Increasing Profitability of Small Scale Orchard Producers through Optimizing Replacement Rate: The Case Study of Ghana

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Abstract

This study sets out to empirically estimate the optimum annual replacement rate and age of cocoa trees in order to maximize the net present value of four common cocoa production systems. The study examines the costs and returns of four common cocoa production systems in Ghana associated with changes in cocoa prices, fertilizer prices, inflation rates, and labor prices. While this study focuses on cocoa, the methodology is applicable to any perennial crop. This study uses empirical yield curves and cost of production data from Ghana to determine when and what percentage of a cocoa orchard should be replaced annually to maximize net present value of revenues over time. Successive versions of the model are solved to determine how input and output price changes affect optimal replacement rates and replacement ages. Producers in both high- and low-income countries are reluctant to cull still productive assets, such as trees that are diminishing in yield over time. The Excel based model developed in this study could provide extension personnel with a simple yet powerful tool to illustrate to producers the benefits of systematic tree replacement. This study provides strong evidence of the benefits of replacing trees at the optimal time and rate.

Introduction

Agriculture has historically played an important role in the Ghanaian economy. It accounted for about 35.40 percent of the gross national product in 2007 (Bank of Ghana, 2008) and employed about 56.00 percent of total population (Central Intelligence Agency (CIA), April 2011). Ghana is the second largest cocoa bean producer in Africa (FAO, 2003) with production reaching a high of 506,358 tons in 2007 (FAO, April 2011). The Bank of Ghana (2008) reported that the cocoa sector alone contributed to approximately 3.40 percent of total gross domestic product (GDP) in 2007, making it the largest export commodity (FAO, April 2011).

Historically, Ghana has experienced volatility in cocoa production. After being recorded as the world's largest cocoa producer in the early 1960s, cocoa production dropped significantly from 450,000 tons per year to a low of 159,000 tons in 1983-84 due to aging trees, widespread disease outbreaks, bad weather, and low producer prices (Congress, April 2011). The decline in production was also caused by bushfires in 1983, which destroyed approximately 60,000 hectares of cocoa farms throughout the country. However, in 1986-87, the output increased to 228,000 tons then followed by 301,000 tons, 293,000 tons, and 305,000 tons in 1988-89, 1990-91, and 1992-93, respectively (Congress, April 2011).

Numerous studies have tried to analyze the causes of declining in cocoa yield. Of the possible factors, increasing tree age is considered as one of the largest contributors to the reduction of perennial tree crop yields. Other causes include disease outbreaks, pests, weather, poor farm management, competition at the world market, and low export prices. Because of the average age impact, culling and replanting are considered necessary to maintain maximum profitability of an orchard throughout its biological life cycle.

This study seeks to empirically estimate the optimum annual replacement rate and age of perennial trees by employing a phased, farm replanting method in order to maximize the present value of a revenue stream over time. The study examines the costs and returns of four common cocoa production systems in Ghana associated with changes in cocoa prices, fertilizer prices, inflation rates, and labor prices. Furthermore, the study analyzes the benefit cost ratio of organic versus non organic production. As microfinance becomes more readily available, producers are moving away from the traditional low input (organic) production to high input (non-organic) production. The study estimates the price premium needed to entice farmers to produce the lower yielding organic cocoa.

This study and its objectives are important because cocoa farmers in Ghana could utilize the model developed in this study as a tool to increase the yield of cocoa and farm profitability. Culling and replacement provide a potential revenue enhancing tool for producers in the low-income world who are typically hesitant to cull productive assets regardless of low yields. The model solutions generate consistent income over time, providing cocoa producers with stable revenue over time. Of course factors outside the farmer's control—like price volatility and government policies—could cause revenue volatility even with the "stable income" plans.

Literature Review

Stages of Production and Steady State

The cocoa production life cycle occurs in four stages: (1) an early period of no yield which normally occurs in 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. The last stage is associated with trees that are past their yield prime. Since some cocoa trees can bear fruit for 50 years and annual yield loss can be marginal over time, it is difficult for producers to decide when and what percentage of trees to replace to maximize the present value of their revenue stream over time.

Theoretically, the neoclassical production function, which is technically described as a nexus of input (resources) and outputs (commodities), can be divided into three stages or regions of production. As described by Debertin (1986), stage I includes input levels from zero units up to the level of use where marginal physical product (MPP) is equal to average physical product (APP). Stage II is where the production function reaches its peak point and MPP is zero. This stage also includes the point where MPP = APP. Stage III, however, exhibits declining output (MPP negative).

These stages are important in understanding where a firm (or individual) should choose to produce to maximize profit. Debertin (1986) states that by operating in stage II, costs can be minimized and output increased by reducing the level of input use. As a result, greater net returns can be achieved.

Therefore, this current study is also designed to maintain the stage of production at stage II, where yield and profit reach their maximum level. We say a solution is in a steady state when the yield and the average age of cocoa trees are constant from the year when the steady state is first achieved until the end of study period.

Net Future Value (NFV) and Net Present Value (NPV)

The concept of future value is not only used and applied by bankers, investors, and economists, but also by the farmers who want to know the future value of their assets. Scott and Moore (1984) state that “future value deals with finding the value of a sum of money or the cost of an item at some future date if we know the corresponding value or cost at the present time" (p. 1). Similarly, Brealey, Myers, and Marcus (2001) define future value as "amount to which an investment will grow after earning interest" (p. 35).

The usefulness of a future value calculation is not limited to determining the earnings (associated with a given interest rate) from an investment, but may also be used to determine the price (associated with a given inflation rate) of a product at the end of the year. The present value, on the other hand, "deals with finding the value of a sum of money or the cost of an item today if we know its value or cost at some future date" (Scott and Moore, 1984, p. 61) and knowing an appropriate discount rate.

Replanting Cocoa Trees

As a fruit tree, a cocoa tree can grow for more than a hundred years and bear fruit up to 50 years. However, as the age of cocoa trees increases past a certain point, the yields markedly decrease. Montgomery (1981) concludes that based on a consensus of opinion, the maximum cocoa yields are obtained at the age 15 to 25 years after planting with a profitable life span over 50 years. Nevertheless, the yields slowly decline at the age of 26 to 45 years and the production costs slightly increase (Montgomery, 1981). Asare and David (2010) suggest that if a cocoa tree produces less than 10 or less pods per year, the farmer should consider replanting.

Replanting is considered as "the planting of the young cocoa trees where old cocoa trees used to grow" (Lass, 2001, p. 212) and thereby includes culling. Lass (2001) suggests that the replanting process in cocoa farms can be done through several methods: partial replanting, total replanting or clear-felling, phased farm replanting, and planting under old cocoa trees. Each replacement method, however, carries its own advantages and disadvantages.

Replacement Models

Replacement models have been widely applied in many areas, for example, in forestry, fruit trees, cattle, and depreciating assets such as equipment and vehicles. According to Perrin (1967), 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" (p. 60). Similarly, Faris (1960) looks at the appropriate time to replace an asset in which it gave the highest return. He concludes that "the optimum time to replace 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). Given the large yield decrease over time, it is apparent that replacement is needed to obtain the highest possible return.

There are two basic types of replacement models that are used in the study of tree crops, deterministic and stochastic. The former assumes the probability of an event occurring to equal one, and the future and net value discounted associated with single-valued yields (Faris, 1960). Conversely, the stochastic assigns probabilities of possible events to be less than one and can use a transition matrix to determine the events' probabilities among the variables through each time period (Ward and Faris, 1968).

Organic Cocoa

The term "organic" is widely used to describe and define not only a chemical free agricultural product, but also to describe an environmentally sustainable method of farming. Codex Alimentarius (1999), an intergovernmental body with over 180 members which is established by the Food and Agriculture Organization of the United Nations (FAO) and the

World Health Organization (WHO), defines organic agriculture as “a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It 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).

An empirical study by Victor, Gockowski, Agyeman, and Dziwornu (2010) examines the cost and benefit of certified organic cocoa production in Ghana using the concept of net present value (NPV). Following the Rainforest Alliance-Sustainable Agricultural Sustainable (RA-SAN) standard of 70 shading trees per hectare, they find that the yield loss is about 30 percent compared to the full sun yield of the High Input no Shade Cocoa (HINSC) system. However, they also find that the benefit of certified cocoa is that the yield increases by 25 percent following certification training, which exceeds the costs of certification. The tradeoff between decreased yield in organic (low input) cocoa and increased profits is an important one as many cocoa producers in Ghana are starting to move away from no input (organic) production to high input (non organic) production as micro finance loans become easier to obtain.

Similarly, based on a feasibility study of organic cocoa in Vietnam, Phuoc et al. (2008) estimate that the yield reduction of organic cocoa farming is about 30 percent relative to conventional farming. Additionally, Phuoc et al. (2008) also estimate a comparison model between production, cost and benefit of conventional and organic cocoa production per hectare and find that conventional farming gives a higher net benefit than organic which is $1,280 (2011 USD) and $1,214 (2011 USD) for conventional and organic, respectively.

Data

Twenty five years of annual data on yield, inputs and costs from Ghana were obtained from Gockowski (2009), and cocoa prices were collected from the International Cocoa Organization (ICCO). The cost structure is calculated by the number of laborers employed per day (6 hours) and the amount of inputs used per hectare for various production practices. The revenue is calculated on yield (kg/ha) multiplied by the price of cocoa ($/kg) on May 2, 2011. Additionally, inflation, which is based on the percentage of annual average inflation in December 2010, is estimated at 10.26 percent (Bank of Ghana, July 2011). The discount rate, which is based on Treasury bill rates for a six month period, is 10.67 percent, the most recent available (Bank of Ghana, July 2011).

Baseline Scenario

Four commonly used cocoa production systems are modeled to estimate the optimal replacement rate and age and net present value (NPV). Low Input, Landrace Cocoa (LILC) production system uses unimproved local landrace cocoa varieties, pesticide and fungicide, and no fertilizer application. Victor et al. (2010) also assume that shade levels for LILC system are moderate. On the other hand, High Input, No Shade Amazon Cocoa (HINSC) uses mixed Amazon hybrid, high input (fertilizer and pesticide), and without shade trees.

Conversely, High Input, Medium Shade Cocoa (HIMSC) uses a mixed Amazon hybrid, high input (fertilizer and pesticide), and medium shade trees. Whereas organic cocoa is considered to have medium shade no inputs and the yield and cost of pod harvesting and collecting, pod breaking, fermentation, drying/sorting, transport to drying site are reduced by 30 percent from the High Input Medium Shade (HIMSC) budget as proposed and estimated by Victor et al. (2010) and Phuoc et al. (2008).

In determining the optimal return associated with cocoa tree replacement, a baseline scenario is established for each of the four production practices using a cost, yield, and price structure as derived from Gockowski (2009). Price is established using ICCO cocoa price at $3,305.79(2011 USD) /metric ton as of May 2, 2011 (ICCO). The baseline scenario assumes that cocoa price increases by a constant three percent per year which is based on the average price increase from 25 years of historical cocoa price data 1986-2010 (International Monetary Fund (IMF), 2011).

Second, labor price is fixed at 3.5 Ghanaian cedi (GHc) /day or $2.37 (2010 USD) as estimated by Gockowski (2009). Third, the fertilizer, insecticide, and fungicides prices are also constant at GHc 14.7 /50 kg or $9.98 (2010 USD), GHc 16.8 /liter or $11.40 (2010 USD), and GHc 1.8 /sachet (50 gram) or $1.2 (2010 USD), respectively (Gockowski, 2009). Fourth, inflation and discount rate are 10.26 and 10.67 percent per year, respectively (Bank of Ghana, July 2011) as discussed above. Fifth, the exchange rate is held constant at GHc 1.4738 /USD as per 2010 (IMF, 2011).

From the baseline scenario for each of the four production practices, six alternative scenarios are solved to derive the impact of changes in projected (1) cocoa price, (2) fertilizer price, (3) inflation rate, (4) labor price, (5) 20 percent yield loss and 10 percent area infected, and (6) 40 percent yield loss and 10 percent area infected given a hypothetical black pod outbreak, to determine optimal replacement rate and timing to maximize net present value (NPV) under each scenario. The various scenarios are given in tables 1.

Scenario 1 assumes that the cocoa price will increase annually by five percent (from three to five percent), holding all other variables constant. Given the high correlation with increased incomes and chocolate consumption and the rise of the middle class in China and India (who are consuming more chocolate), a 2% increase in price (from increased demand) from the baseline scenario is estimated.

Scenario 2 assumes that fertilizer price will increase five percent annually, holding all other variables constant. This is based on an assumption that the fertilizer subsidy in Ghana will be removed gradually and thus its price will influenced by shortage of supply. In scenario 3, the inflation rate is assumed to increase by 4.74 percentage points (from 10.26 to 15 percent) annually, holding other variables constant. Scenario 4 assumes that labor price will increase by five percent, holding other variables constant. This scenario is based on the Bank of Ghana (July 2011) report on the minimum daily wage where the daily wage rate increased from GHc 3.11 in January 2010 to GHc 3.73 in February 2011.

Scenario 5 assumes that a black pod outbreak occurs and the percentage yield lost is projected at 30 percent and the percentage of the farm infected is 10 percent, holding all other variables constant. As estimated by Padwick (as cited in Lass, 2001), global cocoa production loss due to black pod is roughly 10 percent, whereas Medeiros predicts the loss is about 30 percent. Finally, scenario 6 assumes a similar black pod outbreak but the percentage yield loss is now 40 percent and percentage of the farm infected is 10 percent. Yield loss estimation is based on a finding by Ward et al. (as cited in Lass, 2001) where infected pods rate is more than 30 percent up to 60.90 percent.

Table 1

Baseline and Variations in Assumptions for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), and High Input, Medium Shade Cocoa (HIMSC) Production*

	Baseline Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Cocoa Price (USD/MT)	3305.79	3305.79	3305.79	3305.79	3305.79	3305.79	3305.79
Projected Cocoa Price Increase (per year)	3%	*5%*	3%	3%	3%	3%	3%
Labor Price (GHc)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Projected Labor Price Increase (per year)*	0%	0%	0%	0%	*5%*	0%	0%
Fertilizer Price (GHc)	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Projected Fertilizer Price Increase (per year)*	0%	0%	*5%*	0%	0%	0%	0%
Insecticide Price (GHc)	16.80	16.8	16.80	16.80	16.80	16.80	16.80
Projected Insecticide Price Increase (per year)*	0%	0%	0%	0%	0%	0%	0%
Fungicide Price (GHc)	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Projected Fungicide Price Increase (per year)*	0%	0%	0%	0%	0%	0%	0%
Percentage Yield Loss from Black Pod	0%	0%	0%	0%	0%	20%	40%
Percentage per Hectare Infected by Black Pod	0%	0%	0%	0%	0%	10%	10%
Exchange Rate (USD/ GHc)	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Inflation Rate in Ghana (per year)*	10.26%	10.26%	10.26%	*15.00%*	10.26%	10.26%	10.26%
Discount Rate (%)*	10.67%	10.67%	10.67%	10.67%	10.67%	10.67%	10.67%

* Note: Shaded numbers represent deviations from the baseline scenario.

The baseline organic cocoa production system assumes that yield loss due to converting from conventional to organic farming is 30 percent and premium price associated with organic cocoa is 10 percent. In scenario 1, production loss is assumed 30 percent and premium price is expected to increase by 10 percent (from 10 percent to 20 percent) (Table 2).

Table 2

Assumptions and Variations for Organic Cocoa Production

	Baseline Scenario	Scenario 1
Cocoa Price (USD/MT)	3305.79	3305.79
Projected Cocoa Price Increase (per year)	3%	3%
Labor Price (GHc)	3.5	3.5
Projected Labor Price Increase (per year)	0%	0%
Production loss*	30%	30%
Premium Price for Organic*	10%	*20%*
Exchange Rate (USD/GHc)	1.47	1.47
Inflation Rate in Ghana (per year)	10.26%	10.26%
Discount Rate (%)	10.67%	10.67%

* Note: Shaded numbers represent deviations from the baseline scenario

Methodology

To determine the optimal return, the study employs two basic formulas of the Net Future Value (NFV) framework associated with the replacement rate, year of replacement, and inflation rate; and the Net Present Value (NPV) framework over Net Future Value (NFV) associated with the discount rate. This study considers the importance of the inflation rate (as it is often high in low income countries) as it raises the price level over time and to determine the future value of money. Additionally, the study also takes into account the discount rate to determine present value of money over the future earnings from cocoa farm.

The Net Present Value (NPV) and Net Future Value (NFV) used in the 100 year horizon models are as follows:

1. Net Future Value (NFV)

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

Where: NFV_t = Net Future Value at period t.

Yld_t = Yield (kg/ha) of cocoa at period t for a given hectare.[1]

$P_t(1 + r)^t$ = Cocoa price at period t compounded with inflation rate r.

$C_t(1 + r)^t$ = Cost of cocoa at period t compounded with inflation rate r.

$C_{Pt}(1 + r)$ = Cost of new cocoa replanting at period t compounded with inflation rate r.

2. Net Present Value (NPV)

$$NPV = \sum_{t=1}^{T} NFV_t \frac{1}{(1+r)^t} \quad (2)$$

Where: NPV = Net Present Value

$\sum_{t=1}^{T} NFV_t \frac{1}{(1+r)^t}$ = Summation of Net Future Value (NFV) at period t discounted by discount rate r.

To determine annual average return, we divide NPV by 100 to give the average present value of net revenue. So this average return includes both the steady state years as well is the initial years before the steady-state is achieved.

[1] Yield depends on the age distribution of trees on a given hectare.

Results

Net Present Value (NPV), Replacement Rate, Age of Replacement, Steady State, and Percentage Change of Profit

This section provides the baseline model results as well as the six model iterations for net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit for four cocoa production systems range from (1) Low Input, Landrace Cocoa (LILC), (2) High Input, No Shade Amazon Cocoa (HINSC), (3) High Input, Medium Shade Cocoa (HIMSC), and (4) Organic Cocoa.

Tables 3, 4, and 5 show the same pattern of net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit for the LILC, HINSC and HIMSC models. The table also displays a "Status Quo" solution in which trees are never culled. This is computed to estimate the difference between current production methods and what could be gained by adopting optimal replanting solutions. The optimal solutions suggest that it is most profitable for cocoa producers to replace five percent of their orchards annually, with the age of replacement starting from year five to eleven. In the baseline scenarios, substantial economic gains (279.92, 257.95, and 277.67, percent higher) are associated with using the optimal replacement rates compared with the status quo of retaining a tree until it no longer bears fruit for LILC, HINSC, and HIMSC production systems, respectively.

The result also suggests that when the price of cocoa increases by two percent (from three to five percent) (scenario 1), holding all other variables constant, the age of replacement is postponed one to two years in order to capture benefits of the higher cocoa prices (Table 3, 4, and 5). The solutions indicates that cocoa farmers can acquire 31.40, 31.43, and 31.69 percent higher profit by postponing the replacement age respectively for LILC, HINSC, and the HIMSC production systems.

Table 3
Summary of Net Present Value (NPV), Replacement Rates, Age of Replacement, Steady State and Percentage Change in Profit under Low Input, Landrace Cocoa (LILC)

	Net Present Value (NPV)*	Replacement Rate (Percent)	Age of Replacement (Year)	Steady State (Year)	Percentage Change in Profit
Status Quo	260.58	-	-	-	-
Baseline Scenario	989.99	5	8	27	279.92**
Scenario 1	1,300.80	5	9	28	31.40***
Scenario 2	989.99	5	8	27	0.00***
Scenario 3	15,011.16	5	5	24	1,416.29***
Scenario 4	859.10	5	6	25	-13.22***
Scenario 5	964.05	5	8	27	-2.62***
Scenario 6	938.11	5	8	27	-5.24***

* Denotes the highest net present value in (2010 USD/Ha/ Year)
** The value is compared with Status Quo
*** The value is compared with the Baseline Scenario

In Scenario 2 where fertilizer price increases by five percent, holding all other variables constant, the profit for HIMSC and HINSC declines by 1.71 and 2.55 percent from the baseline, respectively (Table 4). The profit for LILC production system is equivalent to the baseline scenario since no fertilizer is applied as a nutrient supplement.

Additionally, the fertilizer price increase results in a new optimal solution for HIMSC, where the replacement age is accelerated one year to year seven instead of year eight. Replacement age is accelerated because cocoa producers try to minimize the impact of further fertilizer price increases as the producers want to avoid additional fertilizer costs for existing cocoa trees. However, the age of replacement for LILC and HINSC is the same as in baseline scenario even with the increased price of fertilizer. This is due to the fertilizer costs only count 12.50 and 10.44 percent of total cost for HIMSC and HINSC, respectively.

Table 4
Summary of Net Present Value (NPV), Replacement Rates, Age of Replacement, Steady State and Percentage Change in Profit under High Input, No Shade Amazon Cocoa (HINSC)

	Net Present Value (NPV)*	Replacement Rate (Percent)	Age of Replacement (Year)	Steady State (Year)	Percentage Change in Profit
Status Quo	619.56	-	-	-	-
Baseline Scenario	2,217.69	5	9	28	257.95**
Scenario 1	2,914.74	5	11	30	31.43***
Scenario 2	2,179.84	5	9	28	-1.71***
Scenario 3	33,728.66	5	6	25	1,420.89***
Scenario 4	1,898.16	5	8	27	-14.41***
Scenario 5	2,162.10	5	9	28	-2.51***
Scenario 6	2,106.51	5	9	28	-5.01***

* Denotes the highest net present value in (2010 USD/Ha/ Year)
** The value is compared with Status Quo
*** The value is compared with the Baseline Scenario

In scenario 3, when the inflation rate increases by 4.74 percent (from 10.26 to 15 percent) holding all other variables constant, the profit increases by 1,416.29, 1,420.89, and 1,414.97 percent for LILC, HINSC, and HIMSC, respectively. These results indicate that profit per hectare increases exponentially over 100 years. This high increment in profit is partially because the cocoa price is a function of the inflation rate. In this study, it is also assumed that the cocoa price increases at the same rate that the inflation rate increases. On the other hand, an increase in the inflation rate causes a three year acceleration in the initial replacement year, primarly because the cocoa producers minimize the impacts of increased costs associated with labor and materials.

Table 5
Summary of Net Present Value (NPV), Replacement Rates, Age of Replacement, Steady State and Percentage Change in Profit under High Input, Medium Shade Cocoa (HIMSC)

	Net Present Value (NPV)*	Replacement Rate (Percent)	Age of Replacement (Year)	Steady State (Year)	Percentage Change in Profit
Status Quo	389.59	-	-	-	-
Baseline Scenario	1,471.37	5	8	27	277.67**
Scenario 1	1,937.67	5	9	28	31.69***
Scenario 2	1,433.88	5	7	27	-2.55***
Scenario 3	22,290.79	5	5	24	1,414.97***
Scenario 4	1,225.70	5	6	25	-16.70***
Scenario 5	1,432.46	5	8	27	-2.64***
Scenario 6	1,393.55	5	8	27	-5.29***

* Denotes the highest net present value in (2010 USD/Ha/ Year)
** The value is compared with Status Quo
*** The value is compared with the Baseline Scenario

Similarly, in scenario 4 when labor price increases by five percent holding all other variables constant, the profit declines by 13.22, 14.41 and 16.70 percent compared to the baseline results, respectively for LILC, HINSC, and HIMSC. Labor is one of the largest cost components in cocoa farming which accounts for 65.19, 81.88, 78.31 and 98.42 percent of total cost for LILC, HINSC, HIMSC, and Organic Cocoa, respectively. Therefore, a small change in labor price has significant impacts on profitability. The labor price increase also results in a two-year decline the optimal age of replacement. Thus, speeding up the replanting of cocoa trees helps cocoa producers to minimize the impact further cost increases.

In scenario 5 where a 20 percent yield loss due to a black pod outbreak effects on 10 percent of the land being, the optimal replacement rate is five percent and the age of replacement is equivalent to the baseline scenario. Likewise, when yield loss increases to 40 percent from a black pod outbreak with the same 10 percent of land being affected (scenario 6), the optimal replacement age remains unchanged from that of the baseline scenario. These findings indicate that total yield loss due to black pod incidence is two to four percent and profit losses are 2.51 to 5.29 percent in all production systems.

Table 6
Summary of Net Present Value (NPV), Replacement Rates, Age of Replacement, Steady State and Percentage Change in Profit under Organic Cocoa

	Net Present Value (NPV)*	Replacement Rate (Percent)	Age of Replacement	Steady State	Percentage Change in Profit
Status Quo	319.32	-	-	-	-
Baseline Scenario	1,198.57	5	8	28	275.35**
Scenario 1	1,334.76	5	8	30	11.36***

* Denotes the highest net present value in (2010 USD/Ha/Year)
** The value is compared with Status Quo
*** The value is compared with the Baseline Scenario

Table 6 presents the results for organic production where converting from conventional cocoa farming to organic farming causes a 30 percent production loss and a 10 percent premium price is estimated, holding other variables constant. In the baseline scenario, these findings suggest that substantial economic gain can be achieved (275.35 percent increase in profit) when using the optimal replacement rates compared with the status quo of retaining a tree until it bears no fruit. Conversely, in scenario 1 (assuming 30 percent yield loss and 20 percent premium price), the profit increases by 11.36 percent from the baseline scenario.

Table 7
Summary of Production Loss and Premium Price under Organic Cocoa

Production Loss / Price Premium	10%	20%	30%	40%	50%	60%
10%	1,626.60	1,412.59	1,198.57	984.55	770.54	556.52
20%	1,801.71	1,568.23	1,334.76	1,101.29	867.82	634.34
30%	1,976.81	1,723.88	1,470.95	1,218.03	965.10	712.17
40%	2,151.92	1,879.53	1,607.15	1,334.76	1,062.38	789.99
50%	2,327.02	2,035.18	1,743.34	1,451.50	1,159.66	867.82
60%	2,502.13	2,190.83	1,879.53	1,568.23	1,256.94	945.64
70%	2,677.23	2,346.48	2,015.72	1,684.97	1,354.22	1,023.46
80%	2,852.34	2,502.13	2,151.92	1,801.71	1,451.50	1,101.29

Note: Net present values (NPV) under shaded area are greater than the net present value (NPV) for baseline scenario under High Input, Medium Shade Cocoa, $1,471.37 (2010 USD/Ha/Year). Thus those solutions under the shaded area indicate the scenarios where growing organic cocoa would be more profitable than High Input, Medium Shade Cocoa per hectare

Table 7 presents the summary of the net present value (NPV) associated with various levels of production loss and price premiums for organic cocoa production. The table also highlights the tradeoffs that exist between the premium received and the yield of organic cocoa. It shows that when a 10 percent production loss and an 80 percent premium price are assumed, the highest net present value (NPV) is $2,852.34 (2010 USD/Ha/Year). Conversely, when the farm contracts a 60 percent production loss and receives only a 10 percent premium price, the lowest net present value (NPV) is $556.52 (2010 USD/Ha/Year).

As shown in table 7, the lowest production loss and the highest premium price are preferred because it gives the highest net present value (NPV). However, considering 30 percent yield loss as estimated by Victor et al. (2010) and Phuoc et al. (2008) due to converting to organic cocoa, and net present value (NPV) of baseline scenario under HIMSC, $1,471.37 (2010 USD/Ha/Year), the premium price that cocoa growers need is at least 30 percent or $1,470.95

(2010 USD/Ha/Year) to encourage the cocoa farmers to grow their cocoa organically. The shaded areas in table 7 illustrate those combinations (price premium and yield loss) that represent a net present value (NPV) higher than that of traditional production. Theoretically producers should be willing to produce organic cocoa for as little as a 10 percent price premium as long as the associated yield loss with organic production is less than 10 percent. Conversely, producers hypothetically would produce organic cocoa even with a 40 percent yield reduction if they received a 60 percent price premium associated with organics. The information in table 7 is valuable to chocolate manufacturers like Mars and Cadbury to determine what the premium price threshold level is to secure a supply of organic chocolate.

Yield and Profit of Optimal Replacement Model and Status Quo Assuming Zero Percent Price Increase, Inflation and Discount Rates

Table 8 compares the total yield of cocoa and profit over 50 years between the optimal replacement model and status quo (0 percent annual replacement rate) under LILC, HINSC, HIMSC, and Organic Cocoa production systems.

The study finds that that the optimal replacement rate is six percent and the age of replacement is at year nine. It also suggests that the yield can be achieved 10.06 percent higher and the profit 14.55, 13.61, and 11.53 percent higher over 50 years following the optimal solution compared with the status quo of retaining a tree until it no longer bears fruit for LILC, HIMSC, and Organic Cocoa, respectively (Table 8).

Whereas for HINSC, the model estimated that the optimal replacement rate is five percent and the age of replacement is at year seven. It also suggests that the yield and profit can be achieved (4.55 and 5.62 percent higher over 50 years) following the optimal solution compared with the status quo of retaining a tree until it no longer bears fruit (Table 8).

Table 8
Summary of Total Yield and Profit of Optimal Replacement and the Status Quo

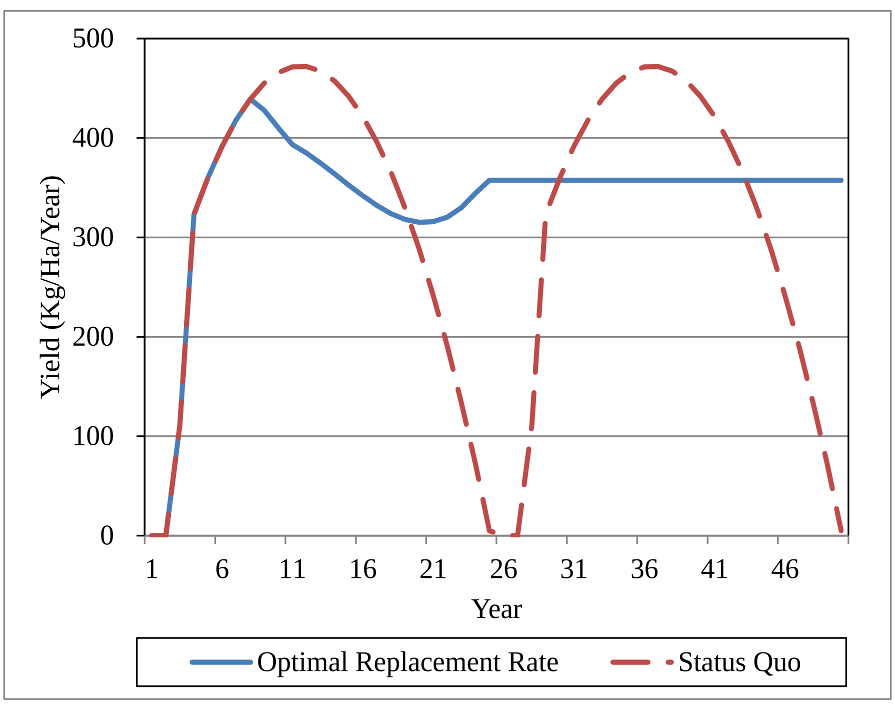
	Yield*			Profit**		
Production System	Optimal Replacement Model	Status Quo	Percentage Change in Yield	Optimal Replacement Model	Status Quo	Percentage Change in Profit
LILC	16,987	15,435	10.06	37,845	33,038	14.55
HINSC	35,472	33,929	4.55	84,028	79,561	5.62
HIMSC	25,480	23,152	10.06	56,009	49,299	13.61
Organic	17,836	16,206	10.06	46,887	42,040	11.53

* Denotes the total yield over 50 years in Kg/Ha.
** Denotes the total profit over 50 years (2010 USD/Ha/Year).

Figure 1 compares the yield of cocoa over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under the LILC production system. Similarly, the graph for profit mirrors the graph for yield of cocoa (Figure 1). Likewise, the graph of yield and profit for HINSC, HIMSC, and Organic Cocoa also has similar shapes from figure 1.

Figure 1

Cocoa Yield Over 50 Years Assuming Zero Percent Price Increase, Inflation and Discount Rates for Status Quo and Replacement Model under Low Input, Landrace Cocoa (LILC)



Conclusion

This study has empirically estimated the optimum annual replacement rate and age of replacement of cocoa trees in order to maximize the net present value (NPV) of cocoa production. Using empirical data from Ghana on yield, cocoa price, cost, inflation and discount rate for four cocoa production systems, the study estimated net present value (NPV) based on the changes in projected cocoa price, labor, fertilizer, insecticide, and fungicide prices, exchange rate, inflation and discount rates.

The study finds that the optimal replacement rate for all scenarios is five percent, whereas the optimal replacement age varies from year five to eleven. From the baseline scenario, substantial economic gains are estimated at 280, 258, 278 and 275 percent higher for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa, respectively, when using the optimal replacement rates compared with the status quo of no replacement.

As reported by the World Resources Institute, 78.5 percent of the Ghanaians live on less than $2 per day (USD). Thus the income for each person in this group is about $730 per year (USD). To put this study and its results in context, the majority of the poor in Ghana are small farmers. If they adopted the optimal replacement model of Low Input, Landrace Cocoa (LILC), their income could be increased by 35.62 percent per year ($989.99, 2010 USD). Similarly, if they adopted optimal replacement model of High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa, the income can be raised by 203.79, 101.56, and 64.19 percent, respectively. This of course, assumes no substantial world market adjustments to these changes in supply.

This study can be used as a tool to increase the yield of cocoa and profit, improve revenue stabilization over time, and as a tool to lift up the people who live under the poverty line in the cocoa sector with less than $2 per day. One important feature of this model is that it allows a producer to reach a steady state revenue. The model can also be used by cocoa producers or extension agents through changing data on yield, cost, cocoa prices, fertilizer prices, inflation rates, and labor prices. The Excel based model is employed to provide extension personnel in low-income countries with a simple yet powerful tool to illustrate to producers the benefits of tree replacement. Besides that, many times in low-income countries, producers sit idly by as their yield decreases and their subsequent profits decrease as well due to the increasing age of cocoa trees. This model changes that by employing an optimal solution where yield and profit can be raised and maintained at steady state levels over time.

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