HORTSCIENCE 47(11):1617–1624. 2012.

Necessary Price Premiums to Incentivize Ghanaian Organic Cocoa Production: A Phased, Orchard Management Approach

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Additional index words. cocoa, organic price premium, organic production, phased replacement

***Abstract*. Price premiums necessary to incentivize switching from conventional (inorganic) to organic cocoa (*Theobroma cacao*) production in Ghana are identified. Optimal, phased-replacement models for orchard management are used to determine when switching from conventional to organic is profitable. The decision is a function of orchard growth stage, price premiums, and yield loss. Results indicate that the net present value (NPV) of organic production under current market conditions is 21% lower than the NPV of conventional production. Analysis shows that, generally, the minimum price premium to convert to organic is just slightly lower, in percentage terms, than the yield reduction caused by growing organically.**

The mounting concerns about food safety, health, environmental, and social welfare issues have increased demand for organic cocoa products in high-income countries. Euromonitor International [as cited in International Cocoa Organization (ICCO), 2007b; Pay, 2009] estimated the sale of worldwide organic chocolate in 2002 at $171 million and increased to $304 million in 2005. Similarly, as reported by Potts et al. (2010), the sales of certified cocoa, which is produced and traded according to standard guidelines of various organizations—Fairtrade, the International Federation of Organic Agriculture Movements (IFOAM), the Rainforest Alliance, UTZ Certified, and other certification organizations—in 2008 accounted for 1.2% of total global cocoa sales. These sales have grown by 248% since 2003 to 2008 (Potts et al., 2010). Nevertheless, the total market share of organically grown cocoa is still relatively very small and accounted for less than 0.5% of the total production in 2002 to 2005 (ICCO, 2006) although demand for organic cocoa is increasing.

For small-scale cocoa producers in Ghana, where 56% of the population works in the agricultural sector [Central Intelligence Agency (CIA), 2011] and 78.5% of the Ghanaians live on less than $2 (U.S. dollars) per day (The World Resources Institute, 2011), growing cocoa organically is often not a choice but a necessity as a result of the high cost of inorganic fertilizer, fungicide, and other inputs and the minimal opportunity for microfinance (Agbeniyi et al., 2010). For producers who cannot afford inorganic inputs and who currently grow organic cocoa, there is a large amount of risk (both in price and in yield) involved with an estimated 30% lower yield compared with conventional (inorganic) production (Phuoc et al., 2008; Victor et al., 2010). However, producer profits could be higher if they could afford inorganic fertilizer. Therefore, a sufficient and stable organic price premium is needed to induce producers to continue growing cocoa organically.

Aside from yield loss from converting to organic farming, the aging of tree stocks also has a significant impact on diminishing cocoa yields (Fig. 1) when the trees are retained beyond their economically productive life (Asare and David, 2010; Gro-Cocoa, 2008; Hardy, 1960; Montgomery, 1981). In many parts of West Africa, cocoa trees are abandoned and not replaced after the trees become old enough in their life cycle to produce yields that are not economically viable (Vos and Krauss, as cited in Gro-Cocoa, 2008). For cocoa producers, weighing the benefits and costs of replacing trees is important because the productivity of a cocoa tree plateaus and then diminishes over time. Because cocoa trees reach peak productivity quickly (at age 12 years) and bear the fruit for up to 50 years, culling and replanting cocoa trees are practices needed to maintain maximum orchard profitability over time. This temporal aspect of yield is also problematic when producers are contemplating switching from conventional production to organic production methods. Given the life cycle of a tree, a producer must not only answer "if" they should switch to organic methods but "when" switching becomes beneficial in the life cycle of an orchard.

Several studies (Arope, 1971; Etherington, 1977; Ismail and Mamat, 2002; Manos and Papanagiotou, 1983; Tisdell and De Silva, 2008; Ward and Faris, 1968) have used replacement models to determine optimal replacement rotations of fruit trees such as plum, peach, palm oil, apple, pear, coconut, and rubber trees. Similarly, several replanting strategies have also been used in cocoa production. According to Murray (as cited in Lass, 2001), the partial replanting method (the removal all poor-yielding trees over several years) has lower yield than a complete replanting (the removal all cocoa and shade trees). However, no complete replanting study has adopted the optimal, phased-replanting method to compare organic and conventional cocoa farming.

This study estimates the price premium necessary to motivate profit maximizing cocoa producers to prefer organic production over conventional cocoa production. We develop a decision tool to empirically estimate NPV using optimal, phased-replacement strategies for 1) a new cocoa farm; and 2) an existing, conventional cocoa farm contemplating converting to organic at various points in an orchard's life cycle. By comparing the NPV of organic and conventional production systems under various scenarios, the price premiums necessary to incentivize producers to produce the lower yielding organic cocoa are identified. The modeling for an existing conventional farm accounts for the fact that when a conventional producer converts to organic production, the producer immediately suffers a yield loss. Additionally, a producer must wait three years for the organic certification that will allow him or her to be compensated with an organic price premium. This study provides 1) a decision tool for producers to determine "if" and "when" it would be optimal to produce organic cocoa; and 2) an estimated organic premium that bulk, organic cocoa purchasers must pay to incentivize cocoa producers to continually produce organic cocoa.

Literature Review

Organic cocoa. The term "organic" is widely used to describe and define both a chemical-free agricultural product as well as to describe an environmentally sustainable method of farming. Codex Alimentarius (1999), an intergovernmental body with over 180 members established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization, defines organic agriculture as "a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It

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Received for publication 26 July 2012. Accepted for publication 12 Sept. 2012.
This work was made possible by funding provided by the World Cocoa Foundation (WCF). In particular we acknowledge the help and advice of Ethan Budiansky of the WCF and the generosity of Jim Gockowski of the International Institute of Tropical Agricultre for the Ghanaian production data. Lastly, we thank Zara Clayton for his modeling assistance.
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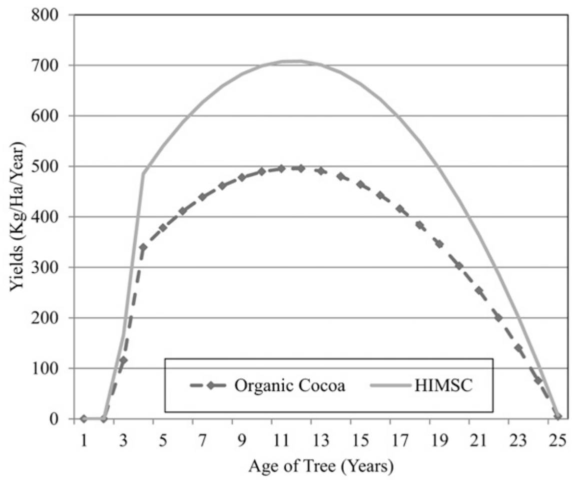

Source: Gockowski (2009).

Fig. 1. Cocoa yield curves over one production cycle (25 years) in Ghana for organic cocoa and High Input, Medium Shade Cocoa (HIMSC) production systems.

emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, cultural, biological and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system'' (p. 2).

Byers and Liu (2008) argue that the pronounced, organic price fluctuations over time are mainly the result of the small volumes traded, quality issues, and an irregular pattern of organic cocoa supply. ICCO (2011b) states that the organic cocoa price is set on the basis of world market prices and Fairtrade premiums (the margin that is paid to producers in addition to the agreed Fairtrade price). The premium price of organic cocoa is estimated to be ≈\$100 (2010 U.S. dollars) to \$300 (2010 U.S. dollars per ton above the market price of conventional cocoa (ICCO, 2007a). In January 2011, the ICCO monthly average of daily cocoa prices was \$3,164.86 per ton (2011 U.S. dollars) (ICCO, 2011a) and premium prices for organic cocoa were \$200 per ton (2011 U.S. dollars) (Fairtrade International, 2011). This indicates the price premium paid for organic cocoa was 6.32% above the ICCO price in Jan. 2011. Besides receiving a premium price, ICCO (2011b) also claims that certified producer organizations also receive better ''capacity-building'' through practical training and guaranteed ''market access'' to the Fairtrade organization.

However, the costs and benefits of growing cocoa organically must balance. Cocoa producers who want to become certified organic cocoa growers must follow all requirements that are set by Fairtrade or other organic certifying organizations. These requirements include standardization of production and marketing, inspection arrangements, and labeling requirements (ICCO, 2006). Other requirements consist of issues such as ''the cocoa beans must be grown on land which has been free of prohibited substances for three years prior to harvest. Cocoa beans grown on land which is 'in transition' to organic (during the first three years after switching from conventional farming, for instance) cannot be labeled organic'' (ICCO, 2006, p. 4). This is problematic for impoverished producers switching from conventional production to organic production. The conversion results in lower yields with no premium organic price for the first three years of organic production.

Producers who switch from conventional to organic also incur other additional costs associated with the Fairtrade Labeling Organization (FLO) system such as certification fees and documentation costs, higher variable costs (associated with the organic labor-intensive practices), and social and environmental costs (FLO-Cert, 2011; ICCO, 2005, 2006). The costs associated with the organic standard, which have to be paid by the producer organization (farm or cooperative) to the organic certification body, generally include the cost of an initial application fee and an annual certification fee on a fixed basis or in proportion to sales set at 3% of farm gross revenues (ICCO, 2006). In general, organic fees vary depending on the particular cooperative and marketing arrangements. By using the 3% instead of a specific list of costs, our computed price premiums are general. Exact premiums would vary across producers depending on how they elect to pay their certification and application fees. Specifically, FLO-Cert (2011) provides a cost structure of applying for FLO certification which is generally set for a cooperative as follows: (1) application fee, (2) initial certification fees, (3) annual certification fees, (4) a follow up audit fee, (5) and an additional auditor fee. Additionally, ICCO (2005) states that FLO certification collects a fee of 0.45% of the FOB (freight on board) value when the cocoa is sold under fairtrade conditions.

Agriculture has historically played an important role in the Ghanaian economy. It accounted for 35.4% gross national product in 2007 (Bank of Ghana, 2011a) and employed 56% of the total population (CIA, 2011). Ghana, the world's largest cocoa producer in the early 1960s, produced 614,500 tons of cocoa (Food and Agriculture Organization of the United Nations, 2011a) in 2007, which contributed ≈3.4% of total gross domestic product that year (Nimoh et al., 2011). Ghana is actively engaged in the Fair Trade cocoa market with roughly 10% of total purchases from 2002 to 2006 labeled as Fair Trade-certified (Vigneri and Santos, 2008). The Ghanaian Cocoa Board (Cocobod) has market channels for Fair Trade cocoa to be sourced and exported. They trace the cocoa back to a cooperative and not an individual farmer to ensure the standards of Fair Trade are being met.

Certification of organic cocoa in Ghana has been more difficult. A 2001 survey conducted by the Sustainable Tree Crop Program revealed that over 50% of Ghana producers used no agrochemicals and were in essence de facto organic producers (Afari-Sefa et al., 2010). Although a large percentage of the Ghanaian cocoa is produced organically, it cannot be verified by a governing board so it cannot be sold as organic. In 2009 the Cocoa Abrabopa Association became the first cocoa farmers' association in Ghana to obtain certification from UTZ Certified for organic production. Over 500 Ghanaian cocoa producers, which is only a small fraction of total producers, successfully met the required standards.

Several studies have estimated profits given estimated price premiums and yield losses associated with the omission of inorganic inputs in the production system. For a feasibility study of organic cocoa in Vietnam, Phuoc et al. (2008) estimate that the yield reduction of organic cocoa farming is 30% relative to conventional farming and a 30% price premium is assumed for organic production. Their simulation shows that conventional farming net profits exceed organic cocoa by 5.15% even with the 30% yield loss and 30% price premium. Similarly, Victor et al. (2010) examine the costs and benefits of certified sustainable cocoa production in Ghana using the concept of NPV. The study estimates sensitivity analysis of the farm gate price from FOB prices but does not estimate necessary price premiums for conversion from conventional to organic production. Given an organic fertilizer price subsidy, profitability of Rainforest Alliance-certified cocoa greatly increases as the FOB price increased from the 70% assumed price to 85% of FOB. In addition, following the Rainforest Alliance-Sustainable Agriculture Network standard of 70 shading trees per hectare, Victor et al. (2010) find that the yield loss is 30% compared with the conventional methods of a full-sun, High Input No Shade Cocoa system. Conversely, two multiyear studies find that the no shade with an inorganic fertilizer method increased yields compared with a shade and no-fertilizer method by 68.75% over a 1960 to 1969 study in Ghana (as cited in Willey, 1975) and by 46.01% in Bahia Brazil over a 1964 to 1973 period (Cabala-R et al. as cited in Wessel, 2001).

Many current cocoa producers grow organic cocoa or convert their operation to organic cocoa as a result of the unavailability or high price of inorganic inputs (fertilizer, fungicide, and pesticide). Agbeniyi et al. (2010) use descriptive statistics and a multivariate logit model to examine inorganic fertilizer use among 107 respondents in Cross River State of Nigeria. The study finds that 98.13% of respondents do not use inorganic fertilizer for varying reasons. Approximately 39% of respondents believe the soil is nutrient-rich, 25.23% state that the fertilizer is not always available, 16.82% argue that fertilizer is too costly, 15.89% state that they do not have a credit source to purchase fertilizer, and 0.93% say that the fertilizer arrives too late to be effective.

Life cycle and phased-replanting methods for cocoa production. Ward and Faris (1968) identify four stages in the life cycle of an orchard: 1) an early period of no yield, which normally occurs from years one to year three; 2) a period of increasing yield at an increasing rate; 3) a period of increasing yield at a decreasing rate; and 4) a period of decreasing yields. Stage four is associated with declining revenue because the trees are past their yield maximums. The four life cycle stages also apply to cocoa production, where yields after age 25 years decline slowly and the annual yield loss can be gradual over time although the tree can live for 100 years (Lass, 2001). For cocoa producers, selecting both the optimal timing of culling and the replacement rate to maximize the present value of their income stream over time requires considerable computation.

Figure 1 displays the yield life cycle of cocoa production in Ghana for two production practices: organic cocoa and conventional cocoa [High Input, Medium Shade Cocoa (HIMSC)] over a 25-year period (Gockowski, unpublished data). Alternatively Montgomery (1981) asserts that peak yield occurs at year 15 to 25 after planting with profitable life to 50 years. He further asserts yield declines slowly from year 26 to 45. Asare and David (2010) recommend that cocoa producers start replanting if a cocoa tree produces fewer than 10 pods per year. To address the declining yield phenomenon, Lass (2001) suggests three replanting approaches: 1) partial replanting of poor-yielding trees; 2) periodic total replanting (clear-felling); and 3) phased- replanting (a rotation method in which a certain percentage of cocoa trees is replanted annually on a perpetual basis).

Replacement models. Replacement models have been widely discussed in the literature and applied to many economic problems, including orchard management. The basic principle of asset replacement is "to compare gains from keeping the current asset for another time interval with the opportunity gains which could be realized from a replacement asset during the same period" (Perrin, 1972, p. 60). Similarly, Faris (1960) concludes that "the optimum time to replace an asset is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the following enterprise" (p. 766). In cocoa production, a phased-replacement model can help to stabilize cocoa yield and annual return of cocoa producers over time.

In managing fruit tree orchards, deterministic and/or stochastic replacement models are specified and solved to optimize profit. Deterministic models assume that all future prices, costs, and yields are known with certainty. Stochastic models recognize that future events are drawings from probability distributions. The difference between these two replacement models is that deterministic models optimize NPV and stochastic models maximize expected NPV. As a first approximation to a truly optimal solution, the present analysis uses deterministic assumptions. In their application, Ward and Faris (1968) find that both deterministic and stochastic models give identical results to their particular applications.

Faris (1960) uses a deterministic replacement model for orchard management to solve for the optimal replacement of peach trees. The Faris (1960) replacement model has empirically been adopted in palm oil-producing areas. Arope (1971) solves maximizing NPV for various combinations of yields and prices of oil palm and kernel. He finds that the optimal replacement age exceeds 31 years when associated with different price levels and interest rates. However, to avoid higher harvesting costs and marginal yields resulting from problems engendered by increasing palm oil tree height, Arope (1971) suggests that the replanting should be considered when the tree age is 30 years.

Ismail and Mamat (2002) also apply a deterministic replacement model for palm oil trees using the Faris replacement model and examine outcomes from several scenarios. Tree life is constrained to no more than 32 years as a result of a height consideration; cost variables include land clearing, lining, holing, seedling planting, fertilizer, wage, and price of fresh fruit bunches (FFB), which is based on crude palm oil prices. The optimal replanting age ranges from 25 to 26 years when the FFB price is \$64.10 (2011 U.S. dollars) per ton (Ismail and Mamat, 2002). However, as the FFB price increases to \$70.51 (2011 U.S. dollars) per ton, the optimal replacement age declines to a range of 24 to 25 years.

Mahrizal et al. (2012) solve for the annual, optimal replacement rate (ORR) and initial replacement year (IRY) of conventional cocoa production to maximize NPV by using a phased-replanting method. Using data on cocoa yield, price, cost, inflation, and discount rates, Mahrizal et al. (2012) find that the ORR is 5% to 7% with IRY ranging from year five to year nine as a function of cocoa prices, fertilizer prices, labor prices, and percentage yield loss resulting from disease outbreaks. The optimal solutions across three different production systems show that profits and yields in the baseline scenarios are higher by 5% to 10% compared with the status quo of non-replacement and eventual abandonment (Mahrizal et al., 2012).

Phased-replacement models are relevant for assessing when organic farming is more profitable than conventional farming. Because orchard management is a multiperiod optimization problem, a replacement model helps producers to answer both "is it" profitable to switch to organic production and "when is it" profitable to switch to organic production?

Methods

Because we assume producers are profit maximizers, a replacement model is used to ensure that the comparison between organic and conventional profit levels has each level at their optimal values. The study uses two basic formulas to search for the optimal profits: the annual NFV framework associated with the replacement rate, year of replacement, and inflation rate; and 2) the NPV, which is the sum of the discounted annual NFVs over a 50-year planning horizon. The NPV is maximized with respect to ORR and IRY. Inflation is important in this study because price levels increase over time (inflation is often high in low-income countries) and inflation strongly affects the future value of money. The discount rate is included in this study to determine the present value of future earnings. The ORR and IRY are determined using a two-dimensional matrix to facilitate a grid search procedure. Following Mahrizal et al. (2012), the grid search procedure initially lets the ORR range from 4% to 10% and the IRY range from year 5 to year 20. The NPV is computed for each combination of ORR and IRY so that the optimal solution is identified by the grid search procedure. The optimal solution is the ORR and IRY combination that gives the highest NPV. In all scenarios solved, the optimum ORR and IRY are interior solutions.

To compute the long-term impact of the optimal replacement model on cocoa production and to reach a steady state, the NPV and NFV for 50 years (two production cycles in a clear-and-plant once every 25-year strategy) are modeled as:

The NFV_t for organic cocoa in year t is defined as:

$$NFV_t = Yld_t * (1 - \Delta YL) * P_t * (1 + \Delta PP_t) * (1 - TO_t) * (1 + r)^t - C_t * (1 + r)^t - C_{Pt} * (1 + r)^t \quad (1)$$

NFV_t for conventional (HIMSC) in year t is defined as:

$$NFV_t = Yld_t * P_t * (1 + r)^t - C_t * (1 + r)^t - C_{Pt} * (1 + r)^t \quad (2)$$

where: NFV_t = net future value in year t.

$Yld_t * (1 - \Delta YL)$ = yield ($kg \cdot ha^{-1}$) of cocoa in year t minus a percentage yield loss for a given hectare (as a result of organic production) and is dependent on the age distribution of trees on that hectare.

Yld_t = yield (kg·ha^{-1}) of cocoa in year t for a given hectare and is dependent on the age distribution of trees on that hectare.

$P_t * (1 + \Delta PP_t) * (1 - TO_t) * (1 + r)^t$ = cocoa price in year t plus a percentage premium for organic and minus a 3% farm gross revenues fee compounded with inflation rate r.

$P_t * (1 + r)^t$ = cocoa price in year t compounded with inflation rate r.

$C_t * (1 + r)^t$ = cost of cocoa production in year t compounded with inflation rate r (where C_t varies between HIMSC and organic because the costs of chemical inputs are not included in the organic model).

$C_{Pt} * (1 + r)^t$ = cost of new cocoa replanting in year t compounded with inflation rate r.

NPV is computed as:

$$\mathrm{NPV} = \sum_{t=1}^{T} NFV_t \frac{1}{(1 + r_d)^t} \qquad (3)$$

where r_d is the discount rate.

Annual average return is calculated by dividing NPV by 50 to give the annual, average present value of profit. The average return includes the return before and during the steady-state years is achieved. "Steady state" implies that the percentage of trees replanted in any one year does not vary from year to year and that the yield from the hectare remains constant over time. In the early years when there is no revenue from cocoa sales, NFVs are negative, reflecting establishment costs. This early deficit indicates a role for some type of credit program.

Data

Data on annual cocoa yields and input use were collected from Ghana for a 25-year period from Gockowski (unpublished data). Total labor cost is calculated by the number of laborers (including the operator) used per day (6 h). Input costs are based on the quantity of inputs used per hectare, all valued at 2011 prices. Revenue is calculated by multiplying yield (kg·ha^{-1}) by the cocoa price (U.S. dollars/kg) as of May 2011 (ICCO, 2011b). Additionally, inflation and the discount rates are estimated at 10.26% and 10.67%, respectively, which are based on the percentages of annual average inflation observed in Dec. 2010 and the six-month Treasury bill rates, the most recent available, respectively (Bank of Ghana, 2011a, 2011b).

The study uses two production systems: organic and conventional. The conventional, which is called the HIMSC production system, is popular among small-scale producers who can obtain loans for inputs. The HIMSC uses mixed Amazon hybrid seed stock, high input (inorganic fertilizer, pesticides, and fungicides), and maintains roughly 70 shade trees per hectare (Victor et al., 2010). The annual, average amounts used of pesticides, fungicides, and inorganic fertilizer for HIMSC were 0.44 L of Confidor, 31.68 sachets (50 g) of Ridomil, and 6.83 50 kg bags of Asaasa Wura fertilizer [0N–22P–18K + 9CaO+7S+6MgO(s) a.i.] (Gockowski, unpublished data).

The organic production system modifies the HIMSC production system in distinct ways. Organic yield is initially assumed to be 30% lower than the HIMSC production level estimated by Gockowski (unpublished data). The estimated 30% lower organic yield is based on the studies of Phuoc et al. (2008) and Victor et al. (2010). Input and labor costs for inorganic fertilizer, pesticide, fungicide applications in conventional production are excluded from costs in the organic model. Organic production includes a 3% of sales farm gross revenues fee, as estimated by ICCO (2006) to represent the cost of application and renewal fees to organic certified organization. Furthermore, ≈70 shade trees per hectare (Victor et al., 2010) are required in organic production.

Establishing a new orchard: baseline scenario. In determining if it is profitable for cocoa producers to produce organic cocoa, a baseline NPV is established for both of the two production systems (organic and conventional) using the cost, yield, and price of inputs that we derive from Gockowski (unpublished data). The cocoa price is obtained from ICCO (2011a). The optimal solution for the baseline scenario uses the assumptions for output prices and premiums, yield loss, and input costs listed in Table 1. The May 2011 ICCO cocoa price of \$3305.79 (2011 U.S. dollars)/metric ton of beans is used as the baseline price. The baseline labor price is fixed at 3.5 Ghanaian Cedi (GHc)/day per laborer or \$2.37 (2010 U.S. dollars) as estimated by Gockowski (unpublished data). Third, baseline fertilizer, insecticide, and fungicides prices, which only apply to the conventional production system, are set at GHc 14.7/50 kg or \$9.98 (2010 U.S. dollars), GHc 16.8/ZL or \$11.40 (2010 U.S. dollars), and GHc 1.8/sachet or \$1.2 (2010 U.S. dollars), respectively (Gockowski, unpublished data). Fourth, baseline inflation and discount rates are 10.26% and 10.67% per year (Bank of Ghana, 2011a, 2011b). The annual prices of cocoa, labor, and the other inputs rise at the inflation rate. Fifth, the baseline exchange rate is held constant at GHc 1.47/U.S. dollar, the average for 2010 (International Monetary Fund, 2011b).

For the baseline scenario of organic cocoa production, yield loss is estimated at 30% (Phuoc et al., 2008; Victor et al., 2010), as discussed previously. Given the range of the price premium from \$100 to \$300 (2010 U.S. dollars) as described by ICCO (2007a), the price premium for organic cocoa in the baseline scenario is set at 10% of the nominal price of cocoa.

Interactions of price premiums and yield losses. For comparison with the baseline results, optimal solutions for organic production across a range of percentage yield loss and percentage price premiums for organic production are computed. A two-dimensional matrix is constructed for organic cocoa production in the newly established orchard scenario to highlight the interactions between yield losses and price premiums. Yield loss in this study is allowed to range from 10% to 40% and the potential price premium ranges from 10% to 40%. The NPVs of the baseline models are used to compare and estimate an appropriate price premium for cocoa producers to switch conventional operations to organic. Two basic scenarios are considered: 1) assumes a producer has purchased virgin ground and needs to decide between producing organic or conventional cocoa; and 2) assumes that a producer has an existing, conventional orchard being managed consistently with an HIMSC optimal solution and wants to know if it would be more profitable to switch to organic. Our results consider this question at five-year increments starting at year five up to year 40.

Results and Discussion

Net present value of organic versus conventional cocoa. We first consider the problem in which the operator has a clear field and wants to determine whether to produce organic or conventional cocoa. In this baseline comparison, it is assumed yields decline by 30% for organic with a 10% price premium for growing organic. Using the phased-replanting approach to solve for the maximum NPV, the results suggest that the baseline scenario under organic production system results in a NPV that is 21% lower than the baseline scenario for the conventional production system. Specifically, cocoa producers using the organic production system receive an estimated average NPVs of \$838.98 (2010 U.S. dollars/ha/year), whereas those producing under the conventional system receive an estimated \$1015.13 (2010 U.S. dollars/ha/year) following the ORR

Table 1. Baseline assumptions over two production cycles (50 year) for High Input, Medium Shade Cocoa (HIMSC) and organic cocoa.

	Baseline scenario for organic cocoa	Baseline scenario for HIMSC
Cocoa price (USD/MT)	3305.79	3305.79
Projected real cocoa price increase (per year)	0%	0%
Labor price (USD/day)	2.37	2.37
Fertilizer price (USD/day)	0	9.98
Insecticide price (USD/day)	0	11.40
Fungicide price (USD/day)	0	1.2
Yield loss	30%	0%
Premium price for organic	10%	0%

Source: Cocoa price from ICCO (2011a); labor, fertilizer insecticide, and fungicide prices computed from data in Gockowski (unpublished data); exchange rate from IMF (2011b); yield loss and premium price for organic cocoa are hypothesized rates.
USD = U.S. dollars.

and IRY of 6% annual replacement rate starting in year nine after planting for both production systems.

The optimal replacement model increases economic gains by 9.39% and 12.79% compared with the status quo approach of no phased-replanting for organic and conventional cocoa, respectively. That is, instead of replanting trees with the 6% ORR and IRY equal to nine for the both production systems respectively (Table 2), producers simply clear and replant every 25 years in the status quo approach.

The study also finds that once the orchard passes year 25, there is essentially a constant yield each year (Fig. 2) following 6% ORR with IRY at year nine. However, the annual, present value of net revenue gradually declines after year 25 because the discount rate is higher than the inflation rate. A constant present value of annual net revenue would result if the discount rate equaled the inflation rate.

Yield loss and price premium. We now address the issue of estimating the minimum premium necessary to make organic more profitable than conventional assuming the producer is at the beginning of the planning horizon. Table 3 presents the optimal NPVs associated with various levels of yield loss and price premiums for organic cocoa production. The table also identifies the optimal crop type (conventional or organic). Trade-offs that exist between the premium received and the organic yield loss become clear. In general we find that higher yield losses demand higher organic price premiums to make organic more profitable than conventional, as expected. Table 3 indicates that if a producer can reduce yield loss to just 10% compared with conventional production, it is optimal to produce organically with a price premium as low as 10%.

However, given the assumed 30% yield loss associated with converting to organic cocoa, and the 21% lower baseline NPV for the organic production system, results imply that a price premium of 27% [NPV of $1019.11 (2010 U.S. dollars/ha/year)] is needed to entice cocoa producers to grow organically. The shaded areas in Table 3 identify those combinations (price premium and yield loss) that represent those scenarios in which the NPV is higher for organic production.

The information presented on Table 3 indicates the minimum price premiums required from chocolate manufacturers to entice producers to produce organically so that the manufacturers can secure a constant supply of organic chocolate. The results also indicate that current organic producers, who are constrained to do so because of a lack of microfinance opportunities to buy conventional inputs (fertilizer, fungicide, etc.), would probably switch to conventional if financing for said inputs became available, say through a microfinance program. Thus, an unintended impact of a microfinance program might be to lead to lower levels of current organic production.

Table 2. Average annual net present value (NPV), optimal replacement rates (ORR), initial replacement year (IRY), steady state, and percentage change in profit over two production cycles (50 years) for the organic and conventional cocoa production systems.

	Annual net present value (NPV)[z]	Optimal replacement rate (ORR; percent)	Age of replacement (yrs)	Steady state (yrs)	Percentage change in profit
Organic status quo[x]	766.92	—	—	—	—
Baseline scenario[w]	838.93	6	9	25	9.39[y]
Conventional status quo	899.99	—	—	—	—
Baseline scenario	1015.13	6	9	25	12.79[y]

[z]Denotes the highest net present value in (2010 US dollars/ha/year).
[y]The value is compared with status quo.
[x]Status quo is non replacement of trees.
[w]Baseline scenario as defined in Table 1.

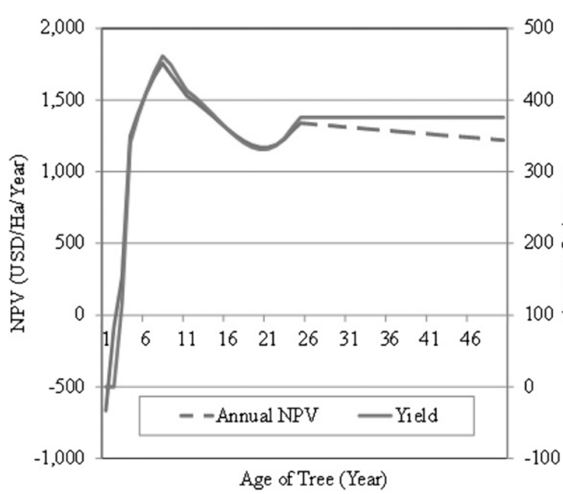

Fig. 2. Cocoa yield and annual net present value (NPV) estimated in this study over a 50-year horizon in Ghana for organic cocoa production systems.

Temporal aspects of switching from conventional to organic production. The second thrust of our investigation is to analyze when an existing conventional producer using the optimal ORR and IRY should convert to organic production. Specifically, we ask the question of when would changes in market conditions be sufficient to justify a producer who is currently producing conventionally to switch to organic production? Recall when a producer switches from conventional to organic, he is faced with an immediate yield reduction but cannot market the cocoa as organic (and thus is excluded from the price premium) until the orchard has been managed using organic methods for three consecutive years. So converting to organic requires price incentives sufficient to compensate the producer for three years of less revenue to capture an eventual enhanced revenue stream. From Figure 1 it can be observed that the cocoa yield differs throughout the life cycle of a cocoa tree for both conventional and organic production. Table 4 presents a three-dimensional matrix. The first dimension is yield loss where yield losses of 10%, 20%, and 30% are hypothesized. The second dimension is the level of the organic price premium where levels of 8%, 18%, 28%, 30%, 32%, and 35% are hypothesized. Finally, the third dimension is the year in which conversion to organic production takes place. It is assumed in the scenarios that the producer faces the beginning of year t and asks if it would be beneficial to convert from conventional to organic. In year t the producer computes the present value of the remaining 50 – t years and asks if conversion in t would be better than remaining in conventional production. Clearly, any year is optimal for conversion if the expected price premium over 50 – t is large enough. Results in Table 4 are computed at five-year intervals from year 5 to year 40.

What our analysis asks is that, if given some constant and known premium and yield loss, are some stages of orchard growth better for conversion than others, ceteris paribus? Essentially our method does this: the orchard is being managed in a conventional mode using the ORR and IRY of the optimal HIMSC solution. In the first year the entire hectare is planted to cocoa trees under the HIMSC assumptions. The orchard is then cultivated according to the optimal ORR of 6% and IRY at year 9. The decision whether to switch to organic production is determined by comparing the NPV for remaining 50 – t years under the HIMSC and the NPV for remaining 50 – t years under organic production still using the ORR of 6% and IRY of 9. If NPV under organic production is higher, producers switch their production to organic. There are various ways to portray the problem of when to switch from conventional to organic. The truly optimal solution would require dynamic programming. In such a formulation, at the beginning of any given year,

Table 3. Optimal average NPV and crop type as a function of yield loss and organic price premium.

	Estimated organic production loss			
Organic price premium	10%	20%	30%	40%
10%	1175.16	1007.04	838.93	670.82
20%	1312.70	1129.31	945.91	762.52
30%	1450.25	1251.57	1052.89	854.22
40%	1587.79	1373.83	1159.87	945.91

Note: Shaded annual net present values (NPV) indicate organic is more profitable than conventional production.

Table 4. Variations in organic price premiums and organic yields in Ghana and their affects on organic adoption.

Switching		Premium price					
yr	Yield loss	8%	18%	28%	30%	32%	35%
	10	Yes	Yes	Yes	Yes	Yes	Yes
5	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
10	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
15	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
20	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
25	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
30	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	No	Yes	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
35	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	No	No	Yes
	10	Yes	Yes	Yes	Yes	Yes	Yes
40	20	No	Yes	Yes	Yes	Yes	Yes
	30	No	No	No	No	No	No

the producer could switch the whole farm or parts of the farm to organic (or from organic to conventional) depending on the expected price premiums and yield losses over the remaining planning horizon and the current state of the orchard. We take a simpler, although suboptimal, approach. In our method we start with an initial HIMSC optimal solution, which is ORR = 6% and IRY = 9. The producer always uses these two rules whether he or she is producing conventionally or organically. However, then at years 5, 10,…, 40 (to keep the computational burden reasonable, we optimize at five-year intervals) we ask: what would the price premium have to be for a given yield loss to make switching to organic more profitable for the remainder of the planning horizon? For example, at year 10 we compute the NPV for the remaining 40 years for the HIMSC solution and compare that with the NPV for the remaining 40 years if the producer switched to organic. If we made the optimization more complex and allowed the ORR and IRY to be recomputed, the needed price premiums might decrease although some preliminary computations indicate such adjustments would be minor. Hence, the necessary premiums computed are biased upward. Table 4 shows the decision of whether to convert to organic production or not given a range yield losses and price premiums. "Yes" indicates that converting to organic is more profitable than remaining in the conventional production. Conversely, "no" indicates that the cocoa producer should remain in conventional production.

As shown in Table 4, our expectations are that as yield loss increases, the reward for converting decreases. Likewise, as the organic premium increases, conversion becomes more desirable. Our expectations are less clear regarding the year of conversion. As the orchard approaches its yield maximum, the marginal temporal benefit for converting might increase because total yield is maximal and so the producer might be able to better endure the three-year yield dropoff without compensating price increases as a result of the required withdrawal of chemical inputs. Alternatively, early conversion means the orchard is not at its maximum output so the revenue decrease is lower in absolute terms thereby encouraging early conversion.

The results strongly confirm the first two expectations. First, as yields decline, the profitability of converting from conventional to organic declines. This can be seen in Table 5, which displays the percentage difference of organic production to the baseline HIMSC. Second, as price premiums rise, the incentive to switch to organic production becomes larger. The profit differences range from 1% to 41% at any given switching year and yield loss. The highest price premium and lowest yield loss are preferable, which occur at 35% price premium and 10% yield loss. Conversely, profit decline ranges from 0.5% to 19% as yield declines by 20% to 30%. The highest profit difference occurs at 10% price premium and 30% yield loss. Table 4 results also show that when yield loss is only 10%, it is profitable to switch to organic production even with a premium price as low as 8% regardless of orchard age. However, when production loss increases to 20%, a cocoa producer would only switch to organic production if he or she were to receive a premium greater than 18% regardless the orchard age. With a 30% yield loss, there is no incentive to switch to organic production when the price premium is 28% or less. However, when the price premium equals or exceeds 30%, conversion for any of the hypothesized yield losses is profitable until year 30.

Results in Table 4 also confirm that as the price premium rises, conversion becomes more profitable, as expected. At an 8% premium, conversion is profitable in only eight of 24 scenarios yet when the premium is 32%, conversion is profitable in 22 of 24 scenarios. This is further reinforced by observing the increase in profitability in any given row of Table 5 as the premium grows.

The stage of growth hypothesis can be evaluated by inspecting both Tables 4 and 5. Table 4 indicates that the age of the orchard does not influence the decision to switch until year 30. However, a close inspection of Table 5 for the years 10, 15, 20, and 25 indicates that the percentage profit difference is slightly higher if the switch to organic is implemented at year 15. At this point, orchard yield is sufficient for the producer to better withstand the loss in revenue as a result of the yield loss and no organic premium for three years. In years 6 to10 yields are very high and in years 20 to 25 yields are relatively lower (see Fig. 2). So at year 15, switching is the most desirable of the scenarios considered because the producer is neither giving up his highest revenue phase of production nor avoiding the lowest revenue phase of production. A further role of time becomes evident in years 30, 35, and 40. In these years switching to organic is not profitable unless the producer receives a large premium (30% or greater). This phenomenon is partly the result of the time limitation to take full advantage of the price premium given the three-year transition period and 50-year study horizon. For orchards less than or equal to 25 years old and price premiums of 32% or less, the age of the orchard does not affect the decision to switch to organic although percentage gains are greatest in year 15.

Table 5. Percentage profit difference between organic and conventional production.

Switching yr	Organic price premium						
	Organic yield loss	8%	18%	28%	30%	32%	35%
	10	10.64	21.58	32.52	34.71	36.90	40.18
5	20	(3.50)	6.23	15.95	17.90	19.84	22.76
	30	(17.64)	(9.13)	(0.62)	1.08	2.78	5.34
	10	10.96	21.80	32.64	34.81	36.98	40.23
10	20	(3.22)	6.42	16.06	17.99	19.91	22.80
	30	(17.39)	(8.96)	(0.52)	1.16	2.85	5.38
	10	11.29	22.16	33.03	35.20	37.37	40.63
15	20	(2.91)	6.76	16.42	18.35	20.28	23.18
	30	(17.10)	(8.64)	(0.19)	1.50	3.19	5.73
	10	11.19	21.99	32.79	34.95	37.11	40.36
20	20	(2.99)	6.61	16.22	18.14	20.06	22.94
	30	(17.17)	(8.77)	(0.36)	1.32	3.00	5.52
	10	10.77	21.24	31.71	33.80	35.90	39.04
25	20	(3.38)	5.92	15.23	17.09	18.95	21.74
	30	(17.54)	(9.40)	(1.25)	0.37	2.00	4.45
	10	10.55	20.72	30.89	32.92	34.95	38.00
30	20	(3.62)	5.42	14.46	16.27	18.08	20.79
	30	(17.78)	(9.87)	(1.96)	(0.38)	1.20	3.57
	10	10.18	19.86	29.53	31.47	33.41	36.31
35	20	(4.00)	4.60	13.21	14.93	16.65	19.23
	30	(18.18)	(10.65)	(3.12)	(1.61)	(29.17)	2.15
	10	9.46	18.19	26.92	28.67	30.42	33.04
40	20	(4.74)	3.02	10.78	12.33	13.89	16.22
	30	(18.95)	(12.15)	(5.36)	(4.00)	(2.64)	(0.60)

Note: profit of organic cocoa production is divided with High Input, Medium Shade Cocoa (HIMSC) production system.

It should also be noted that the orchard goes into steady state at year 25 for the HIMSC solution being considered. So any change after this point for a given year is the same problem if the planning horizon is changed to a 50-year rolling horizon. The optimal behavior changes in years 30, 35, and 40 because of how the orchard is being valued in year 51. In our model formulation, there is no salvage value in year 51 so that essentially the producer simply walks away from the orchard. However, if a salvage value were included into the model, then the optimal behavior in years 30+ could change from those portrayed in Table 4. If an organic orchard were valued more highly in a year 51 salvage value than a conventional orchard, then it would be profitable to convert to organic in years 30, 35, and 40 at lower premiums than displayed in Table 4. So the salvage value affects later period solutions. However, it can also be argued that as of, say year 40, the owner might anticipate transferring his interest in the orchard to a son or daughter whose horizon would be extended beyond the remaining 10 years. Such an assumption favors a rolling horizon model. Thus, in analysis such as ours, the important findings are in earlier years of the solution because common sense indicates that the view of the future 30 years hence will surely be different from the view of such years in the present. Also, a discount rate greater than the inflation rate makes assumptions about model structure in the distant future unimportant to what the current decision should be.

Conclusions

This study identifies the necessary price premiums to incentivize profit maximizing producers to switch from conventional to organic production. Deterministic profits defined as annual NPV are empirically estimated for organic and conventional cocoa production systems using an optimal phased-replanting approach. Empirical data from Ghana on yield, cocoa price, production costs, inflation, and discount rates were used in constructing the models. The study finds that the baseline scenario under organic production system results in a NPV 21% lower than the baseline scenario under conventional production systems.

Given a yield loss and price premium, this study investigates whether the age of the orchard influences when a conventional producer can profitably switch to organic production. The study finds that tree age is not a major determinant of when to switch (at least for 10% to 30% yield losses and price premiums between 8% and 35%). The model results also reveal that switching from conventional to organic requires an increase in the price premiums toward the end of the planning horizon. The increased premium is required because producers have a limited time to take advantage of the premium. A general rule of thumb for the solutions is that in the first 25 years, the decline in yield must be matched with a price premium in percentage terms that is slightly less than the yield loss.

The study also estimates the yield loss and premium price tradeoff for organic cocoa. Considering a 30% yield loss and the NPV of a conventional production system, the study reveals that price premium between 28% and 30% should be offered to entice cocoa producers to grow cocoa organically. The current premium price of organic cocoa, however, is estimated to be ≈$100 to $300 per ton above the market price of conventional cocoa resulting in a price premium of ≈6.32% to 9.48%. This is far below the estimated premium needed to entice producers to switch to organic production. Information on yield loss and price premium tradeoff is very important to cocoa producers to determine whether organic production is sufficiently profitable to be adopted. For manufacturers, the information indicates the price premium necessary to secure a reliable supply of organic cocoa. This study would seem to indicate that if the increase in demand for organic cocoa is to be met through current production acres that a larger price premium will be needed.

The obvious challenge for producers to produce conventionally is to obtain credit up front to purchase inorganic inputs. Given the advent of organizations like the Cocoa Abrabopa Association (CAA) established in 1998 in Ghana, credit is becoming more accessible to producers. The CAA works with input suppliers such as Ghana COCOBOD and Wienco Ghana Ltd. to supply agricultural inputs to producers. They extend credit in the form of inputs such as fertilizer, insecticide, and fungicide. As a result, producers now have the choice to produce either organically or conventionally making the results from this study more pertinent to their decision-making process.

Literature Cited

Afari-Sefa, V., J. Gockowski, N. Agyemnan, and A. Dziwornu. Econoimc cost–benefit of certified sustainable cocoa production in Ghana. Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, 19–23 Sept. 2010.

Agbeniyi, S., M. Ogunlade, and K. Oluyole. 2010. Fertilizer use and cocoa production in Cross River State, Nigeria. ARPN Journal of Agricultural and Biological Science 5:10–13.

Arope, A.B. 1971. Economic considerations regarding the determination of optimum ages for oil palm replanting in Malaysia. MARDI Agricultural Economic Buletin 1:1–13.

Asare, R. and S. David. 2010. Planting, replanting and tree diversification in cocoa systems. Learning about sustainable cocoa production: A guide for participatory farmer training. Manual No. 2. Development and Environment Series 13-2010. Forest & Landscape Denmark, Hørsholm, Denmark.

Bank of Ghana. 2011a. National consumer price index and inflation rates. 10 July 2011. <http://www.bog.gov.gh/index1.php?linkid=174>.

Bank of Ghana. 2011b. Treasury bill rates. 10 July 2011. <http://www.bog.gov.gh/index1.php?linkid=210>.

Byers, A. and P. Liu. 2008. Value-adding standards in the North-American food market. Trade opportunities in certified products for developing countries. Food and Agriculture Organization of the United Nations, Rome, Italy.

Central Intelligence Agency. 2011. The world fact book: Ghana. 24 Apr. 2011. <https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html>.

Codex Alimentarius. 1999. Guidelines for the production, processing, labelling and marketing of organically produced foods. 22 June 2011. <http://www.codexalimentarius.net/download/standards/360/cxg_032e.pdf>.

Etherington, D.M. 1977. A stochastic model for the optimal replacement of rubber trees. Australian Journal of Agricultural Economics 21:40–58.

Fairtrade International. 2011. Fairtrade minimum price and Fairtrade premium table. 12 July 2011. <http://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2011-07-14_EN_Fairtrade_Minimum_Price_and_Premium_table.pdf>.

Fairtrade Labeling Organization (FLO)-Cert. 2011. Fee system small producer organization: Explanatory document. 14 Apr. 2011. <http://www.flo-cert.net/flo-cert/fileadmin/user_upload/certification/cost/en/20120120/PC_FeeSysSPO_ED_23_en.pdf>.

Faris, J.E. 1960. Analytical techniques used in determining the optimum replacement pattern. J. Farm Econ. 42:755–766.

Food and Agriculture Organization of the United Nations. 2011a. Cocoa beans production. Apr. 2011. <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567>.

Gro-Cocoa. 2008. Global research on cocoa—Working with and for farmers. 14 Jan. 2011. <http://www.cabi.org/Uploads/File/Gro%20Cocoa%20pdfs/gro-cocoa14.pdf>.

Hardy, F. (ed.). 1960. *Cocoa manual.* Turrialba, Inter-American Institute of Agricultural Sciences, Costa Rica

International Cocoa Organization (ICCO). 2005. Facts and figures on Fair-Trade cocoa. 11 May 2011. <http://www.icco.org/documents/documentcategory.aspx?dispmode=detailed&catid=82>.

International Cocoa Organization (ICCO). 2006. A study on the market for organic cocoa. 11 May 2011. <http://www.icco.org/documents/documentcategory.aspx?dispmode=detailed&catid=82>.

International Cocoa Organization (ICCO). 2007a. International cocoa organization annual report 2005/2006. 23 May 2011. <http://www.icco.org/pdf/An_report/anrep0506english.pdf>.

International Cocoa Organization (ICCO). 2007b. Assessment of the movements of global supply and demand. 23 May 2011. <http://www.icco.org/Attachment.aspx?id=12r43706>.

International Cocoa Organization (ICCO). 2011a. ICCO daily prices of cocoa beans. 23 May 2011. <http://www.icco.org/statistics/daily_prices.aspx>.

International Cocoa Organization (ICCO). 2011b. The chocolate industry. 22 June 2011. <http://www.icco.org/about/chocolate.aspx>.

International Monetary Fund (IMF). 2011a. Commodity tables. 24 June 2011. <http://www.imfstatistics.org>.

International Monetary Fund (IMF). 2011b. Ghana country tables. 25 May 2011. <http://www.imfstatistics.org>.

Ismail, A. and M.N. Mamat. 2002. The optimal age of oil palm replanting. Oil Palm Industry Economic Journal 2:11–18.

Lass, R.A. 2001. Replanting and rehabilitation of old cocoa farms, p. 210–233. In: Wood, G.A.R. and R.A. Lass. Cocoa Blackwell Science, IA.

Mahrizal, L.L. Nalley, B.L. Dixon, J.S. Popp, and E. Budiansky. 2012. An optimal, phased replanting approach for cocoa trees with application to Ghana. Agricultural Economics. p. 1–31. (in review).

Manos, B. and E. Papanagiotou. 1983. Fruit-tree replacement in discrete time: An application in Central Macedonia. Eur. Rev. Agr. Econ. 10: 69–78.

Montgomery, P.J. 1981. Some thoughts on the life span of cocoa. Planter 57:604–609.

Nimoh, F., K. Baah, and E. Tham-Agyekum. 2011. Investing in the interest of farmers and insurance companies in farm insurance: The case of cocoa farmers in Sekyere West Municipal of Ghana. Journal of Agricultural Science 3(4): 126–135.

Pay, E. 2009. Increasing incomes and food security of small farmers in West and Central Africa through exports of organic and fair-trade tropical products. 15 June 2011. <http://www.fao.org/fileadmin/templates/organicexports/docs/Market_Organic_FT_Cocoa.pdf>.

Perrin, R.K. 1972. Asset replacement principles. Amer. J. Agr. Econ. 54:60–67.

Phuoc, P.H., L.M. Ngoc, N.C. Trung, D. Valenghi, and N.L. Giang. 2008. Feasibility study organic and fairtrade cocoa in Vietnam. Hanoi, Vietnam: Helvetas Vietnam. 15 June 2011. <http://www.helvetas.ch/Vietnam/wEnglish/Documents/Organic-cocoa-feasibility_final_report_EN.pdf>.

Potts, J., J.V. Meer, and J. Daitchman. 2010. The state of sustainability initiatives review 2010: Sustainability and transparency. 15 June 2011. <http://www.iadb.org/intal/intalcdi/PE/2010/07439.pdf>.

The World Resources Institute. 2011. Economic indicators—Ghana. 25 Nov. 2011. <http://earthtrends.wri.org/pdf_library/country_profiles/eco_cou_288.pdf>.

Tisdell, C.A. and N.T. De Silva. 2008. Supply-maximizing and variation-minimizing replacement cycles of perennial crops and similar assets: Theory illustrated by coconut production. J. Agr. Econ. 37:243–251.

Victor, A.-S., J. Gockowski, N.F. Agyeman, and K.A. Dziwornu. 2010. Economic cost-benefit analysis of certified sustainable cocoa production in Ghana. Proc. of the 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, 19–23 Sept. in Cape Town, South Africa. Nov. 2011. <http://ageconsearch.umn.edu/handle/97085>.

Vigneri, M. and P. Santos. 2008. What does liberalization without price competition achieve? The case of cocoa marketing in rural Ghana. IFPRI-GSSP Background Paper n. 14. International Food Policy Research Institute.

Ward, L.E. and J.E. Faris. 1968. A stochastic approach to replacement policies for plum trees. Giannini Foundation Mono. No. 22, University of California, CA.

Wessel, M. 2001. Shade and nutrition, p. 210–233. In: Wood, G.A.R. and R.A. Lass. Cocoa. Blackwell Science, IA.

Willey, R. 1975. The use of shade in coffee, cocoa and tea. Horticultural Abstracts 45: 791–798.