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An Analysis of Yield Gap and Some Factors of Cocoa (*Theobroma cacao*) Yields in Ghana

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Abstract

Although cocoa productivity has recently been increasing in Ghana, it is still low compared with that of other countries such as Cote d'Ivoire and Malaysia. This situation has been attributed to the low adoption of cocoa production technologies. The study was aimed at analysing the yield gap as well as some cocoa yield factors. Cross-sectional socio-economic survey was conducted in six (6) cocoa growing districts: Nkawie, Goaso, Enchi, Oda, Twifo Praso/Assin Fosu and Hohoe. A structured questionnaire was employed in the collection of data from 300 respondents who were randomly chosen with multi-stage cluster sampling technique. The yield gaps and their proportion to yield potentials were estimated using data from the survey and on-station trials. The findings indicated an experimental yield gap of 1 553.4 kg ha^{-1}, accounting for 82.1% of the experimental yield potential whereas farmer-based yield gap was 1 537.2 kg ha^{-1}, also accounting for 82.0% of the farmer (survey) yield potential. The Ordinary Least Square (OLS) regression analysis indicated that frequency of spraying fungicides against black pod disease, spraying insecticides against capsids, weeding of cocoa farms, cocoa variety planted by farmer, area of cocoa farm and total cocoa production variables had a significant impact on cocoa yield. It is recommended that the Government should encourage cocoa farmers, through pragmatic measures, to adopt improved technologies for enhancing productivity instead of focusing on excessive land expansion which eventually leads to low productivity.

Keywords: cocoa, survey, farmers, yield gap, regression, Ghana

1. Introduction

Increasing agricultural productivity or yield is critical to economic growth and development. This can be achieved by using improved agricultural technologies and management systems. Yield refers to production per unit area. Yield gap is calculated by subtracting achieved average yield from the yield potential (Lobell, Cassman, & Field, 2009). Yield potential of a crop is the yield obtained when it is grown in a suitable environment of adequate moisture and nutrients, without pest and disease problems (Gommes, 2006; Lobell et al., 2009). Lobell et al. (2009) indicated that, given the area as well as cropping season, yield potential depends on amount of moisture, sunshine intensity, temperature, crop-sowing date, maturity rating, plant population, and light-use efficiency of photosynthesis. Understanding yield gap is very crucial for it can assist in crop yield predictions since yield potential shows the probable future productivity to be achieved. Also, information on determinants of yield gap can be used in policy interventions for enhancing crop production. Conventionally, yield potential is measured by simulation model of plant metabolic activities which produce the likely highest yield (Gommes, 2006; Lobell et al., 2009). According to Lobell et al. (2009), the "model" yield gap (YG_M), "experimental" yield gap (YG_E), and "farmer" yield gap (YG_F) are linked as follows: $YG_F \leq YG_E \leq YG_M$. YG_F can be smaller compared to YG_E as well as YG_M when farmers fail to maintain soil fertility and control pests and diseases. The alternative methods are surveys on past maximum estimated on-station yields and competitive yields obtained by farmers.

Crop production depends on the crop area and crop yield so to increase production one has to raise either of them. Lobell et al. (2009) noted that there is a higher probability to expand the land area towards crop growth due to congenial environment. However, scientists and policy makers aim at improving yields to reduce excessive land extensions, with a view to ensure food security and conservation of the ecosystem services, and to protect the environment. Although yield increasing technologies may have negative outcomes on the environment, they remain important in achieving sustainable food security (Lobell et al., 2009).

Although cocoa productivity has recently been increasing, it is still low compared with that of other countries such as Cote d'Ivoire and Malaysia. Currently, the national average is around 400 kg ha^{-1}. This higher yield was achieved through the implementation of Cocoa Disease and Pest Control (CODAPEC) and Cocoa High Technology (Hi-tech) programmes by the Ghana Cocoa Board (COCOBOD) in response to the low adoption of Cocoa Research Institute of Ghana (CRIG) technologies by the cocoa farmers (Henderson & Jones, 1990; Donkor, Henderson, & Jones, 1991; MASDAR, 1998; Aneani, Anchirinah, Asamoah, & Owusu-Ansah, 2007). Maximum yields of more than 1 000 $kgha^{-1}$ and about 2 000 $kgha^{-1}$ had been achieved on farmers' farms (Aneani et al., 2007) and on-station trials with fertilizer, and hybrid cocoa (Ahenkorah, Akrofi, & Adri, 1974; Ofori-Frimpong, Afrifa, & Appiah, 2006), respectively. This clearly indicates the extent of yield gap that needs to be closed. Maredia and Minde (2002) concluded that the productivity gap in Africa is heavily determined by non-technological constraints (infrastructure, policies, input/output markets, and adverse climatic conditions) which reduced profitability and adoption of new technologies. Also**, t**he rate of adoption of a new technology depends on the degree of risk and uncertainty associated with it, capital requirement, agricultural policies, and the socio-economic characteristics of farmers.

The current study was a component of a survey conducted for the Ghana Cocoa Farmers' Newspaper Project established by CRIG and Cadbury International Limited with the aim of delivering improved cocoa production practices to farmers to raise their productivities. COCOBOD which plays a regulatory role in the cocoa industry in Ghana has realized the need to increase cocoa production by using productivity-increasing technologies. It is also important to examine the possibility of realizing the yield potential through the use of improved production practices recommended by CRIG. This requires knowledge of specific constraints to productivity in cocoa cropping systems. Thus, the main purpose of this study was to analyze the yield gap and some factors of cocoa yield. Hence, the following research questions are posed: Is there a cocoa yield gap? What are the factors of cocoa yields?

2. Methodology

2.1 Study Areas

The six selected cocoa districts of Ghana, in which the survey was carried out include Nkawie, Goaso, Enchi, Oda, Twifo Praso/AssinFosu and Hohoe (Figure1). From Table1, the lowest mean rainfall of these districts was 945.7 mm and the highest was 2 000 mm whilst the mean temperature recorded was in the range of 22-34 ºC per annum. The altitude above sea level was in the spectrum of 61-890 m. Generally, the areas were located in the moist semi-deciduous rain forest zone, with agriculture, commerce, lumbering and quarrying being the major socio-economic activities engaged in by the populace. The main cash crops cultivated within the study areas include cocoa (*T. cacao*), citrus (*Citrus sinensis*), oil palm (*Elaeis guineensis*) whilst the food crops were maize (*Zea mays*), cassava (*Manihot esculenta*), rice (*Oryza sativa*), yam (*Dioscorea spp.*), and plantain (*Musa sapientum*).

Table 1. Profile of the districts selected for the survey

Region	District	Land area (km^2)	Rainfall (mm)	Temperature (ºC)	Altitude (m)	Vegetation	Socio-economic activities
Ashanti	Nkawie	894.2	1 077	27-31	77	Semi-deciduous rain forest	F and C
Brong-Ahafo	Goaso	1 093.7	1 108	23-33	305	Semi-deciduous rain forest	F and C
Western	Enchi	2 638.0	1 429	22-34	300	Moist semi-deciduous rain forest	F, L, SSM and C
Eastern	Akim Oda	1 090.0	1 784	25-27	61	Semi-deciduous rain forest	F, L, SSM, Q and C
Central	Twifo Praso	1 199.0	1 077	26-30	91	Semi-deciduous rain forest	F, L, SSM,Q and C
Volta	Hohoe	1 403.0	1 526	22-34	890	Moist semi-deciduous rain forest	F and C

Source: Adapted from Aneani et al. (2012).

Note: F = Farming, C = Commerce, L = Logging, SSM = Small-scale mining, Q = Quarrying.

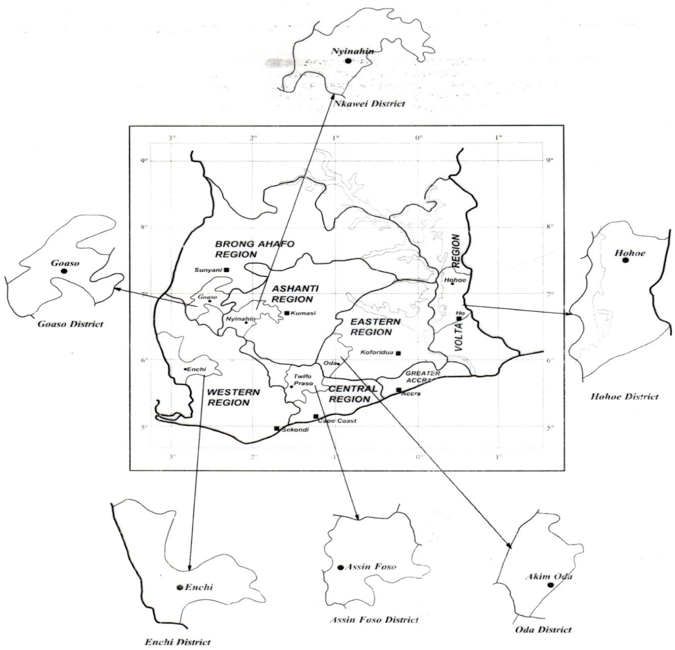

Figure 1. Map indicating the various districts where the base line survey on the Ghana cocoa farmers news paper was conducted

2.2 Sampling and Data Collection

The researchers conducted a cross-sectional survey of selected cocoa-growing districts. The survey started in March and ended in May, 2006 with a total of 300 respondents randomly chosen employing multi-stage sample selection procedure for interviews. The choice of the number of respondents was dependent on precision of 0.94 calculated from a variability of 16.3 years in an age variable of a former survey (Aneani & Asamoah, 2004) and on obtaining a broad representative sample. The sample frame which was a list containing farmers' names was obtained from Licensed Buying Companies (LBCs) operating in the villages surveyed. A four-stage sampling technique was used. The first stage involved the entire six cocoa producing regions to help generalize the key results over the population. The six districts were selected in the second stage whereas 30 villages and 300 respondents were chosen randomly in the third and fourth stages, respectively (Table 2).

Table 2. Selected farmers and communities for the survey

Region	District	Number of Villages per District	Number of Cocoa Farmers
Eastern	Oda	5	50
Ashanti	Nkawie	5	50
Brong-Ahafo	Goaso	5	50
Central	TwifoPraso/AssinFosu	5	50
Western	Enchi	5	50
Volta	Hohoe	5	50
Total		30	300

Data were gathered from the respondents with pretested structured questionnaire that contained items like demographic characteristics of the interviewed farmers, cocoa production technologies and limitations, cocoa output/yield, etc. A response rate of 100% was obtained since all the 300 cocoa farmers were interviewed.

2.3 General Farmer and Farm Characteristics

Table 4 summarizes the demographic and farm characteristics of the respondents. The farmers were advanced in age with an average of 51.5 years whilst their average farming experience was 19.6 years. A mean of 3.3 adult household members worked on the cocoa farm. Farmers had poor educational standard with 52.0% of them reaching middle school and 21.5% having no education at all. For gender, males accounted for 80.0 % whereas females, 20.0 %. Farmers tended to operate small farms with average size of 3.0 ha, yield of 337.9 kg ha^{-1} and cocoa production of 797.4 kg. The variability in cocoa production figures obtained from farmers' passbooks was high. This can be attributed to the diverse temporal and spatial rainfall quantity and distribution. An average cocoa income was GH¢ 717.68 which also had a high variability caused by that of cocoa production.

2.4 On-Station Trial

The data from which the experimental cocoa yield potential was derived was generated from an on-station trial (Ofori-Frimpong et al., 2006). This experiment was mainly aimed at studying the response of new cocoa hybrids to phosphate (P) and potassium (K) fertilizers, with a specific objective to establish the yield potentials of some new cocoa hybrids under P and K fertilization. The trial was carried out at the Cocoa Research Institute of Ghana (CRIG) at New Tafo-Akim for 17 years, but 4-year yield data were used for the analysis. The experimental design used was a split-plot with five cocoa varieties as main plots and 3^2 P K fertilizer factorials as subplots. The fertilizer treatments and cocoa hybrid varieties used in the trial were as follows:

P_1 = 100 kg P_2O_5 ha^{-1}, P_2 = 200 kg P_2O_5 ha^{-1}, P_3 = 400 kg P_2O_5 ha^{-1}

K_1 = 60 kg K_2O ha^{-1}, K_2 = 120 kg K_2O ha^{-1}, K_3= 180 kg K_2O ha^{-1}

V1 = T63/967 x T17/524, V2 = T85/799 x Pa 7/808, V3 = T85/799 x Na 729, V4 = T63/971 x Amel, V5 = T63/971 x T60/887.

2.5 Analytical Framework

The survey data was subjected to descriptive and inferential analyses. The experimental yield gap was calculated as the difference between the estimated national average yield and the maximum experiment-based yield potential achieved in on-station trials at CRIG (Ofori-Frimpong et al., 2006). The farmer yield gap was also computed as the difference between the maximum farmer yield potential and the estimated national average yield which were derived from the yield data of current socio-economic survey (Aneani et al., 2007). The farmer yield potential was estimated as the maximum of the yields achieved by the respondents on their farms**.** The factors of cocoa yields were analysed using a regression model.

2.6 Empirical Model of the Factors of Cocoa Yields

The factors of actual cocoa yield were investigated by regression analysis using the Ordinary Least Square (OLS) technique as employed by Gommes (2006) as well as Strother and Panda (2011). The OLS technique was employed since the dependent variable was a continuous random variable and the independent variables were either continuous or categorical, taking into consideration regression modeling assumptions. The linkages among cocoa productivity and its factors were modeled to establish the important policy variables. Generally, linear function, f(.), was specified as follows:

Y = f (X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12, e)

Where,

Y = Cocoa productivity (kg ha^{-1})

X1 = Age of the cocoa farm (years) (-); The older the farm, the higher the probability that cocoa output and productivity will reduce, causing discouragement in farm maintenance.

X2 = Frequency of spraying against black pod disease by cocoa farmer (+); Black pod disease can sweep rapidly through a farm destroying more than half of the crop in the wet and humid weather (Idachaba & Olayide, 1976; MASDAR, 1998). It has been recommended to farmers by CRIG to spray against black pod with fungicides, 6-9 times per annum to ensure effective control of the disease. Thus, it was assumed that high spraying frequencies could lead to effective control of black pod, resulting in increased output and yield.

X3 = Frequency of spraying against capsids by cocoa farmer (+); capsids attack the cocoa trees by feeding on the succulent foliage and in extreme cases causing death, leading to reduction in cocoa output and yield. It has been recommended by CRIG for farmers to spray against capsids with insecticides 4 times per annum to ensure the effective control of the pests. Therefore, it was posited that high spraying frequencies results in effective capsid control, leading to output and yield increases.

X4 = Education level of cocoa farmer was categorized into literates and illiterates (+): We predicted a positive relationship between this variable and cocoa yield since an educated farmer can evaluate the improved production practices and make informed technical and economical choices to increase adoption.

X5 = Fertilizer application. The fertilizer variable was assumed to be a dummy variable which takes the value 1 if the cocoa farmer applied fertilizer to his/her farm, and otherwise takes the value 0 (+): In Ghana, prolonged cultivation of cocoa on a piece of land has been found to result in soil fertility decline due to soil nutrient mining (Appiah, Ofori-Frimpong, & Afrifa, 2000). Thus, applying fertilizer to such soils can replenish the depleted soil nutrients and hence, increase cocoa output and yield.

X6 = Quantity of fungicides applied to cocoa farm measured in satchets (+): It is hypothesized that the higher the quantity of fungicides applied, the more effective will be the control of black pod disease which tends to decrease cocoa output and yield.

X7 = Farm area quantified in hectares (-): Cocoa farm size was assumed to negatively influence yield because land expansion might increase cocoa output, but in Ghana extensive cocoa cultivation is associated with a decline in soil fertility, leading to low productivity over time (MASDAR, 1998; Seini, 2002).

X8 = Frequency of extension visits by the extension officer (1 = no visit, 2 = at least one visit) (+): The more frequent the exposure of a farmer to extension information of new improved production practices, the more likely he can be convinced to adopt the appropriate technologies to increase yield.

X9 = Cocoa production measured in kilogramme (+): Cocoa production is predicted to be positively related to yield as revenue from increased output could be used to buy yield-increasing resources for cocoa farming.

X10 = Rainfall measured in millimeters (+): A positive relationship was expected to exist between rainfall and yield because water is required by the plant for nutrient absorption and photosynthesis to ensure proper plant growth and development. However, excessive rainfall could impact negatively on yield.

X11 = Cocoa variety planted by cocoa farmer. The cocoa variety variable which was considered a continuous was scored by giving a value 1 if the farmer planted Hybrid variety, a value 2 if the farmer planted

Amazon and a value 3 if the farmer planted Amelonado variety (+): Hybrid cocoa, which is early-bearing and high-yielding and currently recommended to farmers, is an improved variety over the Amazon that is also superior to the Amelonado type. Thus, it is anticipated that a farmer planting hybrid seeds or having a hybrid farm could produce higher cocoa yield than those with Amazon and Amelonado farms, other things being equal.

X12 = Frequency of weeding of the cocoa farm by the cocoa farmer (+): Weeds normally compete with the cocoa tree for water and nutrients. Therefore, the higher the weed control frequency, the better for the plant to develop and produce more output and yield.

e = Error term: It is assumed the error term is independent and normally distributed with mean zero (0) and known variance (σ^2)

3. Results

3.1 Yield Gap Analysis

The analysis of variance indicated a statistically significant interaction between fertilizer and cocoa variety ($F_{0.05\ (60,\ 240)}$ = 3.442, P = 0.0001). For the four-year data, the mean of 1288.55 ± 319.2 kg ha^{-1} was obtained from the P_2K_3 fertilizer combination and cocoa variety 2 (V_2), with a range between 88.9 and 1 891.3 kg ha^{-1}. Table 3 shows the experimental potential, farmer potential and estimated national average yields of cocoa in Ghana estimated with data from the survey and trial. The experimental yield potential for cocoa was estimated using the results from an on-station trial in which an attempt was made to include treatments for optimal management to prevent nutrient, pest and disease stresses. This yield potential was estimated as the maximum value of the interaction effects because of the significant interaction between fertilizer and hybrid cocoa. The experimental cocoa yield gap was estimated to be 1553.4 kgha^{-1} (1891.3-337.9 = 1553.4 kg ha^{-1}). The percentage of yield gap to experimental yield potential was 82.1% ((1553.4/1 891.3) x 100) whilst the percentage of estimated national average yield to experimental yield potential was 17.9% ((337.9/1 891.3) x 100). The analysis of variance of the cocoa yield response of fertilizer and cocoa variety planted by the farmers indicated a statistically significant interaction between fertilizer and hybrid cocoa variety ($F_{0.05\ (3,\ 218)}$ = 2.91; P < 0.05) with mean of 405.2 ± 348.7 kg ha^{-1} having a range between 78.1 kg ha^{-1} and 1875.1 kg ha^{-1} whilst the main effects were not significant. Similarly, the farmer potential was also estimated as the maximum value of the interaction effects of fertilizer and hybrid cocoa variety planted by farmers. The farmer yield gap was also computed as the difference between the farmer yield potential and the estimated national average yield which were derived from the yield data of a socio-economic survey (Aneani et al., 2007). The farmer yield gap was estimated to be 1537.2 kg ha^{-1} ((1875.1-337.9) = 1537.2). The percentage of farmer yield gap to its yield potential was 82.0% ((1537.2/1 875.1) x 100) whereas the percentage of estimated national average yield to farmer yield potential was 18.0% ((337.9/1875.1) x 100). The experimental-based yield gap was observed to be greater than the farmer-based one as postulated by theory although the simulated-based yield gap was not estimated for comparison because of unavailability of its yield potential. This is because no simulation study has been done on cocoa yield in Ghana.

Table 3. Yield gap estimated using two different methods for estimating yield potential for cocoa in Ghana

Item	Experimental potential	Farmer potential	National average
Estimated cocoa yield ($kgha^{-1}$)	1 891.3	1 875.1	337.9
Yield gap ($kgha^{-1}$)	1 553.4	1 537.2	-
Percentage yield gap to potential (%)	82.1	82	-
Percentage estimated average yield to potential (%)	17.9	18	-

Table 4. Descriptive summary of the variables used in ordinary least square (OLS) regression analysis

Variable	Mean	Std. Dev.	Min	Max	N
Actual cocoa yield (kilogramme per hectare).	337.9	255.2	62.5	1 953.1	238
Frequency of weeding.	2.4	0.7	1	6	298
Frequency of spraying against black pod.	1.8	1.6	0	8	289
Frequency of spraying against capsids.	1.9	1.3	0	6	292
Age of cocoa farm (years).	16.9	12.5	1	85	291
Area of cocoa farm (hectares).	2.9	2	1	10	232
Cocoa variety planted	1.8	0.9	1	3	242
Quantity of fungicides applied to cocoa farm (satchet)	30.2	19.8	5	98	100
Total cocoa production (kilogrammes).	797.4	442.9	218.8	2 000.0	174
Fertilizer application (with fertilizer = 33.1%, without fertilizer = 66.9%)					293
Frequency of farm visits by the extension officer (no visit = 55.3%, at least one visit = 44.7%)					293

Table 5. Results of ordinary least square (OLS) regression analysis

	Model: Cocoa Yield		
Independent Variable	Coefficient	t-value	P-value
Constant	224.331	3.058	0.003***
Frequency of weeding	55.085	2.385	0.019**
Frequency of spraying against black pod	-22.202	-2.49	0.014**
Frequency of spraying against capsids	24.033	2.392	0.018**
Fertilizer application	25.013	0.827	0.41
Cocoa variety planted	-28.051	-2.044	0.043**
Age of cocoa farm (years)	0.784	0.531	0.596
Area of cocoa farm (hectares)	-67.486	-10.228	0.000***
Quantity of fungicides applied to cocoa farm (satchet)	-0.101	-0.432	0.667
Frequency of farm visits by the extension officer	-21.838	-0.733	0.465
Total cocoa production (kilogrammes)	0.252	12.057	0.000***
F-statistic (10, 125) = 24.798			
R-squared = 0.665			
Adjusted R-squared = 0.638			
Durbin-Watson = 1.920			
Sample size (n) = 136			

Note: **P < 0.05, *** P < 0.01.

3.2 The Factors of Cocoa Yield

Table 4 contains the descriptive summary of the factors included the OLS model. From the regression outcomes (Table 5), the F-statistics of 24.798 was statistically significant ($P < 0.01$), indicating a joint influence of the independent variables on the dependent variable and that the model existed. The R-squared was 0.665, implying that 66.5% of cocoa yield variation explained by the factors combined. Durbin-Waston statistics was 1.920, showing no autocorrelation in the model. The constant term was significant ($P < 0.01$). Also, the following variables had a significant positive impact on the cocoa yield: frequency of spraying insecticides against capsids ($P < 0.05$), frequency of weeding the cocoa farms ($P < 0.05$), and total cocoa production ($P < 0.01$). Other variables had significant negative impact on yield and these included frequency of spraying fungicides against black pod disease ($P < 0.05$), cocoa variety planted ($P < 0.05$), and area of cocoa farm ($P < 0.001$). However, age of the cocoa farm, fertilizer application, quantity of fungicides applied to cocoa farm, and frequency of farm visit by the extension officer, were statistically insignificant in explaining the variability in the annual cocoa yield levels ($P > 0.05$).

For frequency of weeding, the positive coefficient means that increasing the number of times of weeding by one unit, increased cocoa yield by 55.09 kg ha^{-1}. Concerning black pod control, the negative coefficient implies that as the frequency of black pod control increased by one unit, cocoa yield decreased by 22.20 kg ha^{-1}. This negative relationship was unexpected because of improper fungicide application for black pod control. The analysis indicated a positive relationship between capsid spraying frequency and cocoa yield as expected. As the spraying frequency increased by one unit, there was a corresponding increase in cocoa yield by 24.03 kg ha^{-1}.

Planting or having a poor cocoa variety reduced yield by 28.1 kg ha^{-1}. The negative relationship between cocoa yield and cocoa variety was expected. The varieties were scored with the most preferred given a lowest score and the least preferred the highest. Therefore, a choice made towards the least preferred cocoa variety resulted in a decrease in cocoa yield, that is, the poor cocoa varieties produced lower yields.

In addition, there was a negative relationship between farm size and cocoa yield. With an increase in farm size by one hectare, cocoa yield decreased by 67.49 kg ha^{-1}. Finally, the analysis showed a positive relationship between cocoa yield and cocoa production and this outcome was expected.

The quantity of insecticides applied to cocoa farm, rainfall, and education level of the farmer variables were removed from the cocoa yield model due to multicollinearity and less variation in the data.

4. Discussion

The results indicate that there is a large yield gap to close given the yield potential that can be achieved by researchers or farmers. This is because of relatively poor adoption concerning CRIG's technologies by the cocoa farmers. This study has shown that although farmers controlled weeds, pests and diseases, and applied fertilizer to the farms, farm maintenance was inadequate leading to yields below the potential. Farmers attributed the inadequate farm maintenance to poor access to the production resources such as access to cash/credit, labour, spraying machines and so on (Aneani et al., 2007; MASDAR, 1998). The regression analysis indicated that the frequency of spraying fungicides against black pod disease, frequency of spraying insecticides against capsids, frequency of weeding cocoa farms, cocoa variety planted by the farmer, area of cocoa farm and total cocoa production variables had a significant impact on cocoa yield.

4.1 Yield Potential and Yield Gap

The results indicated that the experimental yield gap was greater than the farmer one and this is consistent with the theory that $YG_F \leq YG_E \leq YG_M$, that is, farmer-based yield gap being less than that of the experiment-based yield gap which in turn is less than the model-based one. The experimental yield potential was also greater than that achieved on farmers' farms. This difference could be explained that on-station trials are conducted under well controlled conditions while the farmer potential is achieved under the influence of various biotic, abiotic and edaphic factors. For instance, Aggarwal, Herbbar, Venugopalan, Rani, and Bala (2008) attributed the challenges in measuring yield potential to changes in soil moisture which depended on rainfall and the soil type.

Lobell et al. (2009) showed global variations in yield gap estimates.

4.2 Weeding Frequency

Regular control of weeds eliminates competition for plant nutrients in the soil, and pests and diseases from attacking the cocoa plant. Cocoa farmers have been advised to weed their farms regularly as excess weeds compete for nutrients, encourage pests and black pod disease, etc. MASDAR (1998) showed that cocoa farmers tended to weed their farms 2.3 times per year as compared to 2.0 times as discovered by Aneani et al. (2007). In addition, COCOBOD (1995) and MASDAR (1998) reported respective figures of 43.6% and 49.0%, being the proportion of cocoa farmers who brushed their farms twice as compared with 48.0% indicated by Aneani et al. (2007). Further, MASDAR (1998) reported that about 6.5% of the cocoa farmers interviewed weeded their farms 4 times as compared with 3.4% indicated by Aneani et al. (2007). Even in this study about 1.0% of the farmers did not weed their farms at all. These pieces of evidence buttress the fact that cocoa farmers are not adhering to the recommendation by CRIG that cocoa farms should be weeded at least 4 times in a year. The policy implication is that farmers ought to be made aware about the importance of weeds and their regular control to ensure healthy farms which can produce higher yields.

The evidence provided by Aneani et al. (2007) indicated that few cocoa farmers (5.7%) used weedicides such as Roundup, Grammozone, Atrazine, Caliherb, etc. to control weeds on their farms, with the majority (92.7%) relying on manual weeding. The use of weedicides, as is being promoted in the media, would help to reduce drastically the tedium involved in manual weed control. However, the environmental impact of the use of these chemicals should be assessed (Owusu-Manu, 1985). To obtain the weedicides will not be a problem since most of the farmers can access them at the farmers' input stores and the open market.

Additionally, studies on other crops have demonstrated the relationship between weeding frequency and yield. Dimes, Muza, Malunga and Snapp (2001) observed in their simulation experiment of maize grain yield response to weeding frequency that yield increased with increasing weeding frequency. Also, Chikoye, Manyong, Carsky, Ekeleme, Gbehounou and Ahanchede (2002) reported that higher weeding frequency manually or by using herbicide was better than lower one in weed control, leading to yield increase. Truong Thi Ngoc Chi, Hossain and Flor Palis (2004) reported that weed and rice disease control influenced rice yield, that is, rice field without weeds and diseases increased rice productivity.

4.3 Frequency of Spraying Against Black Pod Disease

The negative relationship was unexpected and might be attributed to improper and inefficient application of the fungicides and the spraying difficulty which leads to the poor control of the black pod disease (Asante, Aneani, Asamoah, & Baah, 2002). Black pod disease which occurs in all the cocoa growing regions is an important disease of cocoa. It can destroy more than half the crop in wet and humid weather (Idachaba & Olayide, 1976; MASDAR, 1998). It was observed that chemical control of black pod disease by farmers was not adequately practised (COCOBOD, 1995; MASDAR, 1998). Aneani et al. (2007) observed that 29.3% of the cocoa farmers interviewed did not spray against the disease. The non-adoption of the recommended control practices was attributed to the tediousness of the spraying and the cost of the chemicals given that the farms were to be sprayed 5 to 9 times to ensure effective control. The reduction in the percentage of farmers who did not spray their farms was due to the CODAPEC programme, that is, the mass spraying exercise instituted by the Government. Farmers relied solely on the programme instead of spraying to supplement the two sprays of the CODAPEC.

4.4 Frequency of Spraying Against Capsids (Mirids)

The analysis indicated a positive relationship between capsid spraying frequency and cocoa yield as expected. Excessive capsid attack of the cocoa trees can lead to disastrous consequences for productivity (Entwistle, 1985; MASDAR, 1998). Therefore, controlling the pests can increase cocoa yield. In Ghana, the most important cocoa pests are capsids and research at CRIG indicated that these insects can reduce cocoa yields by 25% in 3 years in severe attacks (Owusu-Manu, 1985). It is recommended that cocoa trees be sprayed one to four times a year on both young and mature farms. A farming system survey conducted in 1998 showed that 51% of the interviewed farmers sprayed two or more times a year against capsids. The socio-economic survey conducted concurrently observed that capsid control by the farmers was far less than the recommended as 34% of the farmers did not spray at all (MASDAR, 1998). As a comparison, Aneani et al. (2007) indicated that about 64.7% of the farmer respondents sprayed two or more times per year against capsids while 20.5% did not spray at all. These findings are consistent with that provided by earlier adoption studies conducted by CRIG that cocoa farmers did not control capsids adequately (Donkor et al., 1991; Henderson & Jones, 1990). This development has also implication for the CODAPEC programme being implemented by COCOBOD.

4.5 Cocoa Variety Planted

Cocoa variety planted was found as a key factor influencing cocoa productivity. The negative relationship observed means that planting Amelonado variety instead of hybrid might not improve cocoa yield. This phenomenon can be attributed to the genetic variations among the cocoa varieties. The result is consistent with that of Edwin and Masters (2005) that the adoption of a new cocoa variety increased cocoa yield by at least 42%. Cocoa hybrids of various classes have been widely available at least for the past 35 years or more in Ghana. The hybrids are popular with the farmers because they are early-bearing, high-yielding and produce pods throughout the year. However, the impact desired from the seed gardens has not been achieved partly because farmers use too many seeds by planting at stake and at far higher densities than advised by the extension agency and the institutional problem of the Seed Production Unit (SPU) of COCOBOD. This situation has implication for the COCOBOD's programme of replanting all cocoa farms of more than 30 years with hybrid varieties.

Some farmers often make greater use of seeds from pods taken from their own neighbours' farms as indicated by about 38.1% of the farmers (Aneani *et al.,* 2007). These seeds rarely produce well-yielding trees since they are not true-to-type as they are not artificially pollinated and need to be replaced. However, Aneani and others observed that more cocoa farmers (about 50.0%) sourced their seeds from the seed gardens. Although use of hybrid varieties are on the increase in Ghana, the relatively low yielding Amelonado variety still makes up more than 12% of the tree stock in pure and mixed stands (MASDAR, 1998) as compared to about 11.0% in the Baseline Survey (Aneani et al., 2007). Intercropping has been observed to enhance productivity through proper arrangement and control diseases. Li *et al.* (2009) reported that intercropping improved yield by providing favourable environment. This means that intercropping cocoa varieties with other compatible crops could increase cocoa productivity. The effect of cocoa varieties on yield is determined by how resistant the varieties are to diseases and pests (Tijani, 2005).

4.6 Farm Size and Cocoa Production

Farm size negatively influenced cocoa yield whilst there was a positive relationship between cocoa yield and cocoa production. Possible explanation of this outcome is that, in Ghana, most of the farmers establish their farms through clearing of the forest and burning the debris. This activity causes deforestation, land ruin, and depletion of soil nutrient (Quansah, Drechsel, Yirenkyi, & Asante-Mensah, 2000). With the rapid population growth, to increase crop output is less possible by land extension to fresh areas. This activity causes deforestation, land ruin and depletion of soil nutrients, leading to low crop productivity (Ministry of Science and Environment, 2002; Seini, 2002). For instance, Wiredu, Mensah-Bonsu, Andah and Fosu (2010) also reported a significant inverse relationship between land productivity and land area under cocoa ($P < 0.05$) in Ghana. In a study to explain labour productivity of small-holder farmers in Nigeria, Okoye, Onyenweaku, Ukoha, Asumugha and Aniedu (2008) found farm size and household size to have a statistically significant negative relationship with labour productivity ($P < 0.05$). Also, Kiani (2008) and Thapa (2007) confirmed the hypothesis of inverse relationship between farm size and output per hectare. The forest depletion and environmental degradation can be ameliorated by increasing production per unit area of land, instead of excessive land expansion, by utilizing yield-increasing technologies such as regular weeding, pests and disease control, replenishing soil fertility to compensate for losses from harvesting and leaching, and pruning and shade management.

4.7 Limitation and Future Research

Lack of information on issues of environment, institutions, politics and socio-economy prevented the researchers from including them in the cocoa yield model. Thus, a research can be designed to capture the issues. Additional research need to be conducted on the effect of rainfall and temperature, etc. on cocoa yields since the attempt to model them failed.

5. Conclusion and Recommendation

The analysis has demonstrated that a cocoa yield gap of 1 553.4 kg ha^{-1} existed, accounting for 82.1% of the experimental potential whereas on farmers' farms a yield gap of 1 537.2 kg ha^{-1} existed, also accounting for 82.0% of the farmer potential. The regression analysis indicated that frequency of spraying fungicides against black pod disease, frequency of spraying insecticides against capsids, frequency of weeding cocoa farms, cocoa variety planted by farmer, area of cocoa farm and total cocoa production variable had a significant impact on cocoa yield. The indication of huge yield gap by this study challenges COCOBOD to encourage cocoa farmers through pragmatic measures to adopt the yield-increasing technologies of cocoa production to minimize excessive land expansion.

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