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Increasing Profitability of Small Scale Cocoa Farmers Through Optimizing Replacement Rate

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A thesis submitted in partial fulfillment
of the requirements for the degree of
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By

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ABSTRACT

The objective of this study is to empirically estimate the optimum annual replacement rate and age of replacement of cocoa trees in order to maximize the net present value of four production practices 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. While this study focuses on cocoa, the method is applicable to any tree crop industry. 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 to maximize net present value 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. The Excel based model could provide extension personnel in low-income countries with a simple yet powerful tool to illustrate to producers the benefits of tree replacement. Given that producers in both high- and low-income countries are reluctant to cull still productive assets, such as trees that are diminishing in yield over 100 years, this study illustrates the economic benefits of replacing such trees at the optimal time and rate.

This thesis is approved for recommendation
to the Graduate Council

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DEDICATION

This thesis is dedicated to my wife Rohani Musa, my son Oemar Farouqie Mahrizal, my parents Muhammad Ismail and Ainsyah AR. Their support has motivated me to finish this thesis.

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I. 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), n.d). Ghana is the second largest cocoa bean producer in Africa (FAO, 2003) with total production reaching 506,358 tons in 2007 (FAO, n.d). The Bank of Ghana (2008) reported that this sector alone contributed to approximately 3.40 percent of total gross domestic product (GDP) in 2007 and making it the largest export commodity (FAO, n.d).

Historically, Ghana has experienced the rise and decline 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 diseases outbreaks, bad weather, and low producer prices (Congress, n.d). The decline in production was also caused by bushfires in 1983, which destroyed about 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, n.d).

Numerous studies have tried to examine and analyze the causes of declining in cocoa production. Some of them have also extended their studies to include different sample locations. Of the possible factors contributing to declining cocoa yields, average tree age is considered as one of the largest contributors to the declining of perennial tree crop yields. Other causes include the outbreak of diseases, pests, weather, poor farm management, competition at the world market, and low export prices.

The production cycle of perennial trees can be divided into four stages: (1) an early period of no yield, (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 perennial trees can bear fruit for 40 years and annual yield loss can be marginal, it is difficult for producers to decide when and what percentage of trees to replace to maximize their revenue stream over time. This is due to the absence of analytical tools and understanding among low income producers to estimate cost and revenue that can be realized from cocoa farms throughout the production cycle.

A 2003 study by the Food and Agriculture Organization of the United Nations (FAO) study estimated that the annual cocoa growth rate would decline to about 1.60 percent in 2010 due to the increase in competition at the world market, low export prices, and the outbreak of diseases; such as swollen shoot virus, black pod and mirids. In some cases, cocoa trees that are affected by viruses should be cut down and removed from the cocoa farm (Lass, 2001a). Likewise, Hardy (1960) recommended that trees that are affected by cushion gall should be removed and destroyed at once, even if a few galled trees are found. Meanwhile, if the infected trees are massive in susceptible areas, the cocoa farm owners should remove and destroy all affected trees (p.265).

Montgomery (1981) concluded that based on a consensus of opinion, the maximum cocoa yields are reached at the tree age 15 to 25 years with a profitable life span over 50 years. Nevertheless, the yields slowly decline at the age 26 to 45 (Montgomery, 1981). Therefore, in order to maintain maximum profitability of an orchard throughout the four growth stages, replanting is required. Lass (2001a) suggested 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.

Furthermore, low cocoa production is also associated with the economies of scale. Besanko, Dranove, Shanley, & Schaefer (2010) stated that economies of scale exist as a result of declining average costs and increases in volume of output. In cocoa farming, an economy of scale is related to the farm size. For most of Ghanaian cocoa farmers, cocoa is grown on small-scale farms of a half to one hectare.

Wood and Lass (2001) stated that the size of farm for individual plantings in Africa is very small, which ranges less than one hectare (ha). Likewise, Hill (1956) reported that the average farm size in Ashanti-Akim (in Ghana) area in 1928 was 0.57 ha and the average number of farms per farmer was 0.69 ha. Valley and White as cited in Hill (1962) stated each holding on the average is 0.81 ha. Boateng as cited in Hill (1962) confirmed that "cocoa is usually grown on small farms of from one to two acres" (0.40 to 0.81 ha).

In addition, poor farm management also contributes to the decline of cocoa production. According to Hardy (1960), the decline in cocoa yield is greatly caused by the human factors. He described that the farm is abandoned when "the times are bad," as a result, it leads to a situation where the farmer does not give attention to the cocoa farm such as for pruning, draining, reaping, supplying, disease and pest control, and general orchard sanitation. Hardy (1960) also added that financial assistance and long-term credit are needed to overcome tough conditions.

Therefore, the objective of this study is to empirically estimate the optimum annual replacement rate and age of replacement of perennial trees 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.

This study and its objectives are important because cocoa farmers in Ghana can utilize the model in this study as a tool to increase the yield of cocoa and profit. The model can also bring consistent income, such that cocoa producers could receive stable revenue over time by following the optimal solution. Of course factors outside the farmer's control like price volatility and government policies could cause revenue volatility even with the best of plans.

II. LITERATURE REVIEW

A. Introduction

1. History of Cocoa

The cocoa tree is believed to have originated in the Amazon basin in South America. It belongs to the genus *Theobroma,* a small tree that grew in the wild forests of South and Central America. The Maya Indians used cocoa beans mixed with ground maize and water to create a drink (Urquhart, 1955). Because of its smell and taste, cocoa was also considered as the "food of gods" by the Olmec and the Mayans (United Nation Conference on Trade and Development (UNCTAD), n.da). Cocoa beans had also been used as a medium of monetary exchange during the South American civilizations. In fact, during that period, ten cocoa beans could be used to purchase a horse (World Cocoa Foundation (WCF), n.d).

Christopher Columbus took samples of cocoa beans to Europe out of curiosity. Twenty years later, Hernando Cortes discovered the commercial value of cocoa. In order to improve and find a perfect taste, the Spanish heated and mixed it with sugar and milk. The Spanish were also the first country that introduced cocoa to the European market. In early 17^{th} century, cocoa drinks were famous in Italy and France and later in Holland, Germany, and England. It became a beverage which was restricted to only the wealthier classes throughout Europe (Hardy, 1960).

Since then, the demand for cocoa beans had increased significantly and the cultivation of cocoa had expanded to the Caribbean, Central and South America, Asia, and Africa. Venezuela was recorded as the first country that cultivated cocoa in the 16^{th} century followed by Jamaica around 1670. It was believed that the seed of a *Criollo* type from Venezuela was introduced to Trinidad in 1678 and domesticated there (Wood, 2001). Cocoa was also brought to the

Philippines in 1600 by the Spanish and from there it spreaded to Sulawesi and Java and then to Sri Lanka and India (Ratnam as cited in Wood, 2001). Cocoa planting in the state of Bahia Brazil, which was derived from wild *Amelonado* type of cocoa in Guiana, was first cultivated in 1746 by a French planter who brought the seeds from state of Para. From there, the seeds were taken to São Tomé in 1822 and from São Tomé were brought to Fernando Po in 1855 and then it continued to Ghana and Nigeria (Wood, 2001).

In the current stage of development, cocoa farmers are encouraged to produce high quality cocoa beans. However, at the same time farmers have to deal with several issues related to cocoa production and marketing such as the selection of a cocoa variety, pest and disease outbreak, declining cocoa yields, labor shortages, poor producer outreach, poorly funded extension services, high fertilizer costs, pesticide and herbicide costs and availability, expensive farming equipment, taxation on cocoa beans export, and an ill-defined supply chain.

2. Cocoa Growing Regions

Naturally, the habitat of genus *Theobroma* is in lower canopy of evergreen rain forests. Cocoa can only be grown at 20^o south and 20^o north of the equatorial line and at the low elevations (below 1,000 feet) (Urquhart, 1955). However, the International Cocoa Organization (ICCO) (n.da) noted that cocoa is cultivated in countries within 10^o south and 10^o north of the Equator.

There are specific requirements for cultivating cocoa. It requires heavy rain fall ranging from 1,500 mm and 2,000 mm throughout the year. Drought season, where the rainfall is less than 100 mm per month, is not preferable. Annually, it requires the temperature with a minimum of 18-21 degree Celsius and a maximum of 30-32 degree Celsius but also high humidity as much as 100 percent during the day and 70-80 percent during the night is preferred (ICCO, n.da).

Currently, the major cocoa producing countries are the Cote d'Ivoire, Indonesia, Ghana, Nigeria, Brazil, Cameroon, Ecuador, Togo, Papua New Guinea, Dominican Republic, Columbia, Peru, Mexico, Venezuela, Bolivia, Malaysia, and other tropical countries within 20^o south and 20^o north of the equatorial line.

3. World Cocoa Production

Cocoa production is primarily in the form of cocoa beans. Globally, it has increased substantially since the beginning of the twentieth century. In 1900, cocoa production was approximately 100,000 tons and increased to 200,000 tons by 1910. In the period of 1921 to 1923, annually the production on average was 395,000 tons, and rose to 692,000 between 1934 and 1939, which were to the rise of production in West Africa and Brazil (Urquhart, 1955). Cocoa production continuously increased to approximately 600,000 tons in 1945, since then it reached 1.9 million tons (Wood, 2001).

However, the higher prices experienced since 1947 were not followed by an increase in cocoa production during the 1950's. During the 1950's, the cocoa production was stagnant at around 700,000-800,000 tons. The total production was 1.1 million tons in 1960/61, following the increase of production in Ghana and Nigeria. In the next ten years, West Africa and Brazil contributed as much as 400,000 tons and the global production was approximately 1.5 million tons. The leading cocoa producing countries, Ghana, Nigeria, Brazil, Cote d'Ivoire and Cameroon produced 78 percent of the world cocoa in 1970/71. However, in the period of

1985/86, the leading countries changed to the Cote d'Ivoire, Brazil, Ghana, Nigeria, and Cameroon with total 72 percent of the world total (Wood, 2001).

Table 1
World Cocoa Production

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cote d'Ivoire	1,401	1,212	1,265	1,352	1,407	1,360	1,372	1,384	1,382	1,222
Indonesia	421	428	571	573	642	643	769	740	793	800
Ghana	437	390	341	497	737	740	734	615	729	662
Nigeria	338	340	362	385	412	441	485	361	367	370
Brazil	197	186	175	170	196	209	212	202	202	218
Cameroon	123	122	125	155	167	179	165	179	188	226
Ecuador	100	76	88	88	90	94	88	86	94	121
Other countries	356	354	345	360	369	389	447	437	480	463
World Total	3,372	3,108	3,271	3,579	4,019	4,054	4,272	4,003	4,234	4,082

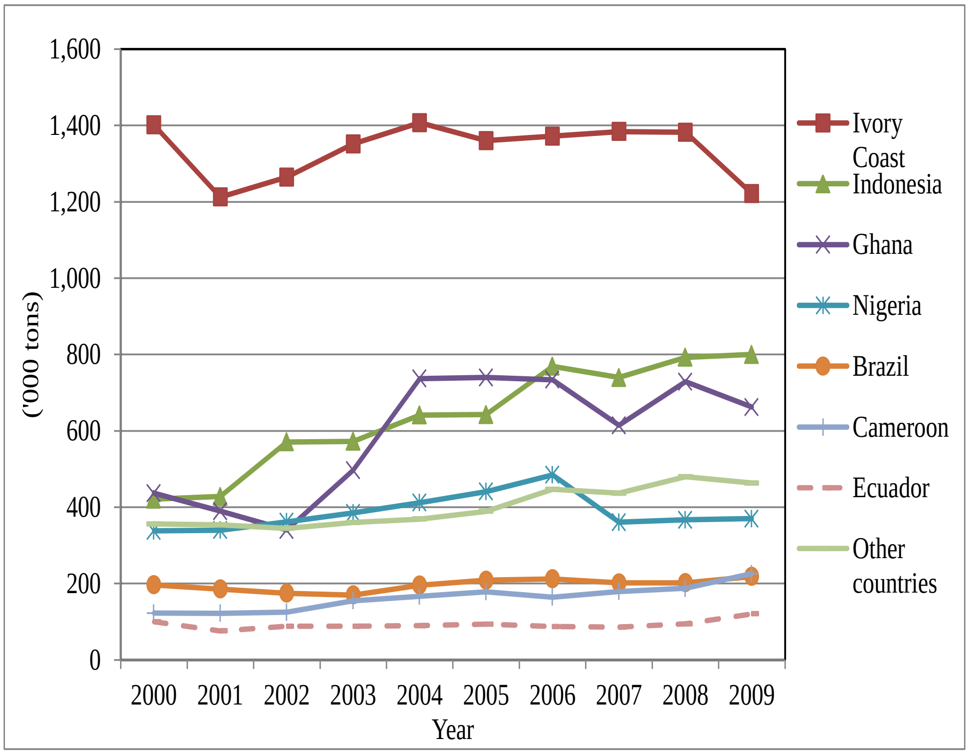
Source: Food and Agriculture Organization of the United Nations (FAO) (2011).
Notes: Data in thousand tons.

Currently, the leading cocoa producing countries have not changed much since the 1970s and 1980s, except that Indonesia has successfully emerged as the second largest cocoa producer after Cote d'Ivoire. Table 1 shows the amount that each country produces. In 2000, Cote d'Ivoire produced 1.4 million tons and slightly fluctuated over the following years until it declined to 1.2 million tons in 2009 due to political unrest.

Conversely, Indonesia has been able to increase its cocoa production from 421,142 tons in 2000 to 800,000 tons in 2009 (Table 1). Similarly, Ghana has also increased its production from 436,600 tons in 2000 to 740,000 ton in 2005, although there was a small drop in production to 662,400 tons in 2009 (Table 1). The fluctuation in production can also be seen in other counties. In 2000, Nigeria produced 338,000 tons of cocoa and then rose to 485,000 tons in 2006 before it fell to 370,000 tons in 2009. Brazil, Cameroon, and Ecuador have similar trends in cocoa production, producing 196,788, 12,600, and 99,875 tons of cocoa, respectively, in 2000 and increasing to 226,000, 226,000, and 120,582 tons, respectively, in 2009.

Figure 1

Global Cocoa Production



The total world production has also increased from 3.3 million tons in 2000 to 4.2 million tons, or a rise of 26 percent, in 2006. Cote d'Ivoire and Indonesia contributed 42 and 12 percent, respectively, to the world cocoa production in 2000.

In 2009, however, the contribution to the world was 30 and 20 percent for Cote d'Ivoire and Indonesia, respectively. According to Akiyama and Nishio (1996), there are several factors that contributed to the expansion of cocoa production in Indonesia, such as “availability of suitable land, low production cost, a highly competitive marketing system resulting from a "hands-off policy" or very limited direct government interventions, relatively good transport infrastructure, favorable macroeconomic policies, and the entrepreneurship of smallholders" (p. i).

Akiyama and Nishio (1996) stated that since Indonesia adopted free marketing and pricing system, smallholders could sell their cocoa either to village collectors, middlemen, exporters, cooperatives, or estates. As the result, it increased their competitiveness on a global scale. With this system, buyers do not need licenses to purchase cocoa beans the way buyers do in Ghana and most of West Africa. Therefore, the farm gate price is about 90 percent of freight on board (FOB) price again high compared to West Africa. Additionally, the government of Indonesia (GOI) built infrastructure in rural areas and established transmigration program (a program of moving landless people from densely populated areas such as the island of Java to others islands that are less densely populated such as Kalimantan, Sumatra, Papua, and Sulawesi), which in turn expanded the smallholder cocoa farms.

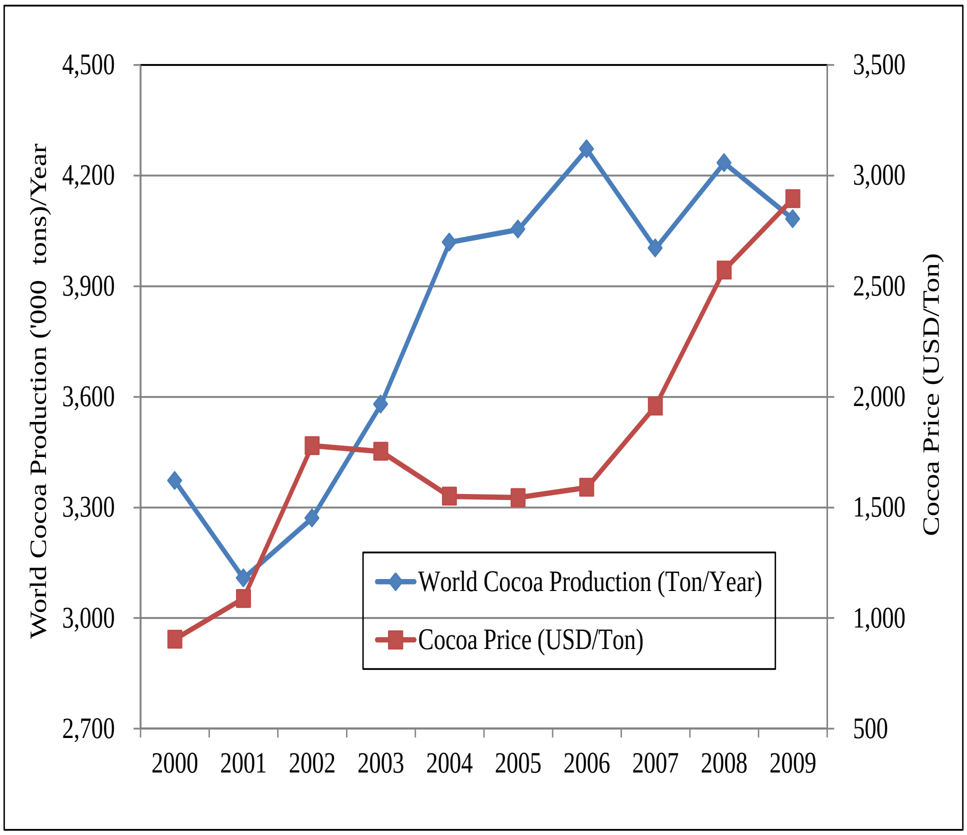
The GOI also implemented a competitive exchange rate policy to boost cocoa price and exports as well as macroeconomic policies to keep the inflation low in the 1980s. The GOI also provided extension services to support the smallholders in 1980s. For example, under a tree crop rehabilitation program (PRPTE), GOI provided cocoa seeds to smallholders. In late 1989 and early 1990, the Central Government also provided loans through state-owned banks under a system called PBSN (National Large Plantation Development) as a part of interest subsidy to state own farms (PTPs) and private plantations.

Another program known as P2WK (Plantation Development in Special Areas) was launched by the Ministry of Agriculture to assist smallholders by providing small grants as a reimbursement of land preparation and planting cost, and provision of seedlings. P2WK covered

205,296 ha of cocoa for the period 1990/91 and 62,767 ha in 1993/94 (Akiyama & Nishio, 1996). A newly introduced initiative by GOI for 2007-2010 covered the replanting of 54,000 ha, rehabilitation of 36,000 ha, and expansion of 110,000 ha (Krisnamurthi, n.d). The GOI is currently implementing programs towards improving livelihood of smallholders, as well as working with Non Government Organizations (NGOs) that have implemented similar programs throughout Indonesia, such as Tunas Bangsa Nanggroe Aceh Darussalam Foundation (YTB), Swisscontact, Ausaid and Keumang Foundation in Aceh province.

Figure 2

World Cocoa Production and Cocoa Price



Source: FAO (2011) and International Monetary Fund (IMF) (2011a).

4. World Cocoa Consumption

Cocoa is mainly consumed in the form of chocolate confectionery, chocolate created products such as cookies, ice creams, or in the form of food products containing cocoa powder such as beverages, cakes, snacks, etc. (ICCO, 2010).

Table 2

Total Chocolate Confectionery Consumption in Selected Countries

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
United States	1498	1441	1546	1558	1562	1646	1633	1566	1547
Germany	820	823	851	866	918	895	920	940	934
UK	551	539	591	600	614	615	624	634	633
Brazil	313	298	312	298	376	359	404	465	487
France	410	406	414	414	439	424	410	444	469
Japan	277	281	273	283	283	285	285	279	275
Italy	207	211	226	230	241	248	225	200	196
Poland	n.a.	n.a.	126	152	154	140	145	138	172
Spain	157	153	148	143	147	138	144	151	149
Australia	112	117	86	88	97	109	119	123	129

Source: CAOBISCO, International Confectionery Association (ICA) as cited in (ICCO, 2010).
Notes: Data in thousand tons.

Based on Association of the Chocolate, Biscuit and Confectionery Industries of the E.U. (CAOBISCO) and International Confectionery Association (ICA) data (as cited in ICCO, 2010), the ten largest chocolate confectionery consuming countries are the United States, Germany, United Kingdom, Brazil, France, Japan, Italy, Poland, Spain, and Australia. Figure 4 shows that the trend of chocolate consumption is positive which indicates an increase in per capita consumption of chocolate over time in most cases.

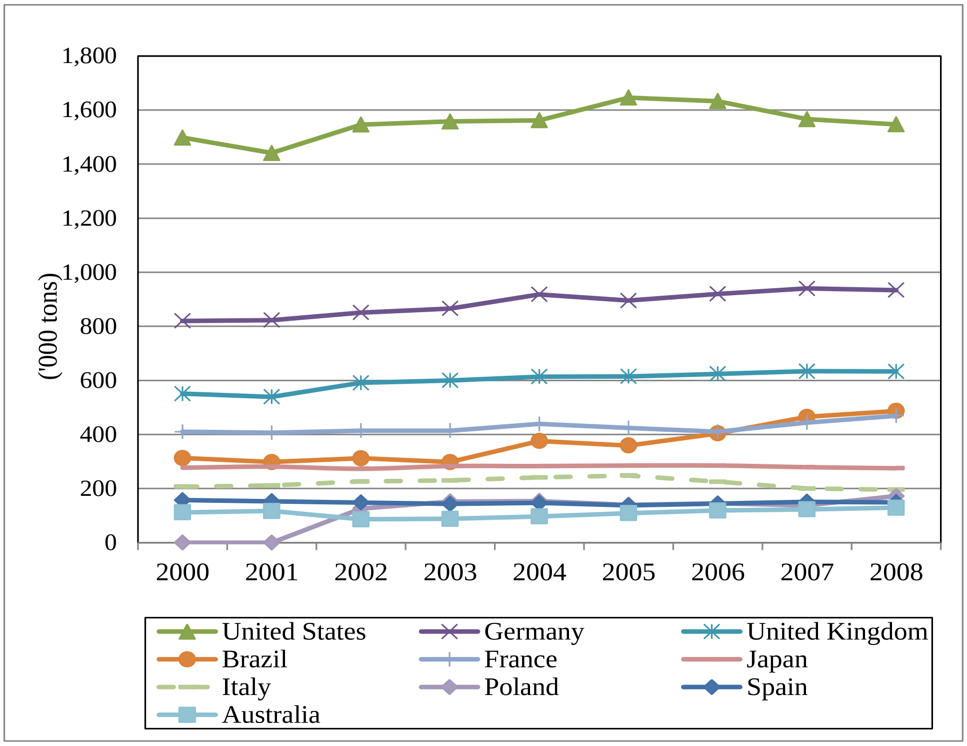
Simmons (2010) reported that global cocoa consumption has grown by an average of 2.5 percent per year over the last 10 years in the order of 3.5 million tons. In general, demand for cocoa is driven by per capita Gross Domestic Product (GDP), prices, tastes, and population growth (Simmons, 2010; Gray, 2001). Several populous countries have recorded a significant growth in cocoa consumption, for instance annual growth in India has reached seven percent, China three percent, Brazil 13 percent, and Russia almost four percent over five years average (Simmons, 2010).

The growth in chocolate consumption is also driven by continuing development of new products. In Europe, chocolate filled products have resulted rapid growth in consumption. Typically, products consist of only 10-15 percent cocoa, but they account for almost 70 percent of the total chocolate product market (Gray, 2001). Additionally, as reported in ICCO (2007b), some components of cocoa, the flavonoids, may decrease low-density-lipoprotein (LDL or "bad" cholesterol) oxidation, helping to prevent cardiovascular diseases. Its high content of antioxidants has also been suggested to reduce the risk of cancer. Therefore, the recent findings on health and nutritional benefits associated with cocoa and chocolate have also boosted the demand for cocoa, specifically for dark and high cocoa content chocolate.

According to Datamonitor (as cited in ICCO, 2007b), dark chocolate products accounted for 33 percent of all chocolate candies launched in 2006. ACNielsen (as cited in ICCO, 2007b) reported that from 2001 to 2005, the sales of dark chocolate in the United States increased by nine percent per year on average and the sales of high cocoa-content dark chocolate increased by 24 percent. Globally, the dark chocolate market is estimated to account for five and ten percent of the total market, with a higher share in Continental Europe than in the United States and the United Kingdom (ICCO, 2007b).

Figure 3

Chocolate Consumption on Selected Countries



Source: CAOBISCO, International Confectionery Association (ICA) as cited in (ICCO, 2010).

World cocoa consumption per capita (excluding China, India, and Indonesia) has increased from 1 kg in period of 2000/01 to 1.10 kg and 1.06 kg in period of 2007/08 and 2008/2009, respectively. A small decline in consumption from 1 kg in 2001/01 to 0.97 kg in 2001/02 was due to lower cocoa consumption in America. The peak level consumption was in 2006/07 and 2007/08 with total cocoa consumption as much as 1.10 kg per head. However, the year 2009/09 show that the world consumption declined to 1.06 kg due to the global economic crisis and higher cocoa prices (Table 3).

Table 3

Total Chocolate Confectionery Consumption

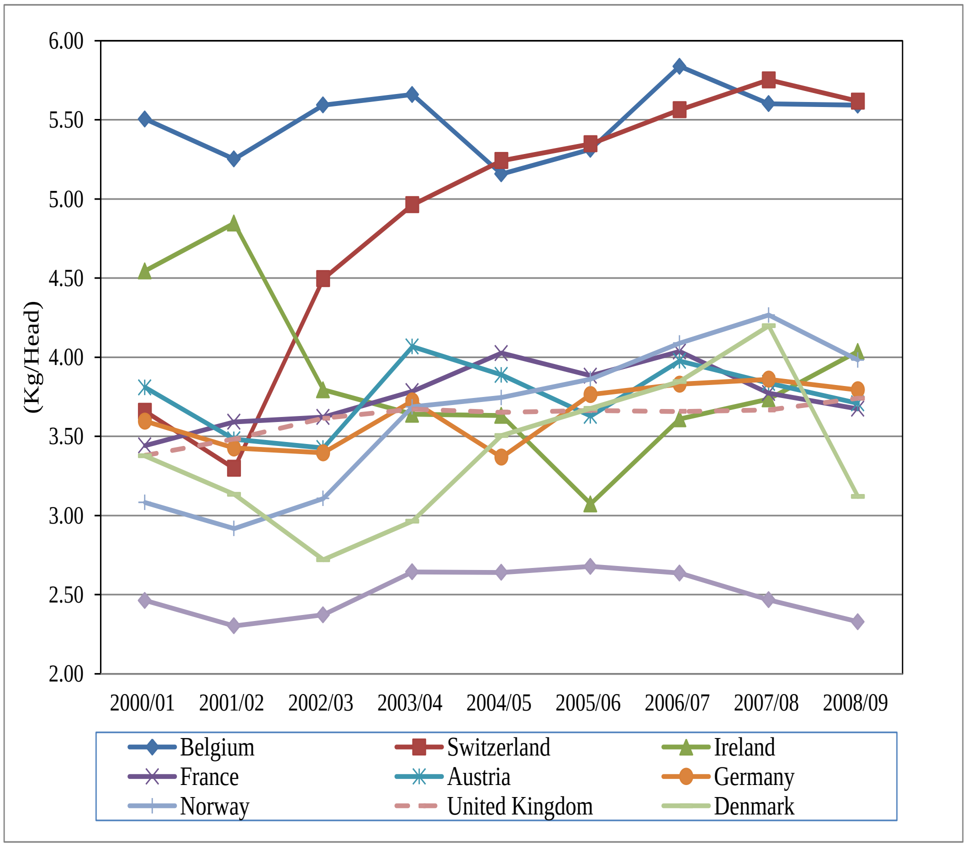
Country	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Belgium	5.505	5.252	5.593	5.66	5.158	5.313	5.838	5.602	5.592
Switzerland	3.658	3.297	4.496	4.963	5.242	5.348	5.563	5.752	5.618
Ireland	4.545	4.847	3.794	3.639	3.632	3.073	3.61	3.736	4.036
France	3.442	3.591	3.622	3.785	4.026	3.883	4.036	3.773	3.674
Austria	3.809	3.481	3.426	4.067	3.888	3.628	3.976	3.837	3.708
Germany	3.596	3.426	3.396	3.723	3.368	3.764	3.829	3.86	3.793
Norway	3.082	2.917	3.107	3.686	3.745	3.862	4.089	4.266	3.982
United Kingdom	3.38	3.483	3.614	3.671	3.652	3.664	3.657	3.666	3.74
Denmark	3.376	3.133	2.72	2.964	3.505	3.676	3.846	4.198	3.12
United States	2.463	2.302	2.372	2.643	2.64	2.678	2.636	2.467	2.328
World Average (excluding China, India and Indonesia)	1.004	0.973	0.987	1.047	1.047	1.075	1.102	1.102	1.059

Source: CAOBISCO, International Confectionery Association (ICA) as cited in (ICCO, 2010).
Notes: The amount is in term of cocoa beans per Kg per capita.

Table 3 shows the total chocolate confectionery consumption for individual countries. Belgium was recorded as the largest chocolate consuming country with an average of 5.50 kg per head and followed by Switzerland with an average of 4.40 kg in the last ten years. Other countries such as Ireland, France, Austria, Germany, Norway, United Kingdom, and Denmark consumed cocoa below 4 kg per capita. The United States alone consumed about 2.50 kg on average.

Figure 4

Per capita Cocoa Consumption (Bean Equivalent)



Source: CAOBISCO, International Confectionery Association (ICA) as cited in (ICCO, 2010).

5. Price of Cocoa

The price of cocoa, like that of all commodities, is determined by demand and supply. However, in some cocoa producing countries, government intervention is prevalent in determining the producer price. For example, the Ghanaian government through its Marketing Board determines the producer price at the beginning of each season (Bulíř, 2002). In Cote d'Ivoire, however, government imposes a high export tariff on cocoa which ultimately lowers the producer price (Hanak-Freud and Freud, as cited in McIntyre, 2001). As a result, the producer share of the FOB price in the Cote d'Ivoire and Ghana in 1997 remained between 48-50 percent, whereas in other producing countries such as Brazil, Dominican Republic, Ecuador, Indonesia, Malaysia and Nigeria, the share of FOB price were between 82-92 percent (McIntyre, 2001).

The price of cocoa also follows the cocoa production cycle seasonally. During the harvest season, the cocoa supply becomes abundant which leads to a decrease in price due to excess supply. As a result, it creates a negative impact on harvesting and motivates the farmers to switch to other crops and the push the world cocoa price up (UNCTAD, n.db).

In general, prices that producers receive are enhanced by world market prices increase, but given different exchange rates and their volatility and inflation rates (which are typically high in the low income countries that produce cocoa) coupled with export tariffs and marketing boards have resulted in market signals being distorted or nearly eliminated. Additionally, government policies toward domestic prices control, input prices and credit costs manipulation to influence production have also affected the producer response to price fluctuations (Akiyama and Duncan, 1984).

Moreover, the political climate in West Africa, which has led to the war in cocoa producing countries (most notably Cote d'Ivoire), directly causes the cocoa price to rise. The recent political unrest in Cote d'Ivoire, the largest cocoa producer country, which saw its exports banned in Europe, led the price of cocoa bean to jump to its highest level to over $3,393 in 2011 (The Guardian, 2011).

Table 4

Cocoa Price

New York & London Base

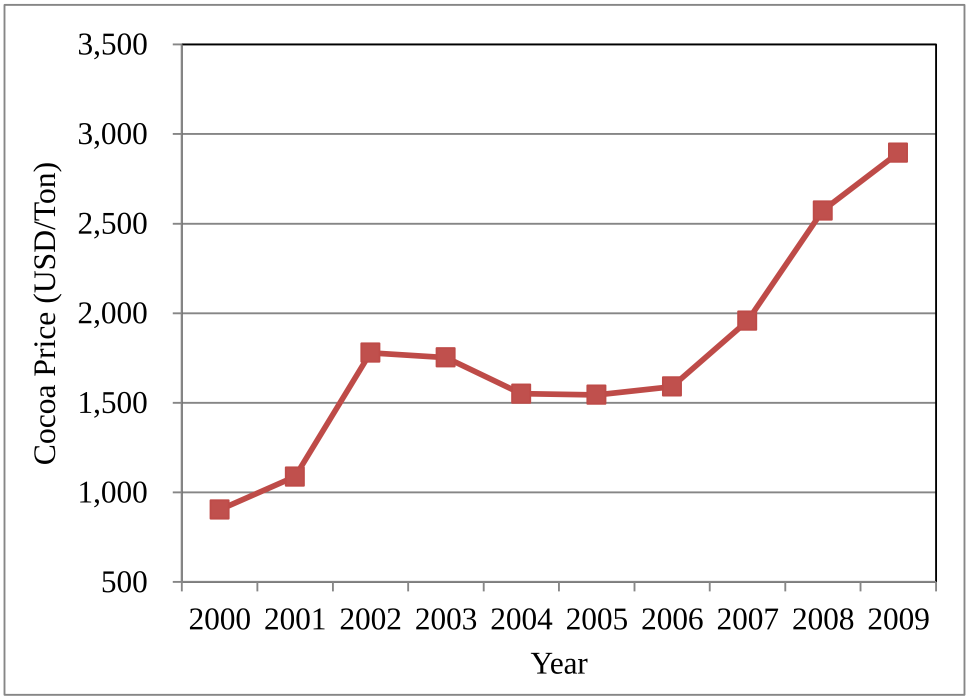
Year	(USD/Ton)*
2000	904
2001	1,088
2002	1,779
2003	1,753
2004	1,551
2005	1,545
2006	1,591
2007	1,958
2008	2,573
2009	2,895

Source: International Monetary Fund (2011a).
* Nominal prices in 2009 USD.

Table 4 shows the cocoa price (USD per ton) at the New York and London Commodity Market during the last ten years. In 2000, cocoa was traded at $904 per ton and it sharply increased more than double that of $1,088 per ton in the following year. The cocoa price continued to rise to $1,779 per ton or an increase of 78 percent in 2002. However, in the year 2004, the price dropped to $1,551 before it increased again to $2,573 and $2,896 per ton in 2008 and 2009, respectively (Table 4).

Figure 5

New York and London Cocoa Price (USD/Ton)



Source: International Monetary Fund (2011a).

6. The Role of the Ghanaian Marketing Board and Ghanaian Government

The Ghana Cocoa Board (Cocobod) is a Ghanaian government-owned institution that was established in 1947. Cocobod's stated objectives are:

> To encourage the production of cocoa, coffee and sheanut; initiate programs aimed at controlling pests and diseases of cocoa, coffee and sheanut; undertake and encourage the processing of cocoa, coffee, sheanut and cocoa waste with the aim of adding value for export and local consumption; undertake, promote and encourage scientific research aimed at improving the quality of cocoa, coffee, sheanut and other tropical crops; regulate the internal marketing of cocoa, coffee and sheanut; secure the most favorable arrangements for the purchase, grading and

sealing, certification, sale and export of cocoa, coffee and sheanut; purchase, market and export cocoa and cocoa products produced in Ghana which is graded under the Cocoa Industry (Regulations) (Consolidation) Decree, 1968 NLCD 278, or any other enactment as suitable for export; and assist in the development of the cocoa, coffee and sheanut industries of Ghana. (Ghana Cocoa Board (Cocobod), n.d)

The role of Cocobod in cocoa production is that it administers the process of internal marketing and also holds the monopoly power in exporting cocoa in Ghana (Williams, 2009). In purchasing cocoa, Cocobod presets producer prices at the beginning of each crop season as a method to stabilize the domestic price setting a price floor and implement tax to ensure Cocobod has working capital. In fact, the stability of domestic producer prices and fiscal revenue has never been completed through pricing strategy (Bulíř, 2002). This is due to the price of cocoa follows the trend of world cocoa price. Additionally, cocoa is a commodity that is subject to government tax. The tax collection is based on the difference between the expected international price and the price paid to farmers and operational cost of Cocobod (Bulíř, 2002).

In 1983, the Ghanaian government started an Economic Recovery Program (ERP) or program of economic stabilization and market reform under the support of the IMF and the World Bank. The program included realignment of relative prices including cocoa, the removal of direct controls and interventions, the restoration of fiscal discipline, and the implementation of structural and institutional reforms (Brooks, Croppenstedt, & Aggrey-Fynn, 2007). In the cocoa sector, Cocobod also followed the structural change in order to improve efficiency at IMF's request. This reform included transferring transport of cocoa to private sector after 1984, shifting feeder road development to the Ministry of Roads and Highways, and the withdrawal of input subsidies. Nevertheless, in 1994, the government subsidized the price of insecticides and fungicides due to the pressure from farmer organizations (Brooks et al., 2007).

The main changes in Cocobod following the structural reform were a reduction of Cocobod's employees from 100,000 at the beginning of the 1980s to 10,400 in 1995 and to 5,100 in 2003. Cocobod ended its control on purchasing cocoa, and opened the competition into internal marketing (Brooks at al., 2007). The partial liberalization in 1993 had replaced Cocobod's position as the single buyer under the Produce Buying Company (PBC) to Licensed Buying Companies (LBCs) and led to more competitive condition in which nearly 20 licensed buyers and 3,000 buying stations currently are in operation (Barrientos, Asenso-Okyere, Asuming-Brempong, Sarpong, Anyidoho, & Kaplinsky, 2007; Kolavalli and Vigneri, 2011). Following the reform, producer prices increased by 68 percent and 70 percent from FOB price in 2003 and 2004 as a part of government policy to revitalize cocoa sector (Dormon, Huis, Leeuwis, Obeng-Ofori, & Sakyi-Dawson, 2004).

In addition purchasing cocoa, a subsidiary of Cocobod, Cocoa Service Division, was also responsible for cocoa extension services. However, this responsibility, then, shifted to the Ministry of Food and Agriculture (MoFA) under the Structural Adjustment Program. A strategy to increase cocoa production was implemented by government in 2001 through subsidized mass-sprayed of farms under the Cocoa Diseases and Pests Control program with no charge to the farmers. The government also implemented interest-free credit scheme called the Cocoa 'Hi-Tech' Program since 2003 with the objective to increase productivity of cocoa by providing fertilizers and pesticides. The program reached about 50,000 farmers in the first year and then increased to 100,000 in the following year. The 'Hi-Tech' Program was jointly managed by the Cocoa Research Institute of Ghana (CRIG), Cocobod and MoFA (Dormon et al., 2004).

Partial liberalization in the Ghanaian cocoa sector has helped the small farmers to receive prompt cash payments, guaranteed a fixed minimum price through the season, and offered more choice of buyers. However, cocoa farmers in high-production areas welcome full liberalization (Vigneri and Santos, 2007) because although guaranteed a price floor, they are also limited to a price ceiling.

B. Cocoa Pests and Diseases

Cocoa is vulnerable to a host of tropical pests and diseases. Based on the review of literature that conducted by Lass (2001a), the production losses, which were caused by pests and diseases, were approximately 20.80 to 29.40 percent of world total production. Several countries such as Ghana, Nigeria, Sierra Leone, Togo, Trinidad and Tobago, West Cameroon, and Windward Islands were considered as the countries that had the highest percentage loss.

There are a number of pests and diseases that attack cocoa trees. The group of pests are mirids or capsids, shield bugs, leaf hoppers, psyllids, aphids, scale insects and mealy bugs, thrips, rink bark borers, cocoa moth (cocoa pod borer), bollworm, armyworm, leaf-cutting ants, ants living off sap-sucking insects, chafer beetles, cocoa beetle, longhorn beetles, *Pantorhytes spp*., ambrosia beetles, nematodes, termites, snails, and vertebrates. Whereas the group of diseases include cocoa swollen-shoot virus, cocoa necrosis virus, cocoa mottle-leaf virus, black pod disease (*phytophthora pod rot*), *Monilia* pod rot (*Monilioppthora* pod rot), witches'-broom, cushion gall, mealy pod, *Diplodia* pot rot and warty pod rot, minor pod disease, *Cetostomella* wilt, dieback, vascular streak dieback, sudden-death disease, pink disease, thread blight, brown root disease, while root disease, collar crack, black root disease, and mistletoes (Willson, 1999).

Some diseases can have a severe impact on cocoa trees and reduce production, for example, black pod rot and other pod diseases cause a direct loss of crop, whereas Vascular-streak dieback makes the cocoa trees too weak to produce, and *Ceretocystis wilt* may even kill the tree (Lass, 2001a). Some diseases can be controlled and eliminated through traditional control, fungicide spraying, changing in level of shade, and improving drainage system. However, certain diseases are still difficult to control, even though the farmers cut down the infected cocoa trees. Nevertheless, diseases still persist and difficult to totally eliminate (Lass, 2001a). Therefore, this study limits its review to black pod rot diseases, *Ceretostomella wilt* and cocoa swollen-shoot virus, since those diseases are closely related to the reduction of yield and replacement of cocoa.

1. Black Pod Rot (*Phytophthora* pod rot)

Black pod rot is mainly caused by the fungi *Phytophthora palmivora, P.megakarya, P.Capsidi* and related species, which are represented in all cocoa growing areas (Brasier and Griffin, as cited in Willson, 1999). The symptoms of black pod can be noticed from the pod appearance. Initially, a small clear spot appears on the pod surface which normally emerges under high humidity after two days of infection. After that, it turns to a chocolate brown color then darkens and within 14 days, which then changes the whole color of a pod to black (Lass, 2001a). Also, as noted by Willson (1999) black pod disease is quickly spread in high humidity condition.

Several studies have estimated the economic loss due to black pot outbreak. As cited in Lass (2001a), Padwick estimated the global total cocoa production loss to be a least 10 percent, whereas Medeiros predicted the loss about 30 percent of the total crop. In one untreated control experiment in Nigeria, Ward et al. (as cited in Lass, 2001a) found that infected pods rate was more than 30 percent with one incidence of 60.90 percent loss. Similarly, in Brazil the rate of infected pods was 30.80 percent (de Figueiredo and Lelis, as cited in Lass, 2001). In Papua New Guinea, the infection incidence was from 1.20 percent in dry year to 95 percent in wetter years (Hicks, as cited in Lass, 2001a), and 50-60 percent in Cameroon (Despréaux; Despréaux et al., as cited in Ndoumbe-Nkeng et al., 2004). The rate of black pod incidence in other countries, as cited in Lass (2001a), estimated around 25-30 percent in Ghana (Wharton), 10-20 percent in Dominican Republic (Guzman), 10-80 percent in Togo (Djiekpor et al.) 25 percent in Brazil (Miranda and da Cruz). Therefore, percentage infected is equal to percentage loss.

There are several approaches to prevent or eliminate black pod incidence, as suggested by Willson (1999) the spread of black pod can be minimized by pruning and reducing the cocoa canopy. In addition, all the harvested pods should be taken away from plantation before opening and the infected pods shell must not be returned because it might spread the disease to the entire farm. Compared with no treatment plot, traditional control by removing disease pod could reduce the black pod rate by 22 percent and 31 percent in the two sites in the first year, and by nine percent and 11 percent in the second year, (Ndoumbe-Nkenga, et al., 2004).

Alternatively, chemical control through spraying copper fungicide can also be used to control pod infection, although it is expensive (in some case prohibitively) and not fully effective. It should be started before the disease builds up and should also spray other pods that have not been affected (Lass, 2001a). Another approach, as suggested by Lass (2001a), is through replanting cocoa trees with disease resistance trees such as an Amazon hybrid. However, for small-scale farmers, adopting hybrid cocoa seems unfeasible due to income and knowledge constraints, unless hybrid seeds are distributed freely as a part of government programs.

According to Boahene (as cited in Taher, 1996) there were several factors which influenced adopting hybrid cocoa; first, individual characteristics, such as age, education, family size, years of farming experience; second, social variables, such as network of relations and social status; and third, the institutional condition in which the farmers operate such as the system of land tenure and the system of acquisition of credit, chemical inputs, labor and information. In concluding his study, Boahene (as cited in Taher, 1996) stated that farmers who received extension service and higher levels of knowledge became more successful adopters.

2. Witches' Broom

Witches' broom disease, which is caused by the fungus *Marasmius perniciosus*, mainly happens in South American countries and some West Indian islands (Willson, 1999). The symptoms of this disease are brooms which are much thicker than normal shoot and produce many short lateral shoots (Willson, 1999). It also turns the pod to black and hard before producing and then damages all beans inside the pod (Urquhart, 1955). Witches' broom has a massive effect on cocoa yield. In extreme condition, it may result in yield loss up to 50 percent of the fruits (Hardy, 1960). However, if the infection is uncontrolled, pod losses may rise to 70 percent (Urquhart, 1955).

Several approaches to control Witches' broom attack are through removing all brooms and infected pods and then continue by burning or burying them, spraying fungicide to minimize *Phytophthora* and *Monilia* attack which in turn may also control the Witches' broom, and finally by planting new clone or hybrid which is resistant to disease (Hardy, 1960). In fact, many small-scale farmers obtain cocoa seeds from cocoa fruit in their neighboring farms or seeds that grow under cocoa trees. Therefore, the cost of cocoa farming can be minimized since there is no nursery required for growing the seeds.

3. *Ceretostomella* Wilt

Caused by fungus *Ceratocystis fimbriata*, this disease damages the cocoa trees through entering the hole bored by beetles, which is known as *Xyleborus ferrugineus* or exists due to cutlass or pruning wounds (Willson, 1999; Lass, 2001a). The spread of this fungus has occurred in some of South America, Central America, West Indies, and Asia (Thorold, as cited in Lass, 2001a). Additionally, the symptom of this disease is to cause the whole or part of the tree to wilt and the affected part will die quickly (Willson, 1999; Lass, 2001a).

Moreover, the fungus spreads through spores that fall from the trees with wood dust and flown by the wind and the beetle. Spraying chemical and destroying infected materials to control beetle or fungus have not succeeded yet. In fact, the recommended approach is to remove and burn all infected branches and deed trees. It may prevent beetle and infected debris to spread on the healthy cocoa trees. One has successfully prevented this fungus through minimizing the damage at pruning and harvesting (Lass, 2001a).

4. Cocoa Swollen-Shoot Virus

This disease is mainly caused by the presence of virus. It is a major problem for cocoa farmers in Ghana and Nigeria. It also has been identified and reported in Cote d'Ivoire and other parts of the world. The most dangerous virus is known as 1A or New *Juaben*, which can kill *Amelonado* seedling within few month and 2 years for mature trees (Willson, 1999).

According to Posnette (as cited in Willson, 1999), this disease is spread from tree to tree by mealy bugs, specifically by *P. njalensis* and *P. citri*. As of now there has been no effective treatment for preventing the infection. However, the control can be made by removing all infected plant through cutting below ground level (Willson, 1999; Lass, 2001a). Other approaches include spraying insecticide and biological controls have not been able to mitigate mealy bugs (Lass, 2001a).

Table 5

Pests and Diseases

Pests	Symptoms	Percentage Yield Loss
Mirids or capsids	Mirids or capsids feed by inserting mouthparts into plant result small water-soaked, mirid lesions, and then turn the plant part to black.[a] It also results in the death of terminal branches and leaves, causing dieback.[c]	Up to 75%[c]
Shield bugs	Shield bugs feed mainly pod and hinder beans development and make pods abort.[b]	5 - 18%[c]
Leaf hoppers	Leaf hoppers create distortion and premature fall of leaf. Also, they attack cushions, pods, and stems, and cause pods to wilt.[b]	n.a
Scale insects and mealy bugs	feed by inserting mouthparts into plant tissue and suck the sap.[a] They teem and damage pods.[b]	25-30%[d] due to Capsid and Mealy bugs effect
Rink bark borers	Rink bark borers may Kill young seedling, and affect branches which may also break off larger tree.	n.a
Cocoa moth (Cocoa pod borer)	Cocoa pod borer laid eggs on cocoa pods (difficult to see), then larvae bore through the husk. They made the pods to be full of frass and difficult to be extracted and fermented.	17%[d]

Vertebrates (Elephants, wild cattle, deer, pigs, monkeys, bats, squirrels, rodents, civet cats, some marsupials, woodpeckers, and parrots.[a]	Nowadays, it is caused by small mammals especially squirrels, rats, and civets. They break the pods and eat the beans.	-11% in Ghana; [a1] 1-15% in Nigeria.[a2] 1-10% São Tomé; [a3] 20% in Dominican Republic; [a4] 20% in Fiji; [a5] under coconut in Malaysia 70-90%; [a6] World average 5-10%[a]
Diseases		
Black pod	The symptoms of black pod can be noticed from the pod appearance. Initially, a small clear spot appear on the pod surface which normally emerges under high humidity after two days of infection. After that, it turns to a chocolate brown color then darkens and within 14 days, it changed the whole color of a pod to black.[f]	10% globally[f1], 30% [f2], 30-60.9% in Nigeria [f3]
Witches' broom	The symptoms of this disease are brooms which are much thicker than normal shoot and produce many short lateral shoots.[b] It also turns the pod to black and hard before producing and then damages all beans inside the pod.[g]	Up to 50 percent.[h] with uncontrolled condition 70 percent.[g] 30% - 40% of global production.[c]
Ceretostomella wilt	It causes the whole or part of the tree to wilt and the affected part will die quickly. [b and f]	n.a
Cocoa swollen-shoot virus	This disease is spread from tree to tree by mealy bugs, specifically by *P. njalensis* and *P. citri*. 1A or New *Juaben* which can kill Amelonado seedling within few month and 2 years for mature trees. [b]	42% within 2 years;[i], 50-60% by third year;[i1] 50%[i2]

Source:

a Entwishtle (2001), a1 Taylor, Wharton; a2 Everard; a3 Toxopeus; a4 Soria; a5 William; Juan and Bose, (as cited in Entwishtle, 2001).
b Willson (1999).
c ICCO (n.de).
d Padi, B., G.K. Owusu and N.K. Kumah (as cited in Anikwe, 2010).
e Fasina et al.; Ndubuaku et al. (as cited in Ndubuaku and Asogwa, 2006).
f Lass (2001a); f1 Padwick; f2 Medeiros; f3 Ward et al. (as cited in Lass, 2001a).
g Urquhart (1955).
h Hardy (1960).
i Legg et al.; i1 Blencowe et al., and Brunt; i2 Glendinning et al. (as cited in Hughes and Ollennu, 1994).

C. Labor, Shade and Fertilizer, and Input Used in Cocoa Farming

1. Labor Usage

Labor is one of the most essential components in cocoa farming. It accounts for the largest portion of production costs. One of the main drivers of this is because almost all production processes require manual labor. Labor usage is measured in term of man-days. Upton (as cited in Lass, 2001b) defined total man-days as "the product of the number of men employed and the average number of days worked by each" (p. 234). Intuitively, the assumption for man-days is that the labor of one man for five days is equal to the labor of five men for one working day.

Lass (2001b) clearly discussed the labor usage under establishment, replanting, maintenance and rehabilitation categories by employing the case studies from several cocoa producing countries. In establishment category, Lass (2001b) elaborated labor usage under planted shade with clear-felling in Brazil, Malaysia, and Trinidad with total man-days labor as much as 199, 49, 78, 82, and 72 for year 0, 1, 2, 3, and 4 respectively for Brazil; 195.1, 80.2, 63.8, and 49.3 for year 1, 2, 3, and 4 respectively for Malaysia; and 137.1, 27.9, 45.8, and 18.5 man-days labor for year 1, 2, 3, and 4 respectively for Trinidad (See appendix, Table 1, 2, 3).

Under thinned forests in Ghana and Cameroon, the total man-days labor is as much as 247, 86, 86, and 86 for year 1, 2, 3, and 4 respectively for Ghana, and 262.8, 81.8, 95.9, and 74.7 for year 1, 2, 3, and 4 respectively for Cameroon (See appendix, table 4 and 5), and total man-labor days under coconuts in Malaysia were 115, 53, and 34 for year 1, 2, and 3 respectively (See appendix, Table 6).

The labor usage components under establishment, which normally take up to four years, include clearing and land preparation, lining and staking, lime application (if applicable), road and drain maintenance and water conservation, shade planting, shade maintenance, nursery construction, filling bags and sowing seed, cultural works in nursery, digging planting holes, planting cocoa, weed control, fertilizer application, pest control, diesase control, and prunning and shapping.

The labor requirement is massive in cocoa sector, although it appears cheap in cocoa producing countries compared to the labor in the United State. Indeed, for the small farmers in those countries, labor is still expensive. Bank of Ghana (n.da) reported that the minimum daily wage in 2010 was $2.11 (2010 USD) and increased to $2.59 (2010 USD) in 2011. Whereas, federal minimum wage in the US is $7.25 per hour (United States Department of Labor, 2011), which is 20.14 times greater than the wage in Ghana for 6 work hours.

Replanting category, on the other hand, had been practiced under old cocoa tree in Costa Rica with the age of 49 years old field. The first step was to reduce the amount of existing shade substantially and replaced it with *Inga* sp. as permanent shade. The temporary shade was also established by planting plantain and pruned branches of old cocoa trees. It also involved some other activities, such as, the weed control using herbicide, pruned, fertilizer, and disease control. These activities required man-days labor as much as 157.1, 111, 56.5, and 40 for year 0, 1, 2, and 3 respectively (See appendix, Table 7).

Similarly, replanting process in Brazil was similar to the replanting method Costa Rica or also known as Turrialba method. However, cocoa farm in Brazil used *Erythrina* spp as shading tree. Mandarino and Santos (as cited in Lass, 2001b) concluded that the replanting method for the first four years in Costa Rica required a total labor of 380 man-days per ha, which was 21 percent lower than 480 man day for replanting under shading tree of *Erythrina* spp. Total man-days labor for replanting process in Brazil were 128, 31, 75, 78, and 68 for year 0, 1, 2, 3, and 4 respectively (See appendix, Table 8).

A comparitive economic study by Alvares-Afonso *et al.* (as cited in Lass, 2001) found that replanting under clear falling required 984 man-days per ha which was lower compared to replanting under old cocoa trees which required 1,033 man-day per ha. However, the latter method produced more yield by as much as 3.53 tons per ha.

The maintenance of mature cocoa, in contrast, included the labor usage for weed control, pest control, disease control, shade management, fertilizer application, road and drain maintenance and water conservation, pruning, roads, paths, and bridges, harvesting and breaking pods, fermentation, drying and bagging. In this category, Lass (2001b) compared the maintenance of mature cocoa under several condition such as maintenance of mature cocoa under coconuts, planted shade, and thinned forest shade in Malaysia with total man labor as much as 62.7, 79.5, and 84.3 man-days labor respectively (See appendix, Table 9).

Conversely, the maintenance of mature cocoa with low disease incidence in Colombia required 96 man-days labor (See appendix, table 10), however, the maintenance of mature cocoa with minimal labor usage through the usage of herbicides to control weed as alternative to labor required as much as 79 man-days labor for 1974 study and 57.9 for 1981 study (See appendix, Table 11).

Based on Gockowski (2009) data on Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC) cocoa production system, total man-days labor requirements over 25 years are used for nursery, cocoa establishment, and production stage. Under LILC, labors are needed as much as 2,468.5 man-days or 98.74 on average per year with composition 151 man-days labor for nursery and cocoa establishment, and 2,317.5 man-days labor for production stage. However, the total man-days labor required for High Input, No Shade Amazon Cocoa (HINSC) is as much as 5,620 or 224.81 on average per year where 201 man-days labor for nursery and cocoa establishment, and 5,419.2 man-days labor for production stage (Table 13).

The maintenance of mature cocoa with minimal labor usage through developing small low six-wheeled tractors to transport wet bean from the farm to fermentation and drying plant were 52.7 and 25.7 man-days labor for the 1968 season and 1983 season respectively (See appendix, table 12). For the maintenance of mature cocoa on a plantation in Cameroon, the total man-days labor were 85 (See appendix, table 13), whereas for the maintenance of mature cocoa by small-holders under the traditional system in Ghana and Nigeria, and Togo, the total labor required as much as 63.8, 71.3, and 43 for Akokoaso, Koransang, and Dominas areas respectively in Ghana and Nigeria; and 290, 140, and 270 for Litimé, Plateau, and Kloto areas respectively in Togo (See appendix, Table 14, 15, respectively).

Finally, the rehabilitation involved all cocoa maintenance, harvesting, pod breaking, and fermentation drying. A case study for this category was the rehabilitation of moribound cocoa in Cote d'Ivoire which required 93, 73, 67, and 67 man-days labor for year 0, 1, 2, and 3-30 respectively (See appendix, table 16). Another case was the rehabilitation of abandoned cocoa farm such as in Equatorial Guinea. This process included weed control, pest control, disease control, shade management, fertilizer application, drainage, pruning, harvesting and breaking, and fermentation, artificial drying and collection of wood, which required 57-88 and 55.1 for year 1 and 2 respectively (See appendix, Table 17).

2. Shade and Fertilizer

Cocoa is a fruit tree that requires shade as a protection from direct sun and wind in order to grow efficiently in its early stages of development. It is also required to protect organic matter on the soil from the sun and utilize the fall of branches and leaves to increase organic matter (Urquhart, 1955) and to affect temperature and humidity around the plant which could result transpiration (Wessel, 2001).

In general, cocoa needs less shade as the age of cocoa trees increases. According to Ahenkorah et al. (as cited in Willson, 1999) a young cocoa tree needs heavy shade which then has to be thinned and removed during the first few years to provide optimum shade level for mature cocoa. Young cocoa trees are also very sensitive to direct sun-light, high solar radiation level, and moisture. Hutcheon (as cited in Wessel, 2001) found that the decline in photosynthetic rate is caused by moisture stress resulted in closure of the stomata during the high radiation period. Several species that are commonly used for shading trees are *Gliricidia sepium, Leucaena glauca and Leucane leucocophala, Albizzia, Erythina poeppigiana and Erythina glauca, Erythina Lithosperma,* and *Parkia javanica* (Willson, 1999).

On the other hand, shade and fertilizer also have a close interconnection in increasing cocoa yield. According to Willson (1999), the fertilizer response will increase as the level of shade is reduced. Conversely, "Shade reduces photosynthesis, transpiration, metabolism and therefore, the demand on soil nutrients and so enables crops to be obtained on soils of lower fertility" (Purseglove, as cited in Beer J., 1987, p. 4).

Similarly, Cunningham and Arnold (1962) reported that cocoa without shade responded much more to fertilizer than shaded cocoa. Empirical evidence on fertilizer, shade, and yield can be traced to the works of Evan and Murray (as cited in Wessel, 2001), Obiri, Bright, McDonald, Anglaaere, & Cobbina (2007), and Ghana 1976/70 (as cited in Willey, 1975).

Table 6 provides yield comparasion between the use of shade, fertilizer and yields of dry cocoa in Ghana. During 1960/61-1968/69, it shows that the use of shade with no fertilizer gave the yield from 555 kg to 1,329 kg/ha, whereas the use of shade with fertilizer resulted the yield about 763 kg to 1,842 kg/ha. Conversely, full sunlight and no fertilizer yielded about 1,222 kg to 2,750 kg/ ha, while the no shade method and fertilizer gave the yield about 2,366 kg to 3,901 kg/ha.

Table 6

The Effect of Shading and Fertility Level on Yields and Dry Cocoa (Kg/Ha)

Year	Shade		No Shade	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
1960/61	788	1,088	2,750	3,901
1961/62	555	763	1,702	2,735
1962/63	758	1,168	2,350	3,307
1963/64	1,163	1,570	2,266	3,395
1964/65	1,329	1,842	2,537	3,678
1965/66	1,130	1,727	1,973	3,283
1966/67	977	1,424	1,352	2,696
1967/68	1,063	1,706	1,340	2,679
1968/69	999	1,800	1,222	2,366

Source: Ghana 1969/70 (As cited in Willey, 1975).

Similarly, table 7 shows that no shade and fetilizer also gave higher yield than shade with fertilizer in Bahia, Brazil. Shade and no fertilizer yielded 907 kg/ha, whereas shade and fertilizer resulted 1,258 kg/ha. Conversely, no shade and no fertilizer gave an estimated yield 1,064 kg/ha, no shade and fertilizer resulted 1,680 kg/ha (Table 7).

Table 7

Effect of Shade Removal and Fertilizer Application on Mature Cocoa in Bahia Brazil. Mean Annual Yields of Twenty-One Sites over the Period 1964-1973 in Kg Dry Beans Per Ha

	No fertilizers	Fertilizers
Shade	907	1,258
No shade	1,064	1,680

Source: Cabala-R et al. (as cited in Wessel, 2001).

As reported in a study by Hurd and Cunningham (1961) on shade, fertilizer and number of cocoa pods, un-shaded cocoa gave more yield than the shaded cocoa and the fertilizer application yielded a small increase in the number of cocoa pods. Table 6 shows that total pods in 1958 for shade with no fertilizer and fertilizer were 12.7 and 14.4 pods respectively. It sharply increased to 39.1 and 48.6 under no shade condition with no fertilizer and fertilizer respectively.

Table 8

Number of Pods Harvested Per Tree

Year	Period of cropping	Shade		No Shade	
		No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
1958	Mid-crop	0.8	1.9	2.1	4.9
	Main crop	11.9	12.5	37.0	43.7
	Total	12.7	14.4	39.1	48.6
1959	Mid-crop	1.2	1.5	4.4	7.1
	Main crop	8.5	10.0	31.0	42.9
	Total	9.7	11.5	35.4	50.0

Source: Hurd and Cunningham (1961).
Note: Mid-crop from 1st July, main crop over rest of year.

2.1 Shade

Full shade is mostly used for young cocoa trees. Ample empirical evidence has shown the relationship between shade, growth of young cocoa, and yield. Evan et al. (as cited in Wessel, 2001), who tested the effect of five light densities, 15, 25, 50, 75, and 100 percent full light and fertilizer on the yield and growth of young cocoa, found that the growth was best for first 12-18 months of cocoa in the field with light intensity of 30 to 60 percent and little effect of fertilizer. At the age of three, the yield of cocoa was low as a respond to 15 and 25 percent light and the fertilizer had little effect. Evidence from Cote d'Ivoire showed that the application of fertilizers, maintaining shade and thinning can extend productive life of cocoa tree for a longer period (Abanda, n.d).

However, yield and response to fertilizer increased as the light intensity rose up to 50 percent, but in the absence of fertilizer and light intensity of more than 50 percent, the yields of cocoa fell significantly. In contrast, the yields increased as a result of fertilizer and 75 percent of light (Murray, as cited in Wessel, 2001).

Besides that, following a regression model by employing the natural logarithm of cocoa yield (per tree) as the dependent variable, Obiri et al. (2007) reported that the traditional system for cocoa with insufficient shade resulted in the highest yield of 800 kg per ha in year 24 with a total yield of 3,503 kg over years 5-15. However, when the farmer planted hybrid cocoa with shade and under labor and money limitations, the highest yield was achieved at age 16. This method gave a peak yield of 970 kg per ha and total yield of 7,367 kg over years 5-15. Therefore, the decision making whether to opt for traditional system or high technology with hybrid cocoa depends on the farmer's level of knowledge, income to purchase inputs such as fertilizers, pesticides and personal equipment, and government support.

On the other hand, Beer, Muschler, Kass, & Somarriba (1998) stated that there are two physiological benefits from shading trees. The first is that the improvement of climatic and site conditions which reduce air and soil temperature extremes, wind speeds, buffering of humidity and soil moisture availability and improvement or maintenance of soil fertility including erosion reduction. Second is to reduce nutritional imbalances and dieback.

2.2 No Shade

The relation between no shade method and yield in cocoa area has widely been discussed in the literature. According to Willson (1999), mature cocoa gives a high yield in the absence of shading trees. Similarly, Wessel (2001); Cunningham and Arnold (1962) stated that yields increased significantly as a large respond from fertilizer and the interaction between full sunlight and nutrient application. In the same tune, Willey (1975) confirmed that in full sunlight, the yield potentials are ultimately higher.

A study by Hurd and Cunningham (as cited in Wessel, 2001) provided detail number of pod production following four treatments to cocoa farm. For treatment with shade, the number of pod harvested was 12.70 pods, whereas treatment with shade and fertilizers resulted 14.40 pods, furthermore, no shade treatment produced 39.1, and no shade and fertilizer treatment generated 48.6 pods. In the same vein, Obiri et al. (2007) examined the cocoa variety, shade and yield in Ghana. They found that hybrid cocoa planted without shading trees gave a peak yield of 1,200 kg per ha in year 12 with a total yield of 10,200 kg over years 5–15.

2.3 Fertilizer

In Ghana, soil degradation, deforestation and pollution from mining industries are the most serious environmental problems (Hansen et al., as cite in Alfsen, Bye, Glomsrød, and Wiig, 1997). Accodding to Diao and Sarpong (2007), long term soil and vegetation degradation are caused by many factors including rapid population growth, increased urbanization, and climatic changes. Whereas the short term degradation is caused by natural factors and human activities such as physical and other characteristics of the soil, climatic conditions for natural factor, and unsustainable farming practices, removal of vegetation cover (including deforestation and overgrazing), mining activities, and urbanization and industrial activities caused by increased population growth pressures for human activities.

Specifically, agricultural farming systems used in Ghana can be categorized as rotational bush fallow, permanent tree crop, compound farming, mixed farming, and special horticultural farming systems. The first is characterized by clearing and burning of the vegetative cover, which may destroy the vegetative cover and make the soil susceptible to erosion and leaching to soil infertility. The second is characterized by the cultivation of a mono-crop such as cocoa and coffee, where during the early age of tree life-cycle, it predisposes the soil to some form of degradation. Other main processes of land degradation in Ghana are physical (in the form of soil erosion, compaction, crusting, and iron-pan formation), chemical (depletion of nutrients, salinity, and acidification), and biological (loss of organic matter) (Diao & Sarpong, 2007). Therefore, fertilizer is critical to boosting cocoa production due to the loss of nutrient from soil.

Willson (1999); Thong and Ng (1978) listed type of fertilizers which are required by cocoa trees, such as nitrogen (N) which is necessary for the production of the vegetative components, Phosphorous (P) is used for growth processes, Potassium (K) is for fruit production, Calcium (Ca) is necessary to optimal pH on soil, Magnesium (Mg) is for soil, Manganese (Mn), Zinc (Zn), Baron, Aluminum, and Chlorine.

In general, the loss of nutrient is also caused by removing yield (beans and husks), immobilization in stem and branches, and leaching of nutrients below the rooting zone (Hartemink, 2005). Despite the age of cocoa trees, potassium, nitrogen, and calcium are the largest nutrients which are loss from cocoa farm (Thong & Ng, 1978). Specifically, Hartemink

(2005) differentiated the loss of nutrient from removal beans and husks using the data from Venezuela. For 1,000 kg dry beans, approximately 20 kg N, 4 kg P, and 10 kg K are removed from the farm. The amount nutrient is increased to about 35 kg N, 6 kg P, and 60 kg K per 1,000 kg beans, when the husks are removed.

Hardy (1960) provided a general application to restore the nutrient loss for mature of non-shaded cocoa and shaded cocoa. For 454 kg dry beans removed from the farm, the amount of nutrients required for the former per 0.4 hectare per year as follow; N 45 kg, P_2O_5 25 kg, K_2O 45 kg, and MgO 11 kg. The latter, however, required the nutrients as follow; N 27 kg, P_2O_5 25 kg, K_2O 45 kg, and MgO 11 kg.

In fact, obtaining those amounts of conventional fertilizers for small scale farmers seems unattainable due to higher price of the fertilizer and unavailable in local market. As a comparison, cocoa farmers in Cote d'Ivoire need as much as 52 kg of cocoa in order to purchase one bag of fertilizer, whereas Indonesian cocoa farmers only need 8 kg of cocoa to get the same amount of fertilizer (FSG Social Impact Advisors, 2009).

FAO (2005b) also stated that Ghanaian farmers have some constraints in using fertilizer such as insufficient credit support to the farmer, high lending rates by commercial banks for the agricultural sector, problems with the marketing of agricultural produce, the dependence on rain for crop production, the dependence on donor sources for funding of agricultural projects, and improper use of fertilizers by farmers.

Table 9

Estimation of Nutrient Requirements of Cocoa Plants at

Different Stages of Development from Whole Plant Analysis

Category of plant development	Range of age of plants (months)	Average nutrient requirements (kg/ha)						
		N	P	K	Ca	Mg	Mn	Zn
Nursery (Seedling)	5-12 in nursery	2.4	0.6	2.4	2.3	1.1	0.04	0.01
Immature	28 in field	136	14	151	113	113	3.9	0.5
Mature (1st year production)	39 in field	212	23	321	140	140	7.1	0.9
Mature (full production)	50-87 in field	438	48	633	373	373	6.1	1.5

Source: Thong and Ng (1978).

The nutrient requirements also depend on the stages of cocoa trees development. Thong and Ng (1978) estimated that as cocoa trees grew, they required greater amount of potassium, nitrogen and calcium, whereas magnesium, phosphorus manganese, and zinc were required less. Additionally, cocoa tree also started to require more nutrients at immature and production stages. Table 7 provides detail nutrient requirements for four stages of plant development.

Furthermore, the effect of fertilizers on the pods has various results. A study in Trinidad found that fertilizer application led to increased yield, however it gave a reduction in the weight of wet cocoa per pod or in other words cocoa beans weights lighter (Havord et al., as cited in Lass, 2001). In contrast, a trial in Malaysia by (Mainstone and Thong 1978, as cited in Lass, 2001) found that an increase of fresh pod weight required for 1 kg dry bean resulted from a yield respond to K. In Nigeria, however, N and P application increased the yield in the series I and II trials on farmers' cocoa, but did not affect wet bean weights. Cunningham and Arnold (1962) found that water-soluble phosphate could significantly increase cocoa yield by 20 percent in

Ghana, however no respond had been found from nitrogen, potassium, magnesium, calcium, and micro-nutrients.

3. Pesticide

FAO (2005a) defined pesticides as "any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport" (p. 6). Similarly, Bateman (2008) referred pesticide as "any substance which is used to control a pest: at any stage in crop production, storage or transport" (p. 14).

Currently, the term of pesticide is no longer limited to pests, but it also applies to any organisms that harm crops, such as insects, diseases, weeds, etc. (Bateman, 2008). The groups of pesticide include fungicides which is used for crop diseases such as black pod; herbicides which is used to kill weeds; and insecticides which is used for controlling insect, pests, mites, nematodes (eelworms), rats and mice, slugs and snails, and bactericides (Bateman, 2008).

Many studies have found huge loss in agricultural production if pesticides were not applied. Pimentel, et al. (1992) estimated the loss would increase from zero to almost 100 percent in absence of pesticide applications. In cocoa production, Sonwa (as cited in Sonwa et al., 2008) estimated the loss due to black pod incidence will be more than 60 percent without pesticide application. Capsids, on the other hand, which affect the yield through breaking down the husk and rotting of the bean mass in larger pods (Entwistle, 2001), incured the production loss to 70 percent (PAN, as cited in Sonwa et al., 2008). Also, in Nigeria, mirid caused 25-30 percent loss in cocoa yield, cocoa pod borer incurred 17 percent loss, and black pod attributed 30-90 percent loss (Fasina et al.; Ndubuaku et al. as cited in Ndubuaku and Asogwa, 2006).

More importantly, pesticide applications have significantly increased the agricultural production and reduced the impact of insect, fungus, and weed attacks. Pimentel et al. (1992) estimated that every dollar spent on pesticides resulted in about four dollars ($4) in crops saved. In cocoa production specifically, several studies have shown positive effect of pesticide applications on disease reduction and yield improvement. A study by Opoku, Assuah, & Aneani (2007) showed that pesticide application could reduce the black pod disease by 25 percent to 48 percent and increased the yield by 10.90 percent to 51.80 percent when Ridomil 72 plus (12 percent metalaxyl + 60 percent copper-1-oxide), which cost $1.22 (2010 USD) per sachet 50 gram, combined with crop sanitation practices were applied. In addition, they also found greater disease control and higher yields could be also achieved when sanitation practices were combined with three fungicide applications than only sanitation practices or combining them with one or two fungicide applications.

Likewise, another study by Tijani (2006a) on costs, returns and productivity of fungicide use in cocoa production under the Structural Adjustment Programme (SAP) in South Western Nigeria found that the use of fungicides were profitable to minimize black pod disease with total net return ranged from $592 (2010 USD) in Osun State to $1,031 (2010 USD) in Ondo State with an average of $851 (2010 USD) for the combined study area. The average cost of purchasing and applying fungicide per hectare was $3 (2010 USD)/ha/treatment in Osun State and $5.15 (2010 USD)/ha/treatment in Ondo State with an overall average of $4.10 (2010 USD).

Similarly, Krauss and Soberanis (2002) comparatively examined cultural control, fungicide treatment, untreated control, and two commercial bio control (*Clonostachys rosea* and *Trichoderma spp.*) on the cocoa diseases *moniliasis*, witches' broom, and black pod in Peru from 1998 to 2000. They found that fungicide treatment and bio control *C. rosea* strain G-4 did not reduce disease. Conversely, *Trichoderma longibrachiatum* and *Trichoderma stromaticum* reduced witches' broom and *Trichoderma virens* reduced black pod. The study also revealed that the yield increased by 15 percent when bio control were combined with other applications. The benefit-cost ratio was highest for cultural control alone, followed by bio control, and lowest for fungicidal control. Overall, bio control gave the highest net returns when combined with fertilization (9.10 percent above cultural control without fertilization), whereas without fertilization, bio control only accounted for 3.60 percent increase.

Despite some advantages of applying pesticides, many cocoa farmers still cannot afford to acquire them. Based on an assessment on agrochemical usage pattern of cocoa farmers in Ondo State, Nigeria, Adeogun and Agbongiarhuoyi (2009) found that cocoa farmers had some constraint to obtain agro-chemical because high cost of chemicals, weak extension linkages, inadequate government support, problem of adulterated chemicals, and low access to government input such as chemicals and poor price of cocoa bean. Similarly, in the humid forest zones of southern Cameroon, the high cost and unavailability were two main constraints among more than 60 percent of the farmers who had already used pesticides (Sonwa, Coulibaly, Weise, Adesina, & Janssens, 2008).

There are a number of pesticides have been used by cocoa farmers. In southern Cameroon, cocoa farmers commonly used Nordox, Kocide, Cacaobre and Ridomil, which were generally copper-based active ingredients (Sonwa, et al., 2008). In Nigeria, Ndubuaku and Asogwa (2006) reported insecticides which were recommended and approved for mired control such as organophosphates (Diazinon, Fenitrothion, Quinalphos); Organic Hydrocarbon (Endosulfan, mixture of Endosulfan and Deltamethrin) and Carbamates (Isoprocarb, Propoxur and Dioxacarb). For disease control, copper-based fungicides were recommended such as Caobre Sandoz, Ridomil Plus, Ridomil Gold, Perenox Kocide 101, Champ DP, Funguran and Copper Nordox. Lass and Wood (1985) also recommended metalaxyl (Ridomil) for controlling black pod. Whereas in Idanre local government area of Ondo state, Nigeria, Tijani (2006a) indentified pesticides namely Gammalin 20, Aldrex 20, Perenox, Cacaobre Sandoz, copper sulphate, Basudin, Thionex and Unden which were classified as ‘highly’ or ‘moderately’ hazardous by the world Health Organization (WHO).

Regardless of the significant contribution in increasing agricultural production, pesticides have caused environmental, social, and public health degradation. According to Pimentel et al. (1992), pesticide benefit is only based on direct crop returns. In general, indirect cost of environmental and economic associated with pesticides does not take into account. Those indirect costs include accidental poisonings like the aldicarb/ watermelon crisis; domestic animal poisonings; unrecorded losses of fish and wildlife and of crops, trees, and other plants; losses resulting from the destruction of soil invertebrates, micro flora, and micro fauna; true monetary costs of human pesticide poisonings; water and soil pollution; and human health effects such as cancer and sterility. Thus, if those costs are included, the total cost will be greater than the benefit (Pimentel et al., 1992).

In fact, in most low income countries, these pesticides are handled by people who are illiterate to read the labels and are not trained on how to apply them. Based on a pesticide practices survey on more than 3,000 farmers in West Africa by Rutherford (2011), about 76 to 97 percent of farmers used high level of chemical with consisted of more than 30 different active substances. The survey also revealed that only 46 percent of them received information on proper use and 10 to 31 percent ever received any formal training on chemical use. However, about 57 percent of farmers used products as recommended (instructions) and 55 percent used any form of protective clothing or equipment. Similarly, a survey by Adeogun and Agbongiarhuoyi (2009) in Ondo state Nigeria found that 58.90 percent of farmers who participated in the survey had no formal education. Likewise, Tijani (2006b) found that farmers did not take necessary precautions to prevent hazards associated with their use. As a result, after applying pesticides, farmers and farm workers suffered headaches, tiredness, vomiting and nausea and skin problems such as skin burn and itching.

D. Organic Cocoa

The term organic is widely used to describe and define not only limited to a chemical free agricultural product but also to describe a sustainable and friendly environmental method of farming. Currently, there are several definitions in use around the world. Codex Alimentarius (1999), an intergovernmental body with over 180 members which was established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), define 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).

Similarly, the International Federation of Organic Agriculture Movements (IFOAM) (n.da), the worldwide umbrella organization for the organic movement, uniting more than 750 member organizations in 116 countries, define "Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

IFOAM (n.db) proposed four basic principles of organic farming namely the principle of health, the principle of ecology, the principle of fairness, and the principle of care. Each of the principles has its own explanation. The former explains that "Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible." The second explicates that "Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them." The third clarifies that "Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities" and the latter elucidates that "Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment" (IFOAM, n.db).

Given the increased demand for organic cocoa products in high income countries and the growing social concern for producers in low income countries, consumers are now shopping holistically on issues such as food safety, health, and environmental issues. Euromonitor

International (as cited in ICCO, 2010) estimated that the sale of worldwide organic chocolate increased from $171 million in 2002 to $304 million in 2005. Pay (2009) estimated that world the global premium chocolate market will grow from $7 billion in 2007 to $12.90 billion (or $3.60 billion in the United States alone) in 2011.

Despite the growing demand for organic cocoa, the share of organic cocoa is still relatively very small which is estimated less than 0.50 percent of the total production (ICCO, n.db). ICCO (n.db) also estimated the production of certified organic cocoa at 15,500 tons, which originally came from Madagascar, Tanzania, Uganda, Belize, Bolivia, Brazil, Costa Rica, Dominican Republic, El Salvador, Mexico, Nicaragua, Panama, Peru, Venezuela, Fiji, India, Sri Lanka and Vanuatu. Another record showed that the sales of sustainable cocoa by the end of 2008, which accounted for 1.20 percent of global sales, reached 46,896 metric tons or grew by 248 percent since the last five years (Potts, Meer, & Daitchman, 2010).

In terms of organic cocoa price, Liu (2008) opined that it strongly fluctuates over time mainly due to the small volumes traded, quality issue, and abnormal supply patterns. Basically, the calculation for certified organic cocoa is set on the basis of world market prices and Fairtrade premiums (ICCO, n.db). On one hand, the cocoa producers who convert their cocoa operation from conventional to organic production will receive a benefit in terms of premium price. ICCO (2007a) estimated that the premium price of cocoa ranges from $100 (2010 USD) and $300 (2010 USD) per ton. In January 2011, ICCO monthly average of daily cocoa prices was $3,164.86 (2011 USD) (ICCO n.dc) and Fairtrade minimum and premium prices for organic cocoa were $2,300 (2011 USD) and $200 (2011 USD), respectively with date of validity started on January 1, 2011 (Fairtrade International, 2011). These figures indicate that the premium price paid to cocoa farmers was only 6.32 percent from ICCO price.

This premium price, however, is used to cover the cost of performing the conditions of cocoa production and certification fees. ICCO (n.db) also stated that other benefits for certified producer organizations are better "capacity-building" and "market access."

In fact, many are still debating the cost and benefit of growing cocoa organically. In order to obtain certified organic cocoa, cocoa producers have to follow all requirements that are set by Fairtrade organization or other organic certified organizations. These requirements include standard of production and marketing, inspection arrangements and labeling requirements. It is also required the cocoa producer to grow the cocoa on land which is pesticide and fertilizer free for three consecutive years before harvesting (ICCO, 2006).

On the other hand, the costs associated with the organic standard include the certification fee that has to be paid by the farmer organization to the organic certification body and other indirect costs. The total fee includes an initial application fee and an annual certification fee on a fixed basis or in proportion to sales of three percent of farm turnover (ICCO, 2006). Specifically, since December 2004 Fairtrade Labeling Organization (FLO) required producer associations and traders to pay certification fees. The fee structure for trader includes the first time application fee up to $2,649 (2011 USD) and the annual certification fee up to $3,973 (2011 USD) which depend on the total annual gross sales. Correspondingly, the fee structure for cocoa producer comprises the initial application fee up to $6,887 (2011 USD), certification renewal $662 (2011 USD) per year, and the fee of the cocoa value sold under fair-trade conditions as much as 0.45 percent of the FOB value (ICCO, 2006).

Besides, turning from non-organic to certified organic cocoa incurs some additional costs which include cost of participation in the FLO system such as certification fees, documentation costs, and the production costs to meet the FLO standards such as additional labor costs in which organic production requires more labor-intensive than conventional farming, social and environmental costs, and opportunity costs due to yield loss after discontinuing to use conventional inputs (ICCO, 2005; ICCO, 2006).

An empirical study by Victor, Gockowski, Agyeman, and Dziwornu (2010) examined the cost and benefit of certified sustainable cocoa production in Ghana using the concept of net present value (NPV). Following Rainforest Alliance-Sustainable Agricultural Sustainable (RA-SAN) standard of 70 shading trees per ha, they found that the yield loss was about 30 percent compared to the full sun yield of the High Input no Shade Cocoa (HINSC) system. However, they also found that the benefit of certified cocoa was the yield increase by 25 percent following certification training, which exceeded the costs of certification.

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

For cocoa producers, the decision to convert their operation to organic farming is not only stimulated by the premium price, but is also caused by the producers' inability to provide conventional fertilizer and pesticide for their farms and the farmers' perception on soil nutrient. A study by Agbeniyi, Ogunlade, & Oluyole (2010) used descriptive statistics and multivariate

Logit model to examine the fertilizer use among one hundred and seven respondents in Cross River State, Nigeria. They reported several reasons why cocoa farmers did not use fertilizer on cocoa farms. About 39 percent of respondents felt that the soil was well fertilized, 25.23 percent opined that the commodity was not always available, 16.82 percent argued that fertilizer was too costly, 15.89 percent stated that they did not have enough money to purchase fertilizer, and 0.93 percent said that they received fertilizer too late.

E. Replanting and Rehabilitation of Cocoa Trees

As a fruit tree, cocoa can grow for more than a hundred years. However, as the age of cocoa trees increases, the yields significantly decrease. Based on an observation survey in Trinidad, Shephard (as cited in Lass, 2001c) found that on average about 50 percent of cocoa trees grew up to 40 years, about 10 percent survived up to 60 years, and only small percentage could live up to 80 years. Similarly, Montgomery (1981) concluded 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 26 to 45 years and the production costs slightly increase (Montgomery, 1981).

Hardy (1960) explained that the decline in cocoa production is caused by four factors; First, diminishing productivity of the site and soil; Second, increasing age of field; Third, poor management; and Fourth; unsuitable cocoa varieties initially planted. The former is caused not only by soil fertility, but also by physical condition of soil which depends on soil structure and texture. Several other factors that cause diminishing productivity are excessive and inadequate shade, physical damage by cutlass wounds, falling branches from shade trees, diseases and pests, and other causes such as poor drainage, weeds and grass, poor tree-sites, reduction in amount of leaf-litter, lack of nutrient balance, deficiency of minor nutrient elements, and soil erosion.

The second factor looks at the increasing age of the field by comparing two old cocoa fields of 50 years old in which they were planted respectively on good and bad soil. A cocoa tree in good soil could produce about 0.59 kg, whereas in bad soil a cocoa tree could only produce up to 0.18 kg per tree. The third factor focuses on human aspect. Hardy (1960) described that the farm is abandoned when "the times are bad," either due to war which are not allowed farmers to go to cocoa farms or find other jobs. As a result, it leads to a situation where the farmers do not give attention to cocoa farm such as for pruning, draining, reaping, supplying, disease and pest control, and general orchard sanitation. The last factor looks at the cocoa varieties. Hardy (1960) believed that new cocoa varieties are high-bearing under a wide range of environment circumstance. Hence, Asare and David (2010) suggested that if a cocoa tree produces less than 10 or less pods per year, the farmer should consider for replanting.

The term rehabilitation and replanting have been widely used in literature. However, in order to avoid the confusion to the meaning of rehabilitation and replanting, this study will list the definition of those terms. Hardy (1960) defined rehabilitation as "the transformation of an old plantation whose yields have declined so as no longer to be profitable" (p. 200). In the same path, Lass (2001c) considered rehabilitation to be "the process of restoring yield by improved cultivation and management of existing mature cocoa trees" (p. 212). Conversely, replanting is considered as "the planting of the young cocoa trees where old cocoa trees used to grow" (Lass, 2001c, p. 212).

Replanting and rehabilitation are considered as essential in order to maintain the profitability of cocoa farm. However, this study will focus its review and analysis only on replanting aspect. As suggested by Lass (2001c), replanting process in cocoa farm can be done through several methods such as partial replanting, complete replanting or clear-felling, phased farm replanting, and planting under old cocoa trees methods. However, each of methods of replacement carries its own advantages and disadvantages.

Partial replanting is a method of replacement of the unprofitable trees over a period of years in order to remove all the poor yielding trees (Lass, 2001c). This method takes a five year period to identify unprofitable trees, prune weak trees, plant temporary shade, and clear field drains. Then, the trees that have been marked are cut down, and followed by planting the young cocoa, fertilize, and prune the young cocoa trees (Lass, 2001c). According to Asare and David (2010) the advantages of partial planting are the farmers still receive revenue from existing cocoa trees while the partial replanting is in process; and there is no new land area required. On the contrary, disadvantages involve the spread of cocoa swollen shoot virus disease from the existing trees to newly planted trees. Also, the farmers have to combine many activities in which considerable amount of labor are required. As concluded by Shephard (as cited in Lass, 2001c), it is expensive to fill or plant every dead tree or blank space over the farm, as it delays no less than fifteen years prior gaining profitable yields and insufficient extra yield to offset the losses from injuries among the surviving trees.

Unlike partial planting, complete replanting involves the removal all cocoa and shade trees. Asare and David (2010) argued that it is the best method of replanting on unproductive farms due to the age of the tree, diseases and pests, and unavailable alternatives to make the farm more productive. The advantage of this method is to disrupt the cycle of disease spreading to the new cocoa trees in the area where swollen shoot disease is prevalent. The disadvantage, however, is the requirement of massive labor and inputs, thus it is considered as a costly method (Asare & David, 2010). Moreover, Murray (as cited in Lass, 2001c, 2001), who compared the yield of complete and partial planting, found that partial planting had much lower yields than complete planting in total yield after five years.

However, complete replanting seems impracticable for smallholder cocoa farmers, since it requires huge capital and labor investment during a short period. Additionally, smallholder cocoa farmers will lose their revenue stream for the first three years by following complete replanting. Therefore, without alternative income to support families for the first three years of production cycle, this method is unfeasible to implement.

Besides partial and complete planting, phased farm replanting is a replanting method by replanting a certain percentage of cocoa trees annually until the entire farm has completely been planted (Lass, 2001c). The advantage of this method is able to spread the labor demand over the time and create one time losses on a part of revenue. However, Lass (2001c) stated that this method is widely adopted on large plantations and farms, but there is no intrinsic explanation why all cocoa farmers, including small scale farmers, cannot adopt this method. One of the areas that implemented this method was Brazil. As reported by Vasconcelos and Alvin (as cited in Lass, 2001c) the cocoa farmers cut down the cocoa trees over forty years of age and replanted within a season with 10 percent per annum. Nevertheless, there was no further report on this application after replanting was completed.

Finally, the planting under old cocoa trees is best applied when cocoa trees are over 30 years old (Asare & David, 2010). Under this method, old cocoa trees are intended to provide shade to the new trees. The success of this method depends on how laborers, supervisors and managers appropriately manage the shade to control weed growth and bring the young cocoa quickly into bearing period (Lass, 2001c). The advantage of using this method is that the income can still be generated from existing trees; old trees provide shade to newly planted cocoa; there is no additional land area required; and it is less expensive than other methods. Conversely, the disadvantage includes possibility of transmitting the disease from old the newly planted trees; damage to young trees when removing old trees (Asare & David, 2010). Therefore, this method is not recommended if the cocoa swollen shoot virus and black pod disease are prevalent.

F. Production Economics Theory, Net Future Value (NFV) and Net Present Value (NPV), and Steady State

1. Stages of Production

The life cycle of production in cocoa farming falls into 4 stages: (1) an early period of no yield which normally takes from year 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.

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, is a declining region where MPP is negative.

These stages are important in understanding where a firm (or individual) should choose to produce to maximize profit. Debertin (1986) stated that by operating at stage II, costs could be minimized and output could be increased by reducing the level of input use. As a result, greater net return can be achieved. This current study is also designed to maintain the stage of production at stage II, where yield and profit reach their maximum level.

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

Future value is an important and useful concept in finance. The concept of future value is not only used and applied by bankers, investors, economist, but also by the farmers who want to know the future value of their assets. Scott and Moore (1984) stated 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) defined 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). A common phrase, "a dollar today is worth more than a dollar tomorrow" is generally used to describe the importance of the present value concept. Theoretically, the present value uses an interest rate or a discount rate to compute present value of future asset/ money.

3. Steady State

Steady state literally means “a stable condition that does not change over time or in which change in one direction is continually balanced by change in another” (The American Heritage dictionary of the English language, 2000). Therefore, in this study, steady state is referred to as a situation where the yield and the average age of cocoa trees are constant from the point where the steady state is achieved until the end of study period or infinity.

G. Replacement Model and Empirical Works

Replacement models have been widely applied in many areas, for example, in forestry, fruit trees, cattle, and depreciating asset such as equipment and vehicle. 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) looked at the appropriate time to replace an asset in which it gave the highest return. He concluded 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). It is clear that replacement is needed to seek 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 focuses on the occurring probability of an event which is equal to one, and the future and net value discounted associated with singled valued yields Faris (1960). Conversely, the latter uses a transition matrix to determine the events’ probabilities among the variables through each time period (Ward and Faris, 1968).

In his seminal work, Faris (1960) discussed the deterministic concept of optimal replacement using three different types of production assets. First production asset is dry-lot cattle feeding operation. Generally, this operation had a short period of production and with revenue being obtained after the asset was sold. Therefore, According to Faris (1960), the cattle should be sold when marginal net revenue equals maximum average net revenue. This model also allowed the optimal replacement to incorporate with the changes in price and cost of production.

Second is timber production. Timber had a long production period and with return being received after the asset was sold. This type of production consisted of some costs such as initial cost of planting, establishing, and maintenance. The decision whether to harvest the forests and replace them at the end of the year or leave them to grow for another year was based on the comparison of which options gave higher expected net revenue. The concept of replacement for timber was "when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the enterprise immediately following" (Faris, 1960, pp. 761-762).

A third example is fruit tree production. In this case is peach tree. Fruit production has a long period of production with revenue being obtained throughout the life of the tree. It had the same principle as timber production where the net revenue was obtained in a lump sum. One advantage of this asset is that the repayment loan for establishing cost could be repaid by the revenue generated from the peach trees before they were replaced. The only additional aspect is that the interest of unpaid balance of the establishing cost should be compounded.

Several empirical works that adopted Faris' model have been done, for example, by Arope (1971) and Ismail and Mamat (2002) in palm oil area. Arope (1971) used combination of yields of oil palm and kernel as a revenue determnination. Instead of using fresh fruit brunches (FFB) price, Arope used crude palm oil (CPO) and kernel prices. She found that the optimal replacement with difference price level and interest rate happened at age from 31 years to more than 35 years. However, Arope suggested that the replanting should be considered at the age after 30 due to palm oil height which could incure higher harvesting cost and marginal yield.

A study by Ismail and Mamat (2002) employed several data and assumptions, for example, production was assumed up to 32 years due to height constraint; cost variable included land clearing lining, holing, seddling planting, fertilizer, and others; wage; and price of fresh fruit brunches (FFB) which was based on CPO prices. The optimum replanting age depanded on the price of FFB, cost, technology, and discount rate. Ismail and Mamat (2002) found that when the price of FFB was $64.10 (2011 USD) per ton, the optimal replanting age ranged from 25 to 26 years. However, when the FFB price increased to $70.51 (2011 USD) per ton, the replacement age declined to range 24 to 25 years.

Furthermore, the deterministic model can also be traced back to the work of Perrin (1972). He examined two different types of asset replacement decisions; a continuous-time replacement model and replacement with technologically improved asset. The former involves the replacement of existing asset "defender" with the purchase of new asset "challenger" in order to maximize present value when net return of existing asset equal to the return from replacement asset. This model can be used to determine the maximum age of wine and time for harvesting the forest.

The latter is used to determine the replacement time for an asset with technologically improved asset. In this part, the existing asset should be kept until the marginal revenue equal to the revenues which could be obtained as interest on the sale value of defender and the capitalized value of challengers. In addition, the asset will also be held for another year if net return from an existing asset is larger. However, deterministic models still have some disadvantages. According to (Etherington, 1977), it has a serious deficiency which assumes constant prices and a fixed yield pattern over the study period. Indeed, price always changes following demand and supply. Whereas the yield is not only determined by the age of tree and weather pattern, but also by inputs application such as fertilizer and pesticide, soil condition, and good farm management.

Following the Perrin' deterministic model, Jayasuriya (as cited in Etherington, 1977) used discrete parametric changes in yield curves, product prices, and interest rate. He concluded that optimal replacement age had little been influenced by changes in rubber latex prices; increased in interest rate prolonged the optimal cycle; fell in all value of annuity was caused by discount term.

The stochastic model, on the other hand, is developed by Ward and Faris (1968) for the replacement of plum trees. In this study, they examined optimal replacement using a Markov Chain Process in the form of matrix and with the movement of transition probabilities from one stage to another. Ward and Faris (1968) also employed dynamic programming technique because the model determined the optimal replacement based on the age, yield, net revenue, the state, and the probability. In contrast, they also utilized the deterministic model to compare the result with deterministic model. In fact, the results that were found in both models were the same. Therefore, Ward and Faris (1968) concluded that the deterministic model is the most appropriate model to be used because it is much simpler and required less data.

In contrast to the net present value (NPV) approach for perennial corps, Tisdell and De Silva (2008) explored maximum sustainable yields (MSY) on coconut with the objective to maximize yield by finding the length of replacement cycle, and to minimize the variability over time through determining the pattern in steady state. In this analysis, Tisdel and De Silva (2008) used data only on density and age as factors that influenced yields and employed the logarithmic functional form. They found that the maximum yield was at age 36 and the optimal yield-maximizing replacement cycle was at 66 years. Tisdel and De Silva (2008) also set two conditions of the age of palms; not uniform and uniform. They recommended that in order to achieve the optimality and reach the steady state, coconut palms should be replaced approximately 1/66 or 1.50 percent each year. However, if the costs had been taken into account, the optimal replacement cycle would be longer.

III. DATA AND METHODOLOGY

A. Data

This study empirically examines the costs and returns to determine the optimal return associated with the timing and replacement rate of four common cocoa production systems in Ghana. The production systems range from (1) Low Input, Landrace Cocoa (LILC) which is a traditional cocoa cultivation that has not largely been influenced by modern agricultural practices, (2) High Input, No Shade Amazon Cocoa (HINSC), (3) High Input, Medium Shade Cocoa (HIMSC), and (4) Organic production. Data on yield, inputs and cost on an annual basis from planting to year 25 are obtained from Gockowski (2009), whereas price of cocoa is obtained from the International Cocoa Organization (ICCO).

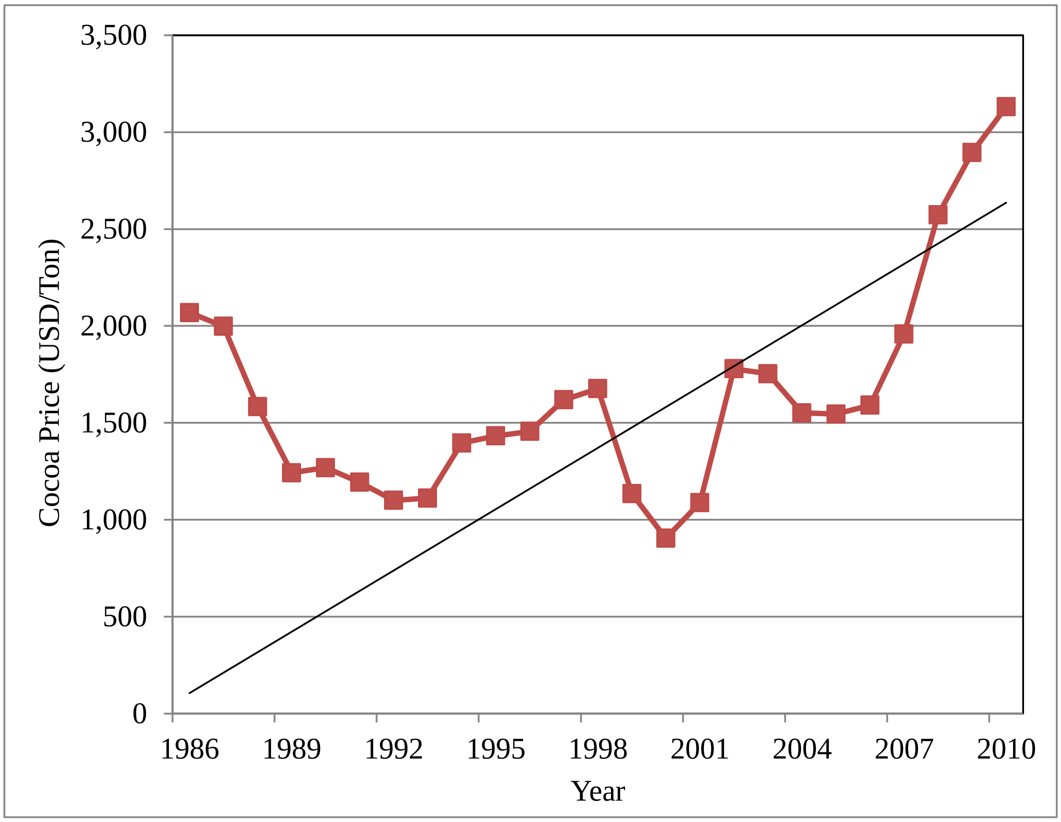
The cost structure is determined by the number of laborers employed per day and the amount of inputs used. The return, however, is calculated based on the amount of yield (kg/ha) multiplied by the current/estimated price of cocoa ($/kg). Each cocoa production system has a different cost and yield structure. Additionally, inflation, which is based on the percentage of annual average inflation in December 2010, was estimated at 10.26 percent (Bank of Ghana, n.da). Whereas the discount rate, which is based on Treasury bill rates for a six month period, was 10.67 percent, the most recent available (Bank of Ghana, n.db).

1. Baseline

In determining the optimal return associated with cocoa replacement, the following variables, which are a part of costs structure and price, are also employed as the basis of estimation in a baseline model. First, ICCO cocoa price is $3,305.79 /metric ton (2011 USD) per May 2, 2011 (ICCO, n.dd). The model assumed that the cocoa price increases by three percent per year which is based on the average price increase from 25 years of historical cocoa price data 1986-2010 (Figure 6) (International Monetary Fund (IMF), 2011a).

Figure 6

Historical New York and London Cocoa Price

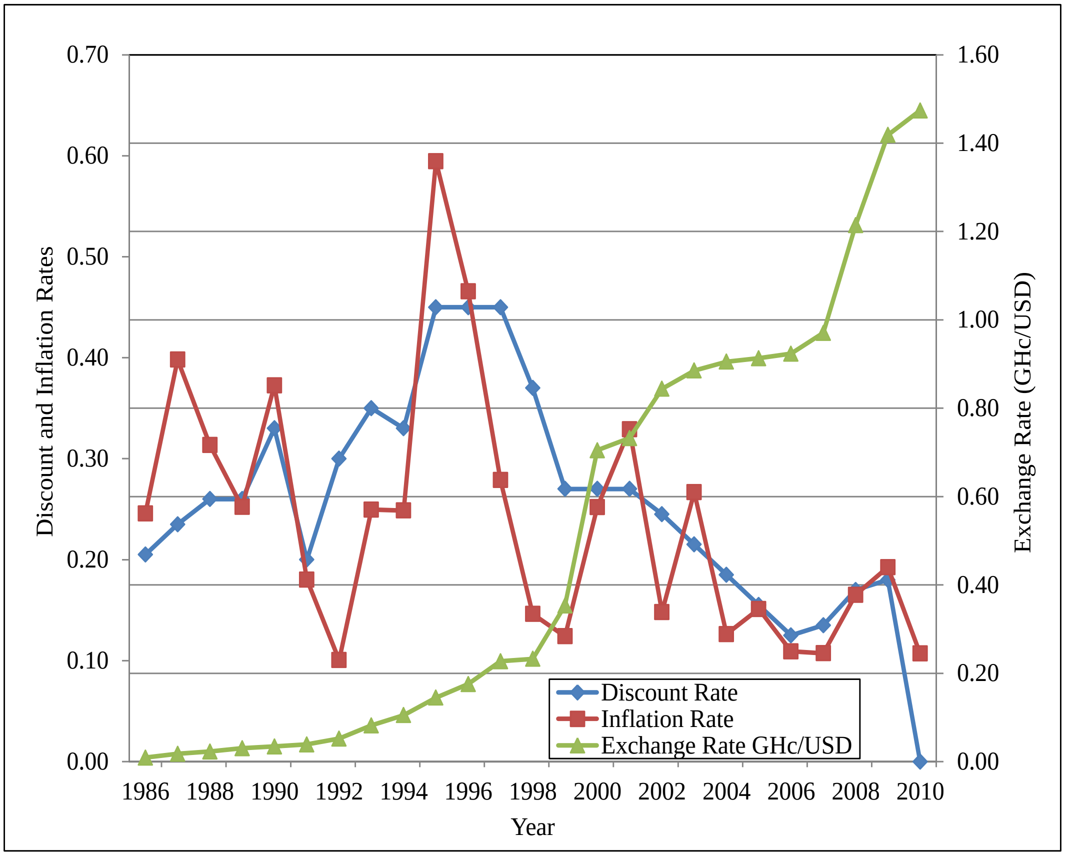


Source: IMF (2011a).

Second, labor price is fixed at GHc 3.5 /day or $2.37 (2010 USD). Third, the fertilizer, insecticide, and fungicides prices are also fixed 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). Third, inflation and discount rate are 10.26 and 10.67 percent per year, respectively (Bank of Ghana, n.db). Fourth, the exchange rate is GHc 1.4738 /USD as per 2010 (IMF, 2011b), Table 10.

Figure 7

Historical Inflation, Discount, and Exchange Rates



Source: IMF (2011b).

Subsequently, a new estimation (models 1-6), which is based on the changes in projected cocoa price, fertilizer price, labor price, exchange rate, inflation and discount rates, percentage yield loss and wide area infected due to black pod incidence, is carried out to determine the highest net present value (NPV) given the replacement rate and time (Table 10-12). Furthermore, this study uses Microsoft Excel as a tool to do model computations and derive solutions.

In this study, model 1 assumes that the cocoa price will increase to five percent (from three to five percent), holding other variables constant. This assumption is built based on a three percent increase in cocoa price associated with an average historical increase from year 1985 to 2010 and a two percent increase which is assumed because of shortage supply due to political unrest in cocoa producer countries and cocoa disease incidence which caused harvest failure (Figure 7).

Model 2 projects the fertilizer price will increase five percent, holding other variables constant. This is based on an assumption that the fertilizer subsidy in Ghana will be removed gradually and influenced by shortage of supply. In model 3, the inflation rate is expected to increase by 4.74 percent (from 10 to 15 percent), holding other variables constant. In many low income countries such as Ghana, inflation rate is often very high which can reach more than 20 percent historically (Figure 7). Model 4 projects the labor price to increase by five percent, holding other variables constant (Table 10). This is based on the Bank of Ghana (n.da) report on the minimum daily wage which has increased to GHc 3.73 in February 2011.

In model 5, the percentage yield lost due to black pod is projected at 30 percent and the percentage cocoa farm per hectare infected is 10 percent, holding other variables constant (Table 11). As estimated by Padwick (as cited in Lass, 2001a), global cocoa production loss due to black pod is roughly 10 percent, whereas Medeiros predicted the loss about 30 percent. Finally, model 6 assumes the percentage yield loss due to black pod 40 percent and percentage cocoa farm per hectare infected is 10 percent (Table 11). Yield loss estimation is based on a finding by Ward et al. (as cited in Lass, 2001a) where infected pods rate was more than 30 percent up to 60.9 percent. Those estimations are applied to LILC, HINSC, and HIMSC production systems.

However, under Organic Cocoa production system, the baseline model assumes that production loss due to converting from conventional to organic farming is 30 percent and premium price is 10 percent. In model 1, production loss is assumed 30 percent and premium price is expected to increase by 10 percent (from 10 percent to 20 percent) (Table 12).

Table 10

Assumptions for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), and High Input, Medium Shade Cocoa (HIMSC)

	Baseline Model	Model 1	Model 2	Model 3	Model 4
Cocoa Price (USD/MT)	3305.79	3305.79	3305.79	3305.79	3305.79
Projected Cocoa Price Increase (per year)	3%	*5%*	3%	3%	3%
Labor Price (GHc)	3.5	3.5	3.5	3.5	3.5
Projected Labor Price Increase (per year)*	0%	0%	0%	0%	*5%*
Fertilizer Price (GHc)	14.7	14.7	14.7	14.7	14.7
Projected Fertilizer Price Increase (per year)*	0%	0%	*5%*	0%	0%
Insecticide Price (GHc)	16.80	16.8	16.80	16.80	16.80
Projected Insecticide Price Increase (per year)*	0%	0%	0%	0%	0%
Fungicide Price (GHc)	1.8	1.8	1.8	1.8	1.8
Projected Fungicide Price Increase (per year)*	0%	0%	0%	0%	0%
Exchange Rate (USD/ GHc)	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%
Discount Rate (%)*	10.67%	10.67%	10.67%	10.67%	10.67%

* Used to simulate future model.

Table 11

Assumptions for Production Loss due to Black Pod

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

* Used to simulate future model.

Table 12

Assumptions for Organic Cocoa

	Baseline Model	Model 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%

* Used to simulate future model.

2. Low Input, Landrace Cocoa (LILC)

Under LILC system, cocoa are planted at 3 x 3 m spacing (1,100 plants/ha) (Victor et al., 2010). No nursery costs incur as the seeds are directly planted on the soil using unimproved local landrace cocoa varieties. In addition, no fertilizer is applied under this system. The farmers use pesticides (Confidor and Ridomil) to control pests and diseases. Other materials which are used include cutlass, raffia material, basket, pruning knife, and water. The cost of labor and material for planting plantain and cocoyam as intercropped are excluded in this model. Victor et al. (2010) also assumed that shade levels for LILC system are moderate.

The cost structure of labor under the LILC system is divided into two different stages. First, cocoa establishment stage uses labor for slashing, land burning/clearing, digging planting holes, transporting seedlings to site, planting at stake, and formation pruning. Second, the production stage employs labor for under brushing cocoa, structural pruning/chupon removal, pod harvesting and collecting, pod breaking, fermentation, transport to drying site, drying and sorting, and transportation to purchase clerk (Table 13).

3. High Input, No Shade Amazon Cocoa (HINSC)

Cocoa under HINSC system is planted with mixed Amazon hybrid at 3 x 3 m spacing (1,100 plants/ha) and without permanent shade (Victor et al., 2010). Edwin and Masters (2005) categorized mixed Amazon hybrid as "traditional variety" which is derived from Mixed Amazon. Mixed Amazon hybrid is also known as F3 Amazon. Its bearing year is at the age of 5-6, where soil fertility and husbandry practices, especially shade management are sensitive to production period.

The cost of inputs for cocoa cultivation under HINSC system includes polybags, mixed hybrid seeds, watering cans, cutlass, 7.42 bags of 50 kg (371 kg) Asaasa Wura fertilizer (NPK 0-

22-18+9CaO+7S+6MgO(s) active ingredient), 0.48 liter of Confidor pesticide and 36 sachets (50 gram) of Ridomil, which are used to control insects and black pod diseases, respectively. Each agrochemical is applied annually after the first three years, except Confidor which is used for first year for cocoa nursery.

The cost structure of labor under HINSC system is divided into three different stages. First is the nursery which consists of preparing site of 30 square meters, filling the soil into 1,400 polybags, planting cocoa seed, watering nursery, and spraying pesticides. Second is the cocoa establishment stage which uses labor for slashing, tree felling, burning/clearing, digging planting holes, transporting seedlings to site, planting seedling, and formation pruning. Third is the production stage which employs labor for under brushing cocoa, structural pruning/chupon removal, fertilizer application, insecticide application, fungicide application, pod harvesting and collecting, pod breaking, fermentation, transport to drying site, drying and sorting, and transportation to the purchase clerk (Table 13).

Under the nursery section, the difference of 300 seedlings between actual planting and nursery are also based on an estimation of seedling death due to disease attacks during nursery phase and as a substitute of the seedling death due to drought and disease attacks during first three years of planting, based on first hand of experiences in Indonesia.

4. High Input, Medium Shade Cocoa (HIMSC)

In this category, cocoa is planted with mixed hybrid seeds at 3 x 3 m spacing (1,100 plants/ha) and with medium permanent shade. The cost of inputs for cocoa cultivation under HIMSC system includes polybags, mixed hybrid seeds, watering cans, cutlass, 7.42 bags of 50 kg (371 kg) Asaasa Wura fertilizer (NPK 0-22-18+9CaO+7S+6MgO(s) active ingredient), 0.48 liter of Confidor pesticide and 36 sachets (50 gram) of Ridomil which are used to control insect and cocoa black pod diseases respectively. Each agrochemical is also applied annually after the first three years, except Confidor which is used for first year for cocoa nursery (Table 13). The cost structure of labor under HIMSC system is the same as in High Input, No Shade Amazon Cocoa (HINSC) (Table 14).

5. Organic Cocoa

The budget for organic cocoa is derived from the HIMSC budget. In this category, cocoa is planted at 3 x 3 m spacing (1,100 plants/ha) with medium permanent shade. The model maintains several input costs such as polybags, mixed hybrid seeds, watering cans, cutlass, and personal protection equipment and storage. However, all materials related to agrochemical applications such as 7.42 bags of 50 kg (371 kg) Asaasa Wura fertilizer (NPK 0-22-18+9CaO+7S+6MgO(s) active ingredient), 0.48 liter of Confidor pesticide and 36 sachets (50 gram) of Ridomil are excluded from the cost structure (Table 14).

Conversely, the labor cost under Organic Cocoa system is the same as in High Input, No Shade Amazon Cocoa (HINSC), except the model excludes the labor cost for fertilizer, pesticide, fungicide applications, and the cost of application and certification for certified cocoa (Table 13).

The study also excludes the cost and revenue from plantain, cocoyam, and timber as temporary shade for newly planted cocoa trees because this study tries to estimate the timing and replacement rate based on cost and return from cocoa only. On the other hand, since the organic budget is derived from high inputs budget, the model estimates yield reduction as 30 percent as proposed and estimated by Victor et al. (2010) and Phuoc et al. (2008). However, the premium price of certified cocoa is included in the analysis as a basis of estimation.

Table 13

Summary Inputs, Labor, and Yield for Low Input, Landrace Cocoa (LILC) and High Input, No Shade Amazon Cocoa (HINSC)

	LILC			HINSC		
	Unit	Price*	Total	Unit	Price*	Total
Inputs						
Fertilizer (Asaasa wura 50 kg/Bag)	-	9.97	-	170.66	9.97	1,702.20
Insecticides (Confidor/ Liter)	2.76	11.40	31.46	11.07	11.40	126.19
Fungicides (Ridomil 50 g/Sachet)	792.00	1.22	967.30	828.00	1.22	1,011.26
Polybags/ Piece	-	0.01	-	1,680.00	0.01	11.40
Local landrace seeds direct seed	1,333.20	-	-		-	-
Mixed hybrid seeds	-	-	-	67.20	0.07	4.70
Watering cans	-	10.18	-	2.00	10.18	20.36
cutlass	23.00	3.39	78.03	23.00	3.39	78.03
Raffia material	10.00	20.36	203.56	-	-	-
Basket	360.00	2.71	977.07	-	-	-
Mistblower	-	-	-	-	-	-
Pruning knife	10.00	4.75	47.50	-	-	-
Water	608.33	1.36	825.53	-	-	-
Total Inputs	-	-	3,130.43	-	-	2,954.14

Table 13 continued

	LILC			HINSC		
	Unit	Price*	Total	Unit	Price*	Total
Labor (Man-days/ Day)						
Nursery						
Preparing site (30 sq m)	-	2.37	-	4.00	2.37	9.50
Filling 1400 polybags	-	2.37	-	3.60	2.37	8.55
Planting seed	2.40	2.37	5.70	2.40	2.37	5.70
Watering nursery	-	2.37	-	57.60	2.37	136.79
Spraying pesticides	-	2.37	-	1.20	2.37	2.85
Total Labor for Nursery	2.40	2.37	5.70	68.80	2.37	163.39
Cocoa establishment						
Slashing	16.47	2.37	39.11	75.00	2.37	178.11
Tree felling	-	2.37	-	4.00	2.37	9.50
Burning/cleaning	19.76	2.37	46.93	30.00	2.37	71.24
Digging planting holes	52.17	2.37	123.90	6.00	2.37	14.25
Transporting seedlings to site	18.97	2.37	45.05	3.60	2.37	8.55
Planting at stake	37.94	2.37	90.11	3.60	2.37	8.55
Formation pruning	3.29	2.37	7.82	10.00	2.37	23.75
Total Labor for Cocoa Establishment	148.61	2.37	352.91	132.20	2.37	313.95

Table 13 continued

	LILC			HINSC		
	Unit	Price*	Total	Unit	Price*	Total
Labor (Man-days/ Day)						
Production Stage						
Underbrushing cocoa	1,136.20	2.37	2,698.26	1,380.00	2.37	3,277.24
Structural pruning/chupon removal	75.75	2.37	179.88	230.00	2.37	546.21
Fertilizer application	-	2.37	-	69.00	2.37	163.86
Insecticide application	-	2.37	-	92.00	2.37	218.48
Fungicide application	-	2.37	-	92.00	2.37	218.48
Pod harvesting and collecting	152.50	2.37	362.15	631.08	2.37	1,498.69
Pod breaking	635.40	2.37	1,508.95	1,037.70	2.37	2,464.34
Fermentation	12.71	2.37	30.18	76.18	2.37	180.92
transportation to drying site	25.42	2.37	60.36	435.53	2.37	1,034.31
Drying/sorting	76.25	2.37	181.07	1,134.53	2.37	2,694.31
Transportation to purchase clerk	203.33	2.37	482.86	241.17	2.37	572.72
Total Labor for Production Stage	2,317.54	2.37	5,503.71	5,419.19	2.37	12,869.56
Grand Total Labor	2,468.54	2.37	5,862.33	5,620.19	2.37	13,346.90
Yield**	7,717.36	3.53	27,204.62	16,964.56	3.53	59,802.12

Source: ICCO (n.d).

*All prices are in 2010 USD where 1 USD is 1.4738 Ghc (IMF, 2011b).

** Total yield in 25 years.

Table 14

Summary Inputs, Labor, and Yield for High Input, Medium Shade Cocoa (HIMSC) and Organic Cocoa

	HIMSC			Organic Cocoa		
	Unit	Price*	Total	Unit	Price*	Total
Inputs						
Fertilizer (Asaasa wura 50 kg/Bag)	170.66	9.97	1,702.20	-	-	-
Insecticides (Confidor/ Liter)	11.07	11.40	126.19	-	-	-
Fungicides (Ridomil 50 g/Sachet)	828.00	1.22	1,011.26	-	-	-
Polybags/ Piece	1,680.00	0.01	11.40	1,680.00	0.01	11.40
Local landrace seeds direct seed	-	-	-	-	-	-
Mixed hybrid seeds	67.20	0.07	4.70	67.20	0.07	4.70
Watering cans	2.00	10.18	20.36	2.00	10.18	20.36
Cutlass	23.00	3.39	78.03	23.00	3.39	78.03
Raffia material	-	-	-	-	-	-
Basket	-	-	-	-	-	-
Mistblower	-	-	-	-	-	-
Pruning knife	-	-	-	-	-	-
Water	-	-	-	-	-	-
Total Inputs	-	-	2,954.14	-	-	114.49

Table 14 continued

	HIMSC			Organic Cocoa		
	Unit	Price*	Total	Unit	Price*	Total
Labor (Man-days/ Day)						
Nursery						
Preparing site (30 sq m)	4.00	2.37	9.50	4.00	2.37	9.50
Filling 1400 polybags	3.60	2.37	8.55	3.60	2.37	8.55
Planting seed	2.40	2.37	5.70	2.40	2.37	5.70
Watering nursery	57.60	2.37	136.79	57.60	2.37	136.79
Spraying pesticides	1.20	2.37	2.85	-	2.37	-
Total Labor for Nursery	68.80	2.37	163.39	67.60	2.37	160.54
Cocoa establishment						
Slashing	75.00	2.37	178.11	75.00	2.37	178.11
Tree felling	4.00	2.37	9.50	4.00	2.37	9.50
Burning/cleaning	30.00	2.37	71.24	30.00	2.37	71.24
Digging planting holes	6.00	2.37	14.25	6.00	2.37	14.25
Transporting seedlings to site	3.60	2.37	8.55	3.60	2.37	8.55
Planting at stake	3.60	2.37	8.55	3.60	2.37	8.55
Formation pruning	10.00	2.37	23.75	10.00	2.37	23.75
Total Labor for Cocoa Establishment	132.20	2.37	313.95	132.20	2.37	313.95

Table 14 continued

	HIMSC			Organic Cocoa		
	Unit	Price*	Total	Unit	Price*	Total
Labor (Man-days/ Day)						
Production Stage						
Underbrushing cocoa	1,380.00	2.37	3,277.24	1,380.00	2.37	3,277.24
Structural pruning/chupon removal	230.00	2.37	546.21	230.00	2.37	546.21
Fertilizer application	69.00	2.37	163.86	-	2.37	-
Insecticide application	92.00	2.37	218.48	-	2.37	-
Fungicide application	92.00	2.37	218.48	-	2.37	-
Pod harvesting and collecting	430.63	2.37	1,022.66	301.44	2.37	715.86
Pod breaking	708.09	2.37	1,681.58	495.66	2.37	1,177.11
Fermentation	51.98	2.37	123.45	36.39	2.37	86.42
transportation to drying site	297.19	2.37	705.78	208.04	2.37	494.04
Drying/sorting	774.17	2.37	1,838.50	541.92	2.37	1,286.95
Transportation to purchase clerk	164.56	2.37	390.81	115.19	2.37	273.57
Total Labor for Production Stage	4,289.62	2.37	10,187.05	3,308.64	2.37	7,857.39
Grand Total Labor	4,490.62	2.37	10,664.39	3,508.44	2.37	8,331.88
Yield**	11,576.04	3.53	40,806.93	8,103.23	3.53	28,564.85

Source: ICCO (n.d).

*All prices are in 2010 USD where 1 USD is 1.4738 Ghc (IMF, 2011b).

** Total yield in 25 years.

B. 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 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. In other words, taking inflation into account, the price of the same amount of labor and materials will be nominally more expensive in the future.

Additionally, the study also takes into account the discount rate to determine present value of money over the future earnings from cocoa farm. Discount rate considers the importance of the time value of money. The basic notation of discount rate is that the money available today is more valuable than the same amount of money available in the future due to the possibility to earn certain amount of interest over a period of time and the risk of anticipated future cash flows.

Cocoa is a perennial crop that generates costs and returns over the life cycle. Figure 8 shows the yields that are estimated over the 25 year period for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa (Gockowski, 2009). Conversely, figure 9 shows the cost incurred over the 25 year period for LILC, HIMSC, HINSC, and Organic Cocoa. The cost fluctuation under LILC system is caused by inputs procurement such as raffia material (rope) every 5 years, basket every 2 years, and pruning knives every 5 years.

Figure 8

Yield and Age of Tree for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa

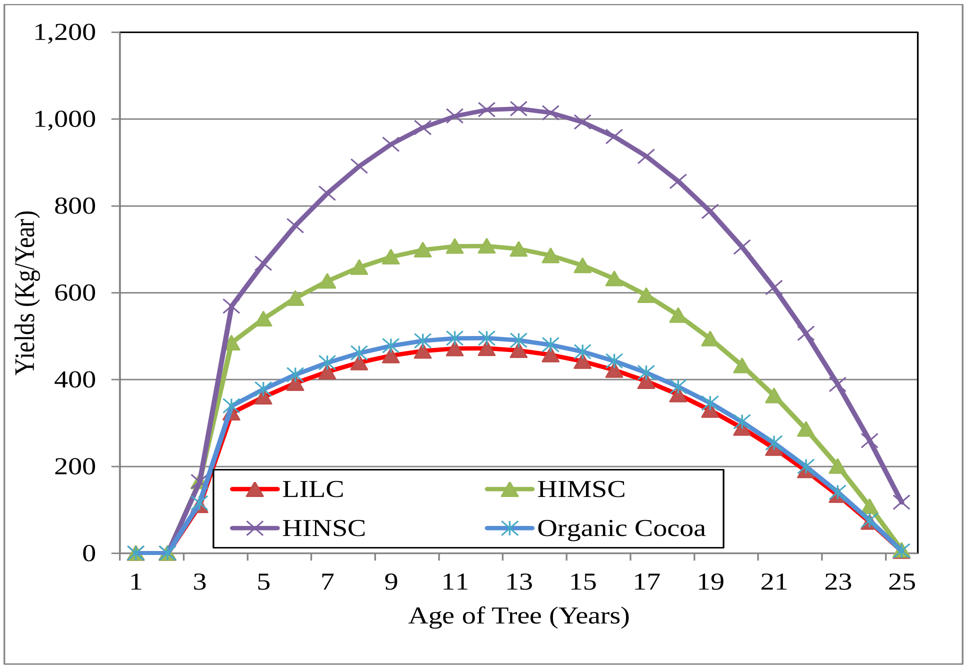
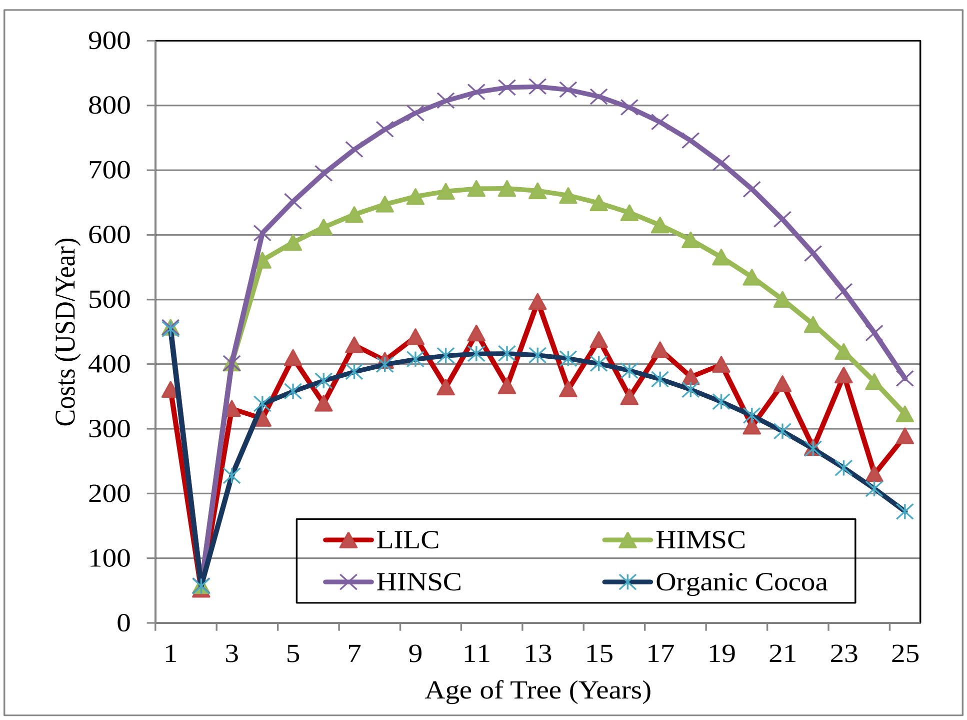


Figure 9

Cost and Age of Tree for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa



The Net Present Value (NPV) and Net Future Value (NFV) used in 100 year study are as follow:

1. Net Future Value (NFV)

$$NFV = \sum_{t=1}^{T} \mathrm{Yld}_t * \mathrm{P}_t(1+\mathrm{r})^{\mathrm{t}} - \sum_{t=1}^{T_{NP}} \mathrm{C}_t(1+\mathrm{r})^{\mathrm{t}} - \sum_{t=T_{NP}+1}^{T} \mathrm{C}_{Pt}(1+\mathrm{r})^{\mathrm{t}} \quad (1)$$

Where: NFV = Net Future Value

Yld_t = Yield (kg/ha) of cocoa at period t.

$\mathrm{P}_t(1+\mathrm{r})^{\mathrm{t}}$ = Cocoa price at period t compounded with inflation rate r.

$\mathrm{C}_t(1+\mathrm{r})^{\mathrm{t}}$ = Cost of cocoa at period t compounded with inflation rate r.

$\mathrm{C}_{Pt}(1+\mathrm{r})^{\mathrm{t}}$ = Cost of new cocoa replanting at period t compounded with inflation rate r.

2. Net Present Value (NPV)

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

Where: NPV = Net Present Value

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

To determine annual average return, the model divided the NPV by 100, since the goal is to estimate NFV for 100 years in order to ensure steady state achieved.

The process of determining the highest return involves several steps. First, given the baseline estimation data on yield, price, cost, inflation and discount rate, the model estimates Net

Future Value (NFV) associated with percentage and year of cocoa replacement. Second, the model computes Net Present Value (NPV) over Net Future Value (NFV) and divides the result by 100 to determine the average profit per year over the study period. Finally, new estimation is employed by taking into account the changes in projected cocoa price, fertilizer price, labor price, exchange rate, inflation and discount rates, and percentage yield loss and wide area infected due to black pod incidence (model 1-6).

The decision of replacement rate and year of replacement are determined based on the highest Net Present Value (NPV) over Net Future Value (NFV). A matrix is developed to compute various combinations of percentage of replacement rates which range from four percent to 10 percent and year of replacement from year 5 to year 20. A combination of percentage of replacement rates and year of replacement which gives the highest Net Present Value (NPV) will be selected as the basis of optimal replacement.

IV. RESULTS

This chapter presents the results of the model's solution to the optimal annual replacement rate and age of replacement of 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 production as described in the previous chapters.

A. Low Input, Landrace Cocoa (LILC)

Low Input, Landrace Cocoa (LILC) is defined as a production system that used unimproved local landrace cocoa varieties and no fertilizer application.

1. Low Input, Landrace Cocoa (LILC) Baseline Model

The baseline model under the Low Input, Landrace Cocoa (LILC) production system employs several assumptions which are described in table 10.

Table 15 presents the optimal annual replacement rate and age of replacement under these initial baseline assumptions. The model suggests that it is most profitable for cocoa producers to replace five percent of their orchards beginning in year eight to generate average net present value (NPV) of $989.99 (2010 USD/Ha/Year).

Conversely, with a zero percent annual replacement rate, the annual average net present value (NPV) is $260.58 (2010 USD/Ha/Year) over the study period which is 100 years. These results suggest that substantial economic gain can be achieved (279.92 percent higher) or $729.41 (2010 USD) per year when using the optimal replacement rates compared with the status quo of retaining a tree until it no longer bears fruit.

Table 15

Average Net Present Value (NPV) for Baseline Model under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year)

Replacement Rate*/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	900.56	988.07	947.61	876.42	801.38	729.59	658.33
6	900.52	989.24	950.68	880.71	806.54	735.38	671.91
7	900.15	989.87	953.78	885.33	812.24	741.92	679.02
8	899.37	989.99**	956.57	890.03	818.21	748.88	686.74
9	898.15	989.55	958.87	894.60	824.32	756.15	694.88
10	896.44	988.49	960.35	898.77	830.30	763.45	703.22
11	894.19	986.76	960.98	902.24	835.91	770.63	711.53
12	891.35	984.29	960.71	904.71	840.79	777.29	719.55
13	887.92	981.06	959.52	905.99	844.70	783.26	727.01
14	883.83	977.02	957.35	906.10	847.26	788.09	733.62
15	879.14	972.22	954.24	905.12	848.47	791.64	739.05
16	873.77	966.57	950.12	902.95	848.30	793.44	742.98
17	867.78	960.13	945.03	899.63	846.83	793.77	745.01
18	861.13	952.87	938.95	895.16	844.01	792.58	745.37
19	853.89	944.87	931.97	889.62	839.97	790.01	744.17
20	846.08	936.15	924.13	883.06	834.76	786.11	741.49
Average	883.39	974.82	950.68	895.03	832.75	771.39	715.24
Max	900.56	989.99**	960.98	906.10	848.47	793.77	745.37
Min	846.08	936.15	924.13	876.42	801.38	729.59	658.33

* Net present value (NPV) at zero percent replacement rate is $260.58 (2010 USD/Ha/Year).
** Denotes the solution with the highest average net present value (NPV).

Furthermore, figure 10 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. If this phenomenon persists, the profit in the long run will be zero. Figure 10 also shows that in the first two years of production cycle, profit is negative due to the establishing cost (planting and annual costs) (Table 13) and no revenue is being realized during early period of cocoa planting. This is due to the fact that cocoa trees start to bear the fruit in their third year.

Figure 10

Net Present Value (NPV) Over 100 Years for Baseline Model under Low Input, Landrace Cocoa (LILC)

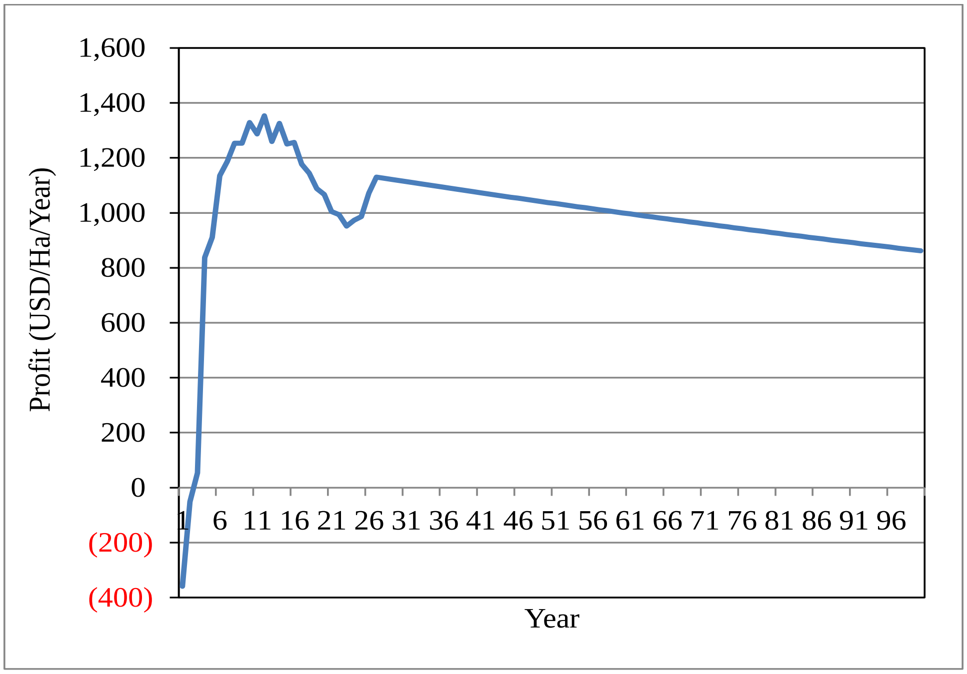


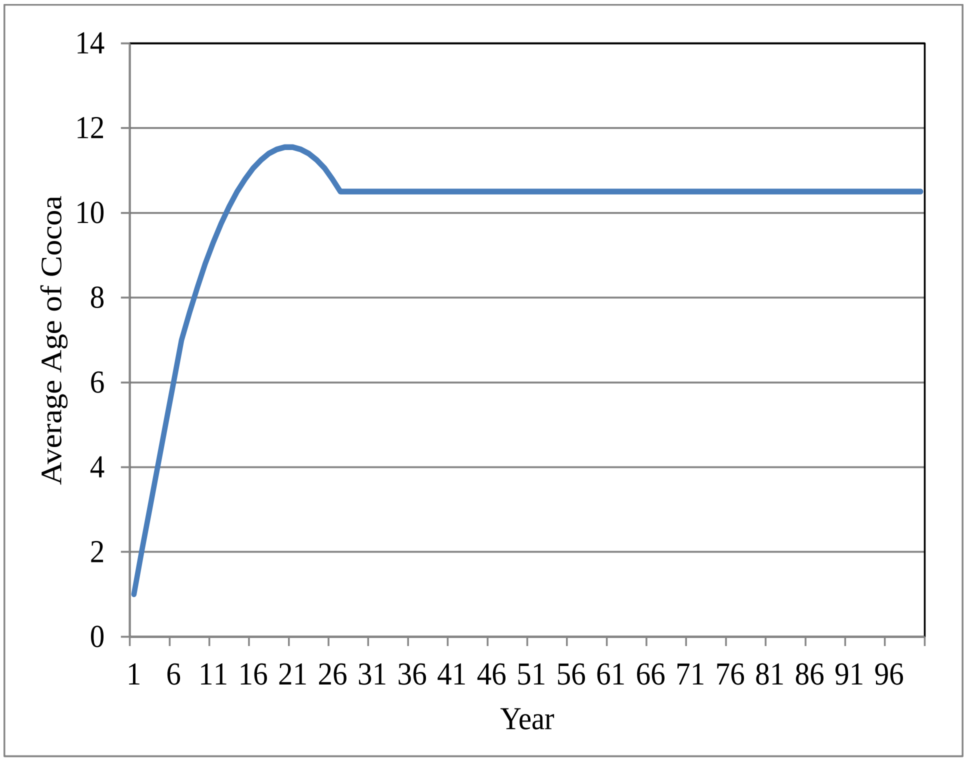
Figure 10 shows that the highest profit is achieved at year 12 with net present value (NPV) $1,353.06 (2010 USD/Ha) before gradually declining due to the impact of higher discount rate than inflation rate after year 27.

Profit can never be achieved as high as the initial $1,353.06 (2010 USD/Ha) in the steady state period. This is due to the age variation of cocoa trees where about 75 percent of cocoa trees at year 12, which is at the highest productivity and bear the fruit at the same time, is 12 years old and about 25 percent of cocoa trees is at one to five years old.

The age of cocoa trees in the steady state ranges from 1 to 20 years old, where only five percent of the cocoa trees are at the highest productivity or at 12 years old. Whereas the rest of cocoa trees are at a period of no yield, a period of increasing yield at an increasing rate, a period of increasing yield at a decreasing rate, and a period of decreasing yields.

Figure 11

Average Age of Cocoa Trees for the Optimal Baseline Model under Low Input, Landrace Cocoa (LILC)



Furthermore, following this optimal solution, all first generation of cocoa trees will have been cut and replaced by the end of the 26th year. Additionally, as presented in figure 11, the average age of a cocoa tree after the replacement phase is 10.5 years. As a result, steady state is achieved beginning at year 27.

2. Low Input, Landrace Cocoa (LILC) Assuming Cocoa Price Increases at Five per Year (Model 1)

Table 16 provides the optimal solution for model 1 (a five not three percent increase in cocoa price annually), where the cocoa price increases by two percent from current price annually. Holding all other variables constant, the model estimated that the optimal annual replacement rate is five percent and the optimal replanting age is postponed to year nine. These results show that as cocoa price increases by two percent, the annual profit can increase as much as 31.40 percent from the baseline assumption or in dollar terms increases from $989.99 (2010 USD/Ha/Year) (Table 15) to $1,300.80 (2010 USD/Ha/Year), Table 16.

Table 16

Average Net Present Value (NPV) Assuming Cocoa Price Increases at Five per Year (Model 1) under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year) +

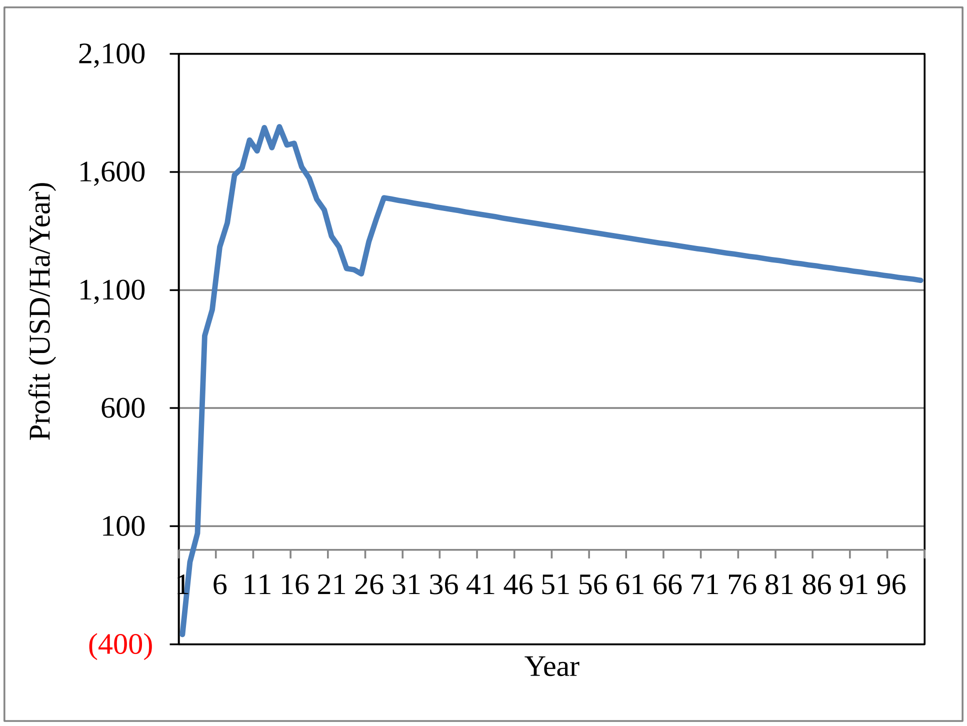
Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,213.06	1,295.92	1,204.85	1,086.66	974.25	873.10	778.93
6	1,213.05	1,298.01	1,209.59	1,092.87	981.42	880.91	794.51
7	1,212.68	1,299.54	1,214.64	1,099.85	989.63	890.00	804.16
8	1,211.85	1,300.49	1,219.58	1,107.28	998.57	900.02	814.96
9	1,210.51	1,300.80*	1,224.09	1,114.87	1,008.06	910.83	826.70
10	1,208.59	1,300.37	1,227.71	1,122.25	1,017.75	922.10	839.12
11	1,206.04	1,299.14	1,230.31	1,128.98	1,027.31	933.58	851.92
12	1,202.75	1,296.99	1,231.78	1,134.58	1,036.22	944.77	864.76
13	1,198.72	1,293.90	1,232.11	1,138.71	1,044.09	955.38	877.24
14	1,193.85	1,289.76	1,231.17	1,141.35	1,050.33	964.75	888.92
15	1,188.17	1,284.59	1,228.98	1,142.52	1,054.80	972.56	899.31
16	1,181.60	1,278.30	1,225.42	1,142.08	1,057.42	978.10	907.82
17	1,174.14	1,270.90	1,220.53	1,140.06	1,058.22	981.59	913.83
18	1,165.78	1,262.36	1,214.24	1,136.41	1,057.15	982.96	917.47
19	1,156.55	1,252.73	1,206.64	1,131.21	1,054.29	982.31	918.86
20	1,146.47	1,242.03	1,197.74	1,124.49	1,049.68	979.69	918.06
Average	1,192.74	1,285.36	1,219.96	1,124.01	1,028.70	940.79	863.54
Max	1,213.06	1,300.80*	1,232.11	1,142.52	1,058.22	982.96	918.86
Min	1,146.47	1,242.03	1,197.74	1,086.66	974.25	873.10	778.93

+Denotes cocoa price increases at five percent not three percent.
* Denotes the solution with the highest average net present value (NPV).

These findings also point out that changes in current price and future prices affect the optimum age of replacement directly. As cocoa price is expected to increase, the optimal time to replace will be postponed to capture these higher prices. In this situation, cocoa producers will take advantage of increasing price by postponing replanting. This behavior of cocoa farmers is categorized as price taker. Additionally, higher estimated price of cocoa also indicates a shorter period of time to recover investment cost.

Figure 12

Net Present Value (NPV) Over 100 Years Assuming a Five Percent Annual Increase in Cocoa Price (Model 1) under Low Input, Landrace Cocoa (LILC)



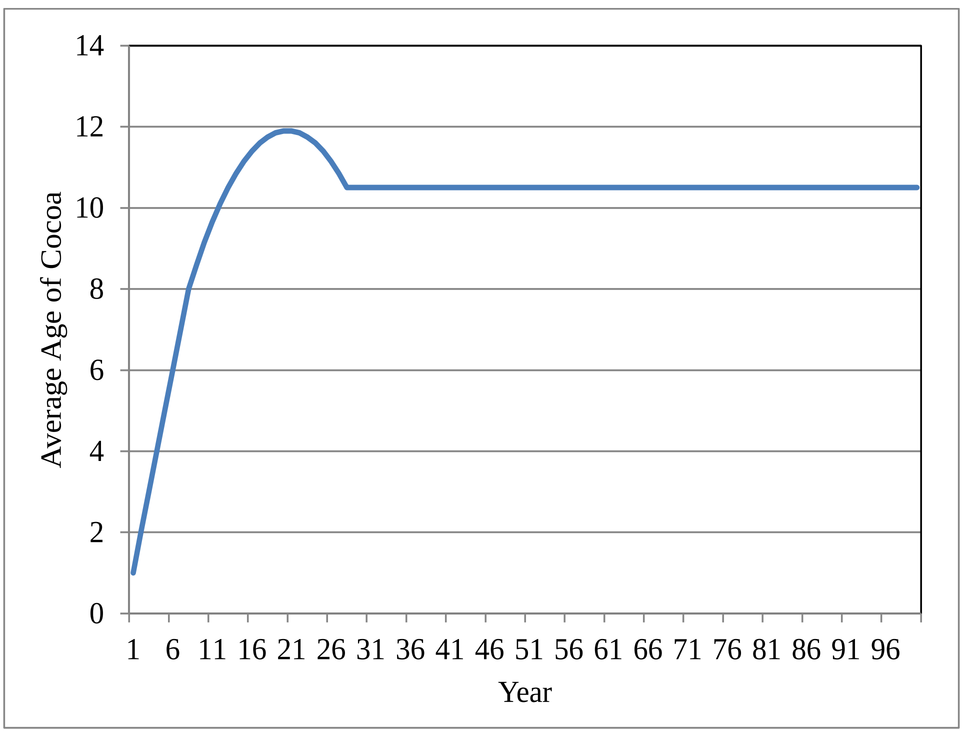
Additionally, figure 12 presents the net present value (NPV) of profit over 100 years, where the highest profit achieved is about $1,791.43 (2010 USD/Ha) at year 14. However, the profit gradually declines after year 28 due to the impact of higher discount rate than inflation rate. Furthermore, net present value (NPV) in the steady state period for model 1 (assuming a five percent annual increase in cocoa price) can never be achieved as high as about $1,791.43

(2010 USD/Ha) as in year 14. In this model, about 70 percent of cocoa trees at year 14, which is at the highest productivity, is 14 years old and about 30 percent of cocoa trees is at one to five years old.

Figure 13 presents the steady state for model 1 (assuming a five percent annual increase in cocoa price) where the optimal solution for the replacement rate is five percent and the replacement age is at year nine. The delay of the replacement age for one year longer in this optimal solution is because the cocoa producers can capture more profits from the increasing cocoa price.

Figure 13

Average Age of Cocoa Trees Assuming a Five Percent Annual Increase in Cocoa Price (Model 1) under Low Input, Landrace Cocoa (LILC)



In this model, all first generation of cocoa trees will have been replaced at the end of year 27. As a result, steady state is achieved beginning of the 28th year until the end of study period with the average age of cocoa tree being10.5 years.

3. Low Input, Landrace Cocoa (LILC) Assuming Fertilizer Price Increases by Five Percent (Model 2)

However, when projected fertilizer price increases by five percent annually as indicated in model 2, holding all other variables constant, the optimal replacement rate, replacement age, profit, average age of cocoa trees, and steady state are equivalent to the baseline model, which are at five percent annual replacement rate, year eight of replacement age, $989.99 (2010 USD/Ha/Year) profit (Table 15), and 10.5 year average age of cocoa trees respectively. This is due to the fact that under Low Input, Landrace Cocoa (LILC) production system, no fertilizer is applied as a nutrient supplement and thus the optimal solution is not affected by an increase in fertilizer price.

4. Low Input, Landrace Cocoa (LILC) Assuming Inflation Rate Increases from Current Ghanaian Rate 10.26 to 15 Percent per Year (Model 3)

When inflation rates rises from the current Ghanaian rate of 10.26 to 15 percent, holding all other variables constant, the optimal annual replacement rate remains at five percent, however the optimal replacement age declines to year five as presented in table 17. This decline is because the cocoa producers try to avoid further cost increase in labor and material.

Table 17

Average Net Present Value (NPV) Assuming Inflation Rate Increases from Current Ghanaian Rate 10.26 to 15 Percent per Year (Model 3) under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year)+

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	13,228.85	15,011.16*	14,412.44	13,283.49	12,095.39	10,966.30	9,863.16
6	13,225.49	15,010.52	14,416.08	13,289.38	12,102.68	10,974.48	9,977.89
7	13,220.82	15,008.04	14,419.51	13,295.84	12,110.99	10,984.09	9,988.27
8	13,214.67	15,003.85	14,422.04	13,302.44	12,119.95	10,994.69	10,000.02
9	13,206.96	14,997.84	14,423.16	13,308.75	12,129.31	11,006.11	10,012.85
10	13,197.55	14,989.83	14,422.05	13,314.17	12,138.58	11,017.90	10,026.46
11	13,186.30	14,979.69	14,418.57	13,317.96	12,147.23	11,029.76	10,040.42
12	13,173.06	14,967.20	14,412.61	13,319.32	12,154.45	11,040.89	10,054.29
13	13,157.73	14,952.27	14,404.07	13,317.64	12,159.52	11,050.82	10,067.42
14	13,140.15	14,934.68	14,392.71	13,313.00	12,161.43	11,058.40	10,079.13
15	13,120.28	14,914.40	14,378.51	13,305.38	12,159.94	11,063.09	10,088.47
16	13,097.92	14,891.20	14,361.19	13,294.48	12,154.99	11,063.56	10,094.51
17	13,073.06	14,865.04	14,340.74	13,280.28	12,146.56	11,060.36	10,095.98
18	13,045.54	14,835.76	14,316.97	13,262.59	12,134.44	11,053.26	10,093.30
19	13,015.37	14,803.37	14,289.91	13,241.46	12,118.71	11,042.35	10,086.60
20	12,982.50	14,767.82	14,259.52	13,216.84	12,099.32	11,027.59	10,075.85
Average	13,142.89	14,933.29	14,380.63	13,291.44	12,133.34	11,027.10	10,040.29
Max	13,228.85	15,011.16*	14,423.16	13,319.32	12,161.43	11,063.56	10,095.98
Min	12,982.50	14,767.82	14,259.52	13,216.84	12,095.39	10,966.30	9,863.16

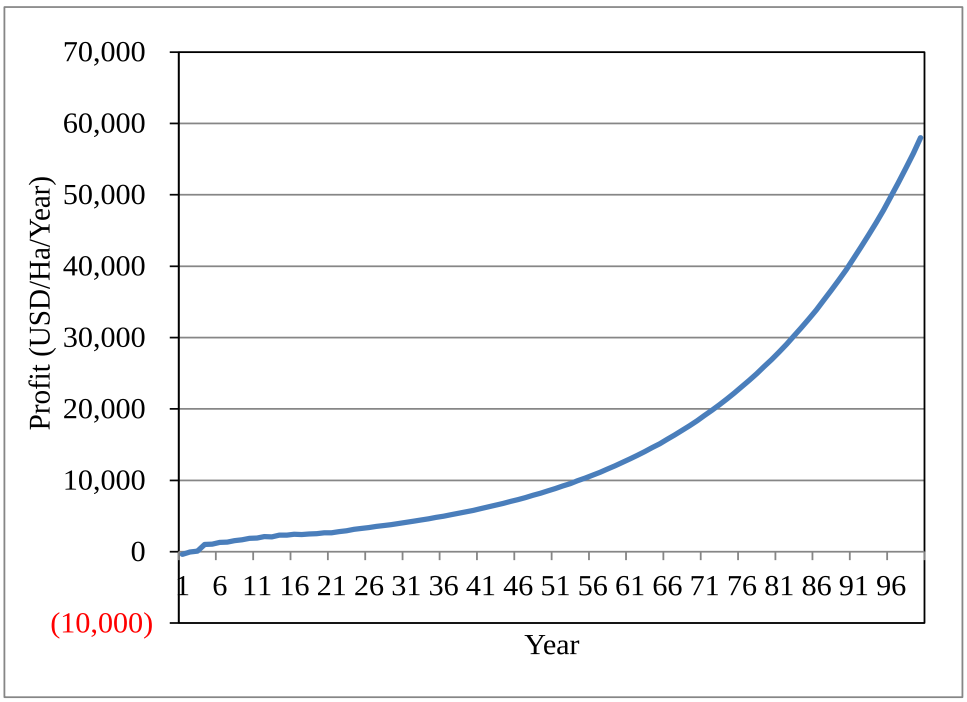
+Denotes an increase of 4.74 percent inflation rate from current Ghanaian rate 10.26 to 15 percent.
* Denotes the solution with the highest average net present value (NPV).

Additionally, the average annual profit in this model increases by 1,416.29 percent from $989.99 (2010 USD/Ha/Year) (Table 15) to $15,011.16 (2010 USD/Ha/Year), Table 17. This high increment is partially because the cocoa price is associated with the inflation rate. If an inflation rate increases, this study also assumes that the cocoa price increases at the same rate.

Figure 14 indicates that profit per hectare increases exponentially over 100 years. This is because the impact of inflation rate is greater than the impact of the discount rate and because cocoa price increases are associated with the increase in the inflation rate. If this phenomenon persists, the profit in the long run will increase to infinity or in other words when the inflation rate is greater than the discount rate, profit will increase gradually to endless point.

Figure 14

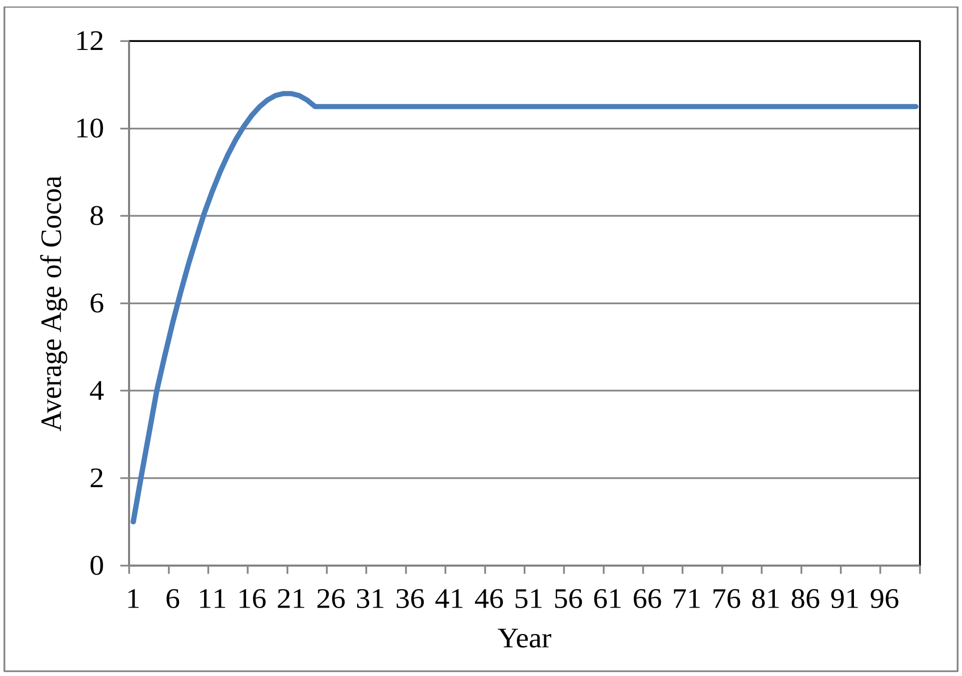
Net Present Value (NPV) Over 100 Years Assuming Inflation Rate Increases from the Current Ghanaian Rate of 10.26 to 15 Percent per Year (Model 3) under Low Input, Landrace Cocoa (LILC)



When inflation rate increases from current Ghanaian rate 10.26 to 15 percent per year (model 3) under Low Input, Landrace Cocoa (LILC), all first generation of cocoa trees will have been cut and replaced by the end of 23rd year. Accordingly, the steady state is reached at the beginning of year 24 following five percent optimal replacement rate and the replacement age at year six. The acceleration in replacement age is intended to minimize the impact of labor and material costs increase. Moreover, as presented in figure 15, the average age of cocoa trees after the replacement phase is 10.5 years.

Figure 15

Average Age of Cocoa Trees Assuming an Inflation Rate of 15 Percent (Model 3) under Low Input, Landrace Cocoa (LILC)



5. Low Input, Landrace Cocoa (LILC) Assuming Labor Price Increases at Five percent per Year (Model 4)

Model 4 (assuming labor price increases at five percent per year), projects labor price to increase from zero to five percent per year, holding other variables constant. As presented in table 18, the optimal replacement rate is five percent and age of replacement shortens to year six. This speeds up the replacement process is because of to the additional cost associated with increasing labor costs.

Table 18

Average Net Present Value (NPV) Assuming Labor Price Increases at Five Percent per Year (Model 4) under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	749.99	858.54	840.93	788.11	727.20	666.50	570.98
6	749.95	859.10*	843.28	791.63	731.57	671.51	616.79
7	749.59	859.03	845.48	795.29	736.30	677.07	622.92
8	748.84	858.46	847.24	798.86	741.10	682.84	629.46
9	747.68	857.38	848.38	802.13	745.85	688.73	636.21
10	746.06	855.72	848.60	804.85	750.31	694.47	642.97
11	743.96	853.46	847.99	806.77	754.24	699.91	649.51
12	741.31	850.51	846.56	807.58	757.31	704.68	655.60
13	738.13	846.90	844.32	807.19	759.32	708.64	660.98
14	734.37	842.57	841.21	805.77	759.91	711.35	665.38
15	730.08	837.57	837.28	803.41	759.22	712.73	668.53
16	725.21	831.84	832.48	800.00	757.33	712.36	670.11
17	719.81	825.44	826.86	795.64	754.34	710.74	669.81
18	713.85	818.35	820.41	790.30	750.22	707.86	668.09
19	707.41	810.66	813.22	784.10	745.11	703.84	665.11
20	700.52	802.40	805.34	777.08	739.06	698.77	660.94
Average	734.17	841.75	836.85	797.42	748.02	697.00	647.09
Max	749.99	859.10*	848.60	807.58	759.91	712.73	670.11
Min	700.52	802.40	805.34	777.08	727.20	666.50	570.98

* Denotes the solution with the highest average net present value (NPV).

This model also shows that as labor price increases by five percent, which adds up additional cost to the total production cost, the profit declines by 13.22 percent or from $989.99 (2010 USD/Ha/Year) (Table 15) to $859.10 (2010 USD/Ha/Year), Table 18. Labor is one of the largest cost components in cocoa farming accounting for 65.19 percent of total cost (Table 13), thus a small change in labor price can have significant impacts on profitability and replacement rate.

These findings also indicate that an increase in labor price affect the optimum age of replacement directly. As labor price is expected to increase, the optimal time to replace cocoa trees will be shortened in order to avoid incurring additional cost. Therefore, speeding up the replanting of cocoa trees helps cocoa producers to avoid further cost increase. Moreover, higher estimated labor price also indicates a longer period of time to recover investment cost.

Figure 16

Net Present Value (NPV) Over 100 Years Assuming Labor Price Increases at Five per Year (Model 4) under Low Input, Landrace Cocoa (LILC)

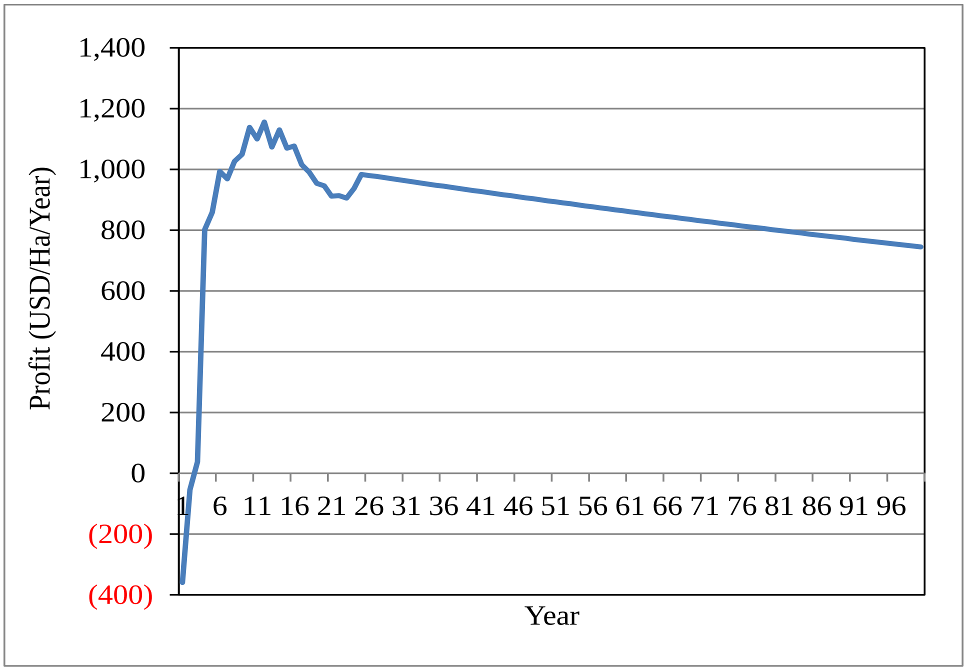


Figure 16 presents net present value (NPV) of profit over 100 years which gradually declines after year 25 due to the greater impact of higher inflation rate than of the discount rate. As presented in figure 16, the highest profit is achieved at year 12 with net present value (NPV) about $1,156.31 (2010 USD/Ha). However, this value can never be achieved in the steady state period. This is due to about 65 percent of cocoa trees at year 12, which is at the highest productivity and bear the fruit at the same time, is 12 years old and about 35 percent of cocoa trees is at one to five years old.

Conversely, the age of cocoa trees in the steady state ranges from 1 to 20 years old, where only five percent of the cocoa trees are at the highest productivity or at 12 years old. Whereas the rest of cocoa trees are at a period of no yield, a period of increasing yield at an increasing rate, a period of increasing yield at a decreasing rate, and a period of decreasing yields.

Figure 17

Average Age of Cocoa Trees Assuming Labor Price Increases at Five per Year (Model 4) under Low Input, Landrace Cocoa (LILC)

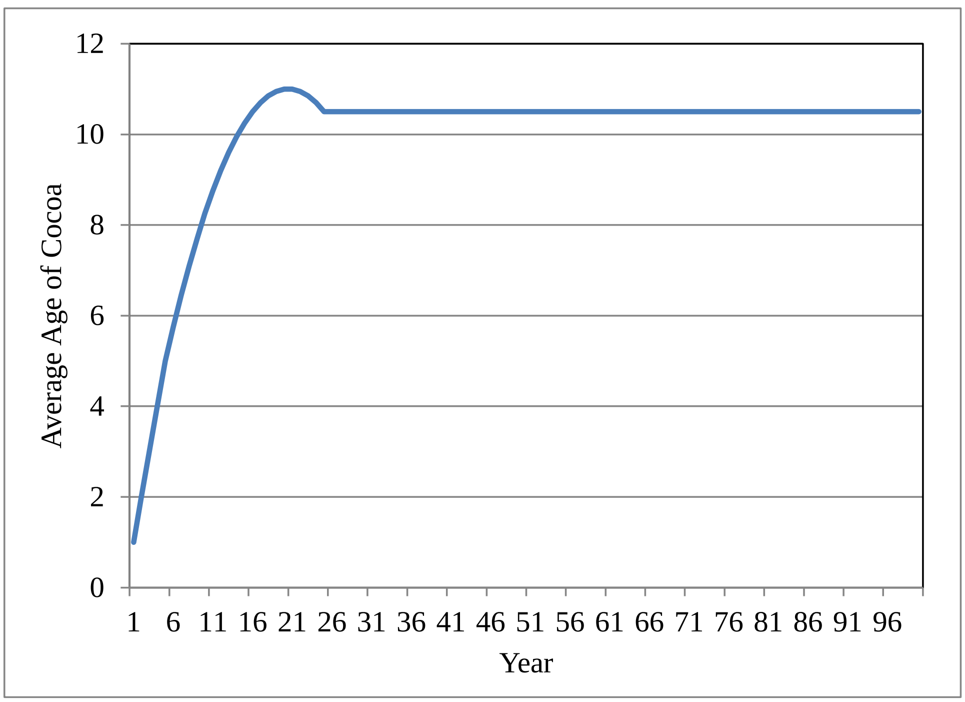


Figure 17 presents the steady state for model 4 (assuming labor price increases at five per year) where the optimal solution for replacement rate is five percent and replacement age is at year six. All first generation of cocoa trees in this model will have been cut and replaced by the end of year 24. Therefore, steady state is achieved beginning at year 25 until the end of study period with the average age of cocoa tree is 10.5 years.

6. Low Input, Landrace Cocoa (LILC) Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5)

Table 19

Average Net Present Value (NPV) Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5) under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	876.56	962.17	922.52	852.82	779.38	709.13	639.29
6	876.53	963.31	925.52	857.02	784.43	714.80	652.74
7	876.18	963.93	928.56	861.54	790.01	721.19	659.69
8	875.43	964.05*	931.29	866.14	795.85	728.00	667.24
9	874.25	963.63	933.54	870.61	801.83	735.11	675.21
10	872.59	962.59	934.99	874.69	807.68	742.26	683.37
11	870.41	960.91	935.62	878.10	813.17	749.28	691.50
12	867.65	958.51	935.35	880.51	817.95	755.80	699.35
13	864.32	955.37	934.20	881.77	821.78	761.66	706.65
14	860.34	951.43	932.09	881.89	824.29	766.38	713.12
15	855.78	946.75	929.06	880.94	825.48	769.86	718.44
16	850.56	941.25	925.05	878.83	825.32	771.63	722.28
17	844.72	934.97	920.09	875.60	823.89	771.96	724.28
18	838.25	927.90	914.17	871.24	821.16	770.81	724.63
19	831.19	920.10	907.37	865.85	817.23	768.31	723.48
20	823.59	911.60	899.72	859.46	812.15	764.52	720.88
Average	859.90	949.28	925.57	871.06	810.10	750.04	695.13
Max	876.56	964.05*	935.62	881.89	825.48	771.96	724.63
Min	823.59	911.60	899.72	852.82	779.38	709.13	639.29

* Denotes the solution with the highest average net present value (NPV).

In model 5 (assuming 20 percent yield loss and 10 percent land infected due to black pod), yield loss due to black pod (*phytophthora pod rot*) is modeled and estimates of replacement rates are obtained. The study assumes that 10 percent of the farm is infected with black pod which results in a 20 percent yield loss. This assumption was built under the premise that a farm will typically contract black pod but the entire farm will not be affected.

The model found that the optimal replacement rate is five percent and the age of replacement is at year eight (Table 19), which is the same as in baseline model. However, following the optimal solution, profit declines by 2.62 percent or from $989.99 (2010 USD/Ha/Year) (Table 15) to 964.05 (2010 USD/Ha/Year) (Table 19). In this model, black pod causes two percent total yield loss. Therefore, mitigation of black pod incidence through implementing traditional approach or spraying copper base pesticide can mitigate further yield loss.

Figure 18

Net Present Value (NPV) Over 100 Years Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5) under Low Input, Landrace Cocoa (LILC)

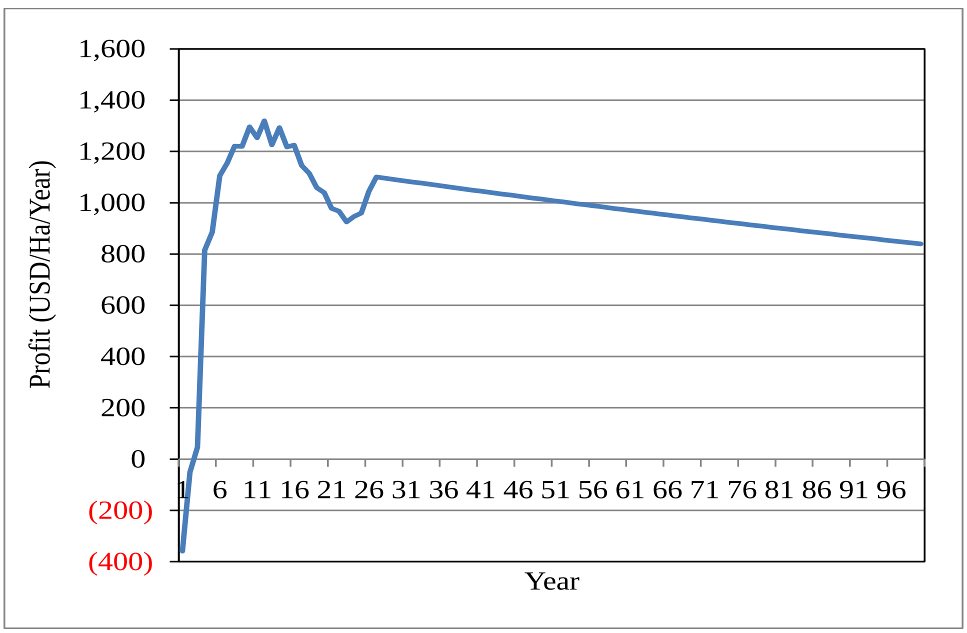


Figure 18 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. Moreover, the highest profit is achieved at year 12 with net present value (NPV) around $1,262.85 (2010 USD/Ha), Figure 18. However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees, the steady state and average age of cocoa trees are also the same as in the baseline assumption under Low Input, Landrace Cocoa (LILC) production system.

7. Low Input, Landrace Cocoa (LILC) Assuming 40 Percent Yield Loss and 10 Land Infected due to Black Pod (Model 6)

Model 6 assumes that there is a 40 percent yield loss due to black pod with the same 10 percent of the farm being infected. The model estimated that optimal annual replacement rate is at five percent and age of replacement is at year eight where total profit declines by 5.24 percent or from $ $989.99 (2010 USD/Ha/Year) (Table 15) to $938.11 (2010 USD/Ha/Year), Table 20.

This model indicates that as yield reduction caused by black pod is greater, the profit decline is also larger. The steady state and average age of cocoa trees are also the same as in the baseline assumption. Additionally, black pod incidence in this model contracts four percent of total yield loss. Therefore, mitigation of black pod incidence through implementing traditional approach or spraying copper base pesticide can mitigate further yield reduction.

Table 20

Average Net Present Value (NPV) Assuming 40 Percent Yield Loss and 10 Percent Land Infected due to Black Pod (Model 6) under Low Input, Landrace Cocoa (LILC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	852.57	936.26	897.43	829.23	757.38	688.67	620.25
6	852.55	937.38	900.37	833.33	762.32	694.21	633.56
7	852.22	937.99	903.34	837.75	767.77	700.46	640.36
8	851.49	938.11*	906.01	842.25	773.49	707.12	647.75
9	850.35	937.70	908.21	846.63	779.34	714.08	655.53
10	848.74	936.70	909.64	850.62	785.06	721.07	663.51
11	846.63	935.07	910.25	853.95	790.44	727.94	671.47
12	843.96	932.72	909.99	856.31	795.12	734.32	679.15
13	840.71	929.67	908.88	857.55	798.86	740.05	686.29
14	836.86	925.84	906.83	857.67	801.32	744.67	692.62
15	832.42	921.29	903.89	856.76	802.49	748.08	697.83
16	827.34	915.93	899.98	854.70	802.35	749.82	701.59
17	821.66	909.82	895.16	851.57	800.96	750.15	703.55
18	815.36	902.93	889.39	847.33	798.30	749.04	703.90
19	808.50	895.33	882.76	842.08	794.48	746.61	702.79
20	801.10	887.05	875.32	835.85	789.54	742.92	700.26
Average	836.40	923.74	900.46	847.10	787.45	728.70	675.03
Max	852.57	938.11*	910.25	857.67	802.49	750.15	703.90
Min	801.10	887.05	875.32	829.23	757.38	688.67	620.25

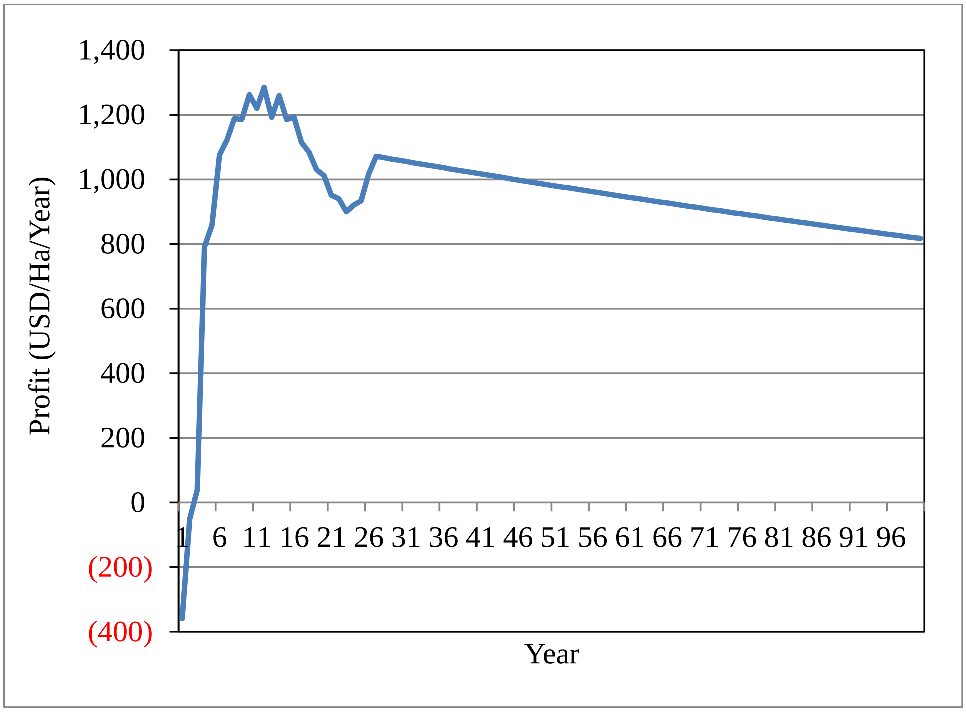
* Denotes the solution with the highest average net present value (NPV).

Figure 19 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. The profit in the long run will be zero if this phenomenon persists.

As presented in figure 19, the highest profit is achieved at year 12 with net present value (NPV) around $1,230.21 (2010 USD/Ha). However, in the steady state period, net present value (NPV) can never be achieved as high as in year 12. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees, the steady state and average age of cocoa trees are also the same as in the baseline assumption under Low Input, Landrace Cocoa (LILC) production system.

Figure 19

Net Present Value (NPV) Over 100 Years Assuming 40 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 6) Low Input, Landrace Cocoa (LILC)



8. Summary of Net Present Value (NPV), Replacement Rate, Age of Replacement, Steady State, and Percentage Change of Profit under Low Input, Landrace Cocoa (LILC)

Table 21 presents the net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit for all models (model 1-6). The optimal replacement rate for all models is five percent, whereas the age of replacement varies from year five to nine.

Table 21
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 Model	989.99	5	8	27	279.92**
Model 1	1,300.80	5	9	28	31.40***
Model 2	989.99	5	8	27	0.00***
Model 3	15,011.16	5	5	24	1,416.29***
Model 4	859.10	5	6	25	-13.22***
Model 5	964.05	5	8	27	-2.62***
Model 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 Model.

It shows that when the price of cocoa increases by two percent (from three to five percent) as presented in model 1 (Table 21), the age of replacement is postponed one year in order to capture the higher output prices. In this situation, cocoa producers will take advantage of increasing output price by postponing replanting. However, when the fertilizer price increases by five percent (model 2), the age of replacement is the same as in baseline model

When the inflation rate increases by 4.74 percent (from 10.26 to 15 percent), the replacement rate declines by three years. This decline is mainly due to the cocoa producers try to use the labor and material now in order to avoid the cost increase in the future.

Similarly, when labor price increase by five percent, the age of replacement declines by two years. This decline is due to the cocoa producers try to avoid further cost increase in labor and material. Therefore, by following this optimal solution, cocoa producers can minimize the impact of labor and material costs increase.

In addition, when 20 percent yield loss combined with 10 percent of land being infected (model 5) due to black pod, the optimal replacement rate is five percent and age of replacement is equivalent to baseline model. Similarly, when yield loss increases to 40 percent and 10 percent land infected (model 6), the optimal replacement age also is the same as in baseline model. These findings indicate that total yield loss is two and four percent respectively. However, the replacement rate and age replacement are the same as they are in the baseline model, except the profit declines by 2.61 to 5.24 percent, respectively.

9. Yield and Profit of Optimal Replacement Model and Status Quo under Low Input, Landrace Cocoa (LILC) Assuming Zero Percent Price Increase, Inflation and Discount Rates

Table 22 compares the total yield of cocoa and profit over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under Low Input, Landrace Cocoa (LILC) production system. For the purpose of comparison, projected cocoa price increase, inflation, and discount rates are assumed zero percent, whereas exchange is fixed at GHc 1.4738 per USD.

Table 22
Summary of Total Yield and Profit under Low Input, Landrace Cocoa (LILC)

Yield*			Profit**		
Optimal Replacement Model	Status Quo	Percentage Change in Yield	Optimal Replacement Model	Status Quo	Percentage Change in Profit
16,987	15,435	10.06	37,845	33,038	14.55

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

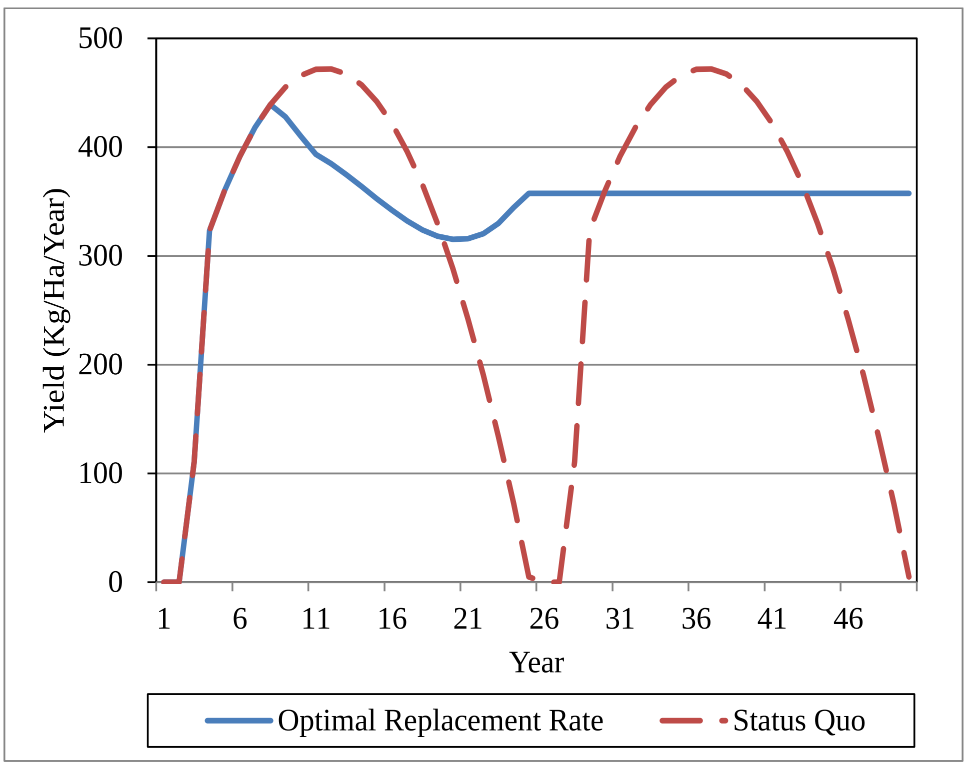
The model estimated that the optimal replacement rate is six percent and the age of replacement is at year nine. The model suggests that the yield and profit can be achieved (10.06

and 14.55 percent higher respectively over 50 years) following the optimal solution compared with the status quo of retaining a tree until it no longer bears fruit (Table 22).

Figure 20 compares the yield of cocoa over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under Low Input, Landrace Cocoa (LILC) production system. Similarly, the graph for profit mirrors the graph for yield of cocoa (Figure 26).

Figure 20

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)



B. High Input, No Shade Amazon Cocoa (HINSC)

High Input, No Shade Amazon Cocoa (HINSC) is a production system that used mixed Amazon hybrid, high input (fertilizer and pesticide), and without shade trees.

1. High Input, No Shade Amazon Cocoa (HINSC) Baseline Model

In this study, the High Input, No Shade Amazon Cocoa (HINSC) baseline model employs the same assumption as in the Low Input, Landrace Cocoa (LILC) as described in table 10.

Table 23

Average Net Present Value (NPV) for the Baseline Model under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year)

Replacement Rate*/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	2,107.00	2,207.10	2,066.19	1,879.08	1,695.68	1,527.63	1,351.73
6	2,106.92	2,210.98	2,073.98	1,889.30	1,707.54	1,540.72	1,391.61
7	2,106.22	2,214.25	2,082.28	1,900.71	1,721.05	1,555.76	1,407.84
8	2,104.75	2,216.54	2,090.57	1,912.84	1,735.76	1,572.37	1,425.89
9	2,102.38	2,217.69**	2,098.28	1,925.19	1,751.23	1,590.11	1,445.35
10	2,098.99	2,217.55	2,104.78	1,937.22	1,766.94	1,608.50	1,465.77
11	2,094.46	2,215.98	2,109.63	1,948.30	1,782.34	1,627.04	1,486.67
12	2,088.71	2,212.85	2,112.58	1,957.81	1,796.82	1,645.14	1,507.50
13	2,081.64	2,208.07	2,113.52	1,965.13	1,809.75	1,662.21	1,527.68
14	2,073.19	2,201.54	2,112.34	1,969.95	1,820.41	1,677.58	1,546.59
15	2,063.30	2,193.20	2,108.96	1,972.19	1,828.24	1,690.54	1,563.53
16	2,051.94	2,183.01	2,103.34	1,971.78	1,833.03	1,700.35	1,577.78
17	2,039.10	2,170.95	2,095.45	1,968.71	1,834.76	1,706.69	1,588.53
18	2,024.78	2,157.04	2,085.30	1,962.98	1,833.43	1,709.58	1,595.44
19	2,009.02	2,141.30	2,072.94	1,954.65	1,829.11	1,709.10	1,598.57
20	1,991.87	2,123.81	2,058.47	1,943.83	1,821.92	1,705.36	1,598.09
Average	2,071.52	2,193.24	2,093.04	1,941.23	1,785.50	1,639.29	1,504.91
Max	2,107.00	2,217.69**	2,113.52	1,972.19	1,834.76	1,709.58	1,598.57
Min	1,991.87	2,123.81	2,058.47	1,879.08	1,695.68	1,527.63	1,351.73

* Net present value (NPV) at zero percent replacement rate is $619.56 (2010 USD/Ha/Year).
** Denotes the solution with the highest average net present value (NPV).

Table 23 presents optimal annual replacement rate and age of replacement for the baseline/ initial assumptions under the High Input, No Shade Amazon Cocoa (HINSC) production system. The model estimated that replacing five percent of the cocoa orchard annually beginning in year nine results in the most profitable turnover for cocoa producers with an annual average net present value (NPV) as much as $2,217.69 (2010 USD/Ha/Year), Table 23.

Conversely, with a zero percent annual replacement rate (the status quo), cocoa producers only acquire an annual average net present value (NPV) of $619.56 (2010 USD/Ha/Year) over the same period. These results suggest that substantial economic gains (257.95 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.

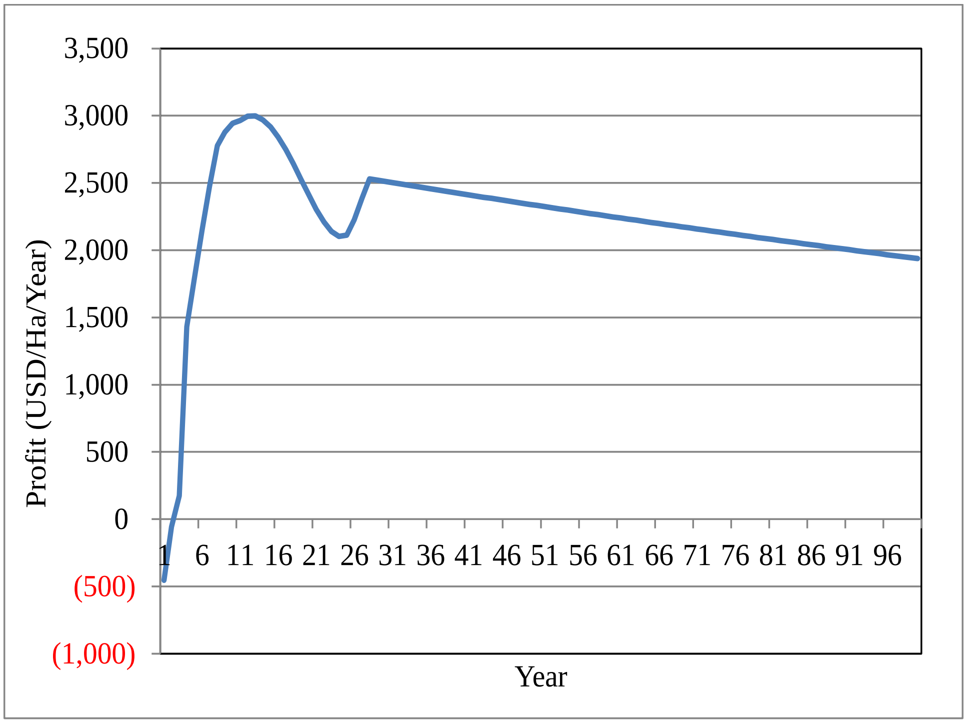
Furthermore, figure 21 presents net present value (NPV) of profit over 100 years which gradually declines after year 28 due to the impact of higher discount rate than inflation rate. If this phenomenon persists, the profit in the long run will also be zero.

The highest profit is achieved at year 13 with a net present value (NPV) around $2,997.65 (2010 USD/Ha) as presented in figure 21. However, this value can never be achieved in the steady state period. The reason is that about 75 percent of the cocoa trees at year 13, which is at the highest productivity and bear the fruit at the same time, is 13 years old and about 25 percent of cocoa trees is at one to five years old.

The age of cocoa trees in the steady state ranges from 1 to 20 years old, where only five percent of the cocoa trees are at the highest productivity or at 13 years old. Whereas the rest of cocoa trees are at a period of no yield, a period of increasing yield at an increasing rate, a period of increasing yield at a decreasing rate, and a period of decreasing yields.

Figure 21

Net Present Value (NPV) Over 100 Years for Baseline Model under High Input, No Shade Amazon Cocoa (HINSC)



Also, the steady state and average age of cocoa trees for the baseline model under High Input, No Shade Amazon Cocoa (HINSC) production system, where the optimal solution for replacement rate is five percent and replacement age is at year nine, is the same as in model 1 (assuming cocoa price increases at five per year) under Low Input, Landrace Cocoa (LILC), Figure 13.

2. High Input, No Shade Amazon Cocoa (HINSC) Assuming Cocoa Price Increases at Five per Year (Model 1)

However, when projected cocoa price increases by two (from three to five percent) percent from current price per year, holding all other variables constant, the model estimated that the optimal annual replacement rate is at five percent and the optimal replanting age is postponed to year 11 as presented in table 24. These results show that as the cocoa price increases by two percent, the annual profit also increases as much as 31.43 percent from the baseline model (Table 23) or increases from $2,217.69 $2,217.74 (2010 USD/Ha/Year) (Table 23) to $2,914.7 (2010 USD/Ha/Year), Table 24.

Table 24

Average Net Present Value (NPV) Assuming Cocoa Price Increases at Five per Year (Model 1) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year) +

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	2,840.40	2,891.29	2,621.72	2,323.30	2,054.30	1,820.39	1,594.01
6	2,840.40	2,897.76	2,633.53	2,337.98	2,070.72	1,837.98	1,638.28
7	2,839.73	2,903.76	2,646.65	2,354.93	2,089.97	1,858.77	1,660.16
8	2,838.21	2,908.67	2,660.37	2,373.58	2,111.58	1,882.36	1,685.15
9	2,835.67	2,912.27	2,673.89	2,393.28	2,135.00	1,908.27	1,712.81
10	2,831.93	2,914.37	2,686.26	2,413.26	2,159.57	1,935.92	1,742.62
11	2,826.84	2,914.74*	2,696.70	2,432.65	2,184.55	1,964.66	1,773.99
12	2,820.25	2,913.21	2,704.82	2,450.45	2,209.06	1,993.69	1,806.22
13	2,812.01	2,909.59	2,710.39	2,465.66	2,232.12	2,022.15	1,838.48
14	2,801.99	2,903.73	2,713.24	2,477.66	2,252.59	2,049.00	1,869.84
15	2,790.10	2,895.50	2,713.21	2,486.25	2,269.47	2,073.11	1,899.26
16	2,776.23	2,884.78	2,710.15	2,491.29	2,282.27	2,093.23	1,925.51
17	2,760.34	2,871.50	2,703.98	2,492.66	2,290.84	2,108.59	1,947.25
18	2,742.37	2,855.60	2,694.64	2,490.31	2,295.14	2,119.11	1,963.60
19	2,722.34	2,837.10	2,682.14	2,484.23	2,295.14	2,124.79	1,974.55
20	2,700.28	2,816.04	2,666.52	2,474.49	2,290.94	2,125.71	1,980.20
Average	2,798.69	2,889.37	2,682.39	2,433.87	2,201.45	1,994.86	1,813.25
Max	2,840.40	2,914.74*	2,713.24	2,492.66	2,295.14	2,125.71	1,980.20
Min	2,700.28	2,816.04	2,621.72	2,323.30	2,054.30	1,820.39	1,594.01

+Denotes cocoa price increases at five percent not three percent per year.
*Denotes the solution with the highest average net present value (NPV).

These findings illustrate that changes in current prices and future prices affect the optimum age of replacement directly. Thus, the higher expected increase in cocoa price, the longer the optimal replanting age will be. In this situation, cocoa farmers will take advantage of increasing price by postponing replanting.

Additionally, the higher estimated price of cocoa also indicates a shorter period of time to recover investment cost. Or in other words, when the cocoa producers borrow capital from the bank to invest in cocoa farming, an increase in the cocoa price indicates that cocoa producers receive higher profit than in the normal situation. Therefore, the installment period for the repayment loan will be shorter when all profit from a cocoa price increase and normal installment are allocated to pay back the loan.

Figure 22

Net Present Value (NPV) Over 100 Years Assuming a Five Percent Annual Increase in Cocoa Price (Model 1) under High Input, No Shade Amazon Cocoa (HINSC)

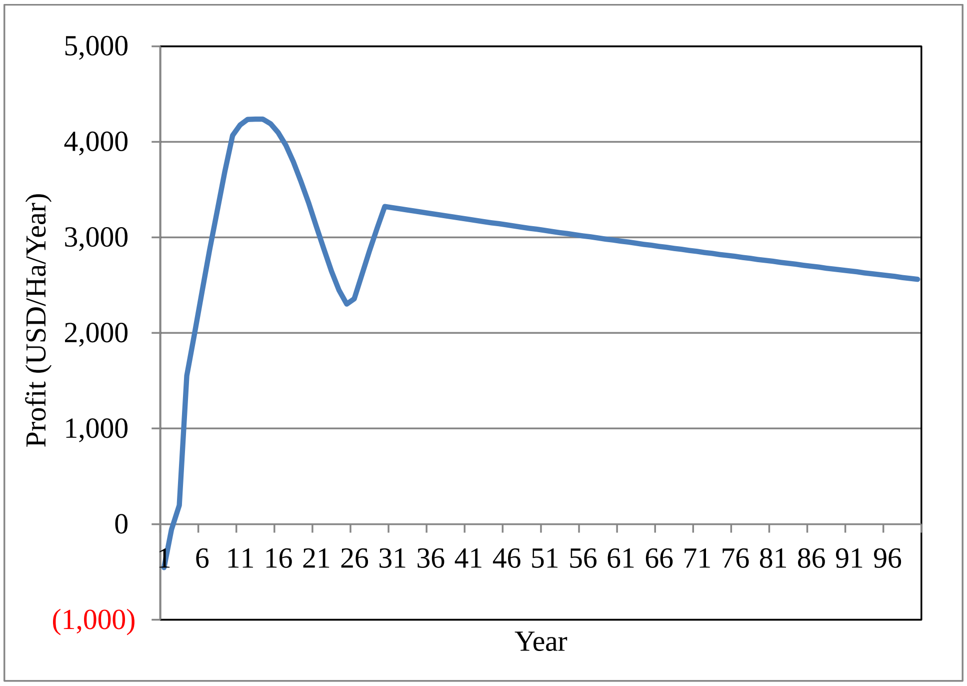


Figure 22 also shows that in the first two years of the production cycle, profit is negative due to the establishment costs (planting and annual costs) and no revenue is being realized during the early period of cocoa planting. This is because the cocoa trees do not start to bear the fruit until year three.

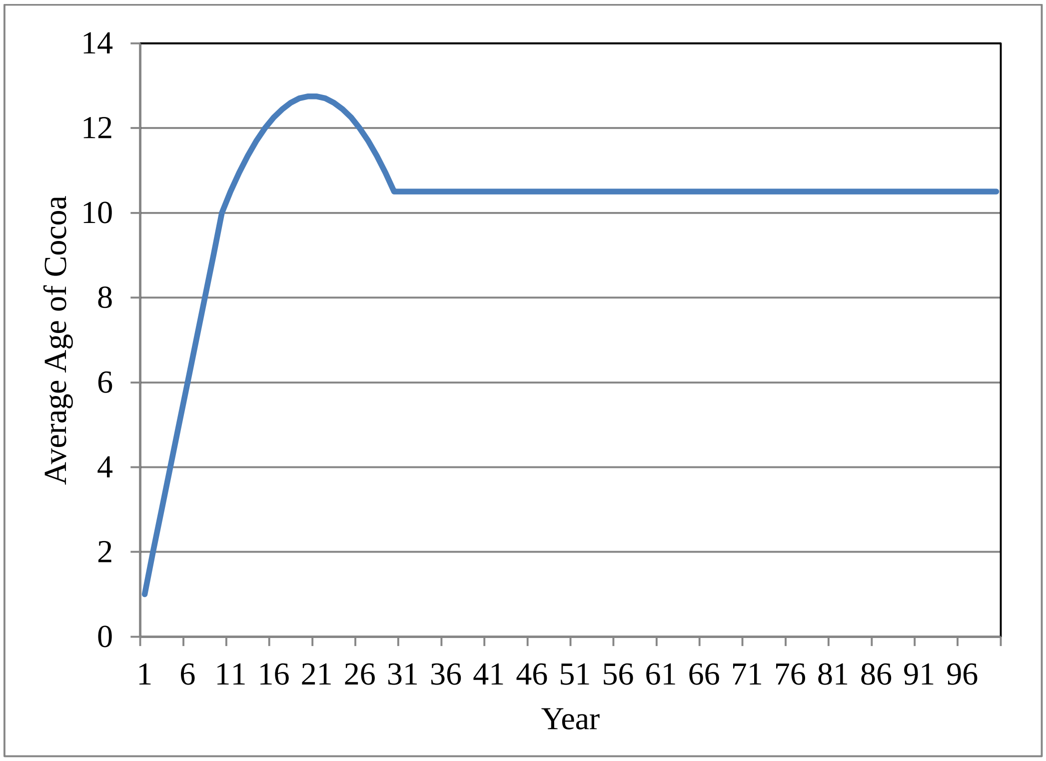
Figure 22 illustrates that the highest profit is achieved in year 13 with a net present value (NPV) around $4,237.97 (2010 USD/Ha). However, it can never reach as high as $4,237.97 (2010 USD/Ha) in the steady state period. The reason is that about 85 percent of cocoa trees at year 13, which is at the highest productivity and bear the fruit at the same time, is 13 years old and about 15 percent of cocoa trees is one to five years old.

Conversely, the age of cocoa trees in the steady state ranges from 1 to 20 years old, where only five percent of the cocoa trees are at the highest productivity or at 13 years old. Whereas the rest of cocoa trees are at a period of no yield, a period of increasing yield at an increasing rate, a period of increasing yield at a decreasing rate, and a period of decreasing yields.

As presented in figure 23, the steady state for model 1 (assuming the cocoa price increases at five percent per year) is achieved at the beginning of year 30 until the end of study period following the optimal replacement rate at five percent and replacement age year 11. All first generation of cocoa trees in this model will have been cut and replaced by the end of year 29. As a result, the average age of cocoa tree is 10.5 years.

Figure 23

Average Age of Cocoa Trees Assuming a Five Percent Annual Increase in Cocoa Price (Model 1) under High Input, No Shade Amazon Cocoa (HINSC)



3. High Input, No Shade Amazon Cocoa (HINSC) Assuming Fertilizer Price Increases by Five Percent per Year (Model 2)

When projected fertilizer price increases by five percent per year, holding other variables constant, the optimal replacement rate and replacement age do not change from the baseline model. As presented in table 25, the optimal solution remains at five percent annual replacement rate and year nine of replacement age.

In fact, an increase in the fertilizer price by five percent results a decline in profit by 1.71 percent or from $2,217.69 (2010 USD/Ha/Year) (Table 23) to $2,179.84 (2010 USD/Ha/Year), Table 25. Moreover, the steady state and average age of cocoa trees for this model is equivalent to the baseline model under High Input, No Shade Amazon Cocoa (HINSC) and model 1 under Low Input, Landrace Cocoa (LILC) (Figure 13).

Table 25

Average Net Present Value (NPV) Assuming Fertilizer Price Increases by Five Percent per Year (Model 2) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	2,057.85	2,170.43	2,037.24	1,855.31	1,675.59	1,510.33	1,326.01
6	2,057.77	2,174.06	2,044.80	1,865.31	1,687.24	1,523.22	1,376.29
7	2,057.07	2,177.01	2,052.81	1,876.44	1,700.48	1,538.01	1,392.27
8	2,055.61	2,178.99	2,060.74	1,888.23	1,714.87	1,554.30	1,410.01
9	2,053.25	2,179.84*	2,068.02	1,900.18	1,729.95	1,571.66	1,429.11
10	2,049.89	2,179.41	2,074.02	1,911.73	1,745.21	1,589.62	1,449.10
11	2,045.40	2,177.57	2,078.35	1,922.28	1,760.09	1,607.65	1,469.51
12	2,039.69	2,174.19	2,080.82	1,931.17	1,773.98	1,625.19	1,489.78
13	2,032.69	2,169.17	2,081.29	1,937.82	1,786.25	1,641.62	1,509.34
14	2,024.32	2,162.43	2,079.68	1,942.02	1,796.16	1,656.27	1,527.55
15	2,014.54	2,153.91	2,075.90	1,943.67	1,803.24	1,668.43	1,543.73
16	2,003.30	2,143.57	2,069.91	1,942.72	1,807.33	1,677.38	1,557.12
17	1,990.61	2,131.39	2,061.69	1,939.15	1,808.40	1,682.93	1,566.94
18	1,976.47	2,117.39	2,051.26	1,932.97	1,806.47	1,685.09	1,572.99
19	1,960.92	2,101.60	2,038.67	1,924.25	1,801.62	1,683.95	1,575.35
20	1,944.02	2,084.11	2,024.02	1,913.10	1,793.97	1,679.64	1,574.18
Average	2,022.71	2,154.69	2,061.20	1,914.15	1,761.93	1,618.46	1,485.58
Max	2,057.85	2,179.84*	2,081.29	1,943.67	1,808.40	1,685.09	1,575.35
Min	1,944.02	2,084.11	2,024.02	1,855.31	1,675.59	1,510.33	1,326.01

*Denotes the solution with the highest average net present value (NPV).

Figure 24 also shows that in the first two years of production cycle, profit is negative due to the establishing cost (planting and annual costs) and no revenue is being realized during early period of cocoa planting because the cocoa trees start to bear the fruit in year three.

Figure 24

Net Present Value (NPV) Over 100 Years Assuming Fertilizer Price Increases by Five Percent per Year (Model 2) under High Input, No Shade Amazon Cocoa (HINSC)

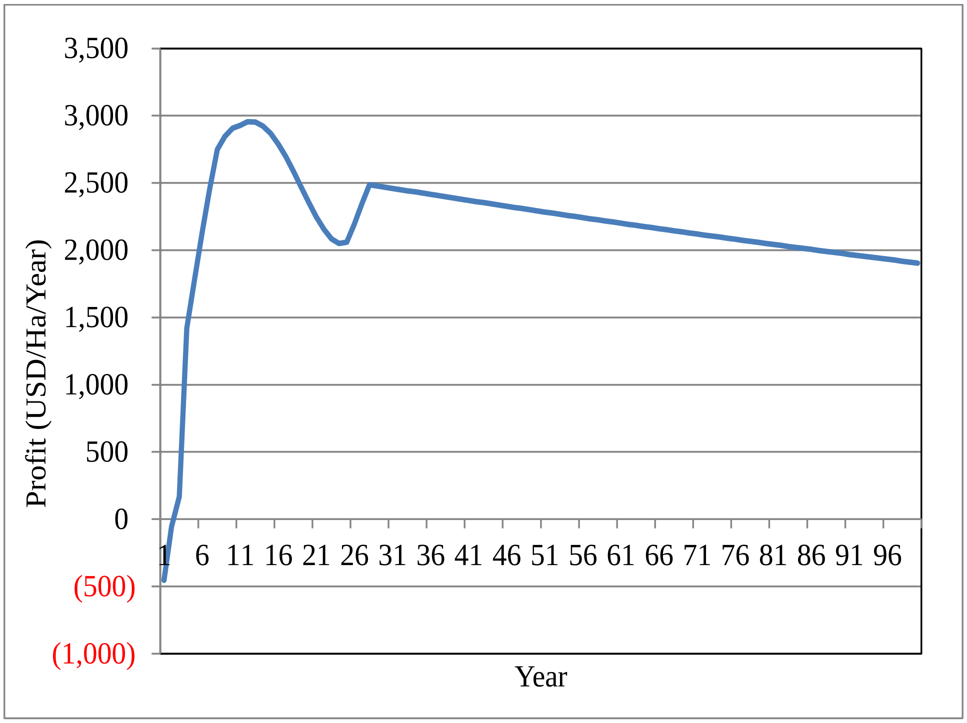


Figure 24 illustrates that the highest profit is achieved at year 12 with a net present value (NPV) around $2,955.78 (2010 USD/Ha). However, it can never reach as high as $2,955.78 (2010 USD/Ha) in the steady state period. One of reasons is that about 80 percent of cocoa trees at year 12, which is at the highest productivity and bear the fruit at the same time, is 12 years old and about 20 percent of cocoa trees is at one to five years old.

4. High Input, No Shade Amazon Cocoa (HINSC) Assuming Inflation Rate Increases from the Current Ghanaian rate 10.26 to 15 Percent per Year (Model 3)

When inflation rates rises from the current Ghanaian rate of 10.26 to 15 percent, holding all other variables constant, the optimal annual replacement rate remains at five percent, but the optimal replacement age declines to year six as presented in table 26. The decline in replacement age is due to the cocoa producers try to avoid further cost increase in labor and material.

Additionally, the average annual profit in this model increases by 1,421 percent from $2,217.69 (2010 USD/Ha/Year) (Table 23) to $33,728.66 (2010 USD/Ha/Year), Table 26. This high increment is due to the cocoa price is associated with inflation rate. If an inflation rate increases, this study also assumes that the cocoa price increases at the same rate.

Therefore, by following this optimal solution, cocoa producers can minimize the impact of labor and material costs increases. In this model, the steady state and average age of cocoa trees are equivalent to model 4 (assuming labor price increases at five per year) under Low Input, Landrace Cocoa (LILC) (Figure 17).

Table 26

Average Net Present Value (NPV) Assuming Inflation Rate Increases from Current Ghanaian rate 10.26 to 15 Percent per Year (Model 3) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year) +

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	31,479.31	33,726.88	31,522.68	28,528.04	25,611.08	22,959.56	20,340.47
6	31,471.09	33,728.66*	31,533.08	28,542.80	25,628.37	22,978.50	20,630.09
7	31,459.87	33,727.71	31,543.98	28,559.72	25,648.76	23,001.15	20,654.30
8	31,445.35	33,723.16	31,554.34	28,578.08	25,671.72	23,027.10	20,682.31
9	31,427.22	33,714.63	31,562.88	28,596.95	25,696.56	23,055.82	20,713.69
10	31,405.16	33,701.74	31,568.02	28,615.18	25,722.39	23,086.59	20,747.85
11	31,378.86	33,684.12	31,568.52	28,631.40	25,748.11	23,118.52	20,784.04
12	31,348.00	33,661.39	31,563.73	28,643.92	25,772.39	23,150.49	20,821.29
13	31,312.25	33,633.17	31,553.23	28,651.06	25,793.59	23,181.13	20,858.43
14	31,271.29	33,599.09	31,536.62	28,651.82	25,809.78	23,208.79	20,894.01
15	31,224.83	33,558.81	31,513.51	28,645.78	25,819.24	23,231.49	20,926.29
16	31,172.59	33,511.98	31,483.54	28,632.55	25,821.13	23,247.03	20,953.19
17	31,114.29	33,458.31	31,446.38	28,611.79	25,815.08	23,254.17	20,972.23
18	31,049.70	33,397.54	31,401.76	28,583.22	25,800.78	23,252.58	20,982.01
19	30,978.64	33,329.45	31,349.47	28,546.61	25,778.03	23,242.04	20,982.30
20	30,900.97	33,253.90	31,289.38	28,501.86	25,746.71	23,222.45	20,973.01
Average	31,277.46	33,588.16	31,499.45	28,595.05	25,742.73	23,138.59	20,807.22
Max	31,479.31	33,728.66*	31,568.52	28,651.82	25,821.13	23,254.17	20,982.30
Min	30,900.97	33,253.90	31,289.38	28,501.86	25,611.08	22,959.56	20,340.47

+Denotes an increase of 4.74 percent inflation rate from current Ghanaian rate 10.26 to 15 percent.
*Denotes the solution with the highest average net present value (NPV).

Figure 25

Net Present Value (NPV) Over 100 Years Assuming Inflation Rate Increases from current Ghanaian rate 10.26 to 15 Percent per Year (Model 3) under High Input, No Shade Amazon Cocoa (HINSC)

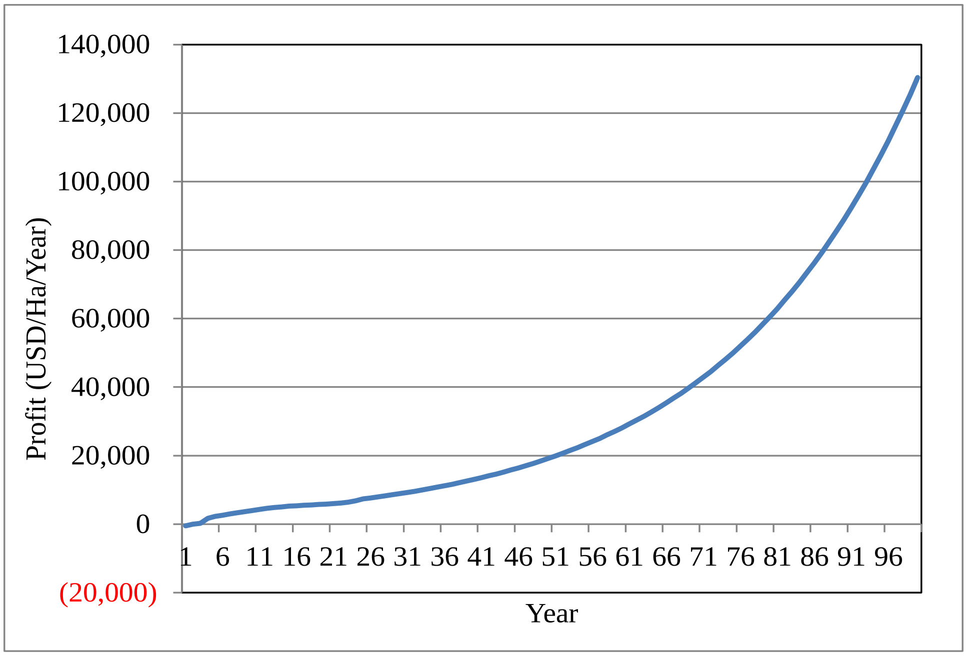


Figure 25 also indicates that profit per hectare increases exponentially over 100 years. This high increment is partially because the cocoa price is associated with the inflation rate. This study also assumes that the cocoa price increases at the same rate as inflation rate increases. Therefore, the profit in the long run will increase to infinity if this phenomenon persists.

5. High Input, No Shade Amazon Cocoa (HINSC) Assuming Labor Price Increases at Five percent per Year (Model 4)

In model 4 (assuming labor price increases at five per year), labor price is projected to increase by five percent, holding all other variables constant. As presented in table 27, the optimal replacement rate is five percent and the age of replacement declines to year eight. This decline is mainly due to the additional cost associated with increasing labor cost.

Table 27

Average Net Present Value (NPV) Assuming Labor Price Increases at Five Percent per Year (Model 4) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,749.65	1,893.27	1,809.32	1,669.20	1,522.01	1,382.21	1,146.83
6	1,749.56	1,895.76	1,815.31	1,677.47	1,531.90	1,393.34	1,266.31
7	1,748.86	1,897.42	1,821.42	1,686.47	1,542.93	1,405.90	1,280.08
8	1,747.44	1,898.16*	1,827.18	1,695.76	1,554.67	1,419.51	1,295.13
9	1,745.18	1,897.85	1,832.08	1,704.87	1,566.71	1,433.74	1,311.07
10	1,741.99	1,896.36	1,835.60	1,713.31	1,578.57	1,448.16	1,327.47
11	1,737.77	1,893.57	1,837.53	1,720.56	1,589.76	1,462.30	1,343.88
12	1,732.44	1,889.41	1,837.77	1,726.07	1,599.76	1,475.65	1,359.81
13	1,725.96	1,883.77	1,836.23	1,729.42	1,608.00	1,487.67	1,374.75
14	1,718.27	1,876.62	1,832.85	1,730.60	1,613.91	1,497.82	1,388.15
15	1,709.33	1,867.91	1,827.59	1,729.55	1,617.20	1,505.48	1,399.43
16	1,699.15	1,857.63	1,820.42	1,726.27	1,617.92	1,510.11	1,407.98
17	1,687.72	1,845.78	1,811.35	1,720.75	1,616.06	1,511.85	1,413.17
18	1,675.08	1,832.40	1,800.42	1,713.04	1,611.70	1,510.74	1,415.18
19	1,661.26	1,817.55	1,787.70	1,703.23	1,604.91	1,506.89	1,414.14
20	1,646.34	1,801.31	1,773.31	1,691.44	1,595.84	1,500.46	1,410.22
Average	1,717.25	1,871.55	1,819.13	1,708.63	1,585.74	1,465.74	1,347.10
Max	1,749.65	1,898.16*	1,837.77	1,730.60	1,617.92	1,511.85	1,415.18
Min	1,646.34	1,801.31	1,773.31	1,669.20	1,522.01	1,382.21	1,146.83

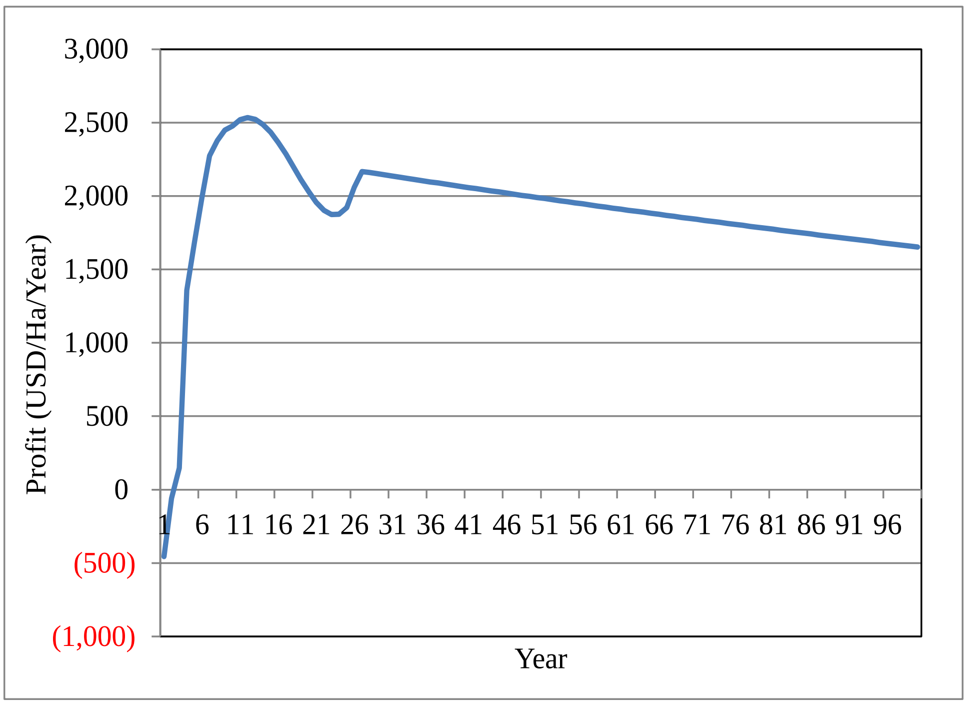
* Denotes the solution with the highest average net present value (NPV).

This model also shows that as labor price increases by five percent, the profit drops by 14.41 percent from $2,217.69 (2010 USD/Ha/Year) (Table 23) to $1,898.16 (2010 USD/Ha/Year), Table 27. Under the High Input, No Shade Amazon Cocoa (HINSC) production system, labor cost accounts for 81.88 percent of total cost (Table 13), therefore a small increase in labor price can substantially diminish profits and change optimal replacement rates.

These findings also indicate that an increase in the labor price affects the optimum age of replacement directly. In this case, as labor price is expected to increase, the optimal time to replace cocoa trees will be quicker in order to avoid incurring additional cost. Therefore, delaying replanting of cocoa trees helps cocoa producers to avoid further cost increase. Moreover, a higher estimated labor price also indicates a longer period of time to recover investment cost.

Figure 26

Net Present Value (NPV) Over 100 Years Assuming Labor Price Increases at Five Percent per Year (Model 4) under High Input, No Shade Amazon Cocoa (HINSC)



Furthermore, figure 26 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. The highest estimated profit is achieved at year 12 with a net present value (NPV) around $2,532.97 (2010 USD/Ha), Figure 38. However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees, the steady state, and average age of cocoa trees in this model are the same as in baseline model under Low Input, Landrace Cocoa (LILC), Figure 13.

6. High Input, No Shade Amazon Cocoa (HINSC) Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5)

Model 5 assumes that black pod causes a yield loss of 20 percent and the percentage of the farm infected with the disease is 10 percent.

Table 28

Average Net Present Value (NPV) Assuming 20 Percent Yield Loss and 10 Percent Land Infected due to Black Pod (Model 5) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	2,054.06	2,151.72	2,013.74	1,830.67	1,651.28	1,486.95	1,314.40
6	2,054.00	2,155.52	2,021.36	1,840.66	1,662.88	1,499.74	1,353.96
7	2,053.32	2,158.72	2,029.48	1,851.81	1,676.08	1,514.46	1,369.83
8	2,051.90	2,160.97	2,037.59	1,863.68	1,690.48	1,530.70	1,387.48
9	2,049.60	2,162.10*	2,045.13	1,875.77	1,705.61	1,548.05	1,406.51
10	2,046.31	2,161.98	2,051.51	1,887.53	1,720.97	1,566.04	1,426.48
11	2,041.91	2,160.46	2,056.25	1,898.39	1,736.04	1,584.17	1,446.92
12	2,036.31	2,157.43	2,059.16	1,907.69	1,750.22	1,601.89	1,467.30
13	2,029.43	2,152.78	2,060.09	1,914.86	1,762.87	1,618.59	1,487.05
14	2,021.20	2,146.43	2,058.97	1,919.60	1,773.31	1,633.63	1,505.55
15	2,011.57	2,138.31	2,055.70	1,921.81	1,780.99	1,646.31	1,522.14
16	2,000.51	2,128.38	2,050.23	1,921.45	1,785.70	1,655.93	1,536.08
17	1,987.99	2,116.63	2,042.55	1,918.47	1,787.41	1,662.15	1,546.62
18	1,974.04	2,103.06	2,032.67	1,912.91	1,786.14	1,665.01	1,553.39
19	1,958.67	2,087.72	2,020.63	1,904.81	1,781.96	1,664.57	1,556.49
20	1,941.96	2,070.67	2,006.53	1,894.27	1,774.97	1,660.96	1,556.05
Average	2,019.55	2,138.30	2,040.10	1,891.53	1,739.18	1,596.20	1,464.77
Max	2,054.06	2,162.10*	2,060.09	1,921.81	1,787.41	1,665.01	1,556.49
Min	1,941.96	2,070.67	2,006.53	1,830.67	1,651.28	1,486.95	1,314.40

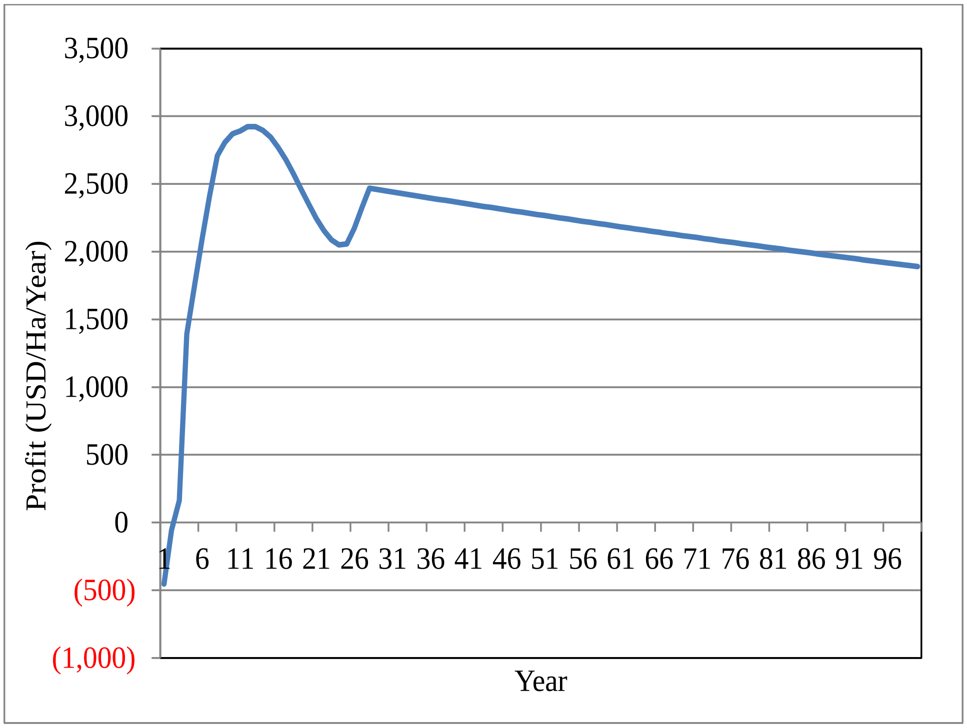
* Denotes the solution with the highest average net present value (NPV).

As presented in table 28, the model estimated that it is most profitable for cocoa producers to replace five percent of cocoa their farms at beginning year nine. In this model, the profit, which cocoa producers receive, declines by 2.51 percent annually or from $2,217.69 (2010 USD/Ha/Year) (Table 23) to $2,162.10 (2010 USD/Ha/Year), Table 28. It shows that, black pod causes two percent total yield loss. Therefore, mitigation of black pod incidence through implementing traditional approach or spraying copper base pesticide can alleviate further yield loss.

Figure 27 presents the net present value (NPV) of profit over 100 years which gradually declines after year 28 due to the impact of higher discount rate than inflation rate. The profit in the long run will also be zero if this phenomenon persists.

Figure 27

Net Present Value (NPV) Over 100 Years Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5) under High Input, No Shade Amazon Cocoa (HINSC)



The highest profit is achieved at year 13 with net present value (NPV) around $2,923.78 (2010 USD/Ha), Figure 27. However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees in this model is the same as in baseline model under High Input, No Shade Amazon Cocoa (HINSC).

However, the steady state and average age of cocoa trees for this model are equivalent to model 1 (assuming a five percent annual increase in cocoa price) under Low Input, Landrace Cocoa (LILC) (Figure 13).

7. High Input, No Shade Amazon Cocoa (HINSC) Assuming 40 Percent Yield Loss and 10 Land Infected due to Black Pod (Model 6)

Model 6 estimates a 40 percent yield loss due to black pod infestation with the same 10 percent of the farm infected. The model indicated that the optimal annual replacement rate is five percent and age of replacement is at year nine. This optimal solution contributes to total annual loss by 5.01 percent or decline from $2,217.69 (2010 USD/Ha/Year) (Table 23) to $2,106.51 (2010 USD/Ha/Year), Table 29.

The model indicates that as yield reduction caused by black pod is greater, the profit decline is also larger. Additionally, black pod incidence in this model contracts four percent of total yield loss. Therefore, mitigation of black pod incidence through implementing a traditional approach or spraying a copper based pesticide can mitigate further yield reduction.

Table 29

Average Net Present Value (NPV) Assuming 40 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 6) under High Input, No Shade Amazon Cocoa (HINSC) (USD/Ha/Year)

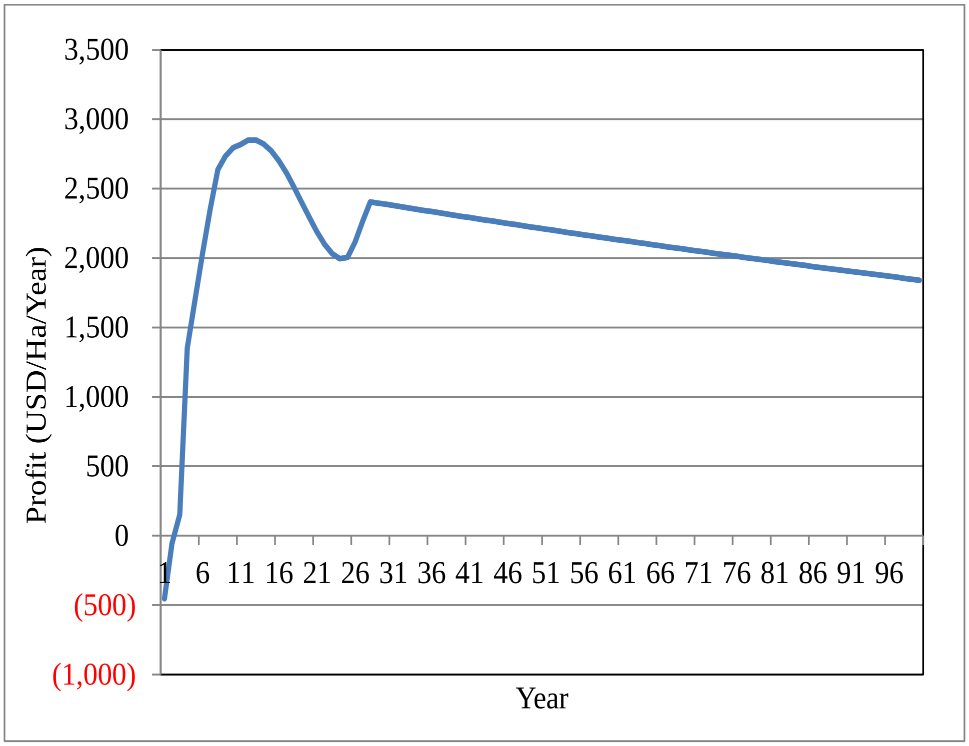
Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	2,001.12	2,096.35	1,961.29	1,782.25	1,606.88	1,446.27	1,277.06
6	2,001.07	2,100.06	1,968.74	1,792.02	1,618.22	1,458.77	1,316.31
7	2,000.42	2,103.19	1,976.68	1,802.92	1,631.12	1,473.15	1,331.82
8	1,999.05	2,105.39	1,984.61	1,814.53	1,645.19	1,489.02	1,349.07
9	1,996.83	2,106.51*	1,991.99	1,826.35	1,659.98	1,505.98	1,367.67
10	1,993.63	2,106.41	1,998.23	1,837.85	1,675.01	1,523.57	1,387.20
11	1,989.36	2,104.94	2,002.88	1,848.47	1,689.75	1,541.30	1,407.18
12	1,983.92	2,102.00	2,005.73	1,857.58	1,703.62	1,558.63	1,427.10
13	1,977.23	2,097.49	2,006.67	1,864.60	1,716.00	1,574.97	1,446.42
14	1,969.22	2,091.31	2,005.60	1,869.25	1,726.21	1,589.68	1,464.51
15	1,959.85	2,083.41	2,002.43	1,871.44	1,733.74	1,602.09	1,480.74
16	1,949.07	2,073.75	1,997.12	1,871.11	1,738.36	1,611.51	1,494.39
17	1,936.89	2,062.31	1,989.66	1,868.24	1,740.07	1,617.61	1,504.70
18	1,923.30	2,049.09	1,980.04	1,862.84	1,738.86	1,620.44	1,511.34
19	1,908.33	2,034.14	1,968.33	1,854.97	1,734.81	1,620.04	1,514.40
20	1,892.04	2,017.53	1,954.59	1,844.71	1,728.03	1,616.55	1,514.01
Average	1,967.58	2,083.37	1,987.16	1,841.82	1,692.87	1,553.10	1,424.62
Max	2,001.12	2,106.51*	2,006.67	1,871.44	1,740.07	1,620.44	1,514.40
Min	1,892.04	2,017.53	1,954.59	1,782.25	1,606.88	1,446.27	1,277.06

* Denotes the solution with the highest average net present value (NPV).

As presented in figure 28, net present value (NPV) of profit over 100 years gradually declines after year 28 due to the impact of higher discount rate than inflation rate. The highest profit is achieved at year 13 with net present value (NPV) about $2,849.91 (2010 USD/Ha), Table 28. However, in the steady state period, net present value (NPV) can never be achieved as high as in year 13. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees in this model is the same as in baseline model under High Input, No Shade Amazon Cocoa (HINSC). However, the steady state and average age of cocoa trees are the same as in model 1 (assuming a five percent annual increase in cocoa price) under Low Input, Landrace Cocoa (LILC) (Figure 13).

Figure 28

Net Present Value (NPV) Over 100 Years Assuming 40 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 6) under High Input, No Shade Amazon Cocoa (HINSC)



8. Summary of Net Present Value (NPV), Replacement Rate, Age of Replacement, Steady State, and Percentage Change of Profit under High Input, No Shade Amazon Cocoa (HINSC)

Table 30 presents the net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit for all models (model 1-6). The optimal replacement rate for all models is five percent, whereas the age of replacement varies from year six to eleven.

Table 30 also shows that the pattern of the net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit under High Input, No Shade Amazon Cocoa (HINSC) are the same as they are under Low Input, Landrace Cocoa (LILC). However, the replacement age for model 2 and model 4 are slight different from the same model under Low Input, Landrace Cocoa (LILC). In this production system, as price of cocoa increases by two percent (from three to five percent) as presented in model 1 (Table 30), the age of replacement is postponed by two years in order to capture the higher output prices. Similarly, an increase in labor price by five percent (model 4), the age of replacement declines by two years.

Table 30
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 Model	2,217.69	5	9	28	257.95**
Model 1	2,914.74	5	11	30	31.43***
Model 2	2,179.84	5	9	28	-1.71***
Model 3	33,728.66	5	6	25	1,420.89***
Model 4	1,898.16	5	8	27	-14.41***
Model 5	2,162.10	5	9	28	-2.51***
Model 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 Model.

9. Yield and Profit of Optimal Replacement Model and Status Quo under High Input, No Shade Amazon Cocoa (HINSC) Assuming Zero Percent Price Increase, Inflation and Discount Rates

Table 31 compares the total yield of cocoa and profit over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under High Input, No Shade Amazon Cocoa (HINSC) production system.

Table 31
Summary of Total Yield and Profit under High Input, No Shade Amazon Cocoa (HINSC)

Yield*			Profit**		
Optimal Replacement Model	Status Quo	Percentage Change in Yield	Optimal Replacement Model	Status Quo	Percentage Change in Profit
35,472	33,929	4.55	84,028	79,561	5.62

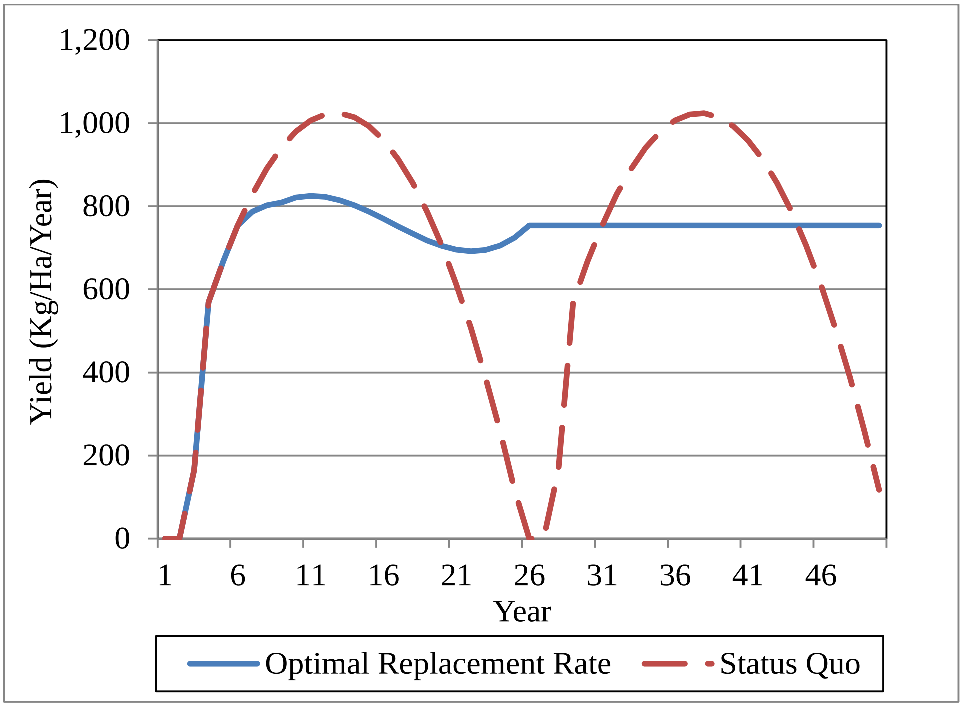
* Denotes the total yield over 50 years in Kg/Ha.
** Denotes the total profit over 50 years (2010 USD/Ha/Year).

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 bear fruit (Table 31).

Figure 29 compares the yield of cocoa over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under High Input, No Shade Amazon Cocoa (HINSC) production system. Similarly, the graph for profit mirrors the graph for yield of cocoa (Figure 29).

Figure 29

Cocoa Yield Over 50 Years Assuming Zero Percent Price Increase, Inflation and Discount Rates for Status Quo and Replacement Model under High Input, No Shade Amazon Cocoa (HINSC)



C. High Input, Medium Shade Cocoa (HIMSC)

High Input, Medium Shade Cocoa (HIMSC) is a production system that used mixed Amazon hybrid, high input (fertilizer and pesticide), and medium shade trees (Table 14).

1. High Input, Medium Shade Cocoa (HIMSC) Baseline Model

Similar to Low Input, Landrace Cocoa (LILC) and High Input, No Shade Cocoa (HINSC), all input prices, cocoa price, inflation and discount rate assumptions for High Input, Medium Shade Cocoa (HIMSC) are also the same as described under those production systems. Table 32 presents the baseline estimation of optimal annual replacement rate and age of replacement for High Input, Medium Shade Cocoa (HIMSC) production system.

Table 32

Average Net Present Value (NPV) for Baseline Model under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

Replacement Rate*/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,345.34	1,468.37	1,407.44	1,302.85	1,192.97	1,088.65	981.04
6	1,345.24	1,470.12	1,411.97	1,309.14	1,200.49	1,097.11	1,002.22
7	1,344.63	1,471.12	1,416.51	1,315.91	1,208.80	1,106.58	1,012.60
8	1,343.44	1,471.37**	1,420.70	1,322.84	1,217.60	1,116.78	1,023.89
9	1,341.58	1,470.80	1,424.15	1,329.58	1,226.58	1,127.42	1,035.82
10	1,339.00	1,469.30	1,426.44	1,335.75	1,235.38	1,138.17	1,048.06
11	1,335.62	1,466.80	1,427.47	1,340.94	1,243.63	1,148.67	1,060.28
12	1,331.39	1,463.23	1,427.20	1,344.70	1,250.91	1,158.53	1,072.11
13	1,326.26	1,458.54	1,425.57	1,346.74	1,256.78	1,167.34	1,083.16
14	1,320.21	1,452.69	1,422.53	1,347.11	1,260.75	1,174.64	1,092.98
15	1,313.21	1,445.64	1,418.04	1,345.78	1,262.67	1,179.95	1,101.13
16	1,305.25	1,437.39	1,412.09	1,342.74	1,262.62	1,182.82	1,107.08
17	1,296.34	1,427.94	1,404.69	1,337.98	1,260.60	1,183.48	1,110.31
18	1,286.50	1,417.32	1,395.86	1,331.55	1,256.65	1,181.95	1,111.10
19	1,275.75	1,405.57	1,385.67	1,323.51	1,250.84	1,178.32	1,109.56
20	1,264.17	1,392.75	1,374.18	1,313.95	1,243.29	1,172.72	1,105.81
Average	1,319.62	1,449.31	1,412.53	1,330.69	1,239.41	1,150.20	1,066.07
Max	1,345.34	1,471.37**	1,427.47	1,347.11	1,262.67	1,183.48	1,111.10
Min	1,264.17	1,392.75	1,374.18	1,302.85	1,192.97	1,088.65	981.04

* Net present value (NPV) at Zero percent replacement rate is $389.59 (2010 USD/Ha/Year).
** Denotes the solution with the highest average net present value (NPV).

The model estimated that the optimal replacement rate for the baseline assumptions is a five percent and replacement age is at beginning of year eight. This combination results in cocoa producers receiving $1,471.37 (2010 USD/Ha/Year) annual average net present value (NPV), Table 32.

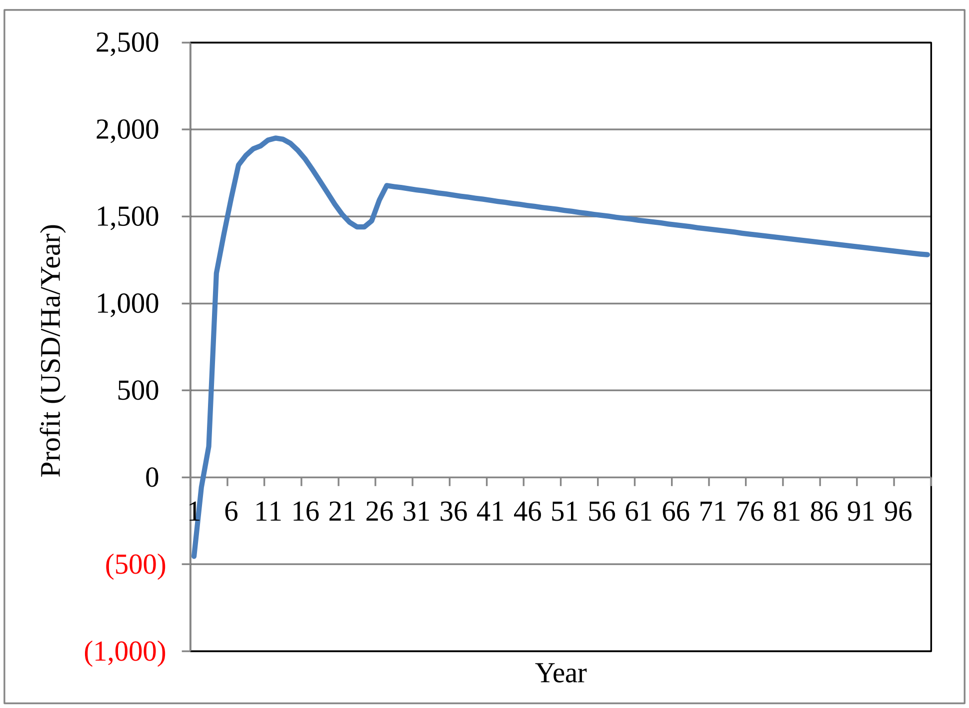
On the other hand, when cocoa producers neglect to replace their orchards in accordance to the optimal solution (zero percent replacement rate), the annual average net present value

(NPV) is estimated to be $389.59 (2010 USD/Ha/Year) over the study period. These results suggest that substantial economic gains (277.67 percent) are associated with using the optimal replacement rates compared with the status quo of retaining a tree until it will no longer bear fruit.

As presented in figure 30, net present value (NPV) of profit over 100 years which gradually declines after year 27 is due to the impact of higher discount rate than inflation rate. In addition, figure 30 also presents the highest profit that is achieved at year 12 with net present value (NPV) around $1,950.78 (2010 USD/Ha). However, this value can never be achieved as high as in year 12 in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees in this model is the same as in baseline model under Low Input, Landrace Cocoa (LILC).

Figure 30

Net Present Value (NPV) Over 100 Years for Baseline Model under High Input, Medium Shade Cocoa (HIMSC)



Besides that, implementing the optimal solution, steady state and average of cocoa trees are the same as in baseline model under Low Input, Landrace Cocoa (LILC) (Figure 13), where all of the first generation of cocoa trees will have been cut and replaced by the end of year 26. The steady state is achieved beginning of year 27 until the end of study period and the average age of cocoa trees is 10.5 years.

2. High Input, Medium Shade Cocoa (HIMSC) Assuming Cocoa Price Increases at Five per Year (Model 1)

Model 1 (a five not three percent increase in cocoa price annually), which is under High Input, Medium Shade Cocoa (HIMSC), projects the cocoa price to rise by two percent (from three to five percent) from its current price, holding all other variables constant.

As presented in table 33, the model indicates that cocoa farmers can acquire the highest profit by replacing five percent of their orchards annually and postponing the replacement age to year nine. The delay of the replacement age for one year longer in this optimal solution, which is different from baseline model under High Input, Medium Shade Cocoa (HIMSC), is because the cocoa producers can capture more profit of increasing cocoa price.

The optimal solution shows that as cocoa price increases by two percent, the annual profit increases by 31.69 percent from $1,471.37 (2010 USD/Ha/Year) (Table 32) to $1,937.67 (2010 USD/Ha/Year), Table 33. This high increase in profit is due to the model estimates a total increase of cocoa price by five percent annually, where a three percent increase in cocoa price is associated with an average historical increase from year 1985 to 2010 and a two percent increase is based on an assumption of shortage supply due to political unrest in cocoa producer countries and cocoa disease incidence which caused harvest failure.

Table 33

Average Net Present Value (NPV) Assuming Cocoa Price Increases at Five per Year (Model 1) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year) +

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,814.11	1,930.15	1,793.31	1,618.20	1,452.29	1,303.92	1,161.95
6	1,814.03	1,933.29	1,800.33	1,627.38	1,462.82	1,315.41	1,186.12
7	1,813.42	1,935.62	1,807.80	1,637.69	1,474.89	1,328.70	1,200.31
8	1,812.15	1,937.12	1,815.21	1,648.71	1,488.15	1,343.50	1,216.22
9	1,810.12	1,937.67*	1,821.99	1,659.99	1,502.19	1,359.45	1,233.55
10	1,807.23	1,937.12	1,827.48	1,670.97	1,516.57	1,376.14	1,251.90
11	1,803.39	1,935.37	1,831.45	1,681.04	1,530.72	1,393.09	1,270.86
12	1,798.49	1,932.29	1,833.82	1,689.51	1,544.05	1,409.76	1,289.92
13	1,792.47	1,927.80	1,834.46	1,695.82	1,555.86	1,425.51	1,308.50
14	1,785.24	1,921.79	1,833.26	1,699.98	1,565.36	1,439.64	1,325.94
15	1,776.76	1,914.20	1,830.14	1,701.87	1,572.17	1,451.33	1,341.51
16	1,766.99	1,904.98	1,825.05	1,701.43	1,576.30	1,459.81	1,354.35
17	1,755.89	1,894.10	1,817.93	1,698.62	1,577.69	1,465.21	1,363.53
18	1,743.47	1,881.55	1,808.79	1,693.43	1,576.35	1,467.52	1,369.26
19	1,729.74	1,867.36	1,797.66	1,685.89	1,572.32	1,466.77	1,371.60
20	1,714.76	1,851.58	1,784.61	1,676.09	1,565.67	1,463.09	1,370.65
Average	1,783.64	1,915.12	1,816.46	1,674.16	1,533.34	1,404.30	1,288.51
Max	1,814.11	1,937.67*	1,834.46	1,701.87	1,577.69	1,467.52	1,371.60
Min	1,714.76	1,851.58	1,784.61	1,618.20	1,452.29	1,303.92	1,161.95

+Denotes cocoa price increases at five percent not three percent annually.
*Denotes the solution with the highest average net present value (NPV).

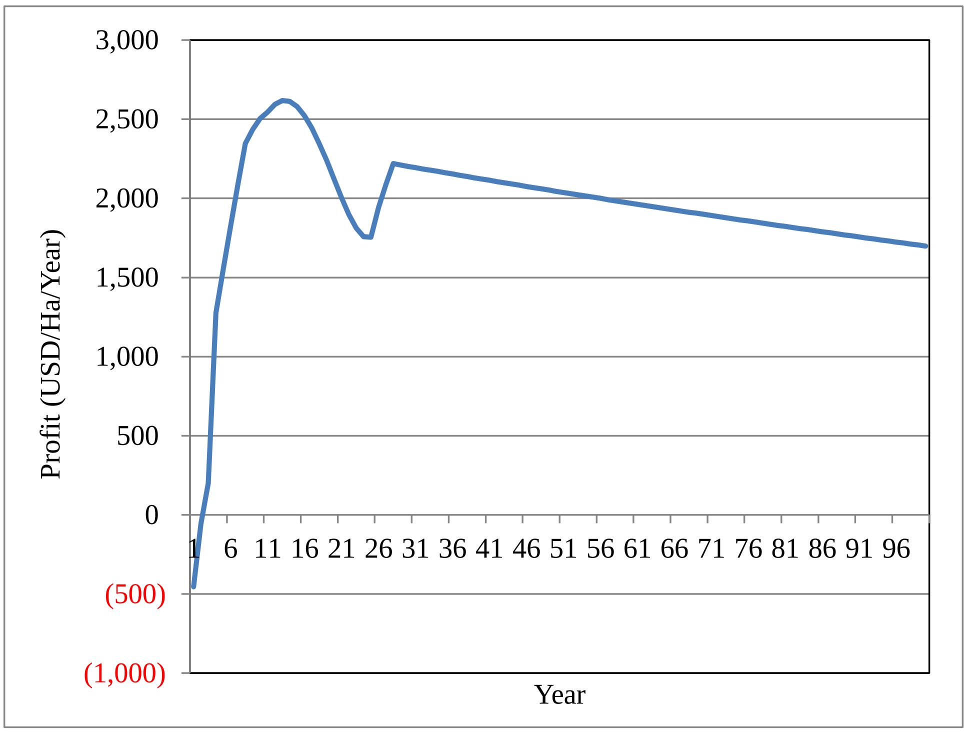
Furthermore, these optimal solutions are also similar to Low Input, Landrace Cocoa (LILC) and High Input, No Shade Cocoa (HINSC) optimal solutions, where changes in current price and future prices affect the optimum replacement age to decline. The findings also indicate that optimal replanting age is postponed as expected cocoa price increases which lead the cocoa farmers to take advantage of higher price. This behavior of cocoa farmers is categorized as price taker. Additionally, period of time to recover investment cost is also shorter as higher estimated price of cocoa.

Figure 31 presents the net present value (NPV) of profit over 100 years where the highest profit is about $2,617.78 (2010 USD/Ha). However, the profit gradually declines after year 28 due to the impact of higher discount rate than inflation rate. The profit in the long run will also be zero because of discounting effect greater than inflation rate.

The net present value (NPV) in the steady state period of model 1 (assuming a five percent annual increase in cocoa price) can never be achieved as high as about $2,617.78 (2010 USD/Ha) as in year 13. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees in this model is the same as in baseline model under High Input, No Shade Cocoa (HINSC).

Figure 31

Net Present Value (NPV) Over 100 Years Assuming a Five Percent Annual Increase in Cocoa Price (Model 1) under High Input, Medium Shade Cocoa (HIMSC)



Likewise, the steady state and average age of cocoa trees in this model (model 1, assuming a five percent annual increase in cocoa price) is the same as in model 1 (assuming a five percent annual increase in cocoa price) under Low Input, Landrace Cocoa (LILC) (Figure 13), where all first generation of cocoa trees will have been cut and replaced at the end of year 27. Steady state is achieved beginning at year 28 until the end of study period with the average age of cocoa tree is 10.5 years.

3. High Input, Medium Shade Cocoa (HIMSC) Assuming Fertilizer Price Increases by Five Percent (Model 2)

When projected fertilizer price increases by five percent per year (model 2), holding all other variables constant, the optimal replacement rate is equivalent to the baseline assumptions which is at five percent, whereas replacement age declines to year seven. The decline in replacement age is due to the cocoa producers try to avoid further cost increase in fertilizer prices.

In fact, an increase in fertilizer price results in declines profit in by 2.55 percent from $1,471.37 (2010 USD/Ha/Year) (Table 32) to $1,433.88 (2010 USD/Ha/Year), Table 34. This decline is caused by an increase in total production cost by 9.60 percent over 100 years. Therefore, by delaying the replacement age, the cocoa farmers can minimize the impact of further input price increases and reach the steady state one year earlier than baseline model.

Table 34

Average Net Present Value (NPV) Assuming Fertilizer Price Increases by Five Percent (Model 2) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,296.19	1,431.70	1,378.49	1,279.07	1,172.88	1,071.35	955.32
6	1,296.08	1,433.20	1,382.79	1,285.14	1,180.19	1,079.61	986.90
7	1,295.48	1,433.88*	1,387.04	1,291.64	1,188.23	1,088.82	997.03
8	1,294.30	1,433.82	1,390.87	1,298.23	1,196.71	1,098.71	1,008.02
9	1,292.46	1,432.95	1,393.89	1,304.56	1,205.30	1,108.97	1,019.57
10	1,289.90	1,431.16	1,395.68	1,310.26	1,213.65	1,119.28	1,031.39
11	1,286.55	1,428.39	1,396.20	1,314.91	1,221.38	1,129.28	1,043.12
12	1,282.37	1,424.57	1,395.44	1,318.06	1,228.07	1,138.57	1,054.40
13	1,277.31	1,419.65	1,393.35	1,319.43	1,233.27	1,146.74	1,064.82
14	1,271.35	1,413.58	1,389.87	1,319.18	1,236.51	1,153.33	1,073.95
15	1,264.45	1,406.35	1,384.98	1,317.26	1,237.67	1,157.84	1,081.32
16	1,256.62	1,397.95	1,378.66	1,313.67	1,236.91	1,159.86	1,086.42
17	1,247.86	1,388.38	1,370.94	1,308.42	1,234.23	1,159.72	1,088.72
18	1,238.19	1,377.67	1,361.83	1,301.54	1,229.69	1,157.46	1,088.65
19	1,227.66	1,365.87	1,351.40	1,293.11	1,223.36	1,153.18	1,086.33
20	1,216.31	1,353.06	1,339.73	1,283.22	1,215.35	1,147.00	1,081.89
Average	1,270.82	1,410.76	1,380.70	1,303.61	1,215.84	1,129.36	1,046.74
Max	1,296.19	1,433.88*	1,396.20	1,319.43	1,237.67	1,159.86	1,088.72
Min	1,216.31	1,353.06	1,339.73	1,279.07	1,172.88	1,071.35	955.32

* Denotes the solution with the highest average net present value (NPV).

Figure 32 presents net present value (NPV) of profit over 100 years which gradually declines after year 26 due to the impact of higher discount rate than inflation rate. Moreover, as presented in figure 32, the highest profit is achieved at year 12 with net present value (NPV) around $1,868.54 (2010 USD/Ha). However, it can never be achieved as high as $1,868.54 (2010 USD/Ha) in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement, where the variation of the age of cocoa trees in this model is the same as in baseline model 1 (assuming a five percent annual increase in cocoa price) under Low Input, Landrace Cocoa (LILC).

As presented in figure 33, steady state for model 2 (assuming fertilizer price increases by five percent per year) can be achieved at the beginning of year 26 following the optimal replacement rate at five percent and replacement age at the beginning of year seven. In this model, all first generation of cocoa trees will have been cut and replaced with new seedling by the end of year 25. Similar to other models under Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), the average age of cocoa tree remains 10.5 years once steady state is achieved.

Figure 32

Net Present Value (NPV) Over 100 Years Assuming Fertilizer Price Increases by Five Percent per Year (Model 2) under High Input, Medium Shade Amazon Cocoa (HIMSC)

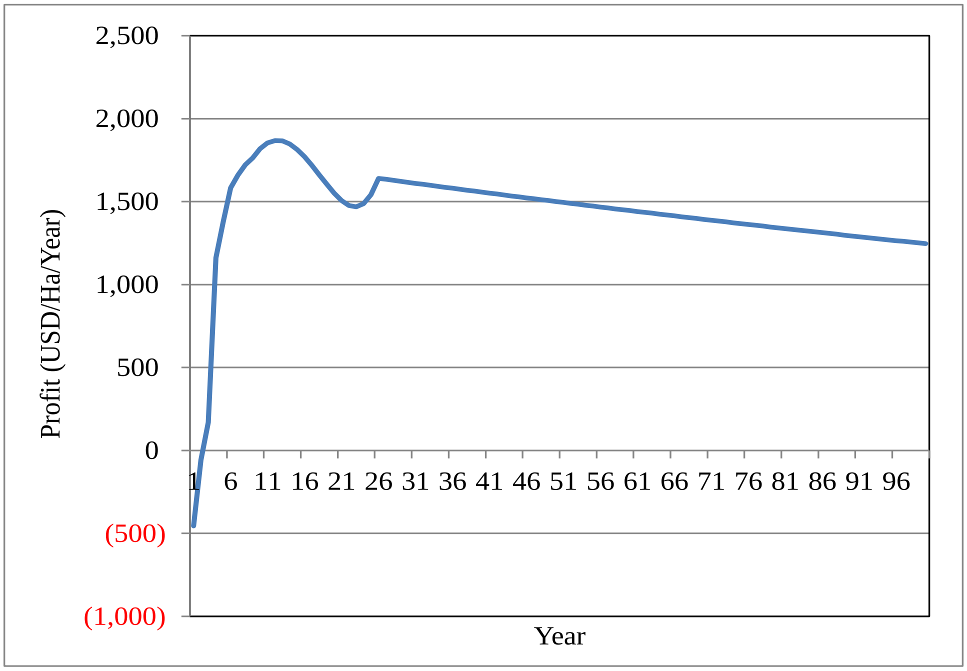
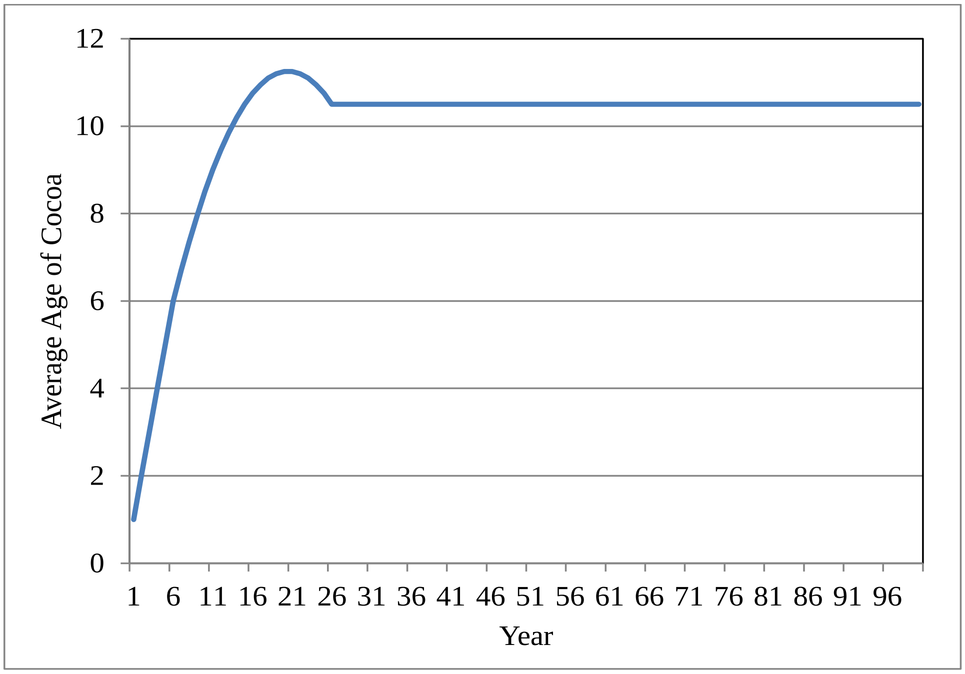


Figure 33

Average Age of Cocoa Trees Assuming Fertilizer Price Increases by Five Percent per Year (Model 2) under High Input, Medium Shade Amazon Cocoa (HIMSC)



4. High Input, Medium Shade Cocoa (HIMSC) Assuming Inflation Rate Increases from Current Ghanaian Rate 10.26 to 15 Percent per Year (Model 3)

Table 35 presents the average net present value (NPV) where inflation rate is estimated to rise from the current Ghanaian rate of 10.26 to 15 percent. Holding all other variables constant, the optimal annual replacement rate is estimated at five percent and the optimal replacement age declines to year five. The decline in replacement age is due to the cocoa producers try to avoid further cost increase in labor and material.

Furthermore, the average annual profit in this model increased by 1,414 percent from $1,471.37 (2010 USD/Ha/Year) (Table 32) to $22,290.79 (2010 USD/Ha/Year), Table 35. This large increase is due to the fact cocoa price is associated with the inflation rate. If an inflation rate increases, this study also assumes that the cocoa price increases at the same rate.

Table 35

Average Net Present Value (NPV) Assuming Inflation Rate Increases from Current Ghanaian Rate 10.26 to 15 Percent per Year (Model 3) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

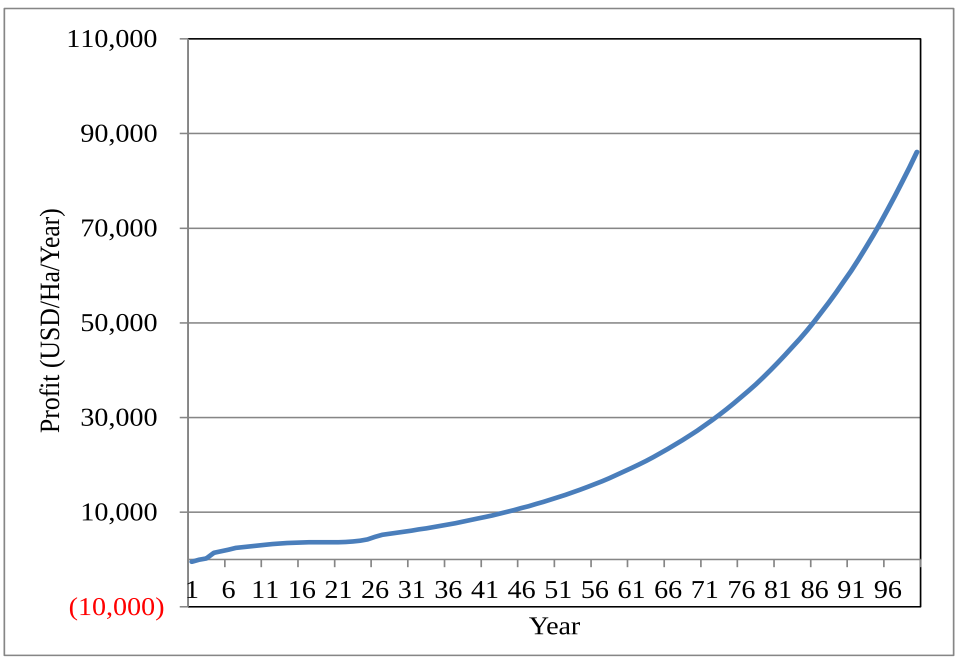
Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	19,777.78	22,290.79*	21,385.37	19,726.12	17,986.27	16,345.12	14,691.94
6	19,772.69	22,289.98	21,390.79	19,734.80	17,996.91	16,357.09	14,863.75
7	19,765.63	22,286.57	21,395.87	19,744.32	18,009.07	16,371.02	14,878.96
8	19,756.41	22,280.66	21,399.83	19,754.12	18,022.32	16,386.58	14,896.16
9	19,744.84	22,272.03	21,401.72	19,763.50	18,036.14	16,403.35	14,915.01
10	19,730.72	22,260.46	21,400.42	19,771.63	18,049.85	16,420.78	14,935.04
11	19,713.87	22,245.69	21,395.64	19,777.49	18,062.64	16,438.18	14,955.68
12	19,694.08	22,227.51	21,387.26	19,779.87	18,073.53	16,454.74	14,976.21
13	19,671.17	22,205.68	21,375.03	19,777.86	18,081.35	16,469.46	14,995.75
14	19,644.95	22,179.98	21,358.70	19,771.55	18,084.69	16,481.12	15,013.25
15	19,615.25	22,150.21	21,338.06	19,760.70	18,082.95	16,488.32	15,027.44
16	19,581.91	22,116.17	21,312.89	19,745.10	18,076.19	16,489.62	15,036.83
17	19,544.79	22,077.71	21,283.02	19,724.54	18,064.21	16,485.41	15,039.66
18	19,503.78	22,034.69	21,248.32	19,698.91	18,046.88	16,475.53	15,036.49
19	19,458.78	21,987.01	21,208.69	19,668.11	18,024.11	16,459.92	15,027.24
20	19,409.75	21,934.63	21,164.11	19,632.13	17,995.91	16,438.59	15,011.96
Average	19,649.15	22,177.49	21,340.36	19,739.42	18,043.31	16,435.30	14,956.34
Max	19,777.78	22,290.79*	21,401.72	19,779.87	18,084.69	16,489.62	15,039.66
Min	19,409.75	21,934.63	21,164.11	19,632.13	17,986.27	16,345.12	14,691.94

+Denotes an increase of 4.74 percent inflation rate from current Ghanaian rate 10.26.
*Denotes the solution with the highest average net present value (NPV).

Figure 34 also indicates that profit per hectare increases exponentially over 100 years. This high increment in profit is partially because the cocoa price is associated with the inflation rate. This study also assumes that the cocoa price increases at the same rate as inflation rate increases. Therefore, the profit in the long run will increase gradually if this phenomenon persists. In other words, as the inflation rate is greater than the discount rate, profit will increase to infinity.

Figure 34

Net Present Value (NPV) Over Time for Model 3 under HIMSC Net Present Value (NPV) Over 100 Years Assuming Inflation Rate Increases from Current Ghanaian Rate 10.26 to 15 Percent per Year (Model 3) under High Input, Medium Shade Cocoa (HIMSC)



Moreover, the average age of cocoa trees after the replacement phase is 10.5 years. This model has the same steady state and average age of cocoa trees as in model 3 (assuming inflation rate increases from current Ghanaian rate 10.26 to 15 percent per year) under Low Input, Landrace Cocoa (LILC), Figure 15.

5. High Input, Medium Shade Cocoa (HIMSC) Assuming Labor Price Increases at Five percent per Year (Model 4)

Table 36

Average Net Present Value (NPV) Assuming Labor Price Increases at Five Percent per Year (Model 4) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,069.66	1,224.99	1,205.66	1,135.64	1,052.72	969.65	818.14
6	1,069.54	1,225.70*	1,208.85	1,140.48	1,058.75	976.62	898.52
7	1,068.95	1,225.49	1,211.76	1,145.46	1,065.20	984.21	907.03
8	1,067.81	1,224.59	1,214.07	1,150.27	1,071.79	992.16	916.07
9	1,066.07	1,222.93	1,215.45	1,154.61	1,078.22	1,000.19	925.35
10	1,063.66	1,220.44	1,215.53	1,158.14	1,084.18	1,007.99	934.59
11	1,060.55	1,217.07	1,214.41	1,160.50	1,089.32	1,015.23	943.48
12	1,056.68	1,212.75	1,212.15	1,161.32	1,093.29	1,021.58	951.68
13	1,052.05	1,207.47	1,208.72	1,160.43	1,095.71	1,026.68	958.86
14	1,046.62	1,201.20	1,204.08	1,158.13	1,096.19	1,030.13	964.62
15	1,040.40	1,193.93	1,198.24	1,154.41	1,094.77	1,031.55	968.60
16	1,033.38	1,185.67	1,191.20	1,149.28	1,091.73	1,030.61	970.36
17	1,025.60	1,176.45	1,182.99	1,142.77	1,087.10	1,027.87	969.48
18	1,017.07	1,166.29	1,173.66	1,134.94	1,080.96	1,023.42	966.67
19	1,007.85	1,155.27	1,163.27	1,125.87	1,073.38	1,017.36	962.07
20	998.00	1,143.46	1,151.93	1,115.67	1,064.51	1,009.81	955.82
Average	1,046.49	1,200.23	1,198.25	1,146.75	1,079.86	1,010.32	938.21
Max	1,069.66	1,225.70*	1,215.53	1,161.32	1,096.19	1,031.55	970.36
Min	998.00	1,143.46	1,151.93	1,115.67	1,052.72	969.65	818.14

* Denotes the solution with the highest average net present value (NPV).

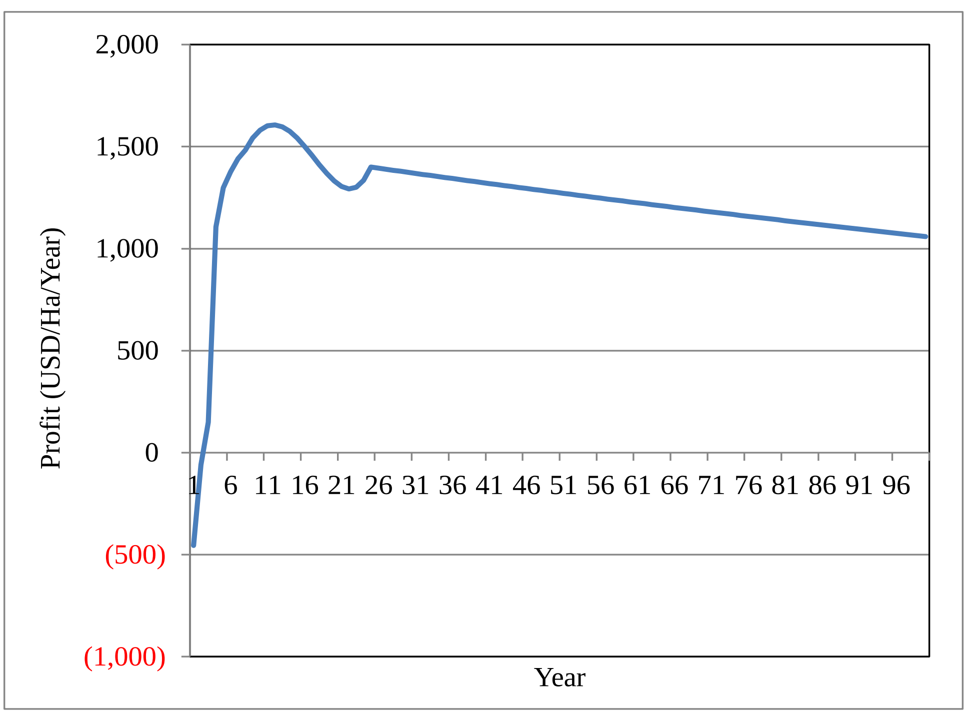
Model 4 (assuming labor price increases at five percent per year) projects labor price to increase by five percent, holding other variables constant. As presented in table 36, the optimal replacement rate is five percent and age of replacement declines to year six. This decline is mainly due to the additional cost associated with increasing in labor costs.

This model also shows that as labor price increases by five percent, which adds up additional cost to the total production cost, the profit declines by 16.70 percent or from $1,471.37 (2010 USD/Ha/Year) (Table 32) to $1,225.70 (2010 USD/Ha/Year), Table 36. Labor is one of the largest cost components in cocoa farming which account for 78.31 percent of total cost (Table 14), thus a small change in labor price can have significant impacts on profitability.

These findings also indicate that an increase in labor price affect the optimum age of replacement directly. In this case, as labor price is expected to increase, the optimal time to replace cocoa trees will be delayed in order to avoid incurring additional cost. Therefore, delaying replanting of cocoa trees helps cocoa producers to avoid further cost increase. Moreover, higher estimated labor price also indicates a longer period of time to recover investment cost.

Figure 35

Net Present Value (NPV) Over 100 Years Assuming Labor Price Increases at Five per Year (Model 4) under High Input, Medium Shade Cocoa (HIMSC)



Furthermore, figure 35 presents net present value (NPV) of profit over 100 years which gradually declines after year 25 due to the impact of higher discount rate than inflation rate. Moreover, the highest profit is achieved at year 12 with net present value (NPV) about $1,607.09 (2010 USD/Ha), Figure 35. However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. The variation of the age of cocoa trees, the steady state, and average age of cocoa trees for this model are the same as in model 4 (assuming labor price increases at five per year) under Low Input, Landrace Cocoa (LILC) (Figure 17).

6. High Input, Medium Shade Cocoa (HIMSC) Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5)

In model 5 (assuming 20 percent yield loss and 10 percent land infected due to black pod), the study assumes that 10 percent of the farm is infected with black pod which results in a 20 percent yield. This assumption was built under the premise that a farm will typically contract black pod but the entire farm will not be affected.

The model found that the optimal replacement rate is five percent and age of replacement is at year eight (Table 37), which is the same as in baseline model. However, following the optimal solution, profit declines by 2.64 percent $1,471.37 (2010 USD/Ha/Year) (Table 32) to $1,432.46 (2010 USD/Ha/Year) (Table 37). Additionally, steady state and average age of cocoa trees are also the same as in the baseline assumption. In this model, black pod causes two percent total yield loss. Therefore, mitigation of black pod incidence through implementing traditional approach or spraying copper base pesticide can mitigate further yield loss.

Table 37

Average Net Present Value (NPV) Assuming 20 Percent Yield Loss and 10 Percent Land Infected due to Black Pod (Model 5) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,309.35	1,429.52	1,369.81	1,267.45	1,159.97	1,057.96	952.49
6	1,309.26	1,431.23	1,374.24	1,273.60	1,167.33	1,066.23	973.46
7	1,308.68	1,432.20	1,378.68	1,280.22	1,175.45	1,075.49	983.61
8	1,307.53	1,432.46*	1,382.78	1,287.00	1,184.06	1,085.46	994.65
9	1,305.74	1,431.91	1,386.16	1,293.60	1,192.84	1,095.87	1,006.30
10	1,303.23	1,430.45	1,388.41	1,299.63	1,201.46	1,106.38	1,018.28
11	1,299.95	1,428.03	1,389.42	1,304.72	1,209.53	1,116.65	1,030.23
12	1,295.84	1,424.56	1,389.17	1,308.41	1,216.65	1,126.31	1,041.81
13	1,290.86	1,420.00	1,387.59	1,310.41	1,222.40	1,134.93	1,052.62
14	1,284.98	1,414.31	1,384.64	1,310.79	1,226.30	1,142.08	1,062.24
15	1,278.17	1,407.45	1,380.27	1,309.51	1,228.19	1,147.28	1,070.21
16	1,270.43	1,399.41	1,374.49	1,306.55	1,228.15	1,150.11	1,076.04
17	1,261.76	1,390.21	1,367.28	1,301.93	1,226.20	1,150.76	1,079.21
18	1,252.17	1,379.86	1,358.69	1,295.68	1,222.36	1,149.29	1,080.00
19	1,241.71	1,368.41	1,348.76	1,287.85	1,216.72	1,145.77	1,078.52
20	1,230.43	1,355.93	1,337.58	1,278.54	1,209.38	1,140.33	1,074.88
Average	1,284.38	1,411.00	1,374.87	1,294.74	1,205.44	1,118.18	1,035.91
Max	1,309.35	1,432.46*	1,389.42	1,310.79	1,228.19	1,150.76	1,080.00
Min	1,230.43	1,355.93	1,337.58	1,267.45	1,159.97	1,057.96	952.49

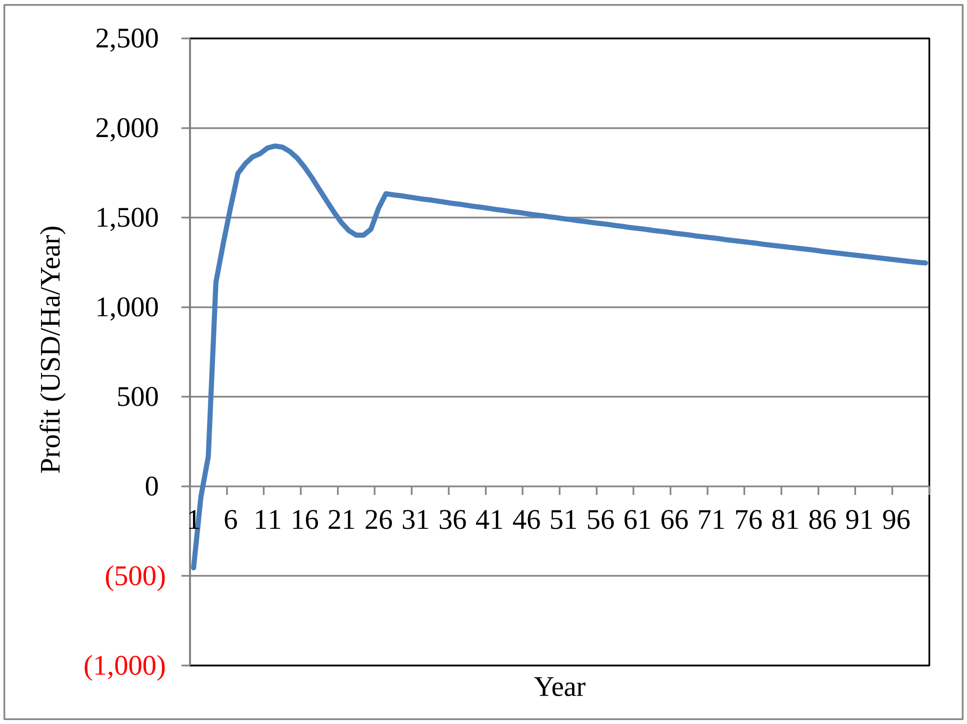
* Denotes the solution with the highest average net present value (NPV).

Furthermore, figure 36 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate.

Moreover, the highest profit is achieved at year 12 with net present value (NPV) around $1,900.16 (2010 USD/Ha), Figure 36. However, this value can never be reached in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. In this model, the variation of the age of cocoa trees, the steady state, and average age of cocoa trees is equivalent to baseline model under Low Input, Landrace Cocoa (LILC) (Figure 11).

Figure 36

Net Present Value (NPV) Over 100 Years Assuming 20 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 5) under High Input, Medium Shade Cocoa (HIMSC)



7. High Input, Medium Shade Cocoa (HIMSC) Assuming 40 Percent Yield Loss and 10 Land Infected due to Black Pod (Model 6)

Model 6 assumes that there is a 40 percent yield loss due to black pod with the same 10 percent of the farm being infected. Yield loss estimation is based on a finding by Ward et al. (as cited in Lass, 2001a) where infected pods rate was more than 30 percent up to 60.9 percent. The model estimated that optimal annual replacement rate is at five percent and age of replacement is at year eight where total profit declines by 5.24 percent or from $1,471.37 (2010 USD/Ha) (Table 32) to $1,393.55 (2010 USD/Ha/Year), Table 38.

Table 38

Average Net Present Value (NPV) Assuming 40 Percent Yield Loss and 10 Percent Land Infected due to Black Pod (Model 6) under High Input, Medium Shade Cocoa (HIMSC) (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,273.36	1,390.66	1,332.17	1,232.05	1,126.98	1,027.27	923.93
6	1,273.28	1,392.34	1,336.50	1,238.06	1,134.16	1,035.35	944.69
7	1,272.73	1,393.29	1,340.84	1,244.54	1,142.10	1,044.39	954.61
8	1,271.62	1,393.55*	1,344.86	1,251.17	1,150.52	1,054.15	965.40
9	1,269.89	1,393.02	1,348.16	1,257.62	1,159.11	1,064.32	976.79
10	1,267.46	1,391.61	1,350.37	1,263.52	1,167.53	1,074.60	988.50
11	1,264.28	1,389.26	1,351.37	1,268.50	1,175.42	1,084.64	1,000.19
12	1,260.29	1,385.89	1,351.14	1,272.11	1,182.40	1,094.08	1,011.51
13	1,255.46	1,381.46	1,349.61	1,274.08	1,188.02	1,102.52	1,022.08
14	1,249.75	1,375.92	1,346.75	1,274.46	1,191.84	1,109.52	1,031.49
15	1,243.13	1,369.25	1,342.51	1,273.23	1,193.70	1,114.61	1,039.29
16	1,235.60	1,361.43	1,336.88	1,270.37	1,193.69	1,117.39	1,045.01
17	1,227.17	1,352.48	1,329.88	1,265.88	1,191.80	1,118.04	1,048.11
18	1,217.85	1,342.41	1,321.52	1,259.81	1,188.08	1,116.63	1,048.91
19	1,207.68	1,331.26	1,311.85	1,252.20	1,182.60	1,113.22	1,047.48
20	1,196.70	1,319.11	1,300.97	1,243.14	1,175.46	1,107.94	1,043.96
Average	1,249.14	1,372.68	1,337.21	1,258.80	1,171.46	1,086.17	1,005.75
Max	1,273.36	1,393.55*	1,351.37	1,274.46	1,193.70	1,118.04	1,048.91
Min	1,196.70	1,319.11	1,300.97	1,232.05	1,126.98	1,027.27	923.93

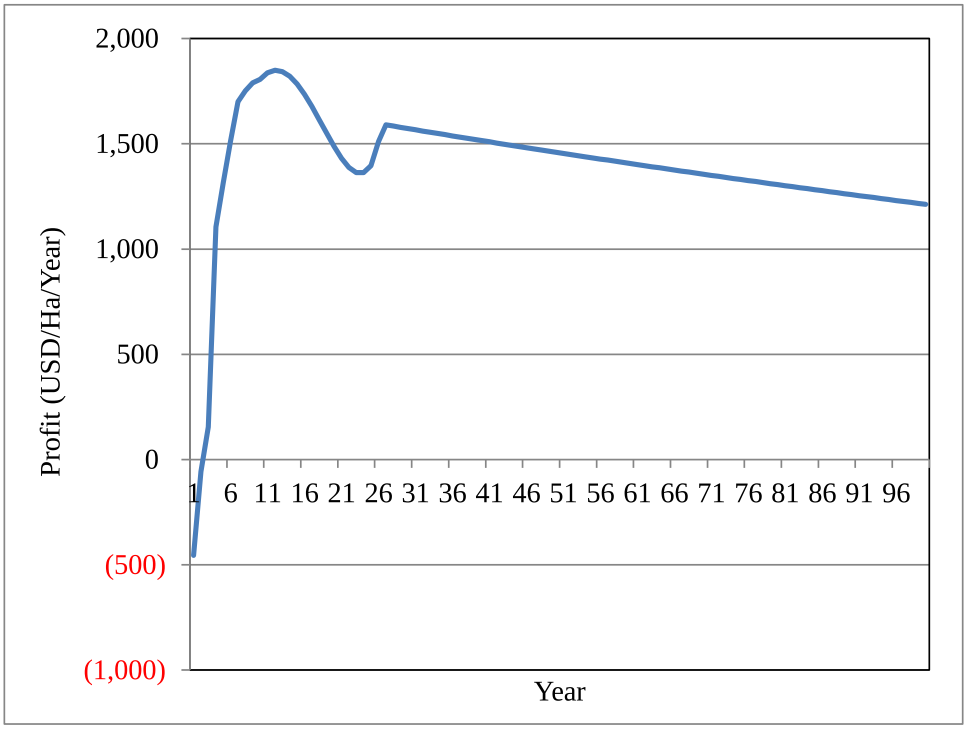
* Denotes the solution with the highest average net present value (NPV).

Figure 37 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. It also shows that in the first two years of production cycle, profit is negative due to the establishing cost (planting and annual costs) and no revenue is being realized during early period of cocoa planting. This is due to the cocoa trees start to bear the fruit in year three.

Figure 37 illustrates that the highest profit is achieved at year 12 with net present value (NPV) around $1,849.53 (2010 USD/Ha). However, in the steady state period, net present value (NPV) can never be achieved as high as in year 12. In this model, the variation of the age of cocoa trees, the steady state, and average age of cocoa trees following the optimal replacement rate and age of replacement are equivalent to baseline model under Low Input, Landrace Cocoa (LILC) (Figure 11).

Figure 37

Net Present Value (NPV) Over 100 Years Assuming 40 Percent Yield Loss and 10 percent Land Infected due to Black Pod (Model 6) High Input, Medium Shade Cocoa (HIMSC)



8. Summary of Net Present Value (NPV), Replacement Rate, Age of Replacement, Steady State, and Percentage Change of Profit under High Input, Medium Shade Cocoa (HIMSC)

The net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit for all models (model 1-6) are presented in table 39. In this production system, the optimal replacement rate for all models is five percent and the age of replacement varies from year five to nine.

Table 39 also shows the same pattern of the net present value (NPV), replacement rate, age of replacement, steady state, and percentage change in profit under High Input, Medium Shade Cocoa (HIMSC) as they are under Low Input, Landrace Cocoa (LILC). The only different is in model 2 (fertilizer price increases by five percent), where the age of replacement under High Input, Medium Shade Cocoa (HIMSC) is delayed one year. This different is mainly due to no fertilizer input is applied under Low Input, Landrace Cocoa (LILC) production system.

Table 39
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 Model	1,471.37	5	8	27	277.67**
Model 1	1,937.67	5	9	28	31.69***
Model 2	1,433.88	5	7	27	-2.55***
Model 3	22,290.79	5	5	24	1,414.97***
Model 4	1,225.70	5	6	25	-16.70***
Model 5	1,432.46	5	8	27	-2.64***
Model 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 Model.

9. Yield and Profit of Optimal Replacement Model and Status Quo under High Input, Medium Shade Cocoa (HIMSC) Assuming Zero Percent Price Increase, Inflation and Discount Rates

Table 40 also compares total yield of cocoa and profit over 50 years between optimal replacement model and status quo (zerto percent annual replacement rate) under High Input, Medium Shade Cocoa (HIMSC) production system.

Table 40

Summary of Total Yield and Profit under High Input, Medium Shade Cocoa (HIMSC)

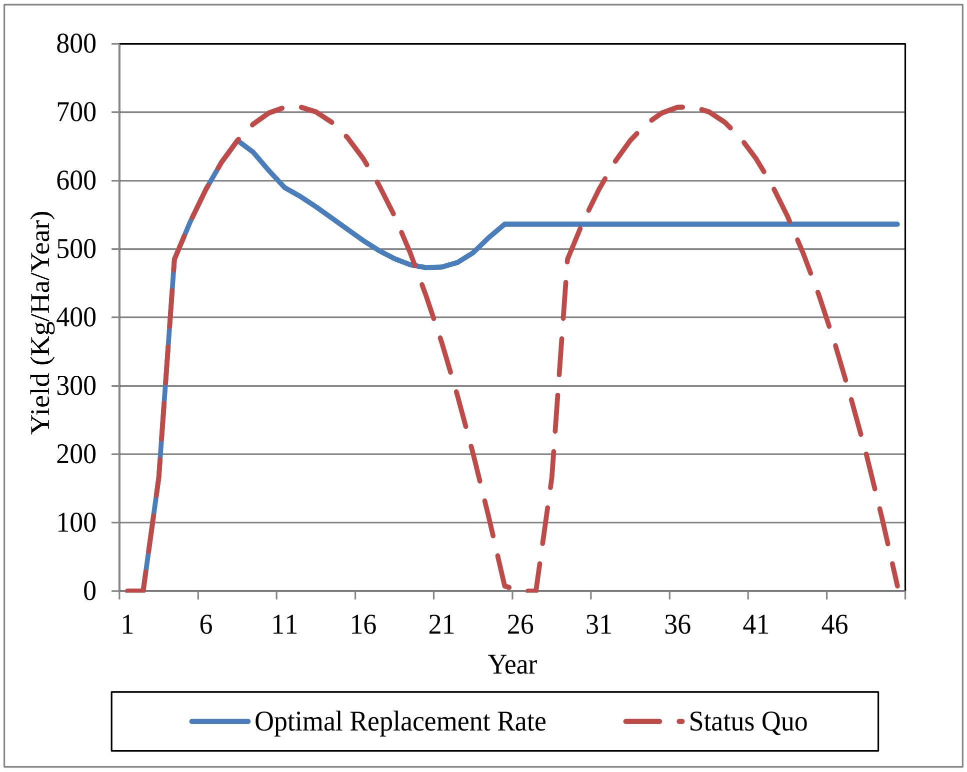
Yield*			Profit**		
Optimal Replacement Model	Status Quo	Percentage Change in Yield	Optimal Replacement Model	Status Quo	Percentage Change in Profit
25,480	23,152	10.06	56,009	49,299	13.61

* Denotes the total yield over 50 years in Kg/Ha.

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

Figure 38

Cocoa Yield Over 50 Years Assuming Zero Percent Price Increase, Inflation and Discount Rates for Status Quo and Replacement Model under High Input, Medium Shade Cocoa (HIMSC)



The model estimated that the optimal replacement rate is six percent and the age of replacement is at year nine. Following the optimal solution, the yield and profit can be achieved (10.06 and 13.61 percent higher over 50 years) compared with the status quo of retaining a tree until it bears no fruit (Table 40).

Figure 38 compares the yield of cocoa over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under High Input, Medium Shade Cocoa (HIMSC) production system. Similarly, the graph for profit also mirrors the graph for yield of cocoa (Figure 38).

D. Organic Cocoa

Organic cocoa is derived from High Input, Medium Shade Cocoa (HIMSC), where the yield and cost of pod harvesting and collecting, pod breaking, fermentation, drying/sorting, transport to drying site are reduced by 30 percent as proposed and estimated by Victor et al. (2010) and Phuoc et al. (2008) as a consequence to farm cocoa organically. Organic cocoa is a pesticide and fertilizer free production system, which has to be in line with organic farming definition by Codex Alimentarius (1999) and International Federation of Organic Agriculture Movements (IFOAM) (n.da) in order to be considered as organic cocoa.

Besides that, 10 percent premium price is estimated based on the Fairtrade's premium price which ranges from $100 and $300 per ton (ICCO, 2007a). This production system however, excludes the fees associated with converting conventional farming to certified organic farming. There costs are initial application fee, annual certification fee on a fixed basis or in proportion to sales of three percent of farm turnover, documentation costs; and increasing in production costs (ICCO, 2005; ICCO, 2006).

1. Organic Cocoa Baseline Model

The baseline model under Organic Cocoa production system employs several assumptions which are described in Table 12.

Table 41

Average Net Present Value (NPV) for Baseline Model under Organic Cocoa (USD/Ha/Year)

Replacement Rate*/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,101.69	1,195.90	1,146.94	1,063.85	976.49	893.35	813.43
6	1,101.60	1,197.39	1,150.61	1,068.91	982.55	900.17	824.32
7	1,101.09	1,198.29	1,154.29	1,074.35	989.21	907.76	832.65
8	1,100.09	1,198.57**	1,157.68	1,079.90	996.25	915.91	841.68
9	1,098.54	1,198.16	1,160.50	1,085.31	1,003.41	924.40	851.19
10	1,096.40	1,197.00	1,162.42	1,090.26	1,010.44	932.97	860.95
11	1,093.61	1,195.03	1,163.32	1,094.44	1,017.03	941.34	870.68
12	1,090.13	1,192.19	1,163.16	1,097.52	1,022.86	949.20	880.11
13	1,085.92	1,188.43	1,161.90	1,099.23	1,027.59	956.24	888.92
14	1,080.97	1,183.74	1,159.50	1,099.59	1,030.84	962.11	896.77
15	1,075.25	1,178.08	1,155.93	1,098.59	1,032.47	966.42	903.31
16	1,068.75	1,171.45	1,151.18	1,096.19	1,032.49	968.83	908.15
17	1,061.49	1,163.85	1,145.26	1,092.42	1,030.94	969.44	910.86
18	1,053.47	1,155.30	1,138.19	1,087.29	1,027.82	968.30	911.61
19	1,044.73	1,145.85	1,130.01	1,080.86	1,023.21	965.46	910.47
20	1,035.30	1,135.53	1,120.79	1,073.21	1,017.19	961.02	907.54
Average	1,080.56	1,180.92	1,151.36	1,086.37	1,013.80	942.68	875.79
Max	1,101.69	1,198.57**	1,163.32	1,099.59	1,032.49	969.44	911.61
Min	1,035.30	1,135.53	1,120.79	1,063.85	976.49	893.35	813.43

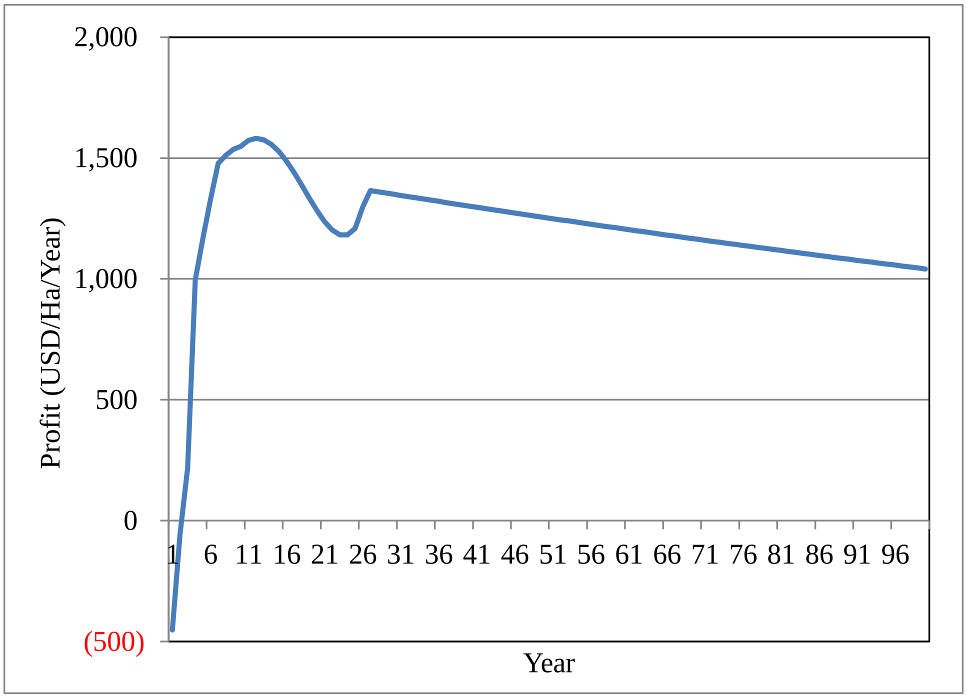
* Net present value (NPV) at zero percent replacement rate is $319.32 (2010 USD/Ha/Year).
** Denotes the solution with the highest average net present value (NPV).

Table 41 presents the optimal annual replacement rate and age of replacement under the baseline model. The model suggests that it is most profitable for cocoa producers to replace five percent of their orchards beginning in year eight such that the average net present value (NPV) is $1,198.57 (2010 USD/Ha/Year).

Conversely, with zero percent annual replacement rate, the annual average net present value (NPV) is USD $319.32 (2010 USD/Ha/Year) over the study period which is 100 years. These results suggest that substantial economic can be achieved (275.35 percent higher) when using the optimal replacement rates compared with the status quo of retaining a tree until it bears no fruit. However, a substantial economic gain of this model is lower by 18.25 percent compared to the baseline model under High Input, Medium Shade Cocoa (HIMSC). Moreover, the steady state and average age of cocoa trees in this model are also the same as they are in the baseline model in under Low Input, Landrace Cocoa (LILC) and High Input, Medium Shade Cocoa (HIMSC).

Figure 39

Net Present Value (NPV) Over 100 Years for Baseline Model under Organic Cocoa



Furthermore, figure 39 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate.

Moreover, the highest profit is achieved at year 12 with net present value (NPV) about $1,581.84 (2010 USD/Ha) (Figure 39). However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. In this model, the variation of the age of cocoa trees, the steady state, and average age of cocoa trees are equivalent to baseline model under Low Input, Landrace Cocoa (LILC) (Figure 11).

2. Organic Cocoa Assuming 30 Percent Yield Loss and 20 Percent Premium Price (Model 1)

Table 42

Average Net Present Value (NPV) Assuming 30 Percent Yield Loss and 20 Percent Premium Price (Model 1) under Organic Cocoa (USD/Ha/Year)

Replacement Rate/ Year of Replanting Tree	4%	5%	6%	7%	8%	9%	10%
5	1,227.66	1,331.89	1,278.66	1,187.73	1,091.98	1,000.77	913.39
6	1,227.52	1,333.51	1,282.68	1,193.29	1,098.62	1,008.25	925.00
7	1,226.92	1,334.48	1,286.70	1,199.25	1,105.93	1,016.58	934.14
8	1,225.77	1,334.76*	1,290.41	1,205.33	1,113.64	1,025.53	944.05
9	1,224.01	1,334.28	1,293.48	1,211.24	1,121.50	1,034.83	954.48
10	1,221.59	1,332.96	1,295.55	1,216.65	1,129.19	1,044.22	965.18
11	1,218.45	1,330.73	1,296.50	1,221.21	1,136.39	1,053.38	975.84
12	1,214.54	1,327.54	1,296.28	1,224.55	1,142.76	1,061.98	986.16
13	1,209.82	1,323.33	1,294.83	1,226.38	1,147.91	1,069.68	995.80
14	1,204.28	1,318.09	1,292.12	1,226.72	1,151.44	1,076.07	1,004.38
15	1,197.89	1,311.77	1,288.11	1,225.54	1,153.16	1,080.76	1,011.52
16	1,190.64	1,304.38	1,282.80	1,222.83	1,153.13	1,083.35	1,016.77
17	1,182.54	1,295.92	1,276.18	1,218.58	1,151.33	1,083.95	1,019.69
18	1,173.60	1,286.40	1,268.30	1,212.84	1,147.81	1,082.61	1,020.44
19	1,163.87	1,275.88	1,259.19	1,205.66	1,142.63	1,079.39	1,019.10
20	1,153.37	1,264.41	1,248.92	1,197.12	1,135.89	1,074.40	1,015.78
Average	1,203.90	1,315.02	1,283.17	1,212.18	1,132.71	1,054.73	981.36
Max	1,227.66	1,334.76*	1,296.50	1,226.72	1,153.16	1,083.95	1,020.44
Min	1,153.37	1,264.41	1,248.92	1,187.73	1,091.98	1,000.77	913.39

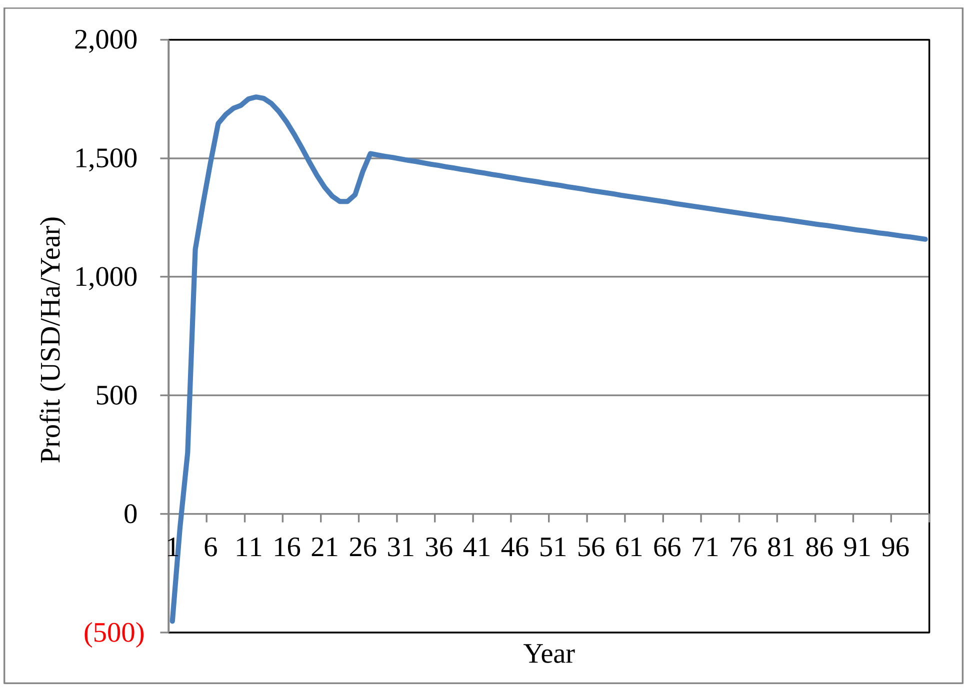
* Denotes the solution with the highest average net present value (NPV).

Model 1 (assuming 30 percent yield loss and 20 percent premium price) projects 30 percent yield reduction and premium price increase by 10 percent from current premium price (10 to 20 percent), holding other variables constant.

The model estimated that optimal annual replacement rate is at five percent and age of replacement is at year eight where total profit increases by 11.38 percent from $1,198.57 (2010 USD/Ha/Year) (Table 31) to $1,334.76 (2010 USD/Ha/Year), Table 42.

Figure 40

Net Present Value (NPV) Over 100 Years Assuming 30 Percent Yield Loss and 20 Percent Premium Price (Model 1) under Organic Cocoa



Furthermore, figure 40 presents net present value (NPV) of profit over 100 years which gradually declines after year 27 due to the impact of higher discount rate than inflation rate. It also shows that the highest profit is achieved at year 12 with net present value (NPV) about $1,759.02 (2010 USD/Ha) (Figure 40). However, this value can never be achieved in the steady state period. This is due to the variation of the age of cocoa trees following the optimal replacement rate and age of replacement. In this model, the variation of the age of cocoa trees, the steady state, and the average age of cocoa trees are equivalent to baseline model under Low Input, Landrace Cocoa (LILC) (Figure 11).

3. Summary of Net Present Value (NPV), Replacement Rate, Age of Replacement, Steady State, and Percentage Change of Profit under Organic Cocoa

Table 43 presents the results of organic production where a simulated black pod outbreak causes two and four percent total yield loss respectively. The models estimated that the replacement rate is five percent and the age of replacement is at year eight for both baseline model and model 1. Therefore, mitigation of black pod incidence through implementing traditional approach or spraying copper base pesticide can mitigate further yield loss.

Table 43
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 Model	1,198.57	5	8	28	275.35**
Model 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 Model.

Table 44, however, presents the summary of net present value (NPV) associated with production loss and premium price of organic cocoa. Because both the premium paid for and the yield of organic cocoa can vary from year to year, table 43 illustrates the tradeoff between the two. It shows that when 10 percent production loss and 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 60 percent production loss and given only 10 percent premium price, the lowest net present value (NPV) is $556.52 (2010 USD/Ha/Year).

As shown in table 44, 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 model under High Input, Medium Shade Cocoa (HIMSC), $1,471.37 (2010 USD/Ha/Year), the premium price that should be given to cocoa growers is at least 30 percent or $1,470.95 (2010 USD/Ha/Year) to encourage the cocoa farmers to grow their cocoa organically.

Table 44
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 model under High Input, Medium Shade Cocoa, $1,471.37 (2010 USD/Ha/Year).

The shaded areas in table 40 illustrate those combinations (price premium and yield loss) that represent a net present value (NPV) higher than or approximately equal to traditional production under High Input, Medium Shade Cocoa (HIMSC). 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 theoretically 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 44 could also be valuable to chocolate manufactures like Mars and Cadbury to determine what the premium price threshold level is to secure a supply of organic chocolate.

4. Yield and Profit of Optimal Replacement Model and Status Quo under Organic Cocoa Assuming Zero Percent Price Increase, Inflation and Discount Rates

Table 45 also compares the total yield of cocoa and profit over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under High Input, No Shade Amazon Cocoa (HINSC) production system.

Table 45
Summary of Total Yield and Profit under Organic Cocoa

Yield*			Profit**		
Optimal Replacement Model	Status Quo	Percentage Change in Yield	Optimal Replacement Model	Status Quo	Percentage Change in Profit
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)

The model estimated that the optimal replacement rate is six percent and the age of replacement is at year nine. Following the optimal solution, the yield and profit can be achieved (10.06 and 11.53 percent higher over 50 years) compared with the status quo of retaining a tree until it no longer bears the fruit (Table 45).

Figure 41 compares the yield of cocoa over 50 years between optimal replacement model and status quo (0 percent annual replacement rate) under High Input, No Shade Amazon Cocoa (HINSC) production system. Similarly, the graph for profit also mirrors the graph for yield of cocoa (Figure 41).

Figure 41

Cocoa Yield Over 50 Years Assuming Zero Percent Price Increase, Inflation and Discount Rates for Status Quo and Replacement Model under Organic Cocoa

V. CONCLUSION

A. Summary

This study has empirically estimated the optimum annual replacement rate and age of replacement of cocoa trees using empirical data from Ghana in order to maximize the net present value (NPV) of four production practices, which range from Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa. 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 found that optimal replacement rate for all models (baseline model - model 7) was five percent, whereas the optimal age of replacement varies from year five to eleven years after planting. From the baseline model substantial economic gains were 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 retaining a tree until it bears no fruit.

The study also found that cocoa price makes cocoa production very risky, where such small movements in price alter profits drastically. A cocoa price increase by two percent (from three to five percent), the annual profit can increase as much as 31.40, and 31.43 percent from the baseline model for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), and High Input, Medium Shade Cocoa (HIMSC), respectively

Additionally, the study compared the yield and profit levels of the optimal replacement model and the status quo (0 percent annual replacement rate), where projected cocoa prices increases, and inflation and discount rates are assumed zero percent. Following the optimal replacement model, it suggests that the yield is 10.06, 4.55, 10.06, and 10.06 percent higher and profit is 14.55, 5.62, 13.61, and 11.53 percent higher over 50 years for Low Input, Landrace Cocoa (LILC), High Input, No Shade Amazon Cocoa (HINSC), High Input, Medium Shade Cocoa (HIMSC), and Organic Cocoa, respectively.

Moreover, the study also estimated the production loss and premium price for organic cocoa. In general, the production loss and premium price are estimated 30 and 10 percent respectively. Theoretically, with a minimum 10 percent price premium and associated with less than 10 percent yield loss, cocoa producers should be willing to produce cocoa organically. Conversely, as yield reduction increases to 40 percent, they should receive a 60 percent price premium associated with producing organic cocoa. In fact, current premium price is $200 (2011 USD) with date of validity started in January 1, 2011 or only 6.32 percent from ICCO price. Ideally, with 30 percent production loss, the cocoa farmers should be compensated with at least 30 percent premium price.

As reported by World Resource Institute (n.d), 78.5 percent of the population in Ghana lives 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 is 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.

Therefore, 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 hypothetical steady state revenue. Small producers in many low-income countries often value yield stability (or revenue stability) as much as yield potential (revenue potential). Thus the results from this model can show producers what their expected profits will be and help them achieve a "safety first" type approach to revenue generation.

The model can also be used by cocoa producers or extension agents in other cocoa producing countries such as Cote d'Ivoire, Indonesia, Nigeria, Brazil and etc. 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, Excel is also “freely” available and accessible on almost every computer to everyone in low-income countries.

Many times in low-income countries, producers sit idly by as their yield decreases and their subsequent profits decrease as well due to 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.

B. Limitations of Study

There are several limitations and shortcomings, although this study was carefully prepared. First, because of limitation time, this research only estimated net present value (NPV) of four productions system.

Second, data in this study are limited to only 25 years. Some estimation might be slightly different from current optimal solutions if more years of observations were included. Third, there were no data available on soil degradation and environmental impact of the four production systems. Fourth, the study also did not estimate the stochastic replacement model.

C. Future Research

There are some areas that should be addressed in future studies. First of all, this study was entirely focused on net present value (NPV). A research on this issue can be extended to compare net present value (NPV) and the real option as an approach to minimize price volatility. Second, future research is also necessary to estimate net present value (NPV) associated with soil degradation and environmental impact. Third, a comparison study can also be extended from current optimal replacement model to stochastic replacement model.

VI. REFERENCES

The American Heritage dictionary of the English language. (2000). Boston: Houghton Mifflin.

Abanda, S. P. (n.d). *Challenges and opportunities facing African policymakers in promoting sustainable development of cocoa, coffee and cashew*. Retrieved July 26, 2011, from Tree Crops: www.treecrops.org/newsandevents/octconf/Essomba.pdf

Adeogun, S. O., & Agbongiarhuoyi, A. E. (2009). Assessment of cocoa farmers chemical usage pattern in pest and disease management in Ondo state. *J. Innov. Dev. Strategy, 3*(2), 27-34.

Agbeniyi, S., Ogunlade, M., & Oluyole, K. (2010). Fertilizer use and cocoa production in Cross River State, Nigeria. *ARPN Journal of Agricultural and Biological Science, 5*(3), 10-13.

Akiyama, T., & Duncan, R. C. (1984). Analysis of the world cocoa market. *World Bank Staff Commodity Working No. 8*.

Akiyama, T., & Nishio, A. (1996). Indonesia's cocoa boom Hands-off policy encourages smallholder dynamism. *Policy Research Working Paper 1580,* pp. 1-44.

Alfsen, K. H., Bye, T., Glomsrød, S., & Wiig, H. (1997). Soil degradation and economic development in Ghana. *Environment and Development Economics, 2*, 119–143.

Anikwe, J. (2010). The seasonal occurrence and control of the cocoa stem borer, Eulophonotus Myrmeleon Fldr. (Lepidoptera: Cossidae) on cocoa in Ibadan, Nigeria. *Libyan Agriculture Research Center Journal Internation, 1*(3), 42-146.

Arope, A. b. (1971, July). Economic considerations regarding the determination of optimum ages for oil palm replanting in Malaysia. *MARDI Agricultural Economic Buletin, 1*(3), pp. 1-13.

Asare, R., & David, S. (2010). Planting, replanting and tree diversification in cocoa systems. Learning about sustainable cocoa production: A guide for participatory farmer training. *Development and Environment Series, 13*.

Bank of Ghana. (n.da). *National consumer price index and inflation rates*. Retrieved July 12, 2011, from Bank of Ghana: http://www.bog.gov.gh/index1.php?linkid=174

Bank of Ghana. (n.db). *Treasury bill rates*. Retrieved July 12, 2011, from Bank of Ghana: http://www.bog.gov.gh/index1.php?linkid=210

Barrientos, S. W., Asenso-Okyere, K., Asuming-Brempong, S., Sarpong, D., Anyidoho, N. A., & Kaplinsky, R. (2007). *Mapping sustainable production in Ghanaian cocoa: A report for Cadbury Schweppes plc*. London: Cadbury Schweppes plc.

Bateman, R. (2008). *Pesticide use in cocoa A guide for training, administrative and research staff*. Retrieved June 20, 2011, from World Cocoa Foundation: http://www.worldcocoafoundation.org/scientific-research/research-library/documents/ManualPesticidesfinalversion_000.pdf

Beer, J. (1987). Advantages, disadvantages and desirable characteristics of shade trees for coffee, cacao and tea. *Agroforestry Systems, 5*, 3-13.

Beer, J., Muschler, R., Kass, D., & Somarriba, E. (1998). Shade management in coffee and cacao plantations. *Agroforestry Systems, 38*, 139–164.

Besanko, D., Dranove, D., Shanley, M., & Schaefer, a. S. (2010). *Economics of strategy* (5th ed.). Hoboken, NJ: John Wiley & Sons.

Brealey, R. A., Myers, S. C., & Marcus, A. J. (2001). *Fundamentals of Corporate Finance.* (Third, Ed.) Boston: The McGraw-Hill Companies.

Brooks, J., Croppenstedt, A., & Aggrey-Fynn, E. (2007, December). Distortions to agricultural incentives in Ghana. *Agricultural Distortions Working Paper 47*, pp. 1-55.

Bulíř, A. (2002). Can price incentive to smuggle explain the contraction of the cocoa supply in Ghana? *Journal of African Economies*, *11* (3), 413-439.

Byers, A., & Liu, P. (2008). *Value-adding standards in the North-American food market. Trade opportunities in certified products for developing countries.* (P. Liu, Ed.) Retrieved June 18, 2011, from FAO: ftp://ftp.fao.org/docrep/fao/010/a1585e/a1585e.pdf

Central Intelligence Agency (CIA). (n.d). *The World Fact Book: Ghana*. Retrieved April 13, 2011, from CIA: 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*. Retrieved June 18, 2011, from Codex Alimentarius : www.codexalimentarius.net/download/standards/360/cxg_032e.pdf

Congress, L. o. (n.d). *A Country Study: Ghana*. Retrieved April 20, 2011, from Library of Congress: http://memory.loc.gov/cgi-bin/query/r?frd/cstdy:@field%28DOCID+gh0089%29

Cunningham, R. K., & Arnold, P. (1962). The shade and fertilizer requirements of cacao (Theobroma cacao) in Ghana. *Journal of the science of food and agriculture, 13*(4), 213-221.

Debertin, D. L. (1986). *Agricultural production economics.* New York: Macmillan.

Diao, X., & Sarpong, D. B. (2007, May). Cost implications of agricultural land degradation in Ghana, An economywide, multimarket model assessment. *Ghana Strategy Support Program (GSSP) Background Paper No. 3*, pp. 1-34.

Dormon, E., Huis, A. V., Leeuwis, C., Obeng-Ofori, D., & Sakyi-Dawson, O. (2004). Causes of low productivity of cocoa in Ghana: Farmers' perspectives and insights from research and the socio-political establishment. *Netherlands Journal of Agricultural Science, 52*(3-4), 237-259.

Edwin, J., & Masters, W. A. (2005). Genetic improvement and cocoa yields in Ghana. *Experimental Agriculture, 41*, 491–503.

Entwistle, P. F. (2001). Insects and cocoa. In G. Wood, & R. Lass, *Cocoa* (pp. 365-443). Iowa: Blackwell Science. (Original work published 1985).

Etherington, D. M. (1977). A stochastic model for the optimal replacement of rubber trees. *Australian Journal of Aricultural Economics, 21*(1), 40-58.

Fairtrade International. (2011, July 14). *Fairtrade minimum price and Fairtrade premium table.* Retrieved July 23, 2011, from Fairtrade International: http://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2011-07-14_EN_Fairtrade_Minimum_Price_and_Premium_table.pdf

Faris, J. E. (1960). Analitical techniques used in determining the optimum replacement pattern. *Journal of Farm Economics, 42*(4), 755-766.

Food and Agriculture Organization of the United Nations (FAO). (2003). *Medium-term prospects for agricultural Commodities projections to the year 2010.* Retrieved April 13, 2011, from FAO: http://www.fao.org/docrep/006/y5143e/y5143e0x.htm

Food and Agriculture Organization of the United Nations (FAO). (2005a). *International code of conduct on the distribution and use of pesticides.* Retrieved June 26, 2011, from ftp://ftp.fao.org/docrep/fao/009/a0220e/a0220e00.pdf

Food and Agriculture Organization of the United Nations (FAO). (2005b). *Fertilizer use by crop in Ghana*. Retrieved May 12, 2011, from Food and Agriculture Organization of the United Nations (FAO): ftp://ftp.fao.org/agl/agll/docs/fertuseghana.pdf

Food and Agriculture Organization of the United Nations (FAO). (2011). *Faostat*. Retrieved June 14, 2011, from http://faostat.fao.org/

Food and Agriculture Organization of the United Nations (FAO). (n.d). *Export: Commodities by country*. Retrieved April 13, 2011, from FAO: http://faostat.fao.org/desktopdefault.aspx?pageid=342&lang=en&country=81

FSG Social Impact Advisors. (2009, March 3). *Managing risk in Côte d'Ivoire's cocoa sector.* Retrieved July 22, 2011, from World Bank: http://siteresources.worldbank.org/INTARD/Resources/335807-1236361651968/Cote_dIvoire_VisionforChange_WBARDPresentationv3.pdf

Ghana Cocoa Board (Cocobod). (n.d). *About us*. Retrieved June 26, 2011, from Ghana Cocoa Board (Cocobod): http://www.cocobod.gh/objectives.php

Ghana, B. o. (2008, September). *The fishing fub-fector and Ghana's economy*. Retrieved April 13, 2011, from Bank of Ghana: http://www.bog.gov.gh/privatecontent/File/Research/Sector%20Studies/fisheries_completerpdf.pdf

Gockowski, J. (2009). International Institute of Tropical Agriculture (IITA). Unpublished.

Gray, A. (2001). *The world cocoa market outlook*. Retrieved July 22, 2011, from LMC INTERNATIONAL: www.treecrops.org/crops/cocoaoutlook.pdf

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

Hartemink, A. E. (2005). Nutrient stock, nutrient cycling, and soil changes in cocoa ecosystems: a review. *Advances in Agronomy, 86*, 227-253.

Hill, P. (1956). *The gold coast cocoa farmer a preliminary survey*. London: Oxford University Press.

Hill, P. (1962). Social factors in cocoa farming. In J. B. Wills (Ed.), *Agriculture and land use in Ghana* (pp. 278-285). London: Oxford Univeristy Press.

Hughes, J. d., & Ollennu, L. (1994). Mild strain protection of cocoa in Ghana against cocoa swollen shoot virus—a review. *plant Pathology*, *43*, 442-457.

Hurd, R., & Cunningham, R. (1961). A cocoa shade and manurial experiment at the West African Cocoa Research Institute III, Physiological results. *Journal of Horticultural Science*, *36*, 126-137.

International Cocoa Organization (ICCO). (2005, May 31). *Facts and figures on Fair-Trade cocoa*. Retrieved May 27, 2011, from International Cocoa Organization: http://www.icco.org/documents/documentcategory.aspx?dispmode=detailed&catid=82

International Cocoa Organization (ICCO). (2006, July 26). *A study on the market for Organic Cocoa*. Retrieved May 27, 2011, from International Cocoa Organization: http://www.icco.org/documents/documentcategory.aspx?dispmode=detailed&catid=82

International Cocoa Organization (ICCO). (2007a). *International Cocoa Organization Annual Report 2005/2006*. London: International Cocoa Organization.

International Cocoa Organization (ICCO). (2007b, March 14). *Assesment of the movements of global supply and demand*. Retrieved July 22, 2011, from http://www.icco.org/Attachment.aspx?id=12r43706

International Cocoa Organization (ICCO). (2010, July 30). *The world cocoa economy: Past and present - 30 July 2010*. Retrieved June 13, 2011, from International Cocoa Organization: http://www.icco.org/Attachment.aspx?Id=tmx70586

International Cocoa Organization (ICCO). (n.da). *Growing cocoa*. Retrieved June 12, 2011, from International Cocoa Organization: http://www.icco.org/about/growing.aspx

International Cocoa Organization (ICCO). (n.db). *The Chocolate industry*. Retrieved June 18, 2011, from International Cocoa Organization: http://www.icco.org/about/chocolate.aspx

International Cocoa Organization (ICCO). (n.dc). *ICCO monthly averages of daily prices*. Retrieved July 24, 2011, from International Cocoa Organization (ICCO): http://www.icco.org/statistics/monthly.aspx?AD=2011&MD=1&AH=2011&MH=6&Tipo=Tabla&Datos=USD

International Cocoa Organization (ICCO). (n.dd). *ICCO daily prices of cocoa beans*. Retrieved May 25, 2011, from International Cocoa Organization (ICCO): http://www.icco.org/statistics/daily_prices.aspx

International Cocoa Organization (ICCO). (n.de). *Pest & diseases*. Retrieved July 24, 2011, from International Cocoa Organization (ICCO): http://www.icco.org/about/pest.aspx

International Federation of Organic Agriculture Movements (IFOAM). (n.da). *Definition of organic agriculture*. Retrieved June 18, 2011, from IFOAM: http://ifoam.org/growing_organic/definitions/doa/index.html

International Federation of Organic Agriculture Movements (IFOAM). (n.db). *The principles of organic agriculture*. Retrieved June 18, 2011, from IFOAM: http://ifoam.org/about_ifoam/principles/index.html

International Monetary Fund (IMF). (2011a). *Commodity tables*. Retrieved May 22, 2011, from International Financial Statistics Online database: www.imfstatistics.org

International Monetary Fund (IMF). (2011b). *Ghana country tables*. Retrieved May 22, 2011, from International Financial Statistics Online database: www.imfstatistics.org

Ismail, A., & Mamat, M. N. (2002). The optimal age of oil palm replanting. *Oil Palm Industry Economic Journal, 2*(1), 11-18.

Kolavalli, S., & Vigneri, M. (2011). Cocoa in Ghana: Shaping the success of an economy. In P. Chuhan-Pole, & M. Angwafo (Eds.), *Yes Africa can Success stories from a dynamic continent* (pp. 201-217). Washington DC: The World Bank.

Krauss, U., & Soberanis, W. (2002). Effect of fertilization and biocontrol application frequency on cocoa pod diseases. *Biological Control, 24*, 82–89.

Krisnamurthi, B. (n.d). *Indonesia cocoa: "Awaken the Giant"*. Retrieved July 20, 2011, from World Cocoa Foundation (WCF): http://www.worldcocoafoundation.org/scientific-research/research-library/documents/6.Menko.pdf

Lass, R. (2001a). Diseases. In G. Wood, & R. Lass, *Cocoa* (pp. 265-365). Iowa: Blackwell Science. (Original work published 1985).

Lass, R. (2001b). Labour usage. In G. Wood, & R. Lass, *Cocoa* (pp. 234-264). Iowa: Blackwell Science. (Original work published 1985).

Lass, R. (2001c). Replanting and rehabilitation of old cocoa farms. In G. Wood, & R. Lass, *Cocoa* (pp. 210-233). Iowa: Blackwell Science. (Original work published 1985).

Lass, R. A., & Wood, G. A. (Eds.). (1985). Cocoa production present constraints and priorities for research. *World Bank Technical Paper Number 39*.

McIntyre, J. (2001, February). *Reforming the cocoa marketing and pricing system in Côte d'Ivoire.* Retrieved July 22, 2011, from Montclair State University: http://msuweb.montclair.edu/~lebelp/CERAFRM067Mcintire2001.pdf

Montgomery, P. (1981). Some thoughts on the life span of cocoa. *Planter, 57*, 604-609.

Ndoumbe-Nkenga, M., Cilas, C., Nyemb, E., Nyasse, S., Bieysse, D., Flori, A., et al. (2004). Impact of removing diseased pods on cocoa black pod caused by Phytophthora megakarya and on cocoa production in Cameroon. *Crop Protection, 23*, 415–424.

Ndubuaku, T. C., & Asogwa, E. (2006). Strategies for the control of pests and diseases for sustainable cocoa production in Nigeria. *African Scientist, 7*(4), 209-216.

Obiri, B. D., Bright, G. A., McDonald, M. A., Anglaaere, L. C., & Cobbina, J. (2007). Financial analysis of shaded cocoa in Ghana. *Agroforest Syst, 71*, 139-149.

Ofori-Frimpong, K., Asase, A., Mason, J., & Danku, L. (n.d). *Shaded versus un-shaded cocoa: Implications on litter fall, decomposition, soil fertility and cocoa pod development.* Retrieved June 16, 2011, from Nature Conservation Research Centre (NCRC): www.ncrc-ghana.org/downloads/Ofori-frimpong_n_mason_07.pdf

Opoku, I. Y., Assuah, M. K., & Aneani, F. (2007). Management of black pod disease of cocoa with reduced number of fungicide application and crop sanitation. *African Journal of Agricultural Research, 2*(11), 601-604.

Pay, E. (2009, September). *Increasing incomes and food security of small farmers in West and Central Africa through exports of organic and fair-trade tropical products.* Retrieved June 3, 2011, from Food and Agriculture Organization of the United Nation (FAO): http://www.fao.org/fileadmin/templates/organicexports/docs/Market_Organic_FT_Cocoa.pdf

Perrin, R. K. (1972). Asset replacement principles. *American Journal of Agricultural Economics, 54*(1), 60-67.

Phuoc, P. H., Ngoc, L. M., Trung, N. C., Valenghi, D., & Giang, N. L. (2008). *Feasibility study organic and fairtrade cocoa in Vietnam.* Hanoi, Vietnam: Helvetas Vietnam.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., et al. (1992). Environmental and economic costs of pesticide use. *BioScience*(42), 750-760.

Potts, J., Meer, J. v., & Daitchman, J. (2010). *The state of sustainability initiatives review 2010: Sustainability and transparency*. Retrieved June 18, 2011, from Inter-American Development Bank: http://www.iadb.org/intal/intalcdi/PE/2010/07439.pdf

Rutherford, M. (2011). Assessing and addressing pesticide practice in cocoa producing countries to meet regulatory standards. *International Workshop on Safe Use of Pesticides in Cocoaand Harmonized Legislation for Food Safety*. Kuala Lumpur: CAB International.

Scott, D. L., & Moore, W. K. (1984). *Fundamentals of the time value of money*. New York: Praeger Publishers.

Simmons, R. (2010). Outlook for cocoa demand. *18th Partnership Meeting & Roundtable Sessions*. Washington DC: LMC International and World Cocoa Foundation (WCF).

Sonwa, D. J., Coulibaly, O., Weise, S. F., Adesina, A. A., & Janssens, M. J. (2008). Management of cocoa: Constraints during acquisition and application of pesticides in the humid forest zones of southern Cameroon. *Crop Protection, 27*, 1159– 1164.

Taher, S. (1996). Factors influencing smallholder cocoa production: A management analysis of behavioural decision-making processes of technology adoption and application. *Wageningen Dissertation Abstracts*, 2145, 1-159.

The Guardian. (2011, January 24). *Cocoa price soars as new Ivory Coast leader suspends exports*. Retrieved June 13, 2011, from The Guardian: http://www.guardian.co.uk/business/2011/jan/24/cocoa-price-ivory-coast-alassane-ouattara-laurent-gbagbo

The World Resources Institute. (n.d). *Economic Indicators -- Ghana*. Retrieved November 3, 2011, from The World Resources Institute: http://earthtrends.wri.org/pdf_library/country_profiles/eco_cou_288.pdf

Thong, K. C., & Ng, W. (1978). Growth and nutrient composition of monocrop cocoa plants on inland Malaysian soils. *Proceedings of International Conference on Cocoa and Coconuts* (pp. 262-286). Kuala Lumpur: The Incorporated Society of Planters.

Tijani, A. A. (2006a). Economic benefits of fungicide use among cocoa farmers in Osun and Ondo states of Nigeria. *Journal of Social Sciences, 12*(1), 63-70.

Tijani, A. A. (2006b). Pesticide use practices and safety issues: The case of cocoa farmers in Ondo State, Nigeria. *Journal of Human Ecology, 19*(3), 183-190.

Tisdell, C. A., & De Silva, N. T. (2008). Supply-Maximizing and Variation-Minimizing replacement cycles of perennial crops and similar assets: Theory Illustrated by coconut production. *Journal of Agricultural Economics, 37*(2), 243-251.

United Nation Conference on Trade and Development (UNCTAD). (n.da). *Information of cocoa.* Retrieved June 11, 2011, from United Nation Conference on Trade and Development (UNCTAD): http://r0.unctad.org/infocomm/comm_docs/docs/training/enInfoco694a.PDF

United Nation Conference on Trade and Development (UNCTAD). (n.db). *Prices.* Retrieved June 13, 2011, from United Nation Conference on Trade and Development (UNCTAD): http://www.unctad.org/infocomm/anglais/cocoa/prices.htm

United States Department of Labor. (2011, January 1). *Wage and hour division (WHD).* Retrieved July 27, 2011, from United States Department of Labor: http://www.dol.gov/whd/minwage/america.htm#Consolidated

Urquhart, D. H. (1955). *Cocoa.* London: Longman, Green.

Victor, A.-S., Gockowski, J., Agyeman, N. F., & Dziwornu, A. K. (2010). Economic cost-benefit analysis of certified sustainable cocoa production in Ghana. *3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference* (pp. 1-19). Cape Town, South Africa: Sustainable Tree Crops Program (STCP).

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

Wessel, M. (2001). Shade and nutrition. In G. Wood, & R. Lass, *Cocoa* (pp. 166-194). Iowa: Blackwell Science. (Original work published 1985).

Willey, R. (1975). The use of shade in coffee, cocoa and tea. *Horticultural Abstracts, 45*(12), 791–798.

Williams, T. (2009, January). An African success story: Ghana's cocoa marketing system. *IDS Working Paper 318,* pp. 1-47.

Willson, K. (1999). *Coffee, cocoa and tea.* Wallingford, Oxon: Cabi Publishing.

Wood, G. (2001). History and development. In G. Wood, & R. Lass, *Cocoa* (4th ed.). Iowa: Blackwell Science. (Original work published 1985).

World Cocoa Foundation (WFC). (n.d). *History of cocoa*. Retrieved June 11, 2011, from World Cocoa Foundation: http://www.worldcocoafoundation.org/learn-about-cocoa/history-of-cocoa.html

XE. (n.d). *The world favorite currency site*. Retrieved May 7, 2011, from XE: http://www.xe.com

VII. APPENDIX

Table 1

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study Under Planted Shade with Clear-Felling In Brazil

Task	Year 0	Year 1	Year 2	Year 3	Year 4	Notes
Clearing Lining and staking	80.0	-	-	-	-	Considered together in this study
Lime application	4.0	-	-	-	-	
Road and drain maintenance and water conservation	5.0	-	-	-	-	
Shad planting	28.0	-	-	-	-	
Shade maintenance	36.0	0.0	16.0	16.0	14.0	
Nursery construction	6.0	-	-	-	-	
Filling bags and sowing seed	10.0	-	-	-	-	
Cultural work in nursery	8.0	-	-	-	-	
Digging planting holes	12.0	-	-	-	-	
Planting cocoa	-	16.0	4.0	-	-	Including nursery work to grow replacements; 8 percent losses assumed
Weed control	10.0	30.0	48.0	48.0	40.0	Significant hand-weeding is usually needed until Year 4 as canopy incomplete
Fertilizer application	-	2.0	4.0	4.0	4.0	
Pest control	-	1.0	4.0	4.0	2.0	From Year 2 onwards 3 rounds spraying
Disease control	-	-	-	-	-	No diseases of importance
Pruning	-	-	2.0	10.0	12.0	Removal of chupons only in Year 2; Formation pruning in Year 3
Total	199.0	49.0*	78.0	82.0	72.0	

Source: After Mandarino and Santos (as cited in Lass, 2001).

Table 2

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study under Gliricidia from Primary Forest in Malaysia

Task	Year 1	Year 2	Year 3	Year 4	Notes
Clearing and land preparation	58.3	-	-	-	Surveying, under brushing, felling and burning
Lining and staking	7.7				-
Lime application	0.0	-	-	-	no lime applied
Road and drain maintenance and water conservation	39.6	5.9	5.0	5.0	
Shade planting	7.9	-	-	-	
Shade maintenance	34.6	7.4	7.4	3.0	
Nursery construction Filling bags and sowing seed Cultural work in nursery	19.8	-	-	-	Considered together; Labor for replacements included in planting supplies
Digging planting holes Planting cocoa	11.6	5.0	3.0	-	Considered together; Labor requirements for nursery work to provide plants included here
Weed control	15.6	40.0	23.0	7.0	
Fertilizer application	0.0	4.5	4.0	3.7	Fertilizer is placed in the planting hole, but labor usage included with planting
Pest control Disease control	0.0	12.4	12.8	16.8	Considered together; Mostly VSD* control; some rodent control
Pruning and shaping	0.0	5.0	8.6	13.8	
Total	195.1	80.2	63.8	49.3	

Source: Graham (as cited in Lass, 2001)
Notes: *VSD; vascular-streak dieback

Table 3

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study on Two Plantations in Trinidad

Task	Year 1	Year 2	Year 3	Year 4	Notes
Clearing and land preparation	0.0	-	-	-	Bulldozer by contract
Lining and staking	7.4	-	-	-	
Lime application	-	-	-	-	No lime applied
Road and drain maintenance and water conservation	0.0	-	-	-	No drainage needed
Shade planting	71.4	-	-	-	Including a wide variety of food crops, except bananas
Nursery construction Filling bags and sowing seed Cultural work in nursery	0.0	0.0	-	-	Material provided by government
Digging planting holes	14.8	1.5	-	-	10 percent losses assumed
Planting cocoa	17.3	1.7	-	-	10 percent losses assumed
Weed control	24.7	14.8	22.2	1.2	Hand-weeding years 1-3; herbicide in year 4
Fertilizer application	1.5	2.5	3.9	-	No fertilizer after Year 4
Pest control	-	-	-	-	No pest of importance
Disease control	-	-	-	-	No diseases of importance
Pruning and shaping	-	-	14.8	14.8	3 rounds from Year 3
Total	137.1	27.9	45.8	18.5	

Source: Lass (as cited in Lass, 2001)

Table 4

Labor Usage for Establishment In Man-Days Per Ha Per Annum for Case Study under Thinned Forest In Ghana

Task	Year 1	Year 2	Year 3	Year 4	Notes
Clearing and land preparation	81.5	-	-	-	Includes 27 for clearing; 20 for felling; 25 for burning; and 32 for *apam*
Lining and staking	0.0	-	-	-	Cocoa was not planted in lines in this study
Lime application	0.0	0.0	0.0	0.0	Not applicable
Road and drain maintenance and water conservation	0.0	0.0	0.0	0.0	Not applicable
Shade planting	14.8	-	-	-	Planting plantain suckers
Shade maintenance	-	2.5	2.5	2.5	Shade thinning
Nursery construction	NA	-	-	-	Not applicable
Filling bags and sowing seed	NA	-	-	-	Not applicable
Cultural work in nursery	NA	-	-	-	Not applicable
Digging planting holes } Planting cocoa	49.4	-	-	-	Considered together in this study
Weed control	98.8	81.5	81.5	81.5	
Fertilizer application	0.0	0.0	0.0	0.0	
Pest control	2.5	2.5	2.5	2.5	Trapping for rodents; No other pest control practices
Disease control	0.0	0.0	0.0	0.0	No disease control normally practiced
Pruning and shaping	0.0	0.0	0.0	0.0	No pruning normally practiced
Total	247.0	86.0	86.0	86.0	

Source: After Okali (as cited in Lass, 2001)

Table 5

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study under Thinned Forest in Cameroon

Task	Year 1	Year 2	Year 3	Year 4	Notes
Clearing and land preparation	99.3	-	-	-	
Lining and staking	40.8	-	-	-	
Lime application	-	-	-	-	
Road and drain maintenance and water conservation	NA	NA	NA	NA	No information available
Shade planting	-	-	-	-	
Shade maintenance	3.2	0.7	0.8	1.2	By poisoning
Nursery construction	37.1	5.8	4.5	-	Considered together in this study; Average losses 15.6 percent in Year 2: 12.2 percent in year 3
Filling bags and sowing seed				-	
Cultural work in nursery				-	
Digging planting holes	11.5	4.1	3.2	-	Considered together in this study; Average losses 15.6 percent in Year 2: 12.2 percent in year 3
Planting cocoa	14.8				
Weed control	49.7	65.5	77.0	65.5	Hand weeding
Fertilizer application	-	-	-	-	No fertilizer applied
Pest control	6.4	5.7	10.4	8.0	Considered together in this study
Disease control					
Pruning and shaping	-	-	-	-	No pruning practiced
Total	262.8	81.8	95.9	74.7	

Source: After Wood (as cited in Lass, 2001)

Table 6

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study under Coconuts in Malaysia

Task	Year 1	Year 2	Year 3	Year 4	Notes
Clearing	2.5	-	-	*	Herbicide application prior to planting
Lining and staking	3.0	-	-	*	
Lime application	NA	-	-	*	Lime in first year but included in fertilization
Road and drain maintenance and water conservation	2.5	2.5	2.5	*	
Shade planting	8.0	-	-	*	About 1,000 *Gliricidia* stakes per ha
Shade maintenance	-	15.0	7.5	*	
Nursery construction	-	-	-	*	Permanent nursery exists
Filling bags and sowing seed Cultural work in nursery	10.5	-	-	*	Considered together in this study
Digging planting holes	5.5	-	-	*	
Planting cocoa	30.0	3.5	0.5	*	
Weed control	31.5	11.5	7.5	*	Hand weeding with hoe to 6 months then herbicide
Fertilizer application	4.0	2.5	3.0	*	
Pest control	17.5	15.0	8.0	*	Up to fifteen rounds per annum with knapsack sprayer and cone jet; some rodent control
Disease control	-	-	-	*	VSD** not a problem
Pruning and shaping	-	3.5	5.0	*	Removal of chupons, overhanging branches and branches close to jorquette
Total	115.0	53.0	34.0	*	

Source: Pers. Comm. With plantation management (as cited in Lass, 2001)
Notes: *Considered as mature
** VSD, vascular-streak dieback

Table 7

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study under Old Cocoa in Costa Rica

Task	Year 0	Year 1	Year 2	Year 3*	Notes
Clearing and land preparation	8.9	-	-	-	
Lining and staking	15.2	-	-	-	
Lime application	0.0	0.0	0.0	0.0	No lime applied
Road and drain maintenance and water conservation	0.0	4.7	0.7	0.0	
Shade planting	54.6	3.7	2.0	0.0	Includes planting plantain for temporary shade
Shade maintenance	46.5	40.5	7.6	5.5	
Nursery construction	NA	NA	-	-	No data available
Filling bags and sowing seed	NA	NA	-	-	No data available
Cultural work in nursery	NA	NA	-	-	No data available
Digging planting holes	9.2	-	-	-	
Planting cocoa	-	26.0	34.9	6.5	
Weed control	13.7	29.4	8.7	19.7	
Fertilizer application	-	4.0	0.0	3.5	
Pest control	1.0	2.7	2.6	0.5	
Disease control	0.0	0.0	0.0	0.0	
Pruning and shaping	8.0	0.0	0.0	4.3	Includes 8 man-days to prune old cocoa in Year 0 which could be considered as preparation for planting
Total	157.1	111.0	56.5	40.0	

Source: after EnrÍquez and Paredes (as cited in Lass, 2001)
Notes: *Data for year 4 not yet published.

Table 8

Labor Usage for Establishment in Man-Days Per Ha Per Annum for Case Study under Old Cocoa in Brazil

Task	Year 0	Year 1*	Year 2	Year 3	Year 4	Notes
Clearing and land preparation	0.0	NA	-	-	-	
Lining and staking	10.0	NA	-	-	-	
Lime application	4.0	0.0	0.0	0.0	0.0	
Road and drain maintenance and water conservation	5.0	0.0	0.0	0.0	0.0	
Shad planting / Shade maintenance	37.0	0.0	25.0	20.0	10.0	Considered together in this study
Nursery construction	6.0	NA	-	-	-	
Filling bags and sowing seed	10.0	NA	-	-	-	
Cultural work in nursery	8.0	NA	-	-	-	
Digging planting holes	12.0	NA	-	-	-	
Planting cocoa	16.0	4.0	-	-	-	Including nursery work to grow replacements; 8 percent losses assumed
Weed control	20.0	24.0	40.0	40.0	40.0	Two rounds in Year 0; four rounds in subsequent year
Fertilizer application	-	2.0	4.0	4.0	4.0	
Pest control / Disease control	0.0	1.0	4.0	4.0	2.0	One round in Year 1: 4 rounds in subsequent years; pest and disease control considered together
Pruning and shaping	0.0	0.0	2.0	10.0	12.0	
Total	128.0	31.0	75.0	78.0	68.0	

Source: After Mandarino and Santos (as cited in Lass, 2001).
Notes: * This is in fact only 6 months in the field.

Table 9

Labor Usage for Maintenance of Mature Cocoa on Various Malaysian Plantations

Task	Labor usage in man-days per ha per annum		
	Case study 9	Case study 10	Case study 11
Weed control	6.2	3.3	6.0
Pest control	3.2	5.6	4.0
Disease control	5.1	5.9	0.5
Shade management	1.0	1.5	10.0
Fertilizer application	2.8	5.2	4.0
Road and drain maintenance and water conservation	7.1	0.6	-
Pruning	4.3	12.8	10.0
Roads, paths, and bridges	2.7	0.3	1.0
Harvesting and breaking pods	23.6	41.8	40.3
Fermentation, drying and bagging	6.7	2.5	8.5
Total	62.7	79.5	84.3

Source: Pers. Comm. With plantation management (as cited in Lass, 2001).

Table 10

Labor Usage for Maintenance of Mature Cocoa in Man-Days per Annum for Case Study of Low Disease Incidence in Colombia

Task	Man-days	Notes
Weed control	24.0	Hand-weeding practiced
Pest control Disease control	6.0	Considered together in this study
Shade management	-	Included with pruning
Fertilizer application	4.0	
Road and drain maintenance and water conservation	10.0	
Pruning	12.0	Pruning of cocoa and reduction of permanent shade considered together
Harvesting and breaking pods Fermentation, drying and bagging	40.0	Assumed to include harvesting transport, fermentation and drying
Total	96.0	

Source: after Barros (as cited in Lass, 2001).

Table 11

Labor Usage for Maintenance of Mature Cocoa in Man-Days Per Annum for Case Study with Minimal Labor Usage in Colombia

Task	1974 study Man-days	1974 study Notes	1981 study Average man-days	1981 study range of man-days	1981 study Notes
Weed control	28.0	4 rounds of hand-weeding	3.4	2.0-5.0	Herbicide application
Pest control	0.0	No pest problems	0.0	0.0	No pest problems
Disease control					
Collection of - diseased pods	6.0	3 rounds spraying per annum	44.1	37.3-51.0	
Other control			3.5	1.6-6-3	
Shade management	6.0	6 rounds per annum	1.2	1.0-1.6	Fewer rounds per annum
Fertilizer application	2.0	-	1-8	1.6-2.3	-
Road and drain maintenance and water conservation	-		1.7	1.6-2.0	Increased attention to drains since 1974
Pruning	37.0	7 rounds light pruning; 2 rounds sanitary pruning per annum	2.2	1.3-3.0	Only 2-3 pruning rounds per annum
Harvesting and breaking pods	NA	Information not included	NA	NA	Information not included
Fermentation, drying and bagging	NA	Information not included	NA	NA	Information not included
Total	79.0	Cultural practices only	57.9	51.5-66.2	Cultural practices only

Source: for 1974 Study: after Gutierrez; for 1981 Study: after Gutierrez (as cited in Lass, 2001).

Table 12

Labor Usage for Maintenance of Mature Cocoa in Man-Days Per Ha Per Annum for Case Study with Minimal Labor usage in Trinidad Using Data from the Same Plantation on 1968 and 1983

Task	1968 season	1983 season
Weed control	12.1	11.1
Pest control Disease control	4.2	0.0
Shade management	16.6 *	2.0
Drainage		1.3
Fertilizer application		0.0
Pruning	12.4	4.9
Harvesting and breaking	12.6	5.7
Collection, fermentation and drying	11.4	0.7
Total	52.7	25.7

Source: after Lass for 1968 data and Montano (pers. Comm.) for 1983 data (as cited in Lass, 2001).

Table 13

Labor Usage for Maintenance of Mature Cocoa in Man-Days Per Ha Per Annum for Case Study from Cameroon (Average of 5 Years Data for 182 Ha)

Task	Man-days	Notes
Weed control	19.0	Four rounds hand-weeding per annum
Pest control	-	No pests of importance
Disease control	23.8	
Shade management	-	No shade management practiced
Fertilizer application	-	No fertilizer application carried out
Drainage	-	No drainage required
Pruning	3.0	
Harvesting and breaking	32.4	Pod breaking carried out centrally at 7.7 man-days per ha per annum
Collection, fermentation and drying	7.1	
Total	85.3	

Source: after Wood (as cited in Lass, 2001).

Table 14

Labor Usage for Maintenance of Mature Cocoa in Man-Days Per Ha Per Annum for Case Study under Traditional System by Small-Holder in Ghana and Nigeria

Task	Man-days per ha per annum*		
	Akokoaso	Koransang	Dominas
Weed control	20.3	12.8	6.0
Other maintenance	1.5	19.5	4.9
Harvesting and breaking	38.5	39.0	32.1
Carrying	3.5		
Total	63.8	71.3	43.0

Source: Becket for Akokoaso; Becket for Koransang; and Okali for Dominas (as cited in Lass, 2001).

Notes: * Labor for fermentation and drying not included in any of the above totals

Table 15

Labor Usage for Maintenance of Mature Cocoa in Man-Days Per Ha Per Annum for Case Study under Traditional System by Small-Holder in Togo

Task	Man-days per ha per annum		
	Litimé	Plateau	Kloto
Weed control	20.0	15.0	20.0
Other maintenance	5.0	4.0	7.0
Harvesting and breaking	23.0	15.0	23.0
Total	48.0	34.0	50.0
Average yield (kg per ha)	290	140	270

Source: after Deuss (as cited in Lass, 2001).

Table 16

Labor Usage in Man-Days Per Ha Per Annum and Yield Projections in Kg Per Ha Per Annum for Case Study of Moribund Cocoa in Cote d'Ivoire

Task	Traditional cultivation	Rehabilitation program			
		Year 0	Year 1	Year 2	Year 3-30
All cocoa maintenance	17.0	67.0	42.0	31.0	31.0
Harvesting and breaking	15.0	26.0	31.0	36.0	36.0
Fermentation, drying	NA	NA	NA	NA	NA
Total	32.0	93.0	73.0	67.0	67.0
Yield	300	500	600	700	700

Source: after Belin (as cited in Lass, 2001).

Table 17

Labor Requirements for Rehabilitation of Abandoned Cocoa As Described In Case Study of Abandoned Cocoa Farm in Equatorial Guinea

Task	Year 1	Year 2	Notes
Weed control			
Under brushing	10-15	-	Initial clearing of farm
Weed control	10-14	10.0	Two rounds hand-weeding per annum
Pest control	-	-	No pests controlled on a routine basis
Disease control	12.0	12.0	Three rounds per annum
Shade management	4-6	6.0	Poised with arboricide
Fertilizer application	-	-	Soil very fertile
Drainage	-	-	Soil free draining
Pruning	20-30	5.0	Including removal of mistletoe
Harvesting and breaking	9.2	18.5	Assuming yield from Year 2 as 600 kg per ha; including carrying wet beans to roadside
Fermentation, artificial drying, and collection of wood	1.8	3.6	Farmer normally sells wet beans; estimate included here for completeness
Total	57.0-88.0	55.1	

Source: Lass (2001)