005). Their complex structure contributes to maintaining a large number of

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ecological characteristics of natural forests thus they play an important role for biodiversity conservation (Sonwa et al. 2009; Bissuela et al. 2009). However, despite the importance of cocoa as cash income source at a closer look traditional AFS have not proven to be profitable due to their low productivity (Sonwa 2004; Gockowski et al. 2010; Eboutou et al. 2010; Jagoret et al. 2011). Low yields are generally attributed to the senescence of cocoa farms (FAO 2002; Jagoret et al. 2011). Neither fertilizers nor herbicides are used (Jagoret et al. 2011) and diseases such as black pod and capsid attacks remain a major challenge even when fungicides and pesticides are applied.

These traditional cocoa AFS have been at the core of local smallholder livelihoods for more than 50 years. 40 % of the existing farms are inherited and were planted before 1950; more than half of the plantations is older than 30 years (PNUE 2009). Cocoa farms are managed with family labor and minimal maintenance level (FAO 2002). Seeds used are called ≪*german cocoa*≫ derived from the plots established during colonial time in the last century.

In the early 1990s, due to the economic crisis that affected the cocoa sector, many farms were abandoned or set aside with minimum management. Only recently international price increase and political instability in Ivory Coast have led to a renewed interest for cocoa production in Cameroon. To boost national production, the government supports system intensification through the use of improved planting material associated to a regular use of farm inputs (fertilizers and pesticides) as well as the establishment of new farms (SDSR 2005).

Traditionally the expansion of cocoa farms has been done primarily on forests land (Gockowski and Sonwa 2010). This has result in major concerns due to the role further cocoa expansion might play in deforestation process and associated carbon emissions, in particular because Cameroon, as a REDD + country is committing to a reduction of its land based carbon emissions. Despites this fact, agricultural policies are mainly focus on the improvement of livelihoods of people involved in cocoa production based on economic returns and do not emphasize any environmental aspects, including the reduction of carbon emission.

The major objectives of the present paper is to (i) evaluate profitability of some models of cocoa farms and their associated parameters (management practices, yields and incomes) and (ii) analyze the relationship between cocoa yield, income and carbon stored in traditional cocoa agroforests to discuss implications of cocoa intensification on carbon emissions in Cameroun.

Materials and methods

Presentation of the study sites

The 49 farms sampled were located in eight villages along a forest cover, market access and population density gradient at the margin of the humid forest zone of Southern Cameroon, roughly within 10°30′–12°30′E and 2°25′–3°25′N. The vegetation cover in the area shows various facies of forest degradation and reciprocal encroachment of "dense humid semi-deciduous forest", "dense humid Congolese forest", and "moist evergreen Atlantic forest" (Letouzey 1985).

Soils of the area are of the Ferrasols group, according to the World Reference Base for Soil Classification (WRB 2006). Annual rainfall shows a bimodal distribution pattern and ranges from 1,350 to 1,900 mm, with an increasing precipitation from north-east to south-west. The bimodal rainfall pattern defines two distinct rowing periods (Fig. 1).

Methods

Primary and secondary data collection

Primary data were collected in cocoa farms sampled mostly based on the willingness of farmers to collaborate. Farmers were interviewed using a semi-structured questionnaire in cocoa farms. On the same plot, trees inventory and measurement for carbon stock estimates were conducted. Interviews focused on: (i) management (use of fertilizer and phytosanitary products, type of seed used) and rehabilitation practices; (ii) production of cocoa, associated crops and tree products (fruit, and non timber forest product–NTPF); (iii) costs for equipment, seed and phytosanitary products, labor and marketing; and (iv) Incomes derived from the harvest of cocoa, associated crops, trees and bush meat (both sale and consumption).

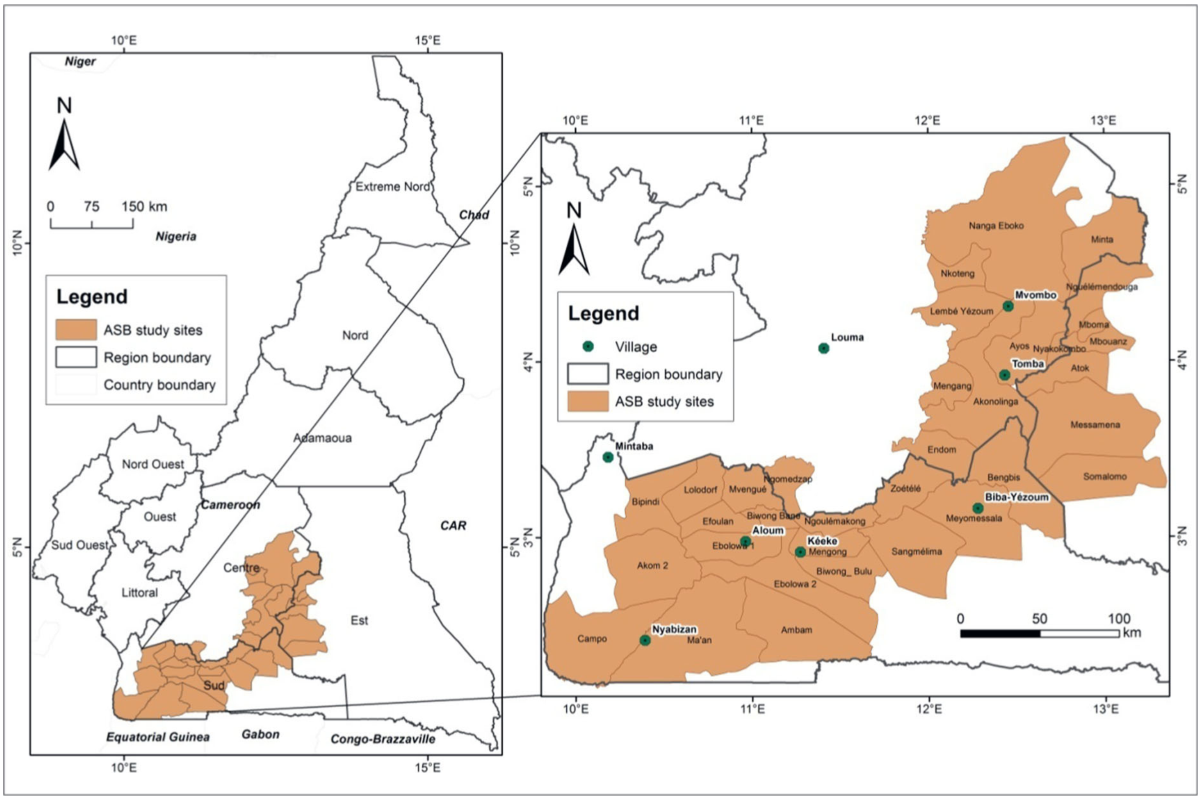

Fig. 1 Study sites (Villages) location

Data to model the hypothetical intensified systems were derived from the fertilizer sub-sector reform program (FSSRP) at the Ministry of Agriculture and Rural Development (MINADER). Information focused on technical prescription for cocoa fertilization, costs of fertilizer and pesticides purchasing, cocoa yields, cocoa tree plants density, costs of different farming operations (establishment, maintenance, management, harvest and marketing).

Hypothetical intensified models designed by the Government were based on improved planting material associated to good management practices with more and adequate use of modern inputs as fertilizers and phytosanitary products (insecticides and fungicides). Very few forest trees are left in the cocoa plot at the establishment time with low densities [35–40 trees/ha (SODECAO 2011)] to provide a minimum of shade. Hired labour is the most commonly used. During the first three years, plantain (*Musa paradisiaca*) can be voluntary established in association with cocoa. Cocoa production is expected to start at the end of the second year and behaves as presented in Table 1 (MINADER 2009).

Table 1 Cocoa productivity of models designed by the governmental extension services

Yields (kg/ha)	Years				
	1	2	3	4	5–30[a]
With fertilizers	0	400	1,000	1,500	967
No fertilizers	0	200	400	1,000	513

[a] Yields in year 5–30 is an assumption based on the calculated averages

Biomass and Carbon stock calculations

Biomass measurements for estimating above and belowground carbon stock were conducted according to the rapid assessment method (RA) developed by the World Agroforestry Centre (Hairiah et al. 2011). A systematic inventory of trees species and diameter at breast height (DBH) record was conducted. The above ground biomass of each tree was estimated using Chave et al. (2005) allometric model developed for moist forest based data from multiple global sites. This allometric model was proved to be suitable for moist Africa forest and showed good fit to data obtained from destructive sampling in Southern Cameroon (Djomo et al. 2010).

Statistical analysis

Traditional cocoa agroforests characterization

Basic descriptive statistics, analysis of variance (ANOVA) and means separations (Fisher tests) were applied to the data on cocoa yield, trees densities, carbon stock and income according to renovation practices in the farms. Correlations between variables were evaluated and tested at 5 % and 1 % limits. Particularly, the relation between rehabilitation practices and the other practices was considered, based on the assumption that rehabilitation practices reflect the general attitude of the farmers to invest/engage in intensification.

To evaluate the cost of family labour the following formula was used:

$$X = \frac{\sum_1^n x}{\sum_1^n y/6}$$

where X was unit cost of family labour per day; x the expenses per activity paid from soil preparation to planting; and y was the number of hours spent for each activity paid from soil preparation to planting. 6 is the number of hours per work day and n the activities.

Intensified models

Based on data provides by governmental extension services, average quantities of fertilizers and pesticides (fungicide and insecticide), yield, cost and incomes were calculated and used for comparison between traditional cocoa agroforests and intensified models.

Profitability estimation and model assumptions

Profitability was estimate for three models of production: (i) a traditional one with no fertilizers, low management practices and differentiated according to rehabilitation practices (no rehabilitated, rehabilitated by expansion and rehabilitated by replacement); (ii) new intensified model without fertilizers and (iii) new intensified model with fertilizers. The NPV was used as indicator of profitability and calculated based on the following assumptions:

Varying discount rates (5, 10, 15 and 20 %). Farmers with limited resources tend to plan on short-term horizons and discount rates are high and subjective;

Life cycle of cocoa tree production: 30 years to account for the shorter life cycle of improved planting materials used for rehabilitation of older traditional cocoa farms and intensified model;

Cocoa is sold at stable price of 2 USD per kilogram of dry cocoa bean which is the average price received by farmers in study sites.

Based on farmer declaration it was assumed that for traditional cocoa AFS, cocoa production starts at the 7th year as well as the associated planted fruit trees. Non timber forest products (which are generally trees that were already in the field at year of establishment) are harvested as from the first year and contribute to the income for the 30 years production horizon of the farm. Annual and biannual associated crops contribution to income is relevant during the first 4 years and decreases with the expansion of cocoa trees canopy. Farmers may continue to plant some of these crops in occasional gaps (space resulting from the death of trees or cocoa plants) in the farm. Bush meat contribution to income starts from the first year and continues until the end of 30 year production cycle of the cocoa plot. Cocoa yield in the traditional systems was assumed to be stable during all the production cycle because in the traditional systems, no significant correlation exists between the declared ages of a cocoa farm and yield (Jagoret et al. 2011).

Results

Characteristics of traditional cocoa farms

Rehabilitation practices

Renovation practice consists of adding new young cocoa trees plants in the existing farm. It can be done to densify cocoa tree stand or to extend the farm size by adding new cocoa plants. In this study, 35 % of farmers applied the rehabilitation practices in their farms with 14 % through farm size expansion and 21 % by replacing the senescent or dead cocoa trees. The two practices can occur in the same farm. This practice of rehabilitation did not show a clear dependence on the age of cocoa farms or age of producers.

Weeding

54 % of cocoa producers weeded their farm once a year as compared to 46 % who did it twice or more. The first or unique weeding was done between March and June; and the second one between September and November. Weeding was manual using cutlass. Only 6 % of producers reported to use herbicides one time a year.

Use of fertilizer and phytosanitary products

Farmers did not use fertilizers but 82 % reported to use pesticides (insecticides and fungicides). Three types of farmer were distinguished: 40 % of farmers used only fungicide; 26 % used only insecticide and 34 % used both insecticide and fungicide. Fungicide treatments were done on average 6 times a year and insecticides treatments 4 times. The type of pesticide used ($\chi^2 = 0.03$), changed according to rehabilitation practices (fungicide are most used in farms rehabilitated by replacement).

Profitability analysis of traditional cocoa farms

Yields estimation

Cocoa yields were low (346 ± 202 kg/ha) and are significantly influenced by the annual frequency of fungicide treatments (below 6 times: 255 ± 199 kg/ha and 6 times 463 ± 201 kg/ha).

Costs and incomes distribution

Average annual production and marketing cost summed up to about 963 USD per hectare including family labour. Total costs presented a high variability. Labour costs were the highest (75 % of total annual costs) with family labour amounting to more than half (53 %). The type of rehabilitation practice applied by the household had a significant effect on the amount of family labour costs: very low (average 1 USD per hectare) for no rehabilitated cocoa farms, average 218 USD per hectare for farms where replacement was applied; 1,215 USD per hectare for cocoa farms that had been expanded.

Table 2 Net present value of each farm management type at various discount rates

Traditional cocoa farms	Net present value			
	Discount rates			
	20 %	15 %	10 %	5 %
All farms	49	146	334	751[a]
No rehabilitated farms	−352	−356	−353	−322
Rehabilitated-expansion	−51	−42	−45	−83
Rehabilitated-replacement	1,457	2,102	3,344	6,071

[a] NPV is in USD per hectare

The average annual gross income (including sales and consumptions) was 995 USD per hectare with a net income of 33 USD per hectare (if internalized costs are considered). In general gross income was composed of 88 % of sales and 12 % of consumption of products from associated systems (crops and NTPF).

Net present value (NPV) estimation

Average NPV values where positive for the traditional system. However if once the rehabilitation method is considered, only the farms rehabilitated by replacement had the positive NPV values (Table 2),

Carbon sequestration in traditional cocoa agroforests

Average carbon stocked in the AFSs (including below and above ground) was 94.2 ± 42 ton/ha. Above ground (living biomass) contributed to more than the 60 % of the overall stock. In that above ground carbon, large trees (DBH > 30 cm) contributed for 84 %, small tress (DBH < 30 cm) 9 % and cocoa 7 %. Large trees include commercial, NTFP and fruit trees species and other forest trees that according to farmers do not have any specific function. Carbon stock correlated significantly ($r = 0.61$) with the density of large trees ($R^2 = 0.38$ and $y = 0.423x + 24.45$, Fig. 2). Commercial timber species were the most common with on average the 26 % (±19 %) of the

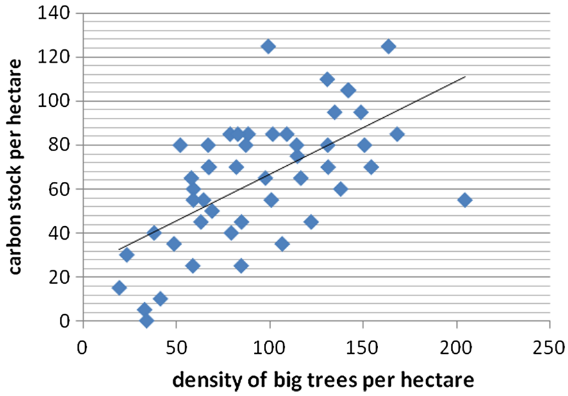

Fig. 2 Relationship between tree density and carbon stocks

trees, followed by the NTFP 15 % (±18 %) and the fruit trees 7 % (±12 %).

Comparing the traditional cocoa agroforests and intensified models of cocoa production

Weeding

In traditional cocoa system, farmers do not respect the frequency and periodicity of weeding as observed in intensified models.

Use of fertilizer and phytosanitary products

Fertilizers are not used in traditional cocoa agroforests. Average declared quantity and frequency of use of pesticides (insecticides and fungicides) are the same that those of new intensified models but present a high variability.

Profitability

Yields

Intensified models promoted by the governmental extension services have the higher yields with an average of 967 kg/ha with fertilizer and of 513 kg/ha without fertilizer showing a yield increase of 54 % and 180 % respectively, as compared to the average value in the traditional AFSs (346 kg/ha).

Costs and Incomes distribution

Intensified model with no use of fertilizers presents lower annual costs (743 USD per hectare), follow by the traditional farming system (966 USD per hectare) and the intensified model with fertilizer (1,128 USD per hectare). Labor represents the highest share of these costs, particularly in the traditional systems: with 75 % for traditional cocoa; 51 % for intensified system without fertilizers and 40 % for intensified one with fertilizers. Although traditional cocoa agroforests invest the lowest in terms of cocoa seeds (only 3 %), they bear the highest costs in terms of purchasing phytosanitary products (10 %).

It was estimated that traditional cocoa agroforests provided lower net income than new intensified models (Table 3). However, its gross income was higher than that of new intensified model with no fertilizers use. Cocoa contributed for 80 % to gross income while the other 20 % was provided by associated products such fruits (*D. edulis*, *Persea americana, Mangifera* sp.*, citrus* sp. etc.), food crops (*Musa* sp.) and cocoyam *(Xanthosoma* sp.), NTFPs (*Irvingia gabonensis*, *Garcinia kola, Ricinodendron heudelotii, Spondias dulcis,* etc.*)* and occasional sale of timber/fire wood and hunting products. *D. edulis* was the most encountered tree species in all cocoa farms.

The gross income in the new intensified models was derived only from cocoa.

Net present value estimation of different farming systems

All farms systems showed positive NPV, and intensified systems had the highest values at all discount rates (Table 4). A 20 % decrease in cocoa prices would result in a negative NPV for the traditional systems at all discount rates; new intensified models with fertilizers would still have positive and higher NPV values than those with no fertilizers having positive NPV values only at 10 % and 5 % discount rates.

Tree densities

Intensified models had very few trees of DBH larger than 30 cm. In these systems *Musaceae*, oil palm and small trees were rarely present as shown in Table 5. In the traditional systems, the density of cocoa trees is highly variable (1,170 ± 544 plants/ha).

Table 3 Income distribution from various sources

Cocoa farming systems	Average gross income	Average net income	Income distribution (%)					
			Cocoa	Food crops	Fruits	NTFP	Hunting	Timber/wood
Traditional farming system	994	33[a]	80	5	10	2	1	1
Intensified without fertilizers	838	99	100	0	0	0	0	0
Intensified with fertilizers	1,518	396	100	0	0	0	0	0

[a] Average net income and average gross income in USD per hectare

Table 4 Net present value for the various systems at various discount rates

Cocoa farming systems	Net present value (in USD per hectare)			
	Discount rates (%)			
	20	15	10	5
Traditional farming system	49	146	334	751
Intensified without fertilizers	552	1,091	2,067	4,083
Intensified with fertilizers	2,249	3,516	5,817	10,604
	With 20 % decrease in prices			
Traditional farming system	−191	−258	−401	−741
Intensified without fertilizers	−319	−119	241	977
Intensified with fertilizers	620	1252	240	478

Discussion

Profitability

Results of the present study indicate that the profitability of traditional cocoa AFSs depends on management practices and that rehabilitation practices are a good proxy for intensification with higher incomes. However, net benefits are positive only if costs of family labor are not accounted for and indeed the margin remains narrow because of overall low levels of productivity.

A big gap exists between traditional systems and the systems currently promoted by the governmental agencies. A part from the quality of cocoa material used for planting and of structural parameters (density of cacao plants and associated trees), the use of fertilizers seems to be the major element guaranteeing system productivity.

Estimates of the contribution of the traditional AFS to household annual gross income appear to be very close to the results reported by Gockowski et al. (2010). Among the secondary products sold, *D. edulis* and oil palm nuts were the most important as well as non-timber forest products.

This study further confirmed how significantly diversification strategies contribute to farmer's income, along the line of studies such as the ones by Sonwa (2004); (Jagoret et al. 2009); Gockowski et al. (2010), making the overall system more profitable (Eboutou et al. 2010). Diversification also increases resilience to cocoa price fluctuations in the international market (Sonwa et al. 2001).

Carbon stocks

The study also confirms the important role of trees in the traditional systems in terms of carbon storage. This is part of the ecosystem services, as well as biodiversity conservation that traditional systems provide (Kotto Same et al. 1997; ASB 2000; Nolte et al.

Table 5 Trees densities for some common species

Cocoa farming systems	Trees density (trees/ha)					
	Cocoa	Musaceae	Big oil palm	Small oil palm	Big trees	Small trees
Traditional farming system	1,170 ± 544	30 ± 71	5 ± 9	5 ± 15	64 ± 29	120 ± 148
Intensified without fertilizers	1,111	0	0	0	35–40	0
Intensified with fertilizers	1,111	0	0	0	35–40	0

2001; Sonwa 2004; Gockowski and Sonwa 2010; Somarriba et al. 2013) and that are condemned to be drastically reduced if intensified systems are adopted. In the present study, the importance of large diameter trees is highlighted, as reported by other authors (Kotto Same et al. 1997; Nolte et al. 2001 and Sonwa 2004). However, the amount of carbon stored could also be influenced by woody biomass (Schoeneberger 2009).

Current management of the tree components could be improved by reducing the number of trees that do not have any particular economic, cultural or ecological function and substituted them by useful species.

Relation between carbon stock, yields and incomes

The general relationship between carbon level and cocoa yield with yield decreasing in a non-linear way under increasing shade (and carbon level along with it) did not apply to the present case. Most likely, this is because of a lack of consistency in management practices, that does not allow separating the effect of single components and practices on productivity. Only the annual frequency of fungicides treatment has a positive effect on cocoa yields; more they respect frequencies and quantities, yields increase. The high diversity of the systems observed made it difficult to assess the existence of clear tradeoffs between carbon stocks, yield and incomes. The factors determining such variability in the systems have to be understood if a transition to more intensified systems has to be designed. For example among the trees associated to cocoa in AFSs, the majority remain of limited use for farmers because, as per their declaration, they do not contribute to farm revenues. An assessment of their ecological and functional role per species should be conducted to promote the selection of useful species.

As suggested by Somarriba et al. (2013) for Central American case studies, it is possible to design cocoa-based agroforest systems that provide both good yields (cocoa and associated crops) and high carbon stocks. However in the case of Southern Cameroon, that would require a major shift in current tree management practices to include carbon storage as a service acknowledged by farmers. Also, a completely new paradigm is required to systems because they have resulted from a long term adaptation process. That would imply an intense learning process to capacitate farmers to spare standing tree species not only on the basis of commercial and socio-cultural considerations but actually on their agro-ecological contribution to system efficiency, both for carbon and cacao yield. Similar strategy for trees association in cocoa farm was earlier suggested by Gockowski et al. (2010). Research should provide information on indigenous native species that can provide those services to maintain the conservation and cultural value of these traditional systems. Specific studies should be conducted to characterize tree species to be systematically used in the systems based on existing local ecological as proposed by Smith (2004). Provision of tree planting material should be secured. Also costs for implementing and managing these systems should be estimated to assess their economical return under carbon credit payment schemes. If Cameroon REDD+ strategy and "mechanism of benefits sharing" will become ready and operational, the sale of carbon stored in the cocoa AFSs could generate a modest income for cocoa farmers additionally to income derived from cocoa and associated tree crops (cocoa, fruits, timber).

Conclusion

Increasing cocoa production through the intensification of smallholder traditional systems and expansion of the cultivated area is at the core of the government strategy for the cocoa sector in Cameroon. Intensification here is based on the use of improved planting material associated to inputs (fertilizer and phytosanitary products). This study on the profitability of traditional cocoa agroforest has highlighted that cocoa agro-forests in southern Cameroon are still managed in a very traditional way characterized by intensive use of family labor, low yields and profitability, high shade/high carbon stock levels, little attention on the quality of associated tree species and planting material, no use of fertilizers and irregular use of pesticides. Still, under current frequency of fungicide use and farm rehabilitation practices, a significant positive effect on cocoa yield and return was observed. Profitability analysis showed that farms rehabilitated by old cocoa replacement were more profitable with high positive NVP at all discount rates. As compared to traditional farming system, the intensified cocoa systems promoted by the ministry of agriculture were more profitable at various discount rates. To overcome the impact on emission in line with the engagement on REDD+, the importance of including associated trees, of their choice and spatial distribution has to be stressed.

Poverty is the major constraint to agricultural intensification and limits investments in chemical inputs use. In the absence of major interventions to support chemical inputs purchase, the design of intensification paths should be gradual and first target the improvement of management practices such as a better management of trees, improvement of maintenance and rehabilitation practices by replacement. Where financial resources are scarce, only good management practices may help to increase yield and profitability of cocoa farms without fertilizers and maintaining a high level of carbon stock.

Technical recommendations for improve cacao production systems should account for the tendency to diversification observed in the traditional systems and not only aim at designing of rehabilitation strategies involving improved planting materials and the use of chemical inputs to maximize production with the elimination trees in traditional farm already exist.

Thus, to promote sustainable development, the government should put in place incentives to encourage farmers not only to produce cocoa to improve their living conditions but also to preserve the environment. To this end, these incentive mechanisms could be in various forms such as fertilizer and agricultural equipment subsidies, infrastructure development at the village level (to facilitate transport, storage and processing of the products) and the development of technical protocol according to various scenarios that could be established for cocoa and trees association (particularly for new cocoa plantations that will be established or currently in establishment). Also, if the implementation of REDD + is triggered, the payment of environmental services could be considered.

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