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Financial analysis of shaded cocoa in Ghana

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Abstract The cultivation of cocoa has been an important driver of tropical deforestation globally. Efforts to reverse this trend are focusing on the reintroduction of shade trees to cocoa plantations. Shade trees are valuable in enhancing biophysical conditions on cocoa (*Theobroma cacao*) fields and contribute to biodiversity and product diversification for smallholder producers. Participatory trials of cocoa agroforests planted with indigenous shade tree species were undertaken with farmers in the Atwima District of the Ashanti Region of Ghana, to increase tree volume on cocoa fields while improving rural livelihoods and enhancing environmental sustainability. An ex ante financial analysis of the technology was undertaken to assess its economic viability. Input–output data were collected from farmer experiments over three seasons and supplemented with data from traditional cocoa fields of varying rotation ages, and secondary data on production in later years of an eighty-year cocoa rotation. A discounted cash flow analysis was carried out to estimate the benefit-cost (B/C) ratio, net present value (NPV), internal rate of return (IRR) and land expectation value (LEV) as well as the sensitivity to a 20% decline in cocoa prices and additional chemical costs for various shade scenarios at a 10% discount rate. It was observed that cocoa production is, in general, profitable. The change from the traditional system to one with hybrid cocoa raised the IRR from 31% to 57% with planted shade and 67% without, although extra agrochemical costs would tend to reduce the profitability of unshaded hybrid cocoa in particular. The age of maximum LEV for the various scenarios suggests that the optimum economic rotation for the hybrid cocoa is between 18 and 29 years, much less than the traditional system.

Keywords Biodiversity · Indigenous shade trees · Profitability · LEV · NPV · IRR

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Introduction

Cocoa (*Theobroma cacao* Linn.) is a world economic crop cultivated in the humid tropics of Africa, Southeast Asia, South America and the Caribbean. World annual cocoa production from these continents stands at about 3 million tonnes with a market value of US$6 billion and 68–70%

of this production coming from West Africa. In West Africa cocoa is essentially a smallholder crop, cultivated on 1.2–1.5 million farms ranging in size from 3 to 7 ha and employing 10 million people. In the 2002/3 crop-year, Ghana was the second largest cocoa producer following Cote D'Ivoire, with a share of 16% of world production (ICCO 2004). The crop is a major cash crop and foreign exchange earner to the Ghanaian economy, contributing about 29% to the GDP of the country (GIPC 2002).

Although cocoa has proved to be a catalyst for economic development, it also has potential as a conservation tool for the rural tropics. Cocoa is naturally an under-storey plant. Traditionally, cocoa has been established by under-planting selectively thinned natural forest to utilise the 'forest rent' of recently cleared areas (Ruf and Zadi 1998). Economic fruit trees such as oil palm (*Elaeis guineensis*), avocado (*Persea americana*) and citrus (*Citrus sinensis*) may also be planted (Osei Bonsu et al. 2002) to provide shade in addition to providing food and cash for the farm household. Shaded cocoa has been described as one of the best examples of permanent agriculture that in some way preserves a forest environment and its biodiversity (Ruf and Schroth 2004), supporting higher levels of biodiversity than most other tropical crops (Rice and Greenberg 2000). This is notwithstanding the valuable ecological services provided by shaded cocoa (Beer et al. 1998) and their considerable potential to contribute to farmers' livelihoods through sales of timber species and other Non-Timber Forest Products (NTFPs). According to Beer et al. (1998) shade trees buffer high and low temperature extremes by as much as 5°C and are capable of producing up to 14 Mg ha^{-1} $year^{-1}$ of litter fall and pruning residues containing 340 kg N ha^{-1} $year^{-1}$. These authors also reported 4–6 m^3 ha^{-1} $year^{-1}$ of merchantable timber from commercial species such as *Cordia alliodora* in cocoa agroforest in Central America. Furthermore, maintaining 10 large or 15 medium trees per hectare helps to reduce damage to cocoa caused by insect pests. Other benefits of shade trees include reduction of weeds and some parasitic plants on cocoa (PAN UK 2001). According to farmers of Gogoikrom-Atwima, in the Ashanti region of Ghana, shade trees act as alternative hosts to parasitic plants such as mistletoe, which otherwise uses the cocoa as a host plant, depriving it of nutrients and thereby reducing yield (Obiri 2004).

In Ghana, one major constraint on the cocoa sector at present is the diminishing volume of valuable shade trees on cocoa farms caused by a number of factors. Because of tree tenure problems in the past, where the shade trees are of economic value their exploitation for timber has tended to destroy cocoa farms during logging by concessionaires, with little or no compensation paid to the farmer. This discouraged the practice of retaining valuable trees on cocoa fields as most farmers deliberately destroyed such trees to avoid the risk of uncompensated damage. Policy changes in the off-reserve concession arrangements and farmer rights under the 1994 Interim Measures (Bamfo 2003) and 1997 Timber Resources Management Act (Act 547) provided favourable incentives for cocoa farmers to retain timber shade trees. However, without tree tenure, farmers had no share of the value of the tree and, moreover, received little compensation, with the majority of them ignorant of the official compensation rates (Richards and Asare 1998). This gave rise to calls for further reform in these policies to ensure equitable benefit flows to entice farmers to retain and plant trees on farmlands (Bamfo 2003). Furthermore, extension recommendations in the recent past have tended to encourage less tree shade for cocoa to enhance yield, particularly for new cocoa hybrids. The introduction of new cocoa varieties that needed less shade and yielded earlier led to increased use of cocoa with little or no shade, although this has been found to be unsustainable because of the associated high levels of inputs of insecticides and fertilisers required. Shade reduction has led to a number of deleterious effects including increases in myrid, psyllid and leafhopper damage (Entwistle 1985); higher weed growth and nutritive demands (Ahenkorah et al. 1974); and young, unshaded cocoa has been observed to produce a high percentage of small, inferior beans (Adu-Ampomah et al. 1998). Cocoa with less than optimum shade has a shorter life cycle. Under certain soil conditions and rainfall regimes shaded cocoa may yield for 60–100 years whereas production may last for only 20 years without shade (Ruf and Zadi 1998). These observations have led to a renewed interest in the establishment of shaded cocoa, not least to offset the reductions in forest cover, which have resulted from cocoa expansion (Ruf and Zadi 1998).

An analysis of the production constraints in the study area revealed that the decline in trees on cocoa fields is reducing cocoa productivity due to a decline in soil productivity and exposure of the crop to environmental hazards such as sun scorch, drought and wild fires. Other associated problems mentioned were increased weed pressure and growth of parasitic plants such as mistletoe, as well as insufficient rainfall that is causing necrosis (yellowing) in cocoa leaves and enhances the development of insect pests such as termites and capsids that ultimately reduce yield and destroy cocoa trees (Obiri et al. 2000).

Ghana has the lowest rainfall amount of all cocoa producing countries (Ruf and Zadi 1998). Thus, if the present trend of the decline in trees on cocoa fields is not checked, a further retreat of the cocoa production frontier is likely, as the climate becomes drier and the moist micro-environment in which the crop thrives is lost. It is estimated that about 25% of the land area of the country needs to be reforested to favour cocoa production (Ruf and Zadi 1998).

To contribute to increasing tree volume on cocoa farmlands a study was designed with the main objective of improving the productivity and sustainability of cocoa farms in West Africa through the utilization of native forest trees in agroforestry systems. Both the agronomic and socio-economic aspects of this topic were studied. This paper reports on an ex ante assessment of the financial profitability of the multi-strata cocoa agro-forest planted with indigenous shade tree species under farmer conditions. The agronomic aspects are reported in Anglaaere (2005a).

Methods

Study area

The study was conducted in Gogoikrom, a village in Atwima District located in the southwestern part of the Ashanti Region of Ghana. The village was selected as occupying one of the areas in the district where most old cocoa lands are being replanted after several years of abandonment and conversion into food crop production. This made it a suitable place for introducing shade trees in cocoa as an agroforestry intervention aimed at converting short fallow cropping systems into perennial agroforests.

Gogoikrom is situated about 13 km from Nkawie, the capital of Atwima District and 48 km from Kumasi, the capital of Ashanti Region. The area has a gently undulating topography and is characterized by a semi-equatorial climate marked by a bi-modal rainfall pattern (peaking in June and October). The mean annual rainfall ranges between 1,700 and 1,850 mm. Temperatures are fairly uniform with mean monthly minimum and maximum temperatures of 27°C and 31°C occurring in August and March respectively. Relative humidity is generally high throughout the year (Atwima District Assembly 1996).

The study area falls within the moist, semi-deciduous ecological zone with forest vegetation characterized predominantly by a *Celtis-Triplochiton* floristic association. The soils are broadly made up of the forest ochrosols and forest ochrosols-oxisol intergrades. The ochrosols are, typically, well drained and fertile, supporting many food crops (maize, cassava, plantain, yam, cocoyam, etc.), whereas the oxisols are prone to leaching and support mainly tree crops (cocoa, oil palm and citrus).

The population of Gogoikrom was about 500 people in 2000. The mean household size is about six people, ranging between 1 and 15. The population is multi-ethnic, comprising a number of ethnic groups, broadly classified as natives and settlers based on residential status. About 85% of the people in the village are settlers, the majority of whom are tenants cultivating cocoa under the *abunu* (50:50) sharecropping arrangement or caretakers under the *abusa* (33:67) sharecropping arrangement. The village economy thus depends heavily on the production of cocoa, as about 60% of plots under cultivation are cocoa fields and over 90% of farmers cultivate the crop. Although the livelihoods of the people are centred on this crop, food crops such as maize, rice, plantain and cassava are also important sources of income for survival, and these may be supplemented by a handful of poultry and small ruminants such as sheep and goats.

Land for farming is typically owned by the indigenous people, but settlers and migrants secure usufruct rights by renting or sharecropping. Farming is largely close to subsistence level. Average cultivated plot size is 1.24 ha (range: 0.1–6.0 ha) with 50% of the plots being less than 1.0 ha. The hoe and cutlass are the major farm implements employed in cultivating crops. Family (67%, used for all farm operations) and hired (23%, particularly for land preparation and weeding) labour are common sources of farm labour, although some farmers may engage communal/pooled labour, particularly for harvesting. Hired labour provided by seasonal male migrants from northern Ghana is extensively used. Farm credit is limited as most farmers lack the collateral required for lending by financial institutions. Income earned from crop enterprises constitutes the main source of funds for household use and farm investment (Obiri 2003).

Gogoikrom is situated at the end of a 6.5 km dirt, but motorable, road that links it with Nkawie, the Atwima district capital and Kumasi, the capital of the Ashanti Region and a nodal business and economic centre for the northern sector of the country. This facilitates marketing of produce both at the farm gate and in markets. With the exception of cocoa, that has a stable government guaranteed price, prices of other crops are determined by market forces (McDonald et al. 2003). Extension services are woefully inadequate: generally, about 73% of farmers in the Atwima district do not have access to extension services and the farmer:extension agent ratio is 1:1,174 (Atwima District Assembly 1996). The village and its surrounding neighbours have no health post, while the nearest hospital is located in Nkawie. There is no school in Gogoikrom: children walk about 1.5 miles to school at a nearby larger village, Kotokuum. Nevertheless, about 45% of the farmers have had some formal education (Obiri 2003).

Planning technology, farmer selection, establishment and management of experiments

A participatory technology development approach was adopted in implementing the study. The cocoa-shade tree technology was identified through different sessions of stakeholder and farmer workshops/discussions and experimented with Gogoikrom farmers over three cropping seasons. The technology was designed based on initial knowledge from the characterization of farming systems/livelihoods of the area and a series of discussions with farmers who then planted and managed the technology on their fields. Researchers also participated by providing cocoa and indigenous tree planting materials and technical backstopping. No formal farmer selection criterion was employed and farmer experimenters voluntarily enrolled at village planning meetings. There were approximately 60 cocoa-producing households in the village, and of these 25 were used for the provision of data on cocoa production, selection being based on the ability to provide reasonable information regarding production on their fields. The sample size was thus in excess of 40%, with no reason to suspect bias in selection.

Typical traditional cocoa fields in their initial years of establishment are often grown in mixtures with cocoyam, plantain, cassava and maize with coppice shoots of desirable, naturally occurring tree species. Consequently, the experiment was similarly established to reflect farmers' practice. Each farmer experiment comprised the mixed hybrid cocoa variety developed by the Cocoa Research Institute of Ghana (CRIG) and seven indigenous shade tree species: *Khaya anthotheca (Welw.) C.* DC., *Pericopsis elata* (Harms) van Meeuwen, *Entandrophragma angolense* (Welw.) DC., *Entandrophragma utile* (Dawe and Sprague) Sprague, *Tetrapleura tetreptera* (Schum. and Thonn) Taub., *Albizia adianthifolia*(Schumach.) W. Wight *and Newbouldia laevis* (P. Beauv.) Seeman ex Bureau intercropped with plantain, cassava and other food crops. Single tree plots were used, in which a single individual of each of the seven tree species represented a plot on each participating farmer's field; and each field represented a block. Within a field the trees were planted at a triangular spacing of 12×12 m. Within each farm two seedlings of each species were planted in separate plots to give rise to two within-block replications. A total of 10 blocks (farms) were established and planting was carried out in the last week of August 2001. Farmers planted their cocoa and other crops according to their usual practice, with the exception of one cocoa plant acting as a control at the same spacing as the timber trees in each block.

Farmers are selective with the types of tree species they keep on cocoa fields, as not all trees are suitable companions for cocoa. Some are thought to have deleterious or allelopathic effects and others have heavy crowns that reduce aeration in the field and intercept rainwater, preventing it from reaching the ground. Trees that harbour pests or pathogens that damage the crop and deplete the soil of moisture essential to cocoa growth are also undesirable for the provision of shade for cocoa. Farmers listed desirable indigenous shade tree species, some of which they planted in the experiment. Usually, tall trees and/or those with light crowns are preferred, possibly because cocoa trees require more filtered sunlight as they mature (Anglaaere 2005b) and also to enhance aeration. Trees that contribute to soil moisture availability for the cocoa, particularly during the dry season, as well as those with some economic and/or food values are desirable (Obiri et al. 2000).

Input–output data

Data employed for the analysis are largely from primary sources gathered from 2000 to 2002, supplemented by secondary data. A seasonal cropping calendar on cocoa production, developed during an initial farming systems/livelihoods characterization workshop, provided basic information on the series of activities undertaken over the productive life of the cocoa. Data on farmer and plot characteristics and on inputs and outputs were gathered in the first two years of establishment of the technology. Since data for the later years of the cocoa rotation were not available, a number of estimates were made, based upon secondary sources.

A productive period of eighty years for the cocoa is considered for this analysis, as it is the traditional rotation age of cocoa in the area. Thus, it is initially assumed that each rotation lasts for eighty years after which the plantation would be re-established. The cocoa yield pattern over the eighty year production period was estimated from data collected from a sample of 25 traditional cocoa fields under different stages of growth in the village. This information was used to generate yield models and provide estimates of cocoa yields and costs of operation beyond the first two years of establishment, as the farmer experiments only began in 2001. Data on quantities of cocoa sold and price per kilo in various years were also gathered on these proxy cocoa fields from farmer cocoa sales record books. However, costs of production and prices considered in the analysis were estimated at 2002 farm gate values and assumed to be constant, in real terms, throughout the rotation. Extra costs incurred by the farmer in adopting the technology are those for tree seedlings and labour cost for establishing the trees (pegging, digging holes and planting). The first four years of production are considered as the establishment phase of the crop. Cocoa closes canopy in about the eighth year. After this period, all operations undertaken are assumed to be the same until the end of the productive life of the crop.

Costs related to protecting the cocoa (removing epiphytes, spraying against pests and diseases, etc.) are important but could not be estimated because farmers interviewed hardly undertook these activities and so were unable to assign costs. No marketing costs are considered as the bulk of the cocoa produce is sold at the farm gate. As mentioned above, there are numerous tenants involved in cocoa cultivation. In order to simplify the analysis, the cost of land for cocoa production is assumed to be the value of the initial sum of goodwill money paid by tenants involved in sharecropping under the *abunu* (50:50) arrangement as this is the common mode of access to land for cocoa cultivation by most people, including some landowning families with insufficient land resources.

Returns estimated from the treatments include income from food intercrops (maize, plantain, cocoyam and cassava) in the establishment phase. These are planted as nurse crops providing early shade and are also important in providing early cash and food for the farm household and cash for the maintenance of the cocoa, while awaiting cocoa proceeds. Cocoa output, i.e. bags of processed beans, and timber yield from four tree species are the long-term tree products estimated in the analysis.

Four of the seven indigenous shade tree species (*Khaya anthotheca, Pericopsis elata, Entandrophragma angolense and Entandrophragma utile)* planted in the experiment are commercial timber species. Timber yield data for these timber species in the natural forest is available (FIP 1989), but that under agroforestry settings or plantations is limited. Tree growth rates in agroforests may be relatively higher than in natural forests where plant density/variation is higher and the forest is not culturally managed. However, the rate of growth of trees in agroforest compared with that of natural forests is unknown, so to estimate the volume of merchantable timber it was assumed that the total rate of growth in each tree species in the cocoa agroforest would be 50% higher than in the natural forest, although tree growth rates of species differ considerably between species and decrease with years. Increasing the respective natural forest figures for *K. anthotheca*, *P. elata, E. angolense* and *E. utile* at 80 years from yield tables (FIP 1989) by 50% produced timber yield in the agroforest for these species (Table 1). The other three indigenous tree species (*Tetrapleura tetreptera, Albizia adianthifolia and Newbouldia laevis*) provide a variety of non-timber products including medicines, stakes, fruits and so on that have not been quantified in the analysis.

The product of the timber yield (in cubic metres), the number of shade trees per species at the end of the rotation and the stumpage price per cubic metre (FSD 2004) gave the timber value of each species per hectare (Table 1). About 70 shade trees per hectare were inter-planted in the cocoa (i.e. 10 trees of each of the seven timber species), 40 of which were timber species. For simplicity, it was assumed that no tree would be removed until the end of the 80-year rotation, although economic thinning to reduce shade density at certain times during the rotation may be necessary. About 15–25 shade trees per hectare, interspersed on the cocoa plantation at the later stages of the rotation, may be ideal (Anglaaere 2005b).

Data analysis

The data were analysed using the Microsoft Excel computer spreadsheet software. The profitability indicators estimated were benefit-cost ratios (B/C ratio), net present values (NPV), internal rates of return (IRR) and land expectation values (LEV), with sensitivity analyses also conducted (Bright 2001; Price 1989). A 10% discount rate was used in assessing the profitability of the technology (Gittinger 1982). Table 2 summarizes the profitability indicators and respective decision criteria.

Note that, although NPV shows the profitability over the length of a single rotation, it cannot be used to directly compare the profitability over rotations of different lengths nor of a series of rotations. To overcome these problems the LEV can be used instead (Bright 2001; Price 1989).

Table 1 Timber values of indigenous shade trees

Shade tree species	Yield (m^3) at year 80 (Natural forest)	Yield (m^3) at year 80 (Adjusted for agroforest)	Price per m^3 (¢'000/m^3)	No. of trees per hectare	Timber value (¢'000/ha)
Khaya anthotheca	2.23	3.35	242.8	10	8056.0
Entandrophragma angolense	0.28	0.42	82.4	10	344.0
Pericopsis elata	0.82	1.23	508.7	10	6208.0
Entandrophragma utile	1.64	2.46	316.1	10	7714.0

Source: Yield values adapted from FIP (1989) and stumpage prices from FSD (2004)

Table 2 Economic indicators used for profitability assessment

Profitability indicator	Formula	Decision criteria
B/C Ratio	$\frac{\sum B_t}{(1+r)^t} \div \frac{\sum C_t}{(1+r)^t}$	BCR ≥ 1.0
NPV	$\sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+r)^t}$	NPV ≥ 0
LEV	$NPV \times \frac{(1+r)^n}{(1+r)^n - 1}$	LEV ≥ 0
IRR	$\sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+r)^t} = 0$	IRR ≥ r

B = benefit, C = cost, t = time in years or rotation/production period, r = discount rate, n = rotation length in years

Results and discussion

Derived cocoa yield/production curves

Adapting work carried out by Ryan et al. (2007), a cocoa yield curve was fitted from a regression of the age of the plantation on cocoa yield using the data from the traditional cocoa fields. Table 3 shows the result from the regression in which the natural logarithm of cocoa yield (per tree) was the dependent variable.

Although the R^2 value was not high, it was the highest of a number of relationships tested and the results indicated a significant relationship between the natural log of cocoa yield and plantation age and its natural log. Furthermore, although it was not possible to validate the model to ensure that there were no major errors or incorrect assumptions (Yates et al. 2007), such models have already been used for cocoa (Ryan et al. 2007) and gum Arabic (Makonda 2003) and sensitivity analysis can be employed to test for variation in some key assumptions. The left hand curve in Fig. 1 shows the derived cocoa yield pattern, with a maximum yield of about 800 kg ha^{-1} occurring in year 24. The equation for estimating the yield of cocoa in any year during the eighty-year production cycle is, therefore:

$$Y = \exp(-1.822 - 0.166A + 3.931\ln(A)) \quad (1)$$

Where Y is cocoa yield ha^{-1} and A is age of the cocoa plantation in years.

Since hybrid cocoa will tend to peak earlier and at a higher level than traditional varieties and a cocoa plantation tends to be less productive over its lifetime with insufficient shade trees (PAN 2001), it is expected that introducing hybrid cocoa will raise peak yields while planting indigenous shade trees with the cocoa will prolong its productive life. However, the profitability of these systems will depend, not only upon the yield pattern, but also on the costs, prices and timings of the cash flows. Before analyzing the economics of the alternatives the growth curves need to be established.

The Ryan et al. (2007) equation takes into account optimum shade for cocoa. Adapting the equation for the traditional Ghanaian system with insufficient shade (i.e. Eq. 1), gave a peak yield of 800 kg ha^{-1} in year 24 with a total yield of 3,503 kg over years 5–15. The farmer experiments were planted with hybrid cocoa. Adapting the Ryan et al. (2007) equation for the hybrid cocoa without planted shade (control) gives a yield peak of 1,200 kg ha^{-1} in year 12 with a total yield of 10,200 kg over years 5–15. However, hybrid cocoa planted with shade under farmer conditions (labour and money constraints), delays the peak to 16 years with a peak yield of 970 kg ha^{-1} and total yield of 7,367 kg over years 5–15, as shown in Fig. 1. The equations for the hybrid and shaded hybrid scenarios are as follows:

$$= \exp(0.0992 - 0.4A + 4.745\ln(A)) \quad (2)$$

$$= \exp(1.6399 - 0.18A + 2.924\ln(A)) \quad (3)$$

Table 3 Output from a regression of age of cocoa plantation on cocoa yield

	Coefficients	Standard error	*t*-statistic	*P*-value
Intercept	–1.822	1.688	–1.079	0.300
Age of cocoa plantation (years)	–0.166	0.047	–3.563	0.004
Natural log of age	3.931	1.014	3.877	0.002

R^2 = 0.54; F = 7.56

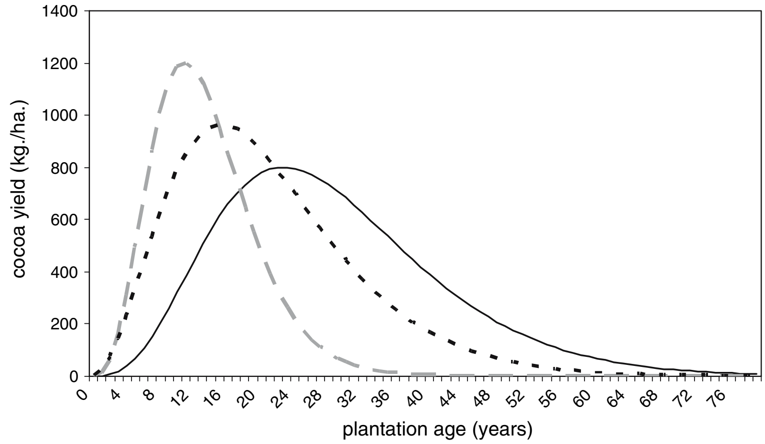

Fig. 1 Derived cocoa yield patterns in hybrid, and shaded hybrid and traditional systems

Cash flow analysis

The summarized cash flow analysis for the cocoa with traditional, hybrid and shaded hybrid technologies is presented in Table 4. The extra variable costs of the planted shade relative to the traditional and hybrid without shade options, that is, the extra costs resulting from adopting the shaded cocoa technology, are those for purchasing and transporting indigenous tree seedlings and labour for planting and felling the trees at the end of the timber rotation. Fertiliser and pesticide costs were not included in the initial analysis as, at the time of the data collection, farmers were not applying fertiliser, nor were they or the extension service able to provide appropriate information.

Table 4 Summary cash flow for traditional, hybrid and shaded hybrid cocoa (80 year cycle)

Item	Traditional	Hybrid	Shaded hybrid
Receipts (¢'000)			
Gross return			
Food crops	5,949	5,949	5,949
Cocoa	207,429	139,743	197,789
Timber	0	0	22,321
Total returns	213,379	145,692	226,059
Expenses (¢'000)			
Labour costs			
General land preparation & maintenance	13,812	13,812	13,812
Food crops (planting, harvesting & haulage)	475	475	475
Cocoa (planting, disease & pests control, harvesting & processing)	99,899	67,301	95,159
Indigenous tree seedlings (planting)	0	0	52
Harvesting timber	0	0	1,984
Other costs			
Land rent (average initial good will money)	322	322	322
Farm tool (machete, chisel, sickle)	2,819	2,819	2,819
Agrochemicals (fungicides & insecticides)	0	0	0
Sprayer rental	0	0	0
Planting materials			
Food crops (Plantain, maize, cassava, cocoyam)	819	819	819
Cocoa seedlings & transport	1,513	1,513	1,513
Indigenous tree seedlings &transport	0	0	34
Marketing costs	0	0	0
Total expenses	116,838	87,060	116,989
Net cash flow (¢'000)	96,541	58,632	109,070

The traditional system yields the highest cocoa returns, while the shaded hybrid generates the highest net cash flow as it also benefits from the timber revenue. The unshaded hybrid system would generate the lowest net cash flow over an 80 year cycle. However, such comparisons are unrealistic since much shorter rotation lengths are likely to be adopted. Furthermore, such cash flow comparisons are not a fair means of assessing profitability because of time delays; discounting is an appropriate means of adjusting for this.

Discounted cash flow

Economic indicators estimated are the B/C ratio, NPV, LEV and IRR. The discounted cash flow results presented in Table 5 show that cocoa production is, in general, profitable at a 10% discount rate. However, the traditional system is the least profitable although it has the longest rotation. The shade effect decreased the BCR, LEV and IRR, from 1.74, ¢24.1 million, and 55% in the un-shaded hybrid system to 1.71, ¢19.4 million, and 46% respectively in the shaded hybrid system, although both systems exhibit greatly improved financial performance compared to the traditional system. Duguma et al. (2001) reported that, even with no value assigned to the tree species, cocoa production in smallholder systems in Cameroon was profitable, with production being more profitable with planted shade trees. Oladokun and Ebge (1999) have also reported the profitability of cocoa shaded with *Cola nitida* in Nigeria.

Although, in practice, hybrid cocoa cultivation might necessitate relatively high fertiliser and pesticide costs which have not been accounted for here, the profitability gap is so large as to make the likelihood of a change in ranking of the alternative systems unlikely. Nevertheless, in the absence of credit availability, these costs could hamper adoption.

The optimum rotation age, as indicated more accurately by the LEV rather than the NPV, fell considerably with the introduction of hybrid cocoa (44–18 years), although this was less marked for the shaded hybrid (29 years).

Sensitivity analysis

The models were re-run to assess the sensitivity to variation in a number of key assumptions. First, sensitivity to a cocoa real price reduction of 20% was modelled. Under these conditions cocoa production is still profitable for all of the systems considered, although quite sensitive to this change. IRR values fall proportionately across the board by between 5 and 9%, while the largest fall in LEV is for unshaded hybrid, although this system still generates the highest figure (Table 6).

A variation in yield would have a similar, but somewhat smaller, effect to variation in price since harvest revenue would fall by the same percentage, but be alleviated by a reduction in harvesting costs.

Although, for reasons outlined above, fertiliser and pesticide costs were not included in the initial model, the sensitivity to their inclusion was tested, for fertilisation costing an assumed 1 million cedis in year 2 and pesticide costs of 100,000 cedis occurring every year from year 4 for hybrid cocoa, assuming no further increase in yields as a result of these operations. The results, also presented in Table 6, indicate that the inclusion of fertilisation costs could reduce profitability, but not sufficiently to make hybrid planting uneconomic. The IRR would fall to 39% and the LEV by 7% to 13.11 mill. cedis,

Table 5 Summary discounted cash flow-cocoa with and without planted shade trees

Economic indicator	Traditional	Hybrid	Shaded hybrid under farmer conditions
B/C Ratio	1.57	1.74	1.71
IRR	31%	55%	46%
Max NPV (×¢’000)	10,734	21,133	18,756
Max LEV (×¢’000)	10,825	24,127	19,437
Age of maximum LEV (years)	44	18	29

Table 6 Sensitivity of profitability of cocoa to price and cost variation

Economic indicator	Traditional	Hybrid	Shaded hybrid under farmer conditions
20% fall in cocoa price			
B/C Ratio	1.31	1.43	1.41
IRR	26%	46%	38%
Max NPV (×¢'000)	5,881	12,324	10,792
Max LEV (×¢'000)	5,934	14,118	11,202
Age of maximum LEV (years)	44	18	29
1 mill. cedis fertiliser cost in year 2			
B/C Ratio	1.57	1.39	1.36
IRR	31%	39%	32%
Max NPV (×¢'000)	10,731	11,498	9,941
Max LEV (×¢'000)	10,825	13,113	10,289
Age of maximum LEV (years)	44	18	29
100,000 cedis pesticide costs each year from year 4			
B/C ratio	1.57	1.39	1.37
IRR	31%	45%	36%
Max NPV (×¢'000)	10,731	11,644	10,023
Max LEV (×¢'000)	10,825	13,421	10,436
Age of maximum LEV (years)	44	18	29

but this implies that fertiliser costs would need to be 8.1 mill. cedis (with no further improvement in yield) for unshaded hybrid cocoa profitability to be matched by that of traditional cocoa. Similarly, annual pesticide costs of 100,000 cedis would reduce IRR to 45% and LEV by around 5% to 13.4 mill. cedis, indicating that the profitability of unshaded hybrid cocoa would only fall to the level of traditional cocoa if pesticide costs were to reach 1.2 mill. cedis annually.

Finally, sensitivity to changes in timber yields and prices was tested, but the effect was very small because of the substantial time delay regarding cash inflows.

Conclusions

We conclude that, even with traditional cocoa varieties, cocoa production is profitable, and continues to be so with a 20% reduction in cocoa price or yield. The introduction of hybrid cocoa greatly enhances profitability. Shaded hybrid cocoa is also much more profitable than the traditional, unshaded system but less than its unshaded counterpart due to the earlier and higher yield peak, although this depends upon the relative positions and shapes of the growth curves. Furthermore, varying the assumptions on chemical costs and timber value could lead to shaded cocoa being more favourable. On the other hand, a rise in the discount rate favours the unshaded hybrid system.

The optimum rotation age varies considerably according to the system adopted. The research suggests that under the present system the economic rotation age is 44 years. Even under current practice, therefore, it may be more economic to replant cocoa after about 40 years, rather than waiting until 80 years as traditionally practised. Ruf and Zadi (1998) suggest that shortening the life cycle for cocoa, even with shade trees, may be preferable to traditional rotation lengths and this concurs with our conclusions that the economic rotation age is only 18 years with unshaded hybrid cocoa, but 29 years if shaded.

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References

Adu-Ampomah Y, Frimpong EB, Abiyry MA, Ofori-Frimpong K, Opuku G, Yeboah SB (1998) Occurrence and distribution of light crop (Category G) beans in the main crop season. Report submitted to the Ghana Cocoa Board, 24 pp

Ahenkora Y, Akrofi GS, Adri KK (1974) The end of the cocoa shade and manuring experiments at the Cocoa Research Institute of Ghana. J Horticult Sci 49:43–51

Anglaaere LCN (2005a) Improving the productivity and sustainability of cocoa farms in West Africa through utilization of native forest trees in agroforestry systems. Unpublished Ph.D. thesis. School of Agricultural and Forest Sciences, University of Wales, Bangor, 331 pp

Anglaaere LCN(2005b) Personal communication

Atwima District Assembly (1996) District development plan. Atwima District, Ashanti-Ghana

Bamfo RK (2003) Policy and institutional reform for forestry: the Ghanaian experience. Africa forest law enforcement and governance conference. October 13–16, 2003. Yaounde, Cameroon, 8 pp

Beer J, Muschler R, Kass D, Somarriba E (1998) Shade management in cocoa and coffee plantations. Agroforest Syst 38:139–164

Bright GA (2001) Forestry budgets and accounts. CABI, 380 pp

Entwistle PF (1985) Insects and cocoa. In: Wood GAR, Lass RA (eds) Cocoa. 4th edn. Longman, London and New York, pp 373–383

Duguma B, Gockowski J, Bakala J (2001) Smallholder cacao (*Theobroma cacao* Linn.) cultivation in agroforestry systems of West and Central Africa: challenges and opportunities. Agroforest Syst 51:177–188

Forest Inventory Project (FIP) (1989) General yield tables for Ghana. In: Seminar proceedings pp 50–52, 29–30 March 1989 Accra

Forest Service Division (FSD) (2004) Stumpage prices for commercial timber species in Ghana. FSD, Kumasi

Ghana Investment Promotion Centre (GIPC) (2002) Ghana investment profile: food production and processing. GIPC. Accra, Ghana

Gittinger JP (1982) Economic analysis of agricultural projects. World Bank, 505 pp

ICCO (2004) International cocoa organisation's quarterly bulletin of cocoa statistics, London

Makonda, FB (2003) Gum arabic studies in Tanzania: production, utilisation and economic potentials. Unpublished PhD Thesis, University of Wales, Bangor, UK, 326 pp

McDonald MA, Obiri BD, Jatango JA, Anglaaere LCN, Cobbina J, Moss C, Nolte C, Weise SF, Gockowski J, Sinclair FL, Bright G, and Young, EM (2003) Shortened bush-fallow rotations for sustainable rural livelihoods in Ghana. (DFID Project R7446) Final Technical Report. 25 pp + appendices

Obiri BD, Ayisi-Jatango J, Anglaaere LCN, Cobbina J, Moss M, McDonald M, Sinclair F, Young E (2000) Livelihood systems and farmers' ecological knowledge in Ghana: a report on three districts. Shortened bush fallow rotations for sustainable livelihoods in Ghana. DFID Project R7446. School of Agricultural and Forest Sciences, University of Wales Bangor, UK, 146 pp

Obiri BD (2004) Improving fallow productivity in the forest and forest-savannah transition of Ghana: a socio-economic analysis of livelihoods and technologies. Unpublished Ph.D. thesis. University of Wales, Bangor, UK, 358 pp

Oladokun MAO, Egbe NE (1999) Yields of cacao/kola intercrops in Nigeria. Agroforest Syst 10:153–160

Osei-Bonsu K, Opoku Ameyaw K, Amoah FM, Oppong FK (2002) Cocoa-coconut intercropping in Ghana: agronomic and economic perspectives. Agroforest Syst 55:1–8

Pesticide Action Network (PAN) UK, (2001) Sustainable cocoa production systems. A briefing for IPM in developing countries project of the european commission. PMN No. 12. London, UK

Price C (1989) The theory and application of forest economics. Blackwell

Rice RA, Greenberg R (2000) Cacao cultivation and the conservation of biological diversity. Ambio 29:167–173

Richards M, Asare A (1998) Incentives for Ghanaian cocoa farmers to keep timber trees. Policy Briefing Note. DFID/FRP R6914

Ruf F, Zadi H (1998) Cocoa: from deforestation to reforestation. In first international workshop on sustainable cocoa growing, 1998, Smithsonian Institute, Panama

Ruf F, Schroth G (2004) Chocolate forests and monocultures: a historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In: Schroth G, da Fonseca AB, Harvey CA, Gascon C, Vasconcelos HL, Izac A-MN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington DC, pp 107–133

Ryan D, Bright GA, Somarriba E (2007) Damage and yield change in cocoa crops due to harvesting of timber shade trees in Talamanca, Costa Rica. Agroforestry Systems (in press)

Yates C, Dorward P, Hemery G, Cook P (2007) The economic viability and potential of a novel poultry agroforestry system. Agroforest Syst 69:13–28