UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

INORGANIC FERTILIZER ADOPTION AND TECHNICAL EFFICIENCY OF COCOA FARMERS IN THE WESTERN REGION OF GHANA

BY

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SEPTEMBER, 2017

DECLARATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree at this University or elsewhere.

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We hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Low output of cocoa has resulted in Ghana losing out to Cote d'Ivoire as the leading producer. The aim of this study was to explore farm households' adoption of inorganic fertilizer and technical efficiency, using cross-sectional data collected from 305 cocoa producing households in the Western Region of Ghana. The Heckman two-stage model was used for both the discrete decision to adopt fertilizer and intensity of fertilizer use while the stochastic frontier framework was used to estimate the productivity and technical efficiency of cocoa production. The regression on propensity score was used to evaluate the effect of fertilizer adoption on technical efficiency. The majority (75%) of the cocoa farmers in the study area adopted fertilizer. The results from the Heckman two-stage model revealed that fertilizer adoption and the intensity of adoption were significantly influenced by socioeconomic, farm-specific and institutional factors. Whereas the stochastic frontier analysis showed that farm size, quantity of fertilizer, quantity of fungicides, affected cocoa output significantly; sex, years of crop farming, farm size, farm assets, income from other crops, benefits gained from NGO services and hired labour affect farmers' technical efficiency. Moreover, the probability of fertilizer adoption was estimated to have a positive and significant effect on farm-level technical efficiency. The result further revealed that technical efficiency ranges between 0.20 and 0.99 with a mean score of 0.75. Thus, 25% of cocoa farm output was lost due to farmers' technical inefficiency. Returns-to-scale was 0.98, indicating that cocoa farm operations were in the stage II of the production function and that farmers, can still do more to increase output. The study concluded that policy interventions should directly target the adoption of inorganic fertilizer and intensity of use by making adequate fertilizer available to farmers at all times of the cropping season in other to achieve higher yield.

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DEDICATION

I dedicate this work to my late brother Paul Bruno Ali and I pray the Good Lord to grant him eternal rest until we meet again.

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LIST OF ACRONYMS

Acronym	Meaning
AgSAP	Agricultural Sector Adjustment Programme
GRI	Ghana Review International
CRIG	Crop Research Institute of Ghana
ERP	Economic Recovery Programme
FASDEP	Food and Agriculture Sector Development Policy
GDP	Gross Domestic Product
GLSS	Ghana Living Standards Survey
GSS	Ghana Statistical Service
ICCO	International Cocoa Organization
IFDC	International Fertilizer Development Center
ISSER	Institute of Statistical, Social and Economic Research
LVA	Latent Variable Approach
MoFA	Ministry of Food and Agriculture
PPA	Pure probability Approach
RUM	Random Utility Model
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme

CHAPTER ONE

INTRODUCTION

1.1 Background

The importance of the agricultural sector to Ghana's development has been recognized by many (Baffoe-Asare et al., 2013; Asamoah, 2014; Obuobisa-Darko, 2015). The sector is a source of livelihood to about 51.5% of Ghana's population and engages about 83% of the rural households (Ghana Living Standard Survey 6, 2014). In rural areas, agriculture activities dominate in rural savannah with about 93% households involved. The corresponding figures for the forest and coastal areas are about 81.3% and 65.4% households respectively (GLSS6, 2014).

Ghana's agricultural sector is credited with about 75% of the country's total export earnings (Aidam, 2012; Ghana Statistical Service, 2014). Intuitively, this means that Ghana's overall economic progress to a very large extent depends on the agricultural sector. With regard to the sector's contribution to Gross Domestic Product (GDP), between 2010 and 2016, the figures as reported by the Ministry of Food and Agriculture (MoFA) show a decreasing trend relative to the other sectors, particularly the services sector. For instance, in 2010, agriculture contributed 29.8% as against a joint contribution of 70.2% of both the service and industrial sectors. The sector's contribution to GDP in 2011 however, declined to 27.2% as against 52.6% in the services sector and 20.2% in the industrial sector. In 2016, the agricultural sector recorded only 19.3% as against 58.1% and 22.6% of the services and industrial sectors, respectively (GSS, 2017).

The main driving force of the agricultural economy is the crop sub-sector of which cocoa is a significant component. Cocoa is a golden crop of social, economic and political interest in Ghana and other major producing countries (Aneani et al., 2012; Aidoo and Fromm, 2015; Anang, 2016). The Agricultural sectors contribution to national development has largely been fueled by the cocoa sub-sector. To the smallholder farmer, cocoa production provides the primary source of direct income and livelihood as it provides jobs for about 794,129 rural households (GSS, 2014). It is also believed to be a source of social prestige for many rural farm households. The activities of the sector such as input delivery and the output market (e.g. licensed cocoa buying companies (LBCs), also create jobs for many people. As at 2013, the sector alone contributed approximating 32% of the total export revenue (ISSER, 2014). Cocoa has played a crucial role in the development and the establishment of several projects in education, health and infrastructure. The COCOBOD (the managing body of the Ghana's cocoa industry) scholarship is awarded to brilliant but needy children from cocoa growing areas into Senior High Schools (Obuobisa-Darko, 2015). There is also the construction of "cocoa roads" and hospitals in cocoa growing areas to facilitate transportation and improve the health of rural dwellers.

In Ghana, cocoa production typically occurs in the forest and transitional belts; namely the Western, Eastern, Ashanti, Central, Volta and the Brong-Ahafo Regions. Ghana has made a trademark in the cocoa sector globally as one of the largest producers and exporters of cocoa beans next to Cote d'Ivoire, the world's leading producer and exporter. However, in terms of the export of quality cocoa beans, Ghana ranks first in the world. Ghana's share of the world cocoa output level as at the 2010/2011, 2011/2012, 2012/2013 and 2014/2015 cocoa cropping seasons were 23.77 %, 21.54 %, 21.24 % and 17.50% respectively (ICCO, 2016).

Cocoa production in Ghana has fluctuated over the last one and half decade ranging from 350, 000 MT in 1998 to about 740, 254.06 MT in the 2014/2015 cocoa cropping season (ICCO, 2016). These fluctuations in output levels could partly be attributed to several factors such as low fertility of soil, high incidence of pests and diseases, inadequate financial supports, inadequate extension services, among others. These have resulted in several interventions by governments and the private sector to shoot up the production and productivity levels of cocoa in Ghana through intensification and structural changes (Danso-Abbeam, 2010). Cocoa production has also been among the many factors widely associated with the disappearance of vast portions of Ghana's rainforest (UNDP, 2012).

In response to the many challenges facing the Ghanaian cocoa industry, governments over the years through COCOBOD has undertaken a lot of structural changes to boost productivity and achieve sustainable growth in the industry. One of such important structural change is the introduction of the Cocoa High Technology (Cocoa Hi-tech, for short). The main goal of the cocoa Hi-tech is to help in the development and dissemination of new cocoa production technologies to accelerate the growth of the industry. The key component of the project was to enhance the intensive use of improved variety of cocoa seedlings, application of fertilizer, insecticides and fungicides.

Among these components of the programme, fertilizer application was considered as very significant to propel productivity growth. As a result, the Ghanaian government introduced the fertilizer subsidy programme in 2008, with the aim of encouraging food crops as well as cash crops, particularly among cocoa farmers to increase fertilizer use so as to increase output levels. Four types of inorganic fertilizers namely: Urea, Sulphate of ammonia, NPK 15:15:15 and NPK 23:10:15 were introduced under the programme. It is expected that adoption of these components of the programme, particularly fertilizer may serve as mitigation against declining soil nutrients and subsequently lead to higher yield (Aneani et al., 2012; Danso-Abbeam et al., 2012). Even though application of fertilizer may lead to higher yield, it may not necessarily translate into higher efficiency and for that matter higher technical efficiency levels.

To ensure a more sustainable increase in output levels in the cocoa sub-sector under intensified cocoa production practices, it is prudent for smallholder, resource-poor farmers to efficiently use scarce resources, including chemical fertilizer to enhance productivity. Case et al. (2009) defines efficiency as the condition where the economy is producing at a least possible cost. Hence, the concept of efficiency is essentially concerned with the relative performance of the procedures involved in transforming inputs into outputs. An Economic theory propounded by Farrell (1975) identifies technical, allocative and economic efficiencies as the three main types of efficiency. Technical efficiency, which is the main focus of the study, is defined as the ability to use given amounts of inputs to achieve a given level of output (Carlson, 1968). Whereas allocative efficiency is defined as the extent to which farmers make efficient decisions by utilizing inputs up to the level at which their marginal contribution to production value is up to the factor costs, economic efficiency deals with the combination of technical and allocative efficiency (Farrell, 1957).

1.2 Problem statement

Historically, the cocoa sector has played a key role in Ghana's socioeconomic development. The cultivation of cocoa has been a major source of livelihood for many people both rural and urban and it is the single most important export crop in Ghana. Even though, Ghana is the second leading producer and exporter of cocoa in the world, the country lags behind other major producing and trading countries such as Cote d'Ivoire and Malaysia in terms of productivity. For instance, Binam et al. (2008) shows that the average cocoa yields in Cote d'Ivoire and Malaysia were 1800 kg/ha and 800 kg/ha respectively compared with 400 kg/ha in Ghana. MoFA (2016) reported 0.5 MT/ha as the average yield in the Ghanaian cocoa industry compared with an achievable yield of about 1 MT. This shortfall in output level is attributed to many factors among which are poor soil conditions, poor farm management practices and the outbreak of pests and diseases (Abekoe et al., 2002). Studies have maintained that cocoa farmers, over the years have responded differently to low productivity by opting for production systems that offer only short-term benefits. This suggests that there is a need to develop policies aimed at boosting long term productivity growth in a sustainable manner. However, this goal of boosting growth in the industry will depend on the levels of productivity which can be shaped by the rate of adoption of cocoa farm technologies especially fertilizer and efficient use of the available resources.

Nevertheless, adoption of fertilizer over the years by Ghanaian cocoa farmers has been very low. Aneani et al. (2012) reported adoption rate of fertilizer by cocoa farmers to be 33 %. Anang (2016) observed fertilizer adoption rates of 60 % among sampled smallholder cocoa farmers in Bibiani-Ahwiaso-Bekwai district of Ghana. The low adoption of farm technologies especially fertilizer has generated policy debate on whether there should be a technological change (new technology) or a technical change (enhancing the existing technology) (Binam et al., 2008). Currently, there is an increasing preference among farmers to expand existing agricultural lands in order to increase output levels. However, it is possible for farmers to increase productivity without necessarily putting extra land under cultivation. This could be done through the adoption of improved technologies such as the chemical fertilizers (MOFA, 2006; COCOBOD, 2007; Wiredu et al., 2011). The rational is that farm-level efforts designed to improve adoption rate and increase farmers' performance would be more prudent and cost-effective than putting extra land under cultivation which will mean destroying forest reserves.

Low rates of fertilizer adoption by cocoa farmers due to high cost, lack of adequate information, among other reasons, and the inefficient use of resources make the improvement of farm level technical efficiency a significant factor in boosting cocoa production. Desired output levels of cocoa just like any other agricultural output level depends on the right combination and optimal use of resources (Danso-Abbeam, 2010). Yet, there is a paucity of empirical evidence that links cocoa fertilizer adoption and farmers' performance indicators (technical efficiencies).

Studies such as Gray (2001); Binam et al. (2008); and Danso-Abbeam et al. (2014) among many other authors have analyzed cocoa farmers' technical efficiency or adoption of cocoa farm management practices. These authors have either focused on technical efficiency or adoption of improved farm technologies as a separate production phenomenon. In spite of these studies, to the best of the researcher's knowledge, limited work exists on cocoa farmers' adoption of inorganic fertilizer and its effect on technical efficiency.

As Doss (2003, 2006) indicated, to improve upon agricultural productivity and rural livelihood in particular, it is important for improved production technologies to be introduced to farmers and this must be accompanied by actual acceptance and adoption of these technologies as well as the efficient use of available resources. Countries like Nigeria, Cameroun and Cote d'Ivoire are more efficient than Ghana in terms of cocoa production in the West African sub-region (Gray, 2001; Binam et al., 2008). Based on these inefficiencies in Ghana's cocoa sub-sector, it is important to find more efficient ways of sustainably increasing output levels so as to improve on the livelihoods of the many Ghanaians who largely depend on the cocoa sub-sector. Therefore, the need to investigate fertilizer adoption and technical efficiency of Cocoa farmers in the Western Region of Ghana is critical and paramount to the growth of the cocoa sub-sector.

1.3 Research Questions and Objectives

1.3.1 Research Questions

The main research question of the study was to find an empirical answer to whether inorganic fertilizer application improves farm level technical efficiency in Ghana's cocoa industry.

The specific questions were:

1. What are the determinants of fertilizer adoption and intensity of adoption among smallholder cocoa farmers?
2. Are cocoa farmers technically efficient in the use of their resources?
3. What are the sources of farmers' technical inefficiency?
4. Does the application of inorganic fertilizer improve farm-level technical efficiency?

1.3.2 Research objectives

The main objective of the study was to identify the determinants of inorganic fertilizer adoption and estimate its effect on the technical efficiency of cocoa farmers

The Specific objectives of the research were to:

1. Identify the determinants of fertilizer adoption and intensity of adoption among cocoa farmers in the Western Region of Ghana;
2. Estimate the technical efficiency level of the cocoa farmers;
3. Identify the sources of farmers technical inefficiency; and
4. Examine the effect of inorganic fertilizer adoption on technical efficiency.

1.4 Justification of the study

It has so far been established that cocoa is a key component of the Ghanaian economy, since it does not only create employment for millions of Ghanaians but also plays other significant roles. For example, in the Ghanaian educational sector brilliant students from cocoa farming areas are awarded scholarships to study in various secondary schools, colleges and Universities across the country.

Unsustainable methods of production have driven cocoa farmers to extend their farming activities into new forest lands, but they are now left with little land for expansion (Aidoo and Fromm, 2015). To overcome some of these major threats posed by the unsustainable cocoa production, there must be a shift in cocoa production methods and its related practices. Thus, the use of improved technologies such as the application of chemical fertilizers, for example, as well as the efficient use of resources must be encouraged if the current levels of outputs are to be improved without the need for more land.

Given that Ghana is the least efficient cocoa producing country in the West African sub-region (Gray, 2001; Binam et al., 2008), increasing productivity and efficiency requires a sound knowledge of the inherent efficiency or inefficiency and related factors. Amos (2007) affirmed that in order to reap the benefits by bridging the gap between actual and potential output levels, it is important to ensure efficient allocation of resources as well as effectively mobilizing the factors of production. This has triggered interests in the world of academia, leading to several studies on efficient resource allocation (See for example, Amos 2007; Binam et al., 2008; Danso-Abbeam et al., 2012; Danso-Abbeam et al., 2014; and Besseah and Kim 2014). Moreover, adoption of fertilizer and its effect on technical efficiency to the best of the researcher's knowledge is largely under-researched. This research, therefore, aims at building on what has already been done by looking at the determinants of the adoption of fertilizer and technical efficiency in the Western region of Ghana.

The western region is the largest cocoa producing region in Ghana. Studies have shown that the region contributes more than 50 % of Ghana's annual production of output.

Production in the region is highly concentrated around the Sefwi areas which can be located at the northern part of the region. More than half of the population in the Sefwi areas earns their livelihood from cocoa production, hence the focus of the study around these areas. For this reason, the findings of this study would provide adequate information for stakeholders such as COCOBOD and other cocoa related NGOs to make policies that will both target inorganic fertilizer adoption and intensity of use. The study would also provide farmers with relevant information on the rewards of attaining technical efficiency in cocoa production. Again the study would provide both farmers and policymakers with information on the effect of fertilizer use on technical efficiency so as to enable them take critical decisions to increase yield while producing quality cocoa beans. This study would also serve as a reference material for students and other researchers who would want to undertake further studies in this area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the theoretical and empirical literature related to the study. Sections 2.2 and 2.3 elaborate on the history of cocoa production in the World and Ghana respectively. Section 2.4 focuses on the theoretical and empirical studies on the concept of adoption. Section 2.5 reviews literature on the theoretical and empirical studies on efficiency measurement. Section 2.6 reviews literature on the impact of technology adoption on technical efficiency.

2.2 History of World's Cocoa production

History has it that the origin of cocoa cannot be mentioned without making reference to the Mayans and Aztecs of South America. It is believed that the Mayans and Aztecs processed cocoa beans and consumed it as a drink (Olud, 2004). They held a belief that the god, 'Tula Quetzalcoatl', brought the seeds of cacao to earth from his garden in the heavens (Motamayor et al., 2002). Even though the crop was believed to have existed much earlier, large-scale production of cocoa only began in the 16th century by the Spanish in Central America after the addition of sugar to the drink made it popular (Olud, 2004). Olud (2004) reported that Dutch, French and English plantation were also later established as a result of the spread of "cocoa drink" across Europe, in the late 17th century and then to Brazil in the 18th century. One person who is also credited with the spread of cocoa to date is Conrad J. van Houten, a Ducth chemist, who invented the "cocoa press" in 1828, to extract cocoa powder from cocoa butter (Olud, 2004). His invention led to the creation of the first chocolate bar in the mid-19th century and as a result, chocolate became affordable to many, this increased the demand for cocoa beans in Europe and hence it became a pan-tropical crop.

Cocoa cultivation was first spread to the Caribbean islands and Trinidad, followed by the Philippines and the East Indies, and then to Sri Lanka, Brazil and West Africa (Young, 1994; UNCTAD, 2005). Although many attempts were made to introduce cocoa into the African sub-region much earlier, it was not until the 19th century that production began on a large-scale in Africa. The Portuguese in the 1880s first established plantations in the islands of São Tomé and Principe. Among the early cocoa producing colonies in Africa, was Fernando Po (now Bioko) in Equatorial Guinea (COCOBOD, 2000).

For nearly 400 years, cocoa has been an important commodity in world trade (Acquaah, 1999). Several countries in the past contributed tremendously to world output level before Ghana and now Cote d'Ivoire. For instance, Ecuador became the world's leading exporter of cocoa around the 1830s after Venezuela and held this place for close to 60 years or more. After which Brazil took over, however, her dominance was short-lived (dominated for only 20 years). Then the Gold Coast (now Ghana) took over as the world's leading producer and exporter in 1911 and held this position for 66 years before losing out to Cote d'Ivoire in 1984 and to date Cote d'Ivoire is still the leading producer and exporter of cocoa beans.

In the early twentieth century, the world's annual production output was less than 125,000 tonnes. This, however, rose to 4.31 million tonnes in the 2010/2011 cocoa season but slightly dropped to 4.15 million tonnes in the 2015/2016 cropping season (ICCO, 2016). Even though there are many producing countries of cocoa, production is highly concentrated in only a few. About 68 percent of the world's total output in 2015/2016 was produced by only three countries: Cote d'Ivoire, Ghana and Indonesia. Out of a total output of 4.15 million tonnes Cote d'Ivoire alone produced 1.69 million tonnes accounting for about 40 percent while Ghana followed with 840,000 MT representing 20.2 percent with Indonesia contributing about 7 percent of world output. Table 2.1 below shows the contribution of the leading producers of cocoa from the 2010/2011 to 2015/2016 cocoa cropping seasons.

Table 2. 1. Share of the World's Leading Cocoa Producers in percentages from 2010/2012 to 2015/2016

Country	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Cote d'Ivoire	35.04	36.42	36.76	39.94	42.56	40.68
Ghana	23.77	21.55	21.24	20.51	17.49	20.22
Indonesia	10.2	10.78	10.68	6.86	7.68	7.22

Source: ICCO Quarterly Bulletin of Cocoa Statistics, Cocoa year 2012/2013 and 2015/16

2.3 The History of Ghana's Cocoa Industry

The Dutch and Basel missionaries (1815 and 1857 respectively) first planted cocoa around the coastal areas and Aburi in Ghana, (GRI, 2007). However, this did not arouse any interest among the locals at the time. It was not until in 1879 that Tetteh Quashie, a Blacksmith, who hails from Osu in Accra returned from Fernando Po (now Bioko) with Amelando cocoa pods (now called Tetteh Quashie in Ghana) and established a farm at

Mampong-Akuapim. This caught the attention of some local farmers and in no time his farm became more of a nursery where other farmers purchased their cocoa seedlings, hence the spread of the crop from Mampong-Akuapim to other parts of the Eastern region and finally to the rest of the country where cocoa is being cultivated today (Amoah, 1995). Currently cocoa is cultivated in six out of the ten regions in Ghana namely: Western, Central, Ashanti, Eastern, Brong-Ahafo and Volta regions. Several reasons could have accounted for the massive interest shown in the crop that led to its spread across the country. For example, the fact that he (Tetteh Quashie) was a local farmer and cultivated the crop under local farming conditions with local farming tools could have played a key role in the farmers showing interest in the crop at the time. Another reason could be that, because the farm was close to them (farmers), they easily monitored its progress and, hence developed interest in the crop.

The spread of cocoa in the country after Tetteh Quashie introduced it in 1879 was very significant at the time and this became evident in 1911 when Ghana became the world's leading producer with a world record of 41,000 MT. By 1960, Ghana's output level reached 400,000 MT before increasing to a record high of 580,869 MT in 1964/65. Production in 1976/77 rapidly fell to 324,000 MT and then continued to decrease to a record low of 158,530 MT in 1983/84. This was attributed to some challenges such as severe drought, bushfires, poor management practices, the incidence of pests and diseases as well as ageing farmers working on ageing farms at the time (GRI, 2007). As a result of the low output levels, Cote d'Ivoire overtook Ghana as the world's leading producer of Cocoa in 1984 (ICCO, 2006).

Between 2000 and 2006, Ghana's cocoa industry saw an increasing trend in output levels. For example, in 2001, cocoa recorded an output level of about 436,000 MT and this was a significant improvement on the output level of the previous season. This figure rose steadily till 2006 where Ghana recorded an output level of about 741,000 MT, thereby surpassing the record of 580,869 MT which was set in 1961 to now cement her place as the second largest producer of the crop after Cote d'Ivoire (COCOBOD, 2006). Production level slightly fell after the 2005/06 season and then in 2011, Ghana recorded an unprecedented production level of about 1,025,000 MT (ICCO, 2013). Output levels have, however, fluctuated since then (see Table 2.2). The success of the industry in the 2010/2011 cocoa cropping season could be attributed to the many intervention made by stakeholders at the time. For instance Baffoe-Asare, et al. (2013), emphasize that in a bid to arrest the falling output level and also to address the production challenges of the sector, the government of Ghana in 2001 initiated the CODAPEC and Cocoa Hi-Tech programmes and these partly accounted for the boost in yield over the period. Another reason that could be attributed to the sudden rise in output level in the season under review was the introduction of the fertilizer subsidy programme in 2008 by the then Government of Ghana.

It must be mentioned that efforts were made through the Economic Recovery Programme (ERP) in the 1980s, to arrest the declining production trend (Owusu-Achaw, 2012). As a result, sector reforms were implemented through the Cocoa Rehabilitation Programme (CRP) and the Agricultural Sector Adjustment Programme (AgSAP). However, these programmes failed in the attempt to boost yield levels even though they brought about changes to several major policies (Owusu-Achaw, 2012).

Table 2. 2. Ghana's production levels compared to her major competitors from 2010/2011 to 2015//2016 (thousand tonnes)

Country	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
World	**4312**	**4080**	**3931**	**4372**	**4230**	**4154**
Cote d'Ivoire	1511	1486	1445	1746	1796	1690
Ghana	1025	879	835	897	740	840
Indonesia	440	440	420	375	325	300

Source: ICCO Quarterly Bulletin of Cocoa Statistics, Cocoa year 2012/2013 and 2015/16.

2.4 Agricultural Technology Adoption

2.4.1 Definition and Concept of Adoption

Agriculture is a vital sector of every developing economy like Ghana and therefore innovations and diffusion of farm technology is key to improving productivity and welfare of many, particularly rural dwellers.

Donkoh et al. (2006) defined technology as "the current state of knowledge of how to combine resources to produce desired products, solve problems, fulfill needs or satisfy wants". They further classified technology as "technical methods, skills, processes, techniques and raw materials". The reasoning behind this definition is that, a technology must aim at changing a given situation (production process) to a more advanced and desirable state. It must make work easier for the user of the technology while producing a better result or outcome than the conventional one.

Donkoh and Awuni (2011) defined adoption as the extent to which a new technology or innovation is used. Feder et al. (1985) had previously acknowledged that for a technology to be adopted, farmers must first have complete knowledge about the said technology and its potential as this only happens in the long run equilibrium. The intuition is that, at the initial stages of the adoption process, farmers may have little or no knowledge about the technology and so may have very low interest whatsoever to adopt. However, with time, they tend to learn more about the technology and eventually tend to appreciate it.

Donkoh and Awuni (2011) stressed that although “adoption” and “diffusion may look similar, in terms of the time frame and population within which they operate, they are different. Feder et al. (1985) cited in Donkoh et al. (2006) differentiated between the two by referring to adoption as ‘when an individual or a household makes use of an innovation and diffusion as when the use of a technology or innovation is spread within an entire community or even it goes global’.

Different disciplines with different schools of thought according to Donkoh et al. (2006) have tried to define adoption from their own perspective. Bonabana-Wabbi (2002) also defined adoption as the decision to accept a technology. Bonabana-Wabbi (2002) stressed that the process of adoption has two dimensions; rate of adoption and the intensity of adoption. The rate of adoption has to do with the speed with which people adopt a given technology over a stipulated time while the intensity of adoption refers to the level of adoption. Rogers (1983) outlined five steps through which an adoption decision must pass through before a technology is finally adopted as: awareness, interest, evaluation, acceptance, trial and then finally adoption. To determine the impact of a technology on a group of people, some knowledge about the rate of diffusion or adoption of the technology and the factors that influence it must first be ascertained (Philip et al., 2000).

In estimating the rate of adoption of a technology, researchers such as Akino and Hayami (1975); Philip et al. (2000) and Maiangwa et al. (2010) have given some insight as to what should be done. Akino and Hayami (1975), for instance posit that in terms of crop production, the rate of adoption can be calculated as the ratio of total land area under which the crop is cultivated with the application of the said technology, to the total land area under which the crop in question is cultivated all expressed as a percentage.

Philip et al. (2000) on the other hand noted that the adoption of a technology follows a logistic curve and that the adoption rates could be determined along the curve over time. Maiangwa et al. (2010) theorize the rate of adoption to be estimated using the ratio of adopters of the said technology to the total number of farmers in the sample, and expressed as a percentage. The above methods of calculating the rate of adoption is most appropriate when we are dealing with a single technology. However, in dealing with a number of technologies, Herdt and Capule (1983) proposed the adoption rate to be calculated as the ratio of the number of technologies adopted to the total number introduced and expressed as a percentage. An arbitrary scale could then be used to classify the value estimated as low, medium or high (Ramaswamy, 1993).

Drawing inspirations from these adoption studies, this study would measure the intensity of adoption of fertilizer as the ratio of the total quantity of fertilizer applied in kilograms to the total land area under cocoa cultivation.

According to Feder et al. (1985), rural sociologists were the first to carry out studies on adoption and diffusion behaviours. Since then economic studies on adoption have drawn their motivation from these early studies. Rogers (1962) was among the early writers on adoption and diffusion. In his study which he conducted on hybrid corn and comparing the results to diffusion rates in other countries, he noticed a common trend: adoption rates were minimal when the technology was initially introduced to farmers; as time progressed the rate of adoption increased and then finally, over a relatively longer period, it decreased.

This notwithstanding, some people for whatever reason it may be, would opt against adopting the technology. Donkoh et al. (2006) assigned some reasons to those who may choose not to adopt a technology. For instance, they (non-adopters) may not see the technology in question to be profitable enough or they might even have an alternative which they perceive to be more efficient than the said technology. Thus the rate of technology adoption initially increases and finally decreases.

2.4.2 Measurement of Adoption

Adoption is an economic term that can be defined as the degree of use of a new technology or innovation. There are many instances where a dependent variable could be dichotomous such as yes or no, receive training or not, adopt a technology or not, among others. These dependent variables are termed as discrete or limited dependent outcomes. Choice models such as logit, probit, Tobit, and Heckman models among others have been used in literature to measure adoption of agricultural technologies. Discrete choice models are usually derived under the utility maximizing behaviour of the decision maker.

Given that the dependent variable of an adoption model is discrete, OLS estimation is inappropriate because the basic assumptions of normality and homoscedasticity of the error term are violated. Also, Greene, (2003) observed the computed probabilities may fall outside 0 and 1.

Most studies have employed either probit or logit to analyze adoption decision. These two choice models are similar in that they produce similar marginal effects. However, they differ slightly based on the transformation or link function. To overcome the limitations of the OLS, choice models present three approaches that can be used. Thus, the pure probability approach (PPA), latent variable approach (LVA) and the random utility approach (RUM). The PPA for example assumes that the dependent variable takes a Bernoulli distribution where the outcomes can assume only two variables. Thus each outcome is associated with a given probability as follows:

$f(1) = \pi$

$f(0) = 1 - \pi$

The likelihood function of the Bernoulli distribution is thus given as

$$L = \prod_{i=1}^{N} \pi^{yi}(1 \quad \pi)^{1= yi} \qquad (2.1)$$

By taking the natural log on both sides of the likelihood function above, we get the log-likelihood function of the Bernoulli distribution as follows;

$$ln\ L = \sum_{i=1}^{N} [\, y_i\, ln(\pi) + (1 - \boldsymbol{y_i})\, ln(1 - \pi)] \qquad (2.2)$$

Given that $\pi_i = g(x_i, b)$, we search for the function g (.) that is less restrictive than the Bernoulli distribution and substitute into the Bernoulli Likelihood function as;

$$L = \prod_{i=1}^{N} g(x_i, b)^{yi}(1 - g(x_i, b))^{1-yi} \qquad (2.3)$$

Taking the logs of the likelihood function produces the log-likelihood function. Whereas a cumulative standard normal distribution function $\Phi(x_i b)$ leads to the Probit model, a cumulative standard logistic distribution function $\Lambda(x_i b)$ produces the logit model.

With the LVA, the dependent variable is treated as a problem of measurement where the existence of a continuous underlying or latent variable is unobserved by the researcher. The unobserved continuous variable is related to the dichotomous dependent variable as follows:

$$Y_i^* = X_i b + e_i \qquad (2.4)$$

$$Y_i = \begin{cases} 1 \ \text{if} \ Y_i^* > t \\ 0 \ \text{if} \ Y_i^* \le t \end{cases}$$

For the sake of convenience, t which is the threshold or cut off value is normally approximated to zero. Thus the probit and logit regression can be considered as a regression of limited information about the dependent variable.

The Tobit model proposed by Tobin (1985) on the other hand is a hybrid of the discrete and the continuous dependent variable and shows the link between a non-negative exogenous variable y_i and an independent variable X_i. The Tobit model assumes a latent unobserved variable y^* which linearly depends on x_i through a parameter vector β and a normally distributed error term u_i which captures the random influence of this relation. The observed variable y_i is equal to the latent variable if the latent variable is higher than zero but equals to zero if otherwise. This is presented as

$$y_i = \begin{cases} y_i^* \; if \; y_i^* > 0 \\ 0 \; if \; y_i^* \leq 0 \end{cases}$$

Where y^* is a latent variable which is equal to $y^* = \beta x_i + u_i$ and $u_i N(0, \sigma^2)$.

Chebil et al. (2009) noted that the log likelihood function of the Tobit model can be written as follows:

$$L = \prod_0 F(y_{0i}) \prod_1 f(y_i) \tag{2.5a}$$

$$L = \prod_0 1 - \boldsymbol{F}[(x_i\beta/\sigma)] \prod_1 \sigma^{-1} f[(y_i - \boldsymbol{x_i}\beta)/\sigma] \tag{2.5b}$$

Where *f*, and *F* are the standard normal density and cumulative distribution functions, respectively. A log-likelihood function can be derived by taking the logs of the likelihood function above. The parameters β and σ can be estimated by maximizing the log-likelihood function.

The choice of the decision maker in this study is in two parts, the discrete decision to use or not to use fertilizer, and the continuous decision on the quantity or intensity of use. Fufa and Hassan (2006) observed that the use of Tobit models to separately estimate the determinant of the probability and intensity of adoption may produce misleading recommendations. This, according to Waithaka et al. (2007), is because the Tobit jointly determines the probability of adoption and intensity of adoption creating a situation of double counting. This has resulted in several authors contesting the Tobit model because the discrete and continuous decisions to adopt are not necessarily mutually inclusive.

To address this short fall in the models discussed above, the Heckman's two step model was used to estimate the probability and intensity of adoption (Mal et al., 2012; Yirga and Hassan, 2013). Heckman's two step model does not only address the separability problem but also addresses the problem of selectivity bias by imposing an exclusive condition in the first step (Heckman, 1979).

The first step of the Heckman's two-step model involves the estimation of a probit regression model expressed as follows:

$$z = \Pr ob(z/z^* > 0) = x\gamma + \varepsilon \tag{2.6}$$

Using g to represent adoption intensity in the second stage of the Heckman two-stage model, g_i^* as the latent variable of adoption intensity, σ as the set of coefficient estimates, and φ as the error term, the second step of the model is a truncated regression expressed as follows:

$$g = E(g/g^* > 0) = x\sigma + \lambda(x\gamma) + \varphi \tag{2.7}$$

The second term on the right hand side is the inverse Mills ratio which corrects for selectivity bias in the truncated regression model. A significant lambda suggests that the intensity of adoption depends on the initial discrete decision to adopt an agricultural technology (Marchenko and Genton, 2012).

2.4.3 Adoption of chemical Fertilizer

Studies have shown that the continuous mining of soil nutrients on cocoa fields as a result of the continuous removal of cocoa pods has led to nutrient deficiencies across agro-ecological zones (Smaling et al., 1993). In order to reverse the increasing trend of soil nutrient mining and improve on soil quality, the issue of fertilizer application must be taken seriously. Olson (1970) noted that about 50% increase in food production can be achieved through fertilizer application. This has been confirmed by several studies in recent time. For instance, fertilizer has been found to increase crop productivity, returns on investments in crop production systems, as well as ultimately enhancing household, national, and global food availability (Sauer and Tchale, 2009; Spiertz, 2010; Olagunju and Salimonu, 2010). This is because fertilizer is able to restore certain depleted nutrients in the soil thereby meeting specific nutritional needs of crops as well as minimizing potential environmental hazards of continuous cropping (Verma and Sharma, 2007).

Despite the prospect of increasing productivity through the application of fertilizer, Africa records the lowest application rate. According to IFDC (2006), between 1980 and 2004, SSA lost about 4.4 million tonnes of nitrogen, 0.5 million tonnes of phosphorus and 3 million tonnes of potassium and this cost the continent about $4 billion worth of soil nutrients a year. The region's rate of fertilizer application at the time was very low, only 8kg/ha annually as against a global average of 93 kg/ha yearly and an annual application rate of 200 kg/ha in East Asia. Even though there have been improvements in fertilizer use in SSA of late, the rates are still low compared to the global average. For instance, compared to the global average of 122.1 kg/ha, SSA only applies 10.5kg/ha, South Asia (176 kg/ha), Latin America and the Caribbean (92.2 kg/ha), the Middle East and North Africa (79.5 kg/ha) (World Bank, 2012). In response to this, several intervention packages were implemented to arrest the situation. The significance of soil degradation and the importance of fertilizer in solving this problem to boost the overall development of the economy of SSA was made manifest in the international fertilizer summit held in Abuja, Nigeria, in June 2006 as it was brought to light, the crucial role of fertilizer inputs for replenishing the nutrients of the depleting soils in the region, while at the same time raising agricultural productivity (IFDC, 2006).

Following the 2006 Abuja declaration, Ghana in 2008 instituted the Fertilizer Subsidy Programme. According to Yawson et al. (2010) this was in tandem with the Food and Agriculture Sector Development Policy (FASDEP I) and also in response to the issues of food security. The aim was to increasing fertilizer use as this was expected to have a positive influence on the production of food crops as well as cash crops (eg. cocoa). The programme basically covered four types of inorganic fertilizer: Urea, Sulphate of ammonia, NPK, 15:15:15 and NPK 23:10:15. .

2.4.4 Determinants of Farm Technology Adoption

Many empirical studies have been carried out on agricultural technology adoption using different models to identify factors explaining farm technology adoption. This section reviews some of the studies that have been done in recent times.

Mmbando and Baiyegunhi (2016) in their quest to explore households' socioeconomic and institutional factors influencing adoption of improved maize varieties (IMVs) in Hai Distict, Tanzania used the logistic regression model. Empirical results from their study pointed out that education, access to credit facilities, access to off-farm income, access to extension services, membership of farmer groups/association and participation in on-farm trials/demonstrations were statistically significant factors influencing farmers' IMVs adoption decision. Ouma and De-Groote (2011) examined the determinants of improved maize seed and fertilizer adoption in Kenya using the Heckman two-stage model. Their study revealed that credit, access to hired labour, education of household head and number of extension contacts significantly influenced a farmer's decision to adopt the technologies.

Again, Wiredu et al. (2015) in examining what determines adoption of fertilizer among rice-producing households in northern Ghana, used the Cragg's and Heckman two-step models to estimate the probability and intensity of adoption separately as was done by (Mal et al., 2012; Yirga and Hassan, 2013). The result revealed that the probability and intensity of adoption were both affected by different factors. The factors that were found to be important in determining adoption include participation in a fertilizer subsidy program, off-farm activities, land-labour ratio, improved seeds and expectation of high yields. Good agricultural practice such as harrowing of fields was also found to be an important determinant of fertilizer adoption. However, Proportion of educated, off-farm activities, land-labour ratio, harrowing of field and dibbling of seeds significantly influenced intensity of adoption. Similarly, studying the welfare impact of adoption of improved cassava varieties by rural households in South Western Nigeria, Afolami et al. (2015) subjected their data to descriptive and inferential statistical analysis. The result demonstrated that adoption of improved cassava varieties increased farm households' income and their annual consumption expenditure thereby increasing the general welfare in South West Nigeria. An analysis of the determinants of adoption indicated that access to improved cassava cuttings within the villages, use of radio, farming experience and farming as a major occupation were significant factors influencing adoption of improved cassava varieties in the study area.

In the Ghanaian cocoa industry, many studies have been conducted on adoption of various technology packages. Baffoe-Asare et al. (2013) employed the Tobit multivariate regression model to examine the socioeconomic factors influencing adoption of CODAPEC and Cocoa High-tech technologies among small-holder farmers in the central region of Ghana. The result revealed that all (Experience, training, age of the household head, gender, household size, age of the farm, social capital) but farm size significantly explained the adoption of the technology in the study area. A Similar study, by Aneani et al. (2012), which was on the adoption of cocoa production technologies by cocoa farmers in Ghana used the multinomial logistic regression model as was applied by (Chan, 2005). The technologies that were investigated were the Crop Research Institute of Ghana recommended ones such as control of capsids with insecticides, control of black pod diseases with fungicides, weeds control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application. The result showed that adoption rates of the technologies were 10.3 %, 7.5 %, 3.7 %, 44.0 % and 33.0 %, respectively. Empirical result from the adoption model also indicated that factors such as access to credit, number of farms, gender, yield, and educational status of farmer, age of farm, migration, and farm size were found to significantly influence the probability of adoption of CRIG-recommended technologies. Anang (2016) in his study titled "a probit analysis of the determinants of fertilizer adoption by cocoa farmers in Ghana" revealed that farmers' age, farm size, Household size, farm income were the critical determinants of adoption. Whereas income from cocoa farm positively influenced the adoption of fertilizer among cocoa farmers, age of household head, household size, farm size and extension contact negatively influence fertilizer adoption. In modeling the determinants of cocoa farmers' investment in agrochemicals in Ghana using Tobit regression model, Danso-Abbeam et al. (2014), noted that factors such as household size, age of cocoa farms, level of education and farm size had significant influence on farmer's decision to invest in agrochemicals.

2.5 Definition and Concept of Efficiency

When an economy produces goods and services at a least cost so as to maximize production levels, that economy is said to be productively efficient. According to Kebede (2001), productive efficiency is defined as the effective use of variable resources for the sole purpose of profit maximization, given that the best production technology is made available. Forsund et al. (1980) also defined productive efficiency as the efficient combination of resources (inputs) to produce any given amount of output at least cost. Chirwa (2007) observes that productive efficiency is the broad umbrella under which technical and allocative efficiency falls. The import of this is that efficiency is the benchmark for evaluating choices in any production level because it is a desirable goal. Leibenstein (1966) defines technical efficiency as the effectiveness with which a given set of input is used to produce an output. By multiplying technical and allocative efficiency, we get economic efficiency. The aim of the manager is thus, to produce higher amount of output at the lowest possible cost. Therefore, the farm manager makes effort to either reduce the cost of a certain level of output or to increase the output with a certain level of costs. These optimization decisions provide similar rules for the allocation of resources and the selection of a technology (Kuwornu, et al., 2013). They noted that since there are other ways of attaining the production goals, the production theory provides the theoretical and empirical framework which helps in selecting the best alternative for a given combination of the farmers' objectives to be achieved.

Farrell, (1957) proposed the frontier as a way to measure productive efficiency. Since then approaches to measuring efficiency have been classified into two main categories: These are the non-parametric programming approach (Charnes et al., 1978) and the parametric programming approach (Aigner and Chu, 1968). The stochastic frontier approach is preferred for assessing efficiency in the agricultural sector because it deals with stochastic noise and permits statistical test of hypothesis pertaining to production structure and degree of inefficiency (Coelli, 1995). In differentiating between these groups, Chirwa (2007) noted that parametric frontier, unlike the non-parametric frontier, imposes a functional form on the production function and makes assumptions on the data. Coelli et al. (1998) differentiated between deterministic and stochastic frontiers which are all forms of the parametric programming approach, by emphasizing that while the deterministic frontier assumes that the deviations from the frontier is as a result of the firms' own doing (inefficiency), the stochastic frontier assumes that the deviations from the frontier could be as a result of events outside the control of the firm such as measurement error and statistical noise and these in part are responsible for a firms' inefficiency. Therefore, stochastic frontier model produces both specification failures and uncontrollable factors independently of the technical inefficiency component by introducing a double-sided random error into the specification of the frontier model.

In the last couple of decades, there have been an increase in the interest of researchers to estimate technical change, efficiency change, and productivity change using stochastic frontier analysis (e.g., Kumbhakar and Lovell, 2000; Greene, 2004). Following the groundbreaking work of Farrell (1957), various modifications and improvements have been made. Aigner and Chu (1968) translated Farrell's frontier into a production function and later, Aigner et al. (1977), Meeuseen and van den Broeck (1977) and Battese and Corra (1977) independently laid the foundation for the stochastic frontier approach. Some authors in the past like Kalirajan (1981), in an attempt to explain variations in output between firms in an industry, estimated stochastic frontiers to predict firm level efficiencies, and then regressed these predicted efficiencies on firm specific variables (such as managerial experience, ownership characteristic and production conditions). To overcome inconsistencies in the assumptions regarding the independence of inefficiency effects in this two-stage estimation procedure, Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) proposed a single stage stochastic frontier in which the inefficiency effects (u_i) is expressed as an explicit function of the vector of firm specific variables and a random error. Other studies such as Kumbhakar and Lovell, (2000); Greene, (2004) have also estimated farm level technical efficiency using the SFA.

On the type of data, early works on technical efficiency made use of cross-sectional data. This notwithstanding, some (e.g Miljkovic and Shaik, 2010) have employed time series data, whilst others have used panel data to estimate fixed effects, random effects, and time variant inefficiencies. It must be stated that most authors hold the view that panel and time series data are the best types of data for studying technical efficiency since they present a clear picture of farm-level efficiency and inefficiency levels over a given period. However, due to the unavailability of past data, this study would rely on cross-sectional data. In recent times, most studies on technical efficiency have largely depended on cross-sectional data.

2.5.1 Determinants of Technical Efficiency

Two approaches have been suggested to estimate the sources of technical efficiency based on the stochastic production functions. These are: the two-stage estimation procedure and the one stage simultaneous estimation approach as suggested by Battese and Coelli, (1995).

In the first stage of the two stage estimation procedure, efficiency scores are derived from an estimated stochastic production function and in the second stage, ordinary least square model or a tobit regression model is used to regress the derived predicted scores on the covariates (Chirwa, 2007).

Critics of this approach argue that inefficiency may depend on the covariates because input choices may be affected by the farmers' knowledge of its own inefficiency level (Chirwa, 2007). In the second approach, the inefficiency effects are expressed as a function of a vector of farm-specific variables (Battese and Coelli, 1995). This implies that, both the parameters of the frontier production function and the inefficiency effects are expressed as a function of other variables.

Chirwa (2007) suggests several factors that influence farm level efficiency of small holder farmers. These include socio-economic and demographic factors, plot-level characteristics, environmental factors and non-physical factors. Several studies in the past have suggested some of these factors to influence farm level technical efficiency. Among such studies are: Essilfie et al. (2011) who used the stochastic frontier to estimate farm level technical efficiency among small scale maize farmers. They observed that while Age of the farmer and years a farmer spends in formal education increase efficiency, household size and off-farm income decrease efficiency. Again, Kuwornu et al. (2013) in estimating technical inefficiency for maize farmers in the Eastern Region of Ghana, noticed that extension visit, FBO membership, frequency of meeting by members of FBOs, formal training in maize farming, cash and in-kind credits are the major determinants of the farmers' technical efficiency level.

In most recent studies, efforts have been made to examine the technical efficiency levels in cocoa production. For instance, Dzene (2010) examined the determinants of technical efficiency of cocoa farmers in Ghana from 2001 to 2006. It was discovered that all (socioeconomic factors and non-labour inputs) but household size and insecticides use intensity significantly impact on technical efficiency. Other factors like fertilizer intensity and quality of farm maintenance also had positive effect and significantly influenced technical efficiency.

Nkamleu et al. (2010) also did a study on the productivity potentials and efficiencies in cocoa production in West and Central Africa (namely Cameroon, Ghana, Nigeria and Cote d'Ivoire). The result affirms the fact that technical efficiency in cocoa production is generally low worldwide, and that bridging the technology gap is essential to explaining the ability of Ghana's cocoa sector in particular to compete with the cocoa sectors in other countries.

Adding to the list of studies in this field is Adedeji et al. (2011) who investigated technical efficiency, determinants of production and the sources of inefficiency in cocoa production in Oyo State, Nigeria. The study revealed that farm size and quantity of fertilizer were the main factors that influenced the productivity of cocoa while level of education, extension contact and family size were the demographic factors found to significantly influence farmers' technical efficiency.

Danso-Abbeam et al. (2012) using the stochastic production function to analyze the production efficiency of cocoa farmers in the Bibiani-Anhwiaso-Bekwai district found experience, household size and farmers' participation in the CODAPEC programme to be the main determinants of technical efficiency with a mean technical efficiency of 49%.

2.6 Impact of Farm Technology Adoption on Farmer's Efficiency Level

Technology adoption and farm level efficiency could both have forward and backward linkages. This is because in-as-much as technology adoption could result in a farmer being efficient in resource use, the conscious effort to efficiently employ scarce resources could also spearhead an adoption decision and the long term effect could be significant changes in performance and other livelihood outcomes. Another way of looking at the link between the two is that adopting a technology may lead to improving farmer welfare and this may lead to high adoption rates of a technology and hence they become technically efficient.

Several methods have been used to evaluate the impact of technologies. Among the methods that have been applied to achieve consistent estimates of impact interventions are simple regression models, instrumental variable (IV) regression, difference in differences (DiD), propensity score matching and regression techniques. All these methods have their various strengths and weaknesses. This study will make do with the regression on propensity score to assess the impact of adoption of fertilizer on technical efficiency levels of farmers. The propensity score according to Li (2013) can be defined as the probability of study participants receiving a treatment based on observed characteristics. It is a special procedure that uses propensity scores to calculate causal effects. Those outcomes that are not observed are called the counterfactuals and form the main problem in making causal inferences (Li, 2013). As a result of the difficulty in estimating an individual's treatment effect which otherwise would have been the difference between observed outcome (Y_1) and unobserved outcome (Y_0), scholars have engineered a way of rather calculating aggregate treatment effects (Morgan & Winship (2007). Thus, the Average treatment effect (ATE) and the Average treatment effect on the treated group (ATT) have been suggested. According to Harder et al. (2010) cited in Li (2013), whereas, "ATE refers to the average effect that would be observed if everyone in the treated and the control groups received treatment, compared with if no one in both groups received treatment, ATT refers to the average difference that would be found if everyone in the treated group received treatment compared with if none of these individuals in the treated group received treatment".

The PSM is also a technique that allows researchers to reconstruct counterfactuals using observational data (Li, 2013). Heckman et al. (1998) observes that the PSM in constructing counterfactuals using observational data reduces two sources of bias i.e. bias due to lack of distribution overlap and bias due to different density weighting. Another advantage of using the PSM is according to Li (2013) is the issue of misspecification of econometric models that could arise if the two samples in this case adopters and non-adopters lack distribution overlap. When this happens, regression analysis cannot tell whether or not there is distribution overlap however, the PSM can accordingly, detect this anomaly between the two groups.

Although, there is a wide range of literature on adoption and impact studies (e.g. Becerril and Abdulai, 2010; Asfaw et al., 2012; Shiferaw et al., 2014), their focus have been on welfare impact. Much less is however known about the impact of fertilizer adoption on the technical efficiency levels of farm households.

Consequently, this study will explore relevant quasi-experimental approach such as regression on propensity score to produce consistent estimates of the impacts of adoption of fertilizer by cocoa farmers on their farm level efficiency.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

The study investigated factors that influence cocoa farmers' adoption decisions as well as intensity of adoption and their resultant effect on technical efficiency. A cross sectional survey design was used and primary data was obtained randomly from cocoa producing households. Personal interviews were conducted using a structured questionnaire. Quantitative and qualitative analysis involving descriptive and econometric tools were employed. This chapter also presents the study area, sampling and data collection techniques.

3.2 Study Area

The Western Region of Ghana covers an area of nearly 24,000km^2, corresponding to about 10 % of Ghana's' total land area, with a coastline of 192 km. It is bordered on the East by the Central Region, to the West by Cote d'Ivoire, to the North by Ashanti and Brong-Ahafo Regions, and to the South by the Gulf of Guinea. The most southern part of Ghana lies in the region, at Cape Three Points. Western Region lies in the equatorial climatic zone that is characterized by moderate temperature, ranging from 22°C to 34°C.

Being the wettest part of Ghana, it has precipitations averaging 1,600 mm per annum, with the two major rainy seasons between May-July and September-October. It also experiences intermittent minor precipitations all year round. This creates a high relative humidity, ranging from 70 to 90 percent in most parts of the region. The wettest part of

Ghana occurs in the South West part of the region. This largely explains the rich vegetative growth, forest and the track record of the region as a major contributor to the nation's agricultural exports. These, notwithstanding, the high rainfall pattern coupled with the many rivers that runs through the region equally have implications for flooding.

The region has about 75 % of its vegetation within the high forest zone of Ghana. The south-western areas of the region are noted for their tropical rain forest, interspersed with patches of mangrove forest along the coast and coastal wetlands, while a large expanse of high tropical forest and semi-deciduous forest is also found in the northern part of the region. The population of the region, according to the 2010 Population and Housing Census, was 2,376,021 with 1,187,774 males and 1,188,247 females. With a population growth rate of 3.2%, the population of the region is projected to have increased to 2,887,078 in 2016 with 1,417,243 males and 1,469,835 females (GSS, 2013 and GSS, 2016). The region is endowed with considerable natural resources which gives it a significant economic importance within the context of national development. It is the largest producer of cocoa, rubber, coconut and one of the major producers of oil palm. The rich tropical forest makes it one of the largest producers of raw and sawn timber as well as processed wood products.

The choice of Western Region as the study area was based on the fact that the region is a major food basket of the country with majority of the people engaged in the sector. The major food crops cultivated in the region include maize, rice, cassava, yam, cocoyam, plantain with cocoa the most important cash crop cultivated in the region. Again, the choice of the Sefwi areas of the Western Region as the study area is based on the fact that over 70% of the indigenes are engaged in cocoa production. (Refer to appendix 2 for the map of the study area).

3.3 Research Design

Following Hailu et al. (2014), the study adopted the across-sectional survey method to ascertain the determinants of adoption of fertilizer and technical efficiency among cocoa farmers in the western region of Ghana. The study made use of two research techniques (quantitative and qualitative methods). The socioeconomic characteristics and other relevant information of the respondents were analyzed using descriptive statistics, whereas the determinants of adoption and the technical efficiency of the farmers were analyzed using quantitative methods. The study basically employed a face-to-face interview through the administration of questionnaires to gather primary data. The two-stage random sampling approach was used to select the respondents (see Asante et al., 2014). The methodological approaches for analyzing the specific objectives of the study included; descriptive statistics (means, percentages and graphs), and the Heckman two-stage regression model to analyze farmers' choice and intensity of adoption. The Stochastic Frontier Analysis (SFA) model was also used to analyze the technical inefficiency levels of farmers. Finally, regression on propensity score was used to analyze the effect of adoption on the technical efficiency levels of farmers.

3.4 Data and target population

The data basically included both qualitative and quantitative variables which were collected from primary sources. Only cocoa farmers were considered in the cross-sectional survey, thus adopters and non-adopters of chemical fertilizer. In the context of this study, farms of respondents must have reached fruiting levels (farms above five years) to be considered for the study. This is to satisfy the assumption that cocoa farms on average, start fruiting after five years of planting and as such puts all cocoa farms considered for this study on the same scale.

The data captured information on farmers' demographic characteristics such as age, sex, level of education and socioeconomic characteristics such as output levels, income and also factors of production such as land size, labour, among many other information that were relevant to achieving the set objectives. Institutional variable were also considered for the study.

3.5 Sample Size Determination

Hair, (2006) and Saunders et al. (2009) noted that limitations such as time, availability of research funding as well as the type of statistical analysis used in a given study among many others makes it very necessary to select a sample from a given population. Saunders et al. (2009) argued that drawing conclusions on a larger sample size have a very high tendency of accurately reflecting the population under review.

Following Nassiuma (2000) as cited in Okuthe et al. (2013) and Oboubisa-Darko (2015), the study estimated the sample size from a known population size and coefficient of variation using the formula specified below;

$$n = \frac{NC^2}{C^2 + (N - 1)e^2} \qquad 2.1$$

Where n= sample size; N= population size; C= coefficient of variation; e= error margin

$$n = \frac{2{,}376{,}021 * (0.35)^2}{(0.35)^2 + (2{,}376{,}021 - 1) * (0.02)^2} \qquad 2.2$$

$n = 306.21$

This figure was approximated to 305 respondents.

3.6 Sampling Techniques

A two-stage sampling technique was used to select a total of 305 respondents. In the first stage, the simple random sampling (lottery method) was used to select six (6) districts out of a total of 22 districts within the Western Region and eighteen (18) communities in the sampled districts. In the second stage, convenient sampling technique was again employed to select 305 respondents from these farming communities. Table 3.1 shows the districts and their respective communities where the survey was carried out.

Table 3. 1. Shows the sampled communities in the various Districts

Districts	Community 1	Community 2	Community 3
Sefwi Wiaswo	Amafie	Dzatokrom	Aboboya
Wassa-Amenfi East	Wassa Saamang	Wassa Saa	Wassa Grumisa
Akotombra	Nkodum	Ayisakrom	Fawokabra
Dadieso	Kwasuo	Atukrom	Kalo
Bodi	Bodi	Afere	Aferewa
Juabeso	Anpobia	Mafia	Proso

Source: field Survey (December, 2016)

3.7 Data Collection Methods and Questionnaire design

Personal interview with the help of a semi-structured questionnaire was used for the survey. The questionnaire was both closed and open ended with the aim of capturing as much as possible information which was relevant to the objectives of the study. The information gathered was strictly used for academic purpose and was therefore treated as confidential. Names of respondents were not mentioned in the research or anywhere else as such respondents' identity were well protected.

3.8 Conceptual Framework

The concept of technology adoption hinges on farmers' decision of choice at a given time. As a result, a farmer may adopt a technology or not if adequate information is made available. Given that a group of farmers belong to the same geographical area, it is most likely that in the presence of adequate information e.g the potential to increase output per acre, they will adopt a particular technology. Agricultural literature predicts socioeconomic, demographic, institutional, farm level and policy factors, among others, to influence adoption. This study focuses on the adoption of inorganic fertilizer and it is expected that all the factors mentioned above will significantly influence this decision making process.

The concept of production efficiency derives its motivation from the fact that given a set of inputs, farmers would want to achieve maximum output. Farmers in the same geographical area may experience differences in their output levels and this could be attributed to the fact that there may be variations in their production technologies, demographic, socioeconomic, and institutional policy factors. These factors together influence adoption decisions and, hence the extent to which the technology is adopted. The decision to adopt or not and the extent of adoption also goes a long way to influence production efficiency and finally impact on farm level technical efficiency. The figure explicitly gives a pictorial view of what happens in the adoption process.

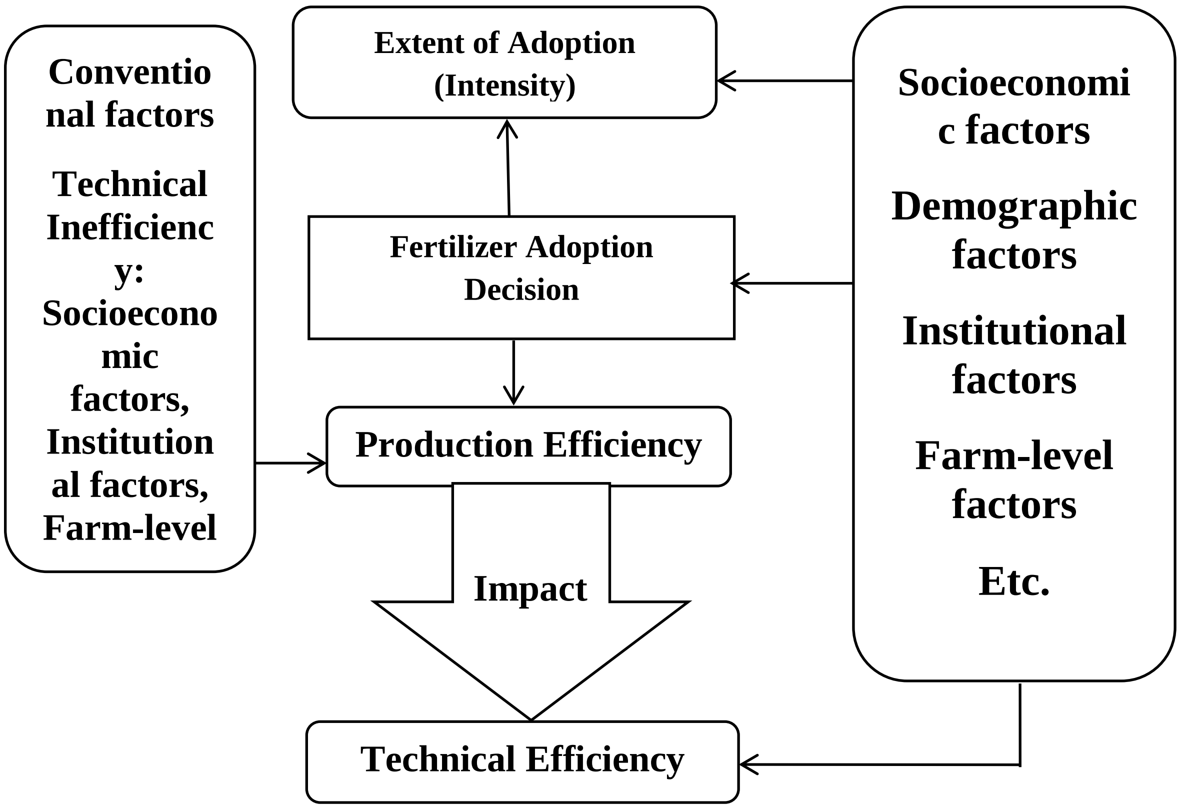

Figure 3. 1. Shows the linkage between adoption and its potential effects on technical efficiency
Source: Author's Conception

3.9 Theoretical framework and Estimation Technique

3.9.1 Farm Technology Adoption Decision

The theory behind choice models is utility maximization. According to Misra et al. (1991) a consumer maximizes his utility by taking a decision about how best a product (fertilizer) maximizes his/her utility. In order to model how farmers achieve this, the microeconomic theory of utility maximization assumes that people make choices that make them happy.

Extending the concept of utility maximization to fertilizer adoption, a utility greater than zero indicates that the farmer will adopt inorganic fertilizer. Conversely, utility less than zero (negative) indicate that the farmer will not adopt inorganic fertilizer. The study, therefore, assumes that the decision of a farmer to adopt inorganic fertilizer is voluntary and that the differences in responses are because farmers have, e.g., different: demographic, socioeconomic, institutional, farm level factors as well as different resource endowments. As a consequence, some farmers will adopt fertilizer if and only if the expected gain from the application of fertilizer is higher than that which is derived from not applying fertilizer.

According to Greene (2008), the observed choice a farmer makes between the various decision levels, reveals which one provides the greatest utility. Hence, farmers will adopt the chemical fertilizer if the utility they expect to derive (U_i^a) from this technology is higher than what they would have if they do not adopt fertilizer, i.e. if ($U_i^a > U_i^b$). This means that the more the quantity of fertilizer applied to a plot of cocoa farm, the more satisfied the farmer becomes. Following Greene (2008), a common formulated linear random utility model is specified as:

$$U_i^a = x_i \beta_a + \varepsilon_{ia} \quad and \quad U_i^b = x_i \beta_b + \varepsilon_{ib} \tag{3.1}$$

Where U_i^a and U_i^b are the utility farmers derive for making an adoption decision, x_i is a set of covariates that influence farmers decision of choice and β_a and β_b are the coefficients to be estimated.

Verbeek (2004) also observed that, for each farmer i, the difference in utility between the adoption decisions as a function of observed characteristics (x_i) and unobserved characteristics (ε_i) can be written as:

$y_i^* = U_1^a - U_i^b = x_i\beta + \varepsilon_i$ With y_i^* a latent variable which is not observable, and $\beta = \beta_a - \beta_b$.

3.9.2 Modeling Adoption of Cocoa Fertilizer

The first objective which is to examine the determinants of adoption of fertilizer will employ the Heckman's two-step procedure. Adoption of fertilizer, involves a two- stage process: the first stage has to do with the probability of adoption using the Probit maximum likelihood function to ascertain whether a farmer adopts the technology or not. The second stage takes into consideration the degree (intensity) to which one adopts the technology (fertilizer) and this is done by means of Ordinary Least Square (OLS) regression model. Because the decision taken in the second stage largely depends on that taken in the first stage, it is likely that the procedure in the second stage is not random thereby creating selectivity bias. This is because only those who are positively affected by the determinants of adoption will fully adopt the technology. Hence, the use of the Heckman two-stage model to correct for this biasness in selection (Heckman, 1976).

For the sample selection model, there must exist an underlying relationship which consists of a latent variable. Heckman's sample selection model, therefore assumes that there exists an underlying relationship.

The latent equation is given by $Y^*{}_j = x_j\beta + u_{1j}$ (3.2)

Where Y_j^* is an unobserved latent variable representing household adoption decision, X_i is a vector of covariates, β is the vector of parameters to be estimated and u_i is an error term with mean 0 and a unit variance of 1.

We then observe only the binary outcome given by the Heckman probit model as:

$$Y_j = \begin{matrix} 1 \;\; if \;\; Y_j^* > 0 & (Adopters) \\ 0 \;\; if \;\; Y_j^* \leq 0 & (Non \quad Adopters) \end{matrix} \qquad (3.3)$$

The dependent variable is observed only if the observation j is presented in the selection equation:

$$yj^{select} = (Zj\delta > 0) \qquad (3.4a)$$

$$\mu_1 \sim N(0,1),$$

$$\mu_2 \sim N(0,1)corr(\mu_1, \mu_2) = \rho \qquad (3.4b)$$

When $\rho \neq 0$, standard probit techniques applied to equation 3.4b will bias results. Thus, the Heckman probit provides consistent, asymptotically efficient estimates for all parameters in such models (Van de Ven and Van Praag, 1981). The estimates of β_i from the probit model of the adoption decision, is used to construct consistent estimates of Inverse Mills ratio (λ_1) and used in the outcome model. The Inverse Mills ratio depicts the probability that an observation belongs to the selected sample and this is computed as;

$$\lambda_i = \frac{\varphi(X_I \alpha)}{\Phi(X_I \alpha)} \qquad (3.5)$$

Where ϕ is the density function of a standard normal variable, Φ is the cumulative distribution function of a standard normal distribution and λ is statistically significant (Heckman 1976).

Following Greene (2003), the intensity of adoption of fertilizer depends on certain factors including the decision to adopt fertilizer. Therefore, the intensity model is given as:

$$Intensity_i = \alpha_i Z_i + \delta_{\mu\varepsilon} \lambda_{Y_1} + \varepsilon_i \qquad (3.6)$$

Where Z_i is a vector of explanatory variables such as socioeconomic factors like age of household head, sex, Number of years in school, household size etc. Also to be included in the model are institutional characteristics such as access to credit facilities, access to extension services etc. social capital such as access to NGO's, membership of farmer-based- organizations, visit to cocoa demonstration farms etc. Since Z_i include endogenous variable adoption decision, the expectation of μ and the expectation of ε are non-zero. That is:

$$E(u) = \bar{u} \neq 0 \qquad (3.7a)$$

$$E(\varepsilon) = \bar{\varepsilon} \neq 0 \qquad (3.7b)$$

These non-zero expectations of the error terms in the selection and outcome equations defeat the assumptions underlying OLS. For OLS, the expectations of the error terms must be zero. Therefore, the error terms u and ε in the adoption decision and the intensity equations, respectively are correlated. Hence, u and ε are jointly normal and independently distributed. As such, the OLS estimates of β_i and α_i will not be BLUE. Again, the error terms u and ε are correlated and this violates OLS assumptions (Maddala, 1983).

As a result, the estimates of β_i from the probit model of the adoption decision is used to construct consistent estimates of inverse Mill's ratio (λ_{Y1}) and used in outcome model as shown in equation 3.5.

3.9.2.1 Definition of Variables and A Priori Expectation for Adoption

Adoption of fertilizer: This is a binary response. That is, 1 if a respondent adopted fertilizer and 0 if a respondent did not adopt fertilizer. This was regressed on the socioeconomic, institutional as well as farm management characteristics listed below.

Intensity of fertilizer Adoption: This represents the response variable in the substantive equation of the Heckman two-stage model. The dependent variable in this case is expressed as follows;

$$Intensity\ of\ fertilizer\ Adoption = \frac{Quantity\ of\ fertilizer\ applied\ in\ kg}{Total\ farm\ size\ for\ cocoa\ production}$$

3.9.2.2 Socioeconomic characteristics

This section offers a brief discussion of the variables hypothesized to influence adoption as shown in Tables 3.2 and 3.3 as follows:

Sex: Aneani et al. (2012) reported that the sex of a cocoa farmer in Ghana is an important variable in his or her adoption decision-making process about a cocoa technology package. Sex is a dummy variable measured as 0 for female 1 and for male. By virtue of the inheritance system, women are usually resource constraint with regard to land and other assets. Moreover, in most parts of Africa, women are generally sidelined in terms of access to external inputs, information, as well as income Lebbie (2004) and Matata et al. (2010). This situation is more pronounced in Ghana's cocoa sector which is largely dominated by men. As noted by Ntege-Nanyeenya et al. (1997), gender could negatively or positively relate to adoption depending on the nature of the said technology. The study hypothesizes that gender will positively influence the adoption of fertilizer.

Age of farmer: This is measured as the number of years of a farmer. Many researchers have used age of household head extensively in adoption studies, but its effect in many instances has been indeterminate and this depends on many factors. According to Nkamleu et al. (1998) older farmers are more likely to adopt innovation as a result of accumulating wealth of experience over years of farming. Older farmers are more conservative and this negatively impacts on adoption while young farmers tend to be more innovative and risk averse (Tiamiyu et al., 2009 and Ghana Cocoa Board 2011). The study hypothesized age of farmer to be indeterminate.

Marital status: This variable is measured as a dummy. Thus 1 if a cocoa farmer is married and 0 if otherwise. It is expected that cocoa farmers who are married would be better placed to have relatively large family sizes and hence be labour sufficient than their unmarried counterparts. Marital status is therefore postulated to positively influence fertilizer adoption decisions.

Years in Cocoa Farming: This is used as a proxy for experience and it is measured as number of years an individual household head has been involved in cocoa production. Experience develops skills and the capacity to address technical or practical problems related to agronomic principles on the field (Nanwata et al., 2010). With increasing experience, a farmer may be able to make critical decision concerning adoption of new technology. Hence, experience is expected to be positively related to adoption.

Farm Size: This measures the total land area under cocoa cultivation of a given farmer. Cocoa farmers with larger farm sizes are usually wealthy as compared to those with smaller farm sizes and so there is a greater likelihood that they would readily adopt high input innovation such as fertilizer. Secondly, large farm size would enable the farmer enjoy economy of scale. Hence, farm size is postulated to have a positive influence on adoption.

Family labour: It is a measure of the total number of household members who actually work on the farm. This was measured in man-hours and is a potential determinant of technology adoption. It is, therefore, expected that family labour would have a positive effect on adoption.

Hired Labour is expected to have a negative relationship with fertilizer adoption on cocoa farms. This is because the greater the number of labourers hired to work on a farm, the higher the cost of production. Farmers may tend to reduce their production cost by reducing the amounts of money spent on purchasing the chemical fertilizer.

Household Size: For the purposes of the survey, we adopted the concept of GLSS 6(2014) that defined a household as a person or a group of people related or unrelated persons who live together in the same housing unit, sharing the same housekeeping and cooking arrangements and are considered as one unit, who acknowledge an adult male or female as the head of the household. Large households of food crop production systems are more likely to adopt improved technologies (Adeoti, 2008). However, cocoa as a cash crop competes with both food and arable crop resources such as land and labour. As such larger household sizes will negatively affect adoption of chemical fertilizer. However, cocoa production is highly labour-intensive especially for transportation, application of inputs (fertilizers, insecticide, fungicides etc.) and weed control among many others. This implies that the availability of labour will positively affect the adoption of fertilizer. In short, the study predicts this variable to have both a positive and negative influence on the adoption of chemical fertilizer.

3.9.2.3 Institutional Characteristics

Farmers' contact with extension agents: It is hypothesized that farmers' contact with an extension agent will have a positive influence on the adoption of the fertilizer. A farmer's encounter with extension agents creates an awareness of improved modern technologies. A positive sign is therefore expected.

Training: This tries to find out whether a farmer has ever attended seminars, workshops and/or conferences on cocoa related issues. Farmers are enlightened on the functioning of new technology and the possible result as well as the challenges expected to be encountered from the application of the said technology. Training increases the level of competence of farmers, which will invariably aid adoption. Training is therefore expected to be positively related to adoption.

Cocoa demonstration fields: This gathers information on whether a farmer has ever participated in a cocoa demonstration field exercise. Demonstration fields are meant to help farmers observe and learn about an improved innovation or technology. This gives the farmers who participate, an in-depth knowledge about the said innovation or technology. It is expected that cocoa farmers who participate in the exercises of a cocoa demonstration field regarding fertilizer application, would adopt the technology. Hence the study hypothesized that participation in cocoa demonstration fields would have a positive influence on farmers' adoption decision.

Membership of a farmer-based-organization: This is a measure of membership to social organization such as cooperative society, unions and churches, etc. Studies by Bandiera and Rasul (2003); Colney and Udry (2010) noted that social capital increases the capacity of an individual to get access to information about current innovation and its benefit of other members. It also increases individual farmer's awareness and as a result increases the likelihood of adoption of new technologies. This study, therefore, postulates a positive effect on adoption of fertilizer.

Cocoa mass Spraying: The Cocoa mass spraying exercise is a government of Ghana initiative that was introduced to tackle some challenges such as disease outbreak, among others. The exercise in the 2015/2016 cropping season mainly aimed at the provision of insecticide and fungicide to farmers in the study area. For the purpose of this study, cocoa mass spraying is measured as a dummy variable. That is, 1 if a cocoa farmer benefited from the cocoa mass spraying exercise and 0 if otherwise. It is expected that all other things being equal, the exercise would relieve farmers of the pressures of having to purchase all inputs by themselves and as a result help them focus on those inputs such as fertilizer that was not covered under the exercise. The study, therefore, hypothesizes cocoa mass spraying to have a positive sign.

3.9.2.4 Farm management characteristics

Age of the farm: This variable captures the age of the cocoa farm. The age of the cocoa farm can either be negatively or positively related to the adoption of an improved technology. In the case of a technologies like the CODAPEC and Cocoa High-Tech, age of the farm negatively influence its adoption (Anim-Kwapong and Frimpong, 2004). This is because most farmers often feel reluctant to spend money on inputs for old cocoa farms due to perceived low returns.

However, when it comes to a technology like fertilizer, it is expected that age of the farm would positively influence the adoption decision since the farmer would want to address the issue of low returns of his/her old cocoa farm.

Table 3. 2. Summary description of the adoption Model variables

Variables	Definition	Expected sign
X_1	Age	-
X_2	Sex	+/-
X_3	MS	+
X_4	Years in Cocoa Farming	+
X_5	Extension Contact	+/-
X_6	Training (Conferences, Workshops and Seminars) Attended by Household Head	+
X_7	FBO membership	+
X_8	Number of Plots lots	+
X_9	Farm Size	+
X_{10}	Average age of Cocoa Farm	+
X_{11}	Family Labour	+
X_{12}	Hired Labour	+
X_{13}	Ln Farm Assets	+
X_{14}	Cocoa Mass Spraying	+
X_{15}	Off-Farm Income	+
X_{16}	Distance	-

Distance: Producers who have their farms closer to their homes will have less difficulty in transporting chemical fertilizers and other inputs used in the production of cocoa. This means that cocoa farmers who have their farms close to their homes will be more likely to adopt chemical fertilizer and those farmers who have their farms far away from their homes, would be less likely to use chemical fertilizer. As a result, the study hypothesized that the sign of the variable "Distance" will be negative.

Farm Assets: This variable measures the value of all farm assets owned by the household. This variable is expected to have a positive relationship with fertilizer adoption decision of the farmer. The higher the value of farmers' farm assets, the implication is that, farmers have if not all, most of the farm equipment. This would play into the hands of owners of these farm assets such that they would not be in a quandary over which input (fertilizer or farm equipment) to purchase with their limited resources within a cropping season.

Off-farm income: Off-farm income has a potential of making cash available for investment in improved technologies, hence, it is hypothesized that off-farm income sources increases likelihood of adopting fertilizer (Mmbando and Baiyegumhi, 2016).

Table 3. 3. Summary description of the adoption Intensity Model variables

Variables	Definition	Expected sign
X_1	Family Labour	+
X_2	Hired Labour	+/-
X_3	Age	+
X_4	HHS	+
X_5	Plots	–
X_6	Farm size	–
X_7	Mass Spraying	+
X_8	Farm Assets	+
X_9	Off-Farm Income	+
X_{10}	Experience (Years in Cocoa farming)	+

3.9.3 The theory of Production

In agricultural production, the relationship between output and input is used to denote a production functional model. Technically, the production function is the transformation of inputs into outputs. Following Kibaara (2005), the specification of a production function is given as follows:

$$Q = f(F, L, \ldots\ldots\ldots\ldots N_i) \qquad (3.8)$$

Where Q represents output, L represents the labour; F represents the amount of fertilizers applied among many other management practices. Farmers' main aim in the production process is to increase output levels while employing minimum amount of inputs or reducing the cost of producing the output Q. The Quadratic functional forms, the linear functional forms and the Cobb-Douglas functional form are some of the ways by which the relationship between production levels can be specified. The marginal physical product (MPP) of an input as defined by Kibaara (2005) is the additional output that can be produced by employing one more unit of that input while all other inputs are fixed. Example:

$$MPP_L = \frac{\partial Q}{\partial L} = f_L \qquad (3.9)$$

The equation 3.9 above is derived from equation 3.8. Diminishing marginal productivity occurs when as labour is being employed indefinitely all other inputs are held constant. This results in a situation where by employing an addition labour would decrease productivity (Kibaara, 2005). The import of this is that, the second derivative of equation (3.9) will be less than zero:

$$\frac{\partial MPP_L}{\partial L} = \frac{\partial^2 q}{\partial L^2} = f_{LL} < 0 \qquad (3.10)$$

On the concept of returns to scale, a production response can either be increasing, decreasing or constant. The returns-to-scale in a production process, simply shows the responds of output to inputs (Kibaara, 2005). The elasticity of production measures the proportionate change in output with respect to a proportionate change in inputs. This is derived by dividing the *MPP* by the *APP* (that is, MPP/APP). Furthermore, the total variable product *(TVP)* is derived by multiplying *TPP* by the output price (that is $TPP/Output\ price$). Given the output price (P_y), its marginal value product *(MVP)* can be computed by multiplying MPP by P_y To determine if the inputs are used at optimum level, the *MVP* is equated to the unit factor price or marginal factor cost *(MFC)*. If *MVP* equals *MFC*, then resources are used efficiently, if *MVP* is greater than *MFC* or less than *MFC*, it simply indicates overutilization or underutilization, respectively. It is important to note that in the traditional production function, socioeconomic characteristics and management are not considered as explanatory variables and are thus put together in the error term. The stochastic frontier production functions deals with the analysis of socioeconomic characteristics of the household that are assumed to be in the composed error term.

3.9.3.1 The Proposed Stochastic Frontier Production Function

Aigner et al., (1977) and Meeusen and Van De Broeck (1977) proposed the stochastic frontier production function. The stochastic production function is defined by:

$$Y_i = f(x_i, \beta) + \varepsilon_i \quad where\ i = 1,2,3,.......,n \qquad (3.12a)$$

$$\varepsilon_i = v_i \quad u_i \qquad (3.12b)$$

Where Y_i represents the output level of the i^{th} sampled farm; $f(X_i;\beta)$ is a suitable function such as the Transcendental Logarithmic (translog) production functions or the

Cobb-Douglas production function, X_i of inputs for the i^{th} farm and a vector, ß, is unknown parameters. The difference between the two functional forms is that, whereas the Cobb-Douglas production function is simple to estimate but restrictive, the translog production function is flexible in that it allows for interactions between inputs and does not impose assumptions on constant elasticity of production or elasticity of substitution between inputs.

ε_i is an error term made up of two components: v_i, a random error having zero mean, $N(0;\sigma^2 v)$ which is associated with random factors such as measurement errors in production and other factors which falls outside the control of the farmer. The random error v_i is assumed to be independently and identically distributed as $N(0;\sigma^2 v)$ random variables and independent of u_i.

On the other hand, u_i is assumed to be a non-negative truncated half normal, $N(0;\sigma^2 v)$ distribution or half exponential distribution. u_i is associated with technical inefficiency of the farm and ranges between zero and one. From equation (3.12a) above, the technical efficiency of cocoa farmers can be expressed as:

$$\hat{TE} = \frac{Y_i}{Y_i^*} = \frac{f(x_1,\beta)exp(v_i - u_i)}{f(x_i,\beta)exp(v_i)} = exp(\quad -u_i) \qquad (3.13a)$$

$$= exp(\quad -u_i)$$

$$exp(\quad - z_i\delta - w_i) \qquad (3.13b)$$

From the above expression, the study can define technical efficiency of cocoa farmers as the ratio of actual output of cocoa to the optimal output, provided the production of cocoa is naturally random. Intuitively, all cocoa farmers who find themselves on the production frontier are said to be technically efficient and hence assigned a value of one, whereas those who fall below the frontier are said to be technically inefficient and are assigned a value less than one. A given cocoa farmers' output falling below the frontier output depicts a gap referred to as technical inefficiency (Battase et al., 1996 and Coeli et al., 1998). Technical inefficiency is, therefore defined as the amount by which the level of production of the farm is less than the frontier output. This is expressed as:

$$U_i = \delta z_i + w_i \qquad (3.14)$$

where z_i is a vector of observable explanatory variables, δ is a vector of unknown parameters and w_i is an unobserved random variables which are assumed to be independently distributed and obtained by truncation of normal distribution with zero mean and constant variance.

The stochastic frontier production function can be established in two ways (Bravo-Ureta and Pinheiro, 1993). First, if no explicit distribution of the efficiency component is made, then the production frontier could be estimated using a stochastic version of Correcting Ordinary Least Squares (COLS). However, if an explicit distribution is assumed, such as exponential, half-normal or gamma distribution, then the frontier is estimated by Maximum Likelihood Estimates (MLE). According to Greene (1980), MLE makes use of the specific distribution of the disturbance term and this is more efficient than COLS. The likelihood function is expressed in terms of the variance parameter δ^2 and π, as:

$$\delta^2 = \delta_u^2 + \delta_v^2 \text{ and } \pi = \frac{\delta_u^2}{\delta_u^2 + \delta_v^2}$$

Where

δ^2 = Total variation

δ_u^2 = variation due to inefficiency

δ_u^2 = variation due to white noise

Following Battese and Coelli (1993), technical efficiencies and their determinants were estimated using a one-step maximum likelihood estimates (MLE) procedure. This is done by incorporating the model for technical inefficiency effects into the production function. This study specifies the stochastic frontier production function using the flexible translog specification and later carries out a log likelihood ratio test to determine if the translog reduces to Cobb-Douglas production function.

3.9.4 Test for Model of Specification

In estimating the stochastic frontier model for cocoa producers in the study area, three main hypotheses were tested. Thus, to examine the appropriateness of the specified model used to determine the presence of inefficiency, and the significance of exogenous factors in explaining inefficiency among cocoa producers in the study area. The three null hypotheses are presented as follows;

1. $H_0 : \beta_{jj} = \beta_{ji} = 0$

The sum of the coefficients of square values and their interaction terms in the translog model is zero.

2. $H_0 : \gamma = \delta_0 = \delta_1 .... \delta_{20}$

There are no inefficiency effects

3. $H_0 : \gamma = \delta_0 = \delta_1 .... \delta_{14}$

The Exogenous factors are not responsible for the inefficiency term μ_i

The three hypotheses stated above would be tested using the generalized likelihood-ratio test statistic specified as;

$$LR(\lambda) = \quad 2[\{ln\, L(H_0)\} \quad \{ln\, L(H_1)\}] \qquad 3.15$$

Where $L(H_0)$ and $L(H_1)$ are the likelihood functions under null and alternate hypotheses respectively. If the given null hypothesis is true, then the test statistic (λ) has a chi-square distribution of degree of freedom which is equal to the difference between the estimated parameters under (H_1) and (H_0). However, if the null hypothesis involves $\lambda = 0$, then the asymptotic distribution involves a mixed chi-Square distribution (Coelli, 1995).

3.10 Empirical Model Specification

To estimate a stochastic frontier production function, a Cobb-Douglas function must be fitted (Aigner et al., 1977) and (Meeusen and Van den Broeck, 1977). A number of previous studies (Chirwa, 2007; Donkoh et al., 2008; Ogundari, 2008; Aneani, 2012 and Danso-Abbeam, 2010) specified a Cobb-Douglas production function to represent the frontier function. However, the Cobb-Douglas imposes a severe prior restriction on the farm's technology by restricting the input substitution elasticity's to unity and the elasticity's of production to be constant (Wilson et al., 1998). The study, therefore adopted the translog production function to address the issue of flexibility of the assumption of constant elasticity of production or constant elasticity of substitution. To achieve this, the empirical model estimated to identify the determinants of technical efficiency among cocoa farmers was specified from equation 3.12a and 3.12b as follows;

$$ln Y_i = \beta_0 + \sum_{i=1}^{5}\beta_i \, ln X_i + \frac{1}{2}\sum_{i=1}^{5}\sum_{i=1}^{5}\beta_{ij} \, ln X_i \, ln X_j + V_i + U_i \qquad (3.16)$$

Where $\ln Y_i$ is a scalar of natural log of cocoa output produced by the farm households. $\ln X_1$ is the natural log of farm size (total land of cocoa farms above 5 years and under cultivation as of the 2016 cropping season), $\ln X_2$ is the natural log of labour (both household and hired labour in man days), $\ln X_3$ is the natural log of quantity of fertilizer used in Kg, $\ln X_4$ is the natural log of quantity of insecticide used in grams, $\ln X_5$ is the natural log of quantity of fertilizer used by the farmer in kilograms.

3.10.1 Measurement of Variables for the Output model

Referring from Table 3.4, this section briefly discusses the variables hypothesized to influence the output of cocoa.

Output of cocoa: This is measured as the quantity of cocoa produced in kilogram per acre of land in the 2015/2016 cocoa cropping season.

Farm size is a measure of the total number of acres of cocoa farm an individual cocoa farmer cultivated as at the 2016 cropping season. Farm size in this study, is expected to positively influence output. Several studies such as Abdulai et al. (2013) and Chiona et al. (2014) found farm size to have a positive effect on output levels of maize respectively.

Labour measures the total number of people (both hired and family) who worked on the farm during the various stages of cultural practices ranging from weeding to drying of the harvested cocoa beans. The study expects labour to have a positive correlation with output.

Fertilizer is the measure of the quantity of fertilizer in kilograms applied on a cocoa farm. It is expected that the more the quantity of fertilizer a farmer applies on a plot of land, the more the output of the farm. Therefore, fertilizer is postulated to have a positive sign.

Insecticide is measured as the quantity of insecticide in grams applied on a cocoa farm in the 2015/2016 cropping season. Insecticide is expected to have a positive influence on cocoa output.

Fungicide is a measure of the quantity of fungicide in grams applied on a cocoa farm in the 2015/2016 cropping season. Fungicide is expected to have a positive influence on output of cocoa.

Table 3.4. Summary description of the output model variables

Variable	Description	Measurement	A priori Expectation
X_1	Log of Farm size	Hectares (ha)	+
X_2	Log of Labour	Man days	+
X_3	Log of quantity of fertilizer	Man days	+
X_4	Log of quantity of Insecticide	Number of times applied per acre	+
X_5	Log of quantity of Fungicide	Number of times applied per acre	+

3.11 Determinants of Technical Inefficiency

Following Kumbhakar and Lovell (2000), this study, defines the term u_i as the inefficiency measure of the farm. Thus, any deviation from the farms production frontier is considered as inefficiency. However, two sources of inefficiency exist, thus those inefficiency effects within the control v_i of the farm households and those outside the control of the farm households u_i. The technical inefficiency effect u_i is a one-sided error (i.e. $u_i \geq 0$) and it is assumed to be independently and identically distributed. Among the many factors that can be responsible for the technical inefficiency effect are differences in resource endowments across farms as well as institutional and socio-economic differences that may affect a farm performance. The inefficiency effect can be expressed as a linear function and is, therefore defined as;

$$u_i = \gamma_0 + \sum_{i\ 1}^{n} \gamma_i^k S_i + \sum_{i\ 1}^{n} \gamma_i^k E_i + \sum_{i\ 1}^{n} \gamma_i^k D + \omega_i \qquad (3.16)$$

Where $\gamma's$ represents the parameters to be estimated, S_i denotes the socioeconomic factors of farm households, I_i denotes institutional factors, D_i denotes developmental organizations.

Empirically, the inefficiency effect model is specified as:

$$\begin{aligned} u_i = {} & \gamma_0 + \gamma_1(HHS) + \gamma_2(sex) + \gamma_3 \ln(Experience) + \gamma_4(Farm\ size) + \gamma_5(Farm\ assets) \\ & + \gamma_6(Income\ \ from\ other\ crops) + \gamma_7(Befits\ \ gained\ \ from\ NGO\ services) \\ & + \gamma_8 \ln(\ farm\,age) + \gamma_9(Hired\ \ Labour) + \varepsilon_i \end{aligned}$$

Following Battase and Coeli (1995), the Maximum Likelihood Estimates (MLE) of the parameters of stochastic frontier production function and the inefficiency model were simultaneously obtained using frontier in STATA 13.

3.11.1 Measurement of variables of the inefficiency model

Referring from Table 3.5, this section briefly discusses the variables hypothesized to influence farmers' technical inefficiency.

Household size: this is measured as the number of people in the same household who eat from the same pot. Large household size can be seen as a constrain to the cocoa farmer since larger households would mean feeding more mouths and hence may limit the farmer in terms of performing agronomic practices. In other words households with many members are more likely to spend more on household expenditure. When this happens they would have little or no capital left to purchase farm inputs and perform other agronomic practices and this may result in inefficiency. Based on this analogy, household size is expected to be negative. Studies such as Danso-abbeam (2012) and Bessem and Kim (2014) found household size to negative influence cocoa farmers' efficiency.

Sex: This is measured as a dummy where males are assigned the value 1 and females are assigned the value 0. It is expected that male farmers would be more technically efficient than their female counterparts *ceteris paribus*. This is because women in general perform very important domestic and economic roles (such as child care, cooking, cleaning among others) in the society that makes them technically inefficient (Abdulai et al., 2013).

Years in Cocoa Farming: Experience is measured as the number of years the individual household head has been engaged in cocoa cultivation. Experience enhances skills and facilitates the capacity to address technical or practical problems related to agronomic principles on the field (Baffoe-Asare et al., 2013). Hence, experience is expected to be negatively related to technical inefficiency.

Farm Size: This variable measures the total land size a farmer cultivates under cocoa production. Larger farm sizes tend to burden farmers in terms of the quantum of inputs required. As such smaller farm sizes enable farmers to combine their resources better. However, as noted by Kyei et al. (2011), farm size increases cocoa farmers' efficiency. Hence, the variable farm size is indeterminate.

Farm assets: This represents the value of all farm assets owned by the household. This variable is expected to have a positive relationship with technical efficiency. A higher value of farmers' farm assets implies that, the farmer has majority of the farm equipment. This would mean that owners of these farm assets would not be undecided about which input (fertilizer or farm equipment) to purchase. It would also mean that owners of farm assets can perform timely agronomic practices leading to higher efficiency levels.

Income from Other Crops: This represents revenue generated by cocoa farmers from the cultivation of other crops. This variable is very important in the sense that not all farmers have off-farm income activities therefore excluding a variable such as this would be biased towards off-farm income earners. Just as in the case of off-farm income, the study postulates income from other crops to positively impact technical efficiency.

Benefits gained from NGO services: Whether a farmer benefits from cocoa related NGO services or not may influence their efficiency levels. Most of these NGOs that render services to farmers are buying companies that tend to provide ready markets for their produce. Easy access to markets has a very high potential of ensuring that farmers are efficient in their production. Hence, the services rendered by these NGOs to cocoa farmers are expected to positively influence technical efficiency.

Age of cocoa farm measures the numbers of years of the cocoa tree. The older a cocoa farm the more likely output would fall. Thus, all factors held constant, the owners of older cocoa farms would be less efficient as compared to relatively young farms (Kyei et al., 2011).

Hired labour: this variable is measured as the number of non-family labour who works on the cocoa farm in man-days. The study hypothesized hired labour to have a negative influence on efficiency since it has the potential of increasing cost of production.

Table 3. 4. Summary Description of the Inefficiency Variables

Variable	Description	A priori expectation
X_1	Household size	-
X_2	Sex	+/-
X_3	Years in cocoa farming (Experience)	-
X_4	Farm Size	+
X_5	Farm assets	-
X_6	Income from other crops	-
X_7	Benefits gained from NGO services	-
X_8	Age of the farm	+
X_9	Hired Labour	-
X_{10}	Family Labour	-

3.12 The Effect of Fertilizer Adoption on Household TE

Following Egziabher et al. (2013) and Alemu et al. (2016), the estimation of the effect of fertilizer adoption on TE is assessed using *Regression on propensity Score.* This study, assumes that the discrete decision to adopt fertilizer or not are mutually exclusive of each other and therefore are strongly correlated with observable household characteristics (Egziabher et al., 2013). When this happens, it may cause complications in estimating the causal effects and therefore may lead to selectivity bias.

To address this problem, the study employed the regression on propensity score techniques as proposed by Imbens (2004) and Wooldridge (2008) and applied in studies by Egziabher et al. (2013) and Alemu et al. (2016). The use of propensity score reduces potential biases created by selection on observed characteristics (Imbens, 2004). The use of regression on propensity score in this study involves two main stages. In the first stage, a probit model of fertilizer adoption is estimated after which propensity score or conditional probability to adopt fertilizer is generated. The propensity score *(PS_i)* can be estimated as;

$$PS_i = p\ (A) = \frac{1}{X} \tag{3.17}$$

The second step involves the use of these scores as an additional control variable in the regression model (in this case, the efficiency part of the SFA procedure). Adding the propensity score as an additional control variable in the inefficiency model further reduces the potential bias created by selection on observable characteristics (Imbens, 2004). This model is referred to as *regression on propensity score*.

The final inefficiency effect model is specified as follows:

$$U_i = \beta_0 + x_j\beta_1 + \beta_2 A + \beta_3 PS + u_{1j} \tag{3.18}$$

Where all variables follow their usual definitions with A representing Adoption and PS representing the propensity score or the estimated conditional probability of being treated. To test for the robustness of the results, the Generalized Likelihood Ratio test was also used to assess the effects of fertilizer adoption on TE

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the analysis and discussions of results obtained from a sample of 305 cocoa farmers in the Western Region of Ghana. Frequencies, percentages and means as well as results from the Heckman two-stage model and Frontier model are presented.

4.2 Respondents' Demographic and Socio-economic Characteristics

The demographic characteristics of this study are age, sex, household size marital status and years in cocoa farming which depicts farmers' experience level. Other variables include; output levels, value of farm assets, off-farm income, and income from other crops. The study further looks at the use of agrochemicals by farmers and this constitutes fertilizer, insecticide and fungicide. Distributions of farm size and output as well as sources of knowledge gained through social networks are presented under this section.

4.2.1 Summary Statistics of Respondents' Socio-demographic Characteristics

Age *of respondents:* The mean age of the respondents is 46.4 years while the minimum and maximum ages are 20 and 87 years respectively. The mean household head of this study slightly deviates from that of GLSS 6 (2014), which noted that the average age of household heads is 45.1 years. For the mean age distribution among both sexes, the study revealed that while the mean age of females in the study area is 46.8 years, that of their male counterparts is 46.3 years. This result also confirms the findings of GLSS6 (2014) which observed that on average females are slightly older than their male counterparts.

From Table 4.1, it was observed that majority of the respondents were 45 years and above since the age categories 45-49, 50-54, and 55- 60 and 65+ jointly constitute 54.43 %.

Sex of Respondents: Generally, males dominate in cocoa production probably due to the tedious nature of the production process, which in principle is more suitable to men than women. This is evident in this study as majority (72.13 %) of the sampled farmers was the male category (see Table 4.1). Another reason that could be associated with the dominance of males in cocoa farming in the study area is the fact that by virtue of the inheritance systems, women are usually resource constraint regarding land and other assets. Also, Lebbie (2004) and Matata et al. (2010) observed that, in most parts of Africa, women are generally sidelined in terms of access to external inputs, information, as well as income.

Household Size: The number of people who constitute households in the study area ranges from 1 to 19. On the average, each household in the study area has about 6 people who eat from the same ‘pot’ and are thus dependent on the household head for their daily upkeep. This is above the Regions average of 4.2 recorded in the 2010 Population and Housing Census and 4.0 obtained by the GLSS6 (2014). This is probably due to the fact that the study was conducted among rural households where population generally are high and for that matter household size. More than half of the respondents interviewed fell between the household size category of 6-10 and this accounted for about 51.8%. Similarly, a significant proportion fell within 1-5 persons per household and this also accounted for about 39.67 %. Meanwhile very few respondents had 16 people and more in their households (see Table 4.1). Given the relatively large family size, it is not surprising as discussed above, to see men dominate cocoa farming. The relatively large family sizes could also serve as family labour, and hence, minimize the cost of labour in the production process.

Marital Status: The study revealed that out of the 305 respondents interviewed, more than half 80.98 % were married. This result is in contrast to that of GLSS6 (2014) which noted that only 38.2 % of the population in rural forest areas are married. The 19 % of the respondents who are not married include widows and widowers, divorced men and women, single men and women who had never married. The about 81 % married people include monogamous and polygamous men as well as women (see Table 4.1)

Table 4. 1. Distribution of Respondents Socio-demographic Characteristics

Variable	Category/Description	Frequency (%)
Age		
	20 to 24	7 (2.3)
	25 to 29	24 (7.87)
	30 to 34	31 (10.16)
	35 to 39	37 (12.13)
	40 to 44	40 (13.11)
	45 to 49	44 (14.43)
	50 to 54	39 (12.79)
	55 to 59	27 (8.85)
	60+	56 (18.36)
Sex		
	Female	85 (27.87)
	Male	220 (72.13)
Household Size		
	1 to 5	121 (39.67)
	6 to 10	158 (51.8)
	10 to 15	22 (7.21)
	Above 16	4 (1.31)
Marital Status		
	No	58 (19.02)
	Yes	247 (80.98)
Experience of cocoa farmers		
	1-5	14 (4.59)
	6-10	61 (20)
	11-15	60 (19.67)
	16-20	55 (18.03)
	21- 25	39 (12.92)
	> 25	76(24.92)
Total number of Observations		305

Source: Field survey (December, 2016)

Years in cocoa farming: Experience gained from the cultivation of cocoa, ranges from a minimum of 2 years to a maximum of 54 years with an average experience of 19 years. The mean years of experience in cocoa farming in the study area is a little above that which was estimated by Aidoo and Fromm (2015). They observed that cocoa farmers mean experience in the Ashanti region was 18 years. Djokoto et al. (2016) also found the mean years of experience among Ghanaian cocoa farmers to be 18 years.

From Table 4.1, it can generally be observed that, farmers who have experience in cocoa farming below 20 years, form the majority (62.29 %) while the rest have experience in cocoa farming above 20 years.

Specifically, majority of the respondents (24.92 %) had an experience above 25 years in cocoa farming. This was followed by the experience category of 6-10 years which constituted about 20 % of the total sample. While about 19.67 % of the respondents had between 11-15 years of experience, 18.03 % had between 16-20 years of experience and the experience category of 21-25 constituted about 12.92 %. The experience category of 1-5 years constituted only 4.59 % of the entire sample population.

4.2.2 Summary Statistics of Respondents' Assets and Source of Income

Farm assets: This variable takes into consideration the value of all fixed inputs that is used in the cultivation of cocoa. From Table 4.2, it is revealed that the total worth of farm assets of respondents ranges from a minimum of 200 Ghana cedis (GH¢) to a maximum of 19,350 Ghana cedis (GH¢). The average value of farm assets as indicated in Table 4.2 is GH¢ 640.85.

Income from other Crops: This is a very important factor that affects adoption decision of a cocoa farmer. According to the field survey, on the average, a cocoa farmer who is into other crop production earns around GH¢ 515.91. Whereas some cocoa farmers who are into the cultivation of other crops gain no returns for their efforts, others earn as much as GH¢ 8000.00. This means that those cocoa farmers who gain some income from other crop farms are better placed to purchase inputs for their cocoa farms especially fertilizer (refer to Table 4.2).

Table 4. 2. Distribution of Respondents Assets and Income

Variable	Mean	Standard Deviation	Minimum	Maximum
Farm Assets in (GH¢)	640.85	1339.43	200	19350
Income from other farm crops (GH¢)	515.91	983.19	0	8000
Off-farm income(GH¢)	426.69	2368.4	0	30000
Farm size	8.3492	6.6175	1	45
Output	22.159	24.9224	1.5	189

Source: Field survey (December, 2016)

Off-farm income: Another very important income source that is of keen interest to the study is household income generated from other non-farm activities. As a result of limited land access, which constrains some farmers from cultivating other food crops, off-farm activities serve as an alternative to gain some extra income. Similar to income gained from other crops, off-farm income has a very high tendency of positively influencing a farmers' decision to adopt chemical fertilizer. From the survey, it was revealed that the average amount farmers earn from their off-farm activities in the study area was GH¢ 426.69. However, while cocoa farmers who were into off-farm activities, earned as much as GH¢ 30,000.00 per annum, others gained nothing GH¢ 0.00 (see Table 4.2).

Farm Size: Cocoa farms in the study area generally measures between 1.5 acres (0.6 ha) to 45 acres (18 ha) with the average farm size around 8acres (3.2 ha) (see Table 4.2). This result contradicts that of Obuobosia-Darko (2015) who observed that among Ghanaian cocoa farmers, the minimum and maximum farm size ranges between 2 acres (0.8 ha) and 10 acres (4 ha) with a mean of 4.90 acres (1.96 ha). However, the result confirms the assertion by Aidoo and Fromm (2015) that cocoa farmers are now increasing farmlands under cultivation in order to achieve increased output. The result further show that about 41.31 % of the respondents operate farms measuring between 1 and 5 acres while only 12 % of the sampled cocoa farmers have farms measuring above 15 acres (6 ha). However, 34.1 % of the respondents had between 5.5-10 acres while 11.8 % had their farms measuring between 10.5 – 15 acres. Given that more than half of the respondents (75.41 %) have between 1-10 acres (0.4-4 ha), the findings corroborates the assertion that Ghanaian cocoa farmers operate on small farmlands under 5 ha (Aneani et al., 2012 and Anang, 2016) (refer to Table 4.3).

Output: Another very important socio-economic characteristic considered in the study is the output level of farmers. Generally, the study revealed that on the average, cocoa farmers output for the 2015/2016 cropping season was about 22 bags which translate into about 1,408 kg. It was again revealed that while some farmers harvested as low as 1.5 bags (96 kg), others harvested as much as 189 bags which is equivalent to 12,096 kg (see Table 4.2). Furthermore, the study observed that while 38.03% of the respondents had below 10 bags (640 kg) of cocoa beans, 27.87 % harvested between 10.5 bags and 20 bags (1280 kg) of cocoa beans. Again, whereas 13.11 % and 8.52 % of the sampled respondents harvested between 20.5-30 bags (1312 kg-1920 kg) and 30.5-40 (1952 kg-

2560 kg) respectively, only 2.95 % had between 40.5-50 bags (2592 kg-3200 kg) (see Table 4.3). A critical look at output per hectare in the study area revealed that averagely, a cocoa farm produces about 7.25 bags/ha (464 kg/ha) with a minimum output of 0.5 bag/ha (32 kg/ha) and a maximum of 36.25 bags/ha (2320 kg/ha). This result is far below the national average of 0.5 MT (500 kg/ha) recorded in 2015 (MoFA, 2016). A possible reason that could account for this shortfall in the average output per hectare in the study area is the fact that most of the farmers did not apply the recommended quantities of fertilizer in the cropping season under study. Again, the question of effectiveness of the mass spraying and the Cocoa Hi-Tech programmes could help explain the short fall in the average output per hectare.

Table 4. 3. Distribution of Respondents Assets and Income

Variable	**Category/Description**	**Frequency (%)**
Farm Size in Acres		
	1- 5	126 (41.31)
	5.5 - 10	104 (34.1)
	10.5 -15	36 (11.8)
	>15	39 (12.79)
Output in Bags		
	≤ 10	116 (38.03)
	10.5 - 20	85 (27.87)
	20.5 - 30	40 (13.11)
	30.5- 40	26 (8.52)
		9 (2.95)
	40.5 -50	
	< 50	29 (9.51)
Number of Observations		305

Source: Field survey (December, 2016)

4.2. 3 Distribution of Respondents Use of Agrochemicals

Fertilizer: The results show that 75.08 % of the farmers in the study area use fertilizer in the production of cocoa (Table 4.4). The result is in contrast with Ogunlade et al. (2009) and Danso-Abbeam (2010) who indicated that majority of cocoa farmers (78.8 %) and (59 %), respectively do not use fertilizer. According to Danso-abbeam (2010) while some farmers attributed the low fertilizer application to their perception that their farms were fertile others bemoaned the high cost of the input.

However, one major reason that was attributed to the high patronage of chemical fertilizer in this study area had to do with the introduction of the cocoa mass spraying exercise. Farmers noted that even though the cocoa mass spraying exercise for the 2015/2016 cocoa cropping season was not enough, as a result of the little benefit they (farmers) had, they were able to save some capital and therefore were able to purchase some quantities of fertilizer.

Insecticide: The result in Table 4.4 clearly shows that almost all the farmers (95.41 %) in the study area applied insecticide to their cocoa crops. The result confirms the findings of Danso-Abbeam (2010). This is an indication that cocoa farmers in the study area, to some extent, may have benefited massively from this component (Insecticide distribution) of the cocoa mass spraying programme (see Table 4.4).

Table 4. 4. Distribution of Respondents Use of Agrochemicals

Variable	Category/Description	Frequency (%)
Fertilizer		
	No	76 (24.92)
	Yes	229 (75.08)
Insecticide		
	No	14 (4.59)
	Yes	291 (95.41)
Fungicide		
	No	29 (9.51)
	Yes	276 (90.49)
Total Number of Observations		305

Source: Field survey (December, 2016).

Fungicide: Table 4.4 shows that about 90 % of the sampled cocoa farmers applied fungicide to their farms. From the survey, it was observed that all those who applied fungicide were those who benefited from the cocoa mass spraying excessive. However, the few who did not apply fungicide claim they did not benefit from the mass spraying exercise and could not also get the chemical to purchase since they were not for sale.

As presented in Figure 4.1, the study further considered the frequency of insecticide applications, since this has a policy implication with regard to achieving efficiency levels in cocoa production in Ghana.

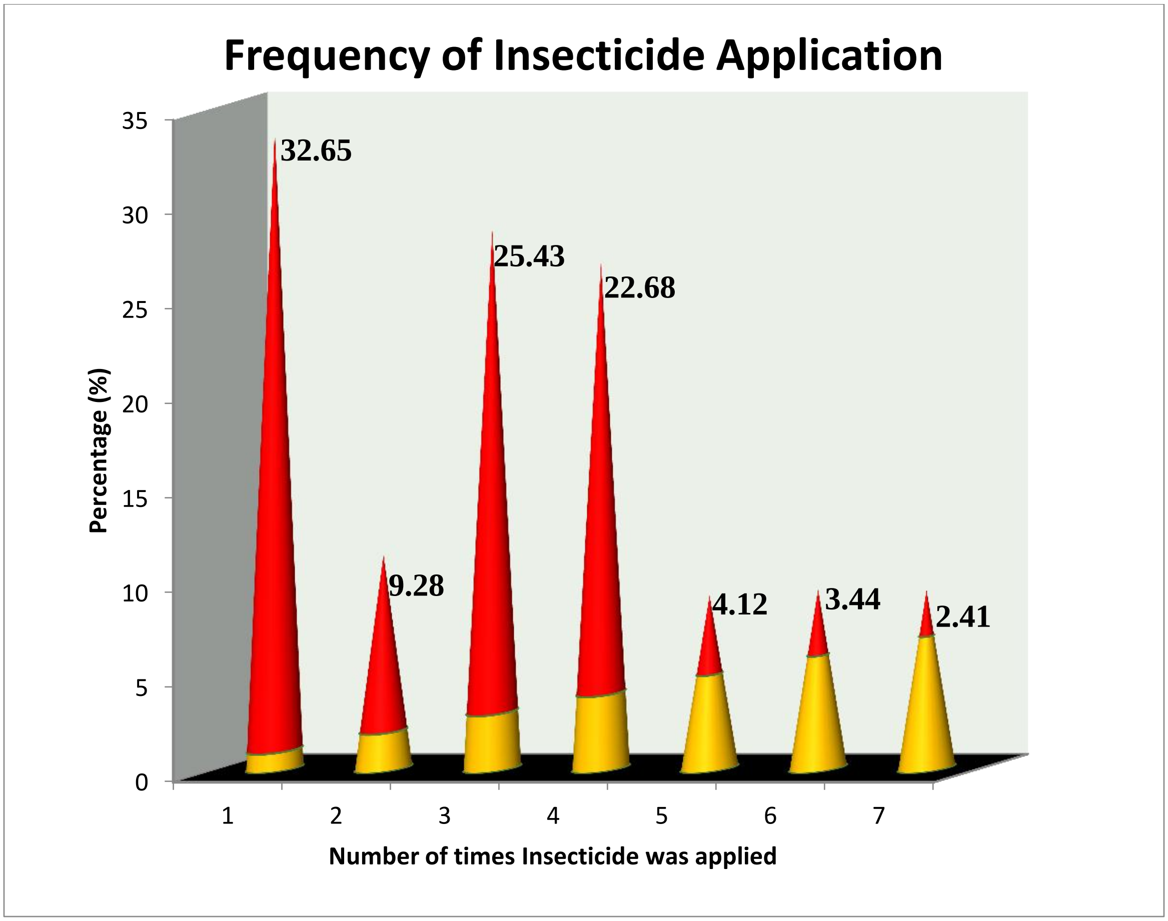

Figure 4. 1. Distribution of Respondents frequency of Insecticide application
Source: Field survey (December, 2016).

It can be seen from Figure 4.1 above that more than half of the farmers did not meet the recommended 4 times of insecticide application. Even though almost the entire sampled cocoa farmers applied insecticide, it is interesting to note that generally the proportion of farmers who applied insecticide decreased as the frequency of application increased. Specifically as much as 32.65 % of the respondents sprayed their cocoa farms only once with insecticide in the 2015/2016 cropping season while 25.43 % and 22.68 % of the farmers sprayed their farms 3 and 4 times respectively. A small proportion (9.28%, 4.12 %, 3.44 % and 2.41 %) sprayed their farms 2, 5, 6 and 7 times, respectively.

Similarly, use of fungicide is very low among cocoa farmers in the study area as shown in Figure 4.2 below. Similar to the case of insecticide use, majority of the respondents (39.34 %) who use fungicide applied it only once in the cropping season. About 48.16 % applied between 2 and 4 times in the season while only 12.49 % applied insecticide between 5 to 7 times.

Considering the fact that as the frequency of application increases, the proportion of farmers who applied the fungicides decreased, it goes to confirm the assertion of the farmers that the cocoa mass spraying exercise which is meant to make these chemicals available to them was not effective in the year under consideration. Anang et al. (2013) in investigating cocoa farmers' assessment of government spraying programme in Ghana revealed that farmers rated the effectiveness of the government spraying programme very low. Some of the reasons cited were, the failure to cover all farms, untimely spraying, failure to follow recommended regimes and the shortage of the chemical.

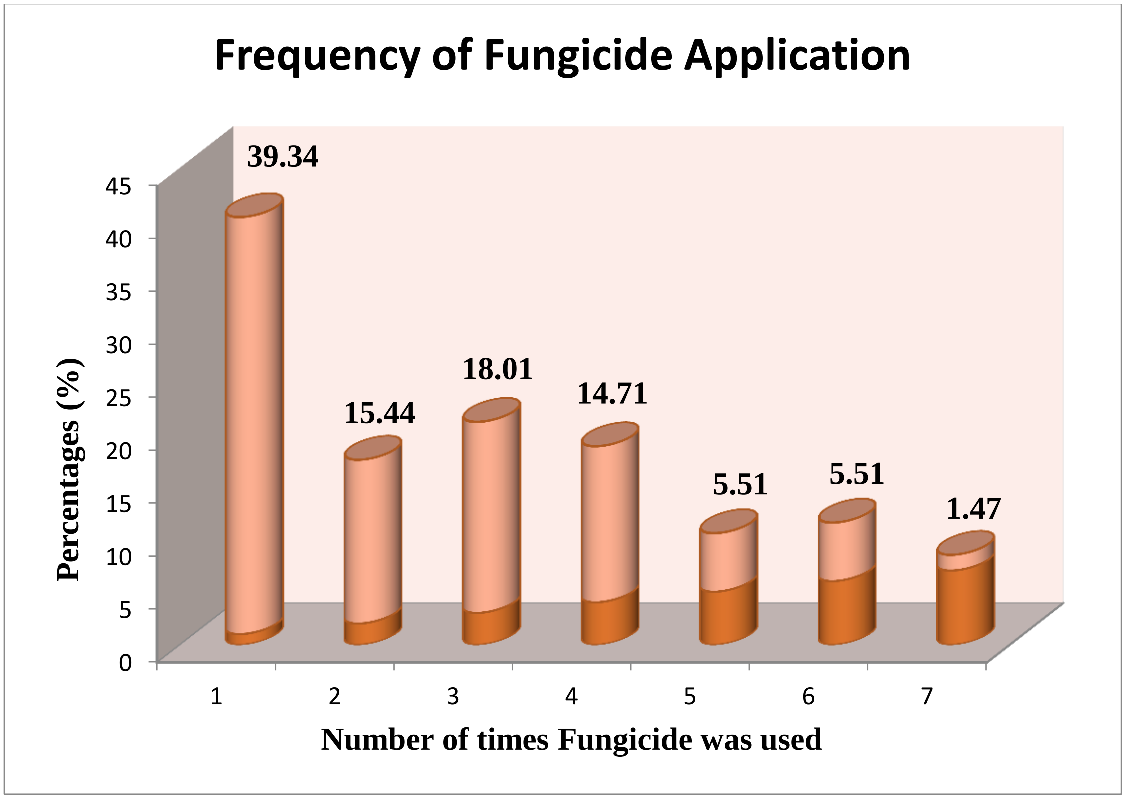

Figure 4. 2. Distribution of respondents' frequency of fungicide application

Source: Field survey (December, 2016).

4.2.4 Distribution of farmers' knowledge gained through social network

Extension contact: In Table 4.5, it is demonstrated that cocoa farmers who had access to extension services in the study area were 58.69 % of the sampled population. The farmers who had no access to extension services attributed it to the fact that extension offices were located too far from the farming communities. This group of respondents also bemoaned the limited number of extension officers in the study area. This result corroborates the finding of Egyir et al. (2011) who noted that more than half (70 %) of the plantain farmers in Ghana have access to extension service.

Conferences, Workshops and Seminars: Cocoa farmers' participation in conferences, workshops and seminars on issues pertaining to cocoa production has a potential of not only increasing output through the adoption of improved agricultural technologies but also ensuring that farmers efficiently allocate their resources. Referring from Table 4.5, it is observed that out of the total sample of 305 respondents interviewed, as many as 227 respondents representing 74.43 % did not participate in any form of conference, workshop and seminar regarding cocoa farming. Thus, only 25.57 % of the respondents ever participated in these conferences, workshop and seminars.

Visits to Cocoa Demonstration Fields: The survey revealed that majority (79.34 %) of the respondents did not participate in on-farm trials or demonstrations. Farmers' participation in on-farm trials or demonstrations increases their knowledge about improved farming technologies (Aneani et al., 2012). Farmers who are knowledgeable about improved farming technologies are more likely to have higher adoption and as a result become efficient in resource use than those who do not know about the improved technologies.

FBO membership: Membership of a farmer based organization is also a very important factor that presents the farmer with the opportunity to learn about improved farming technologies such as fertilizer and hence improve on output (Danso-Abbeam et al., 2014). It can be seen from Table 4.4 that whereas 79.02 % of the respondents in the study area did not belong to any farmer based organization only 20.98 % of the respondents did belong to an FBO.

Farmers benefiting from NGO services: Table 4.5 again shows that more than half (77.05 %) of the respondents did not benefit from any NGO service. One major reason which was given for them not benefiting from these NGOs had to do with the exploitation of farmers by these NGOs.

Table 4. 5. Distribution of Responds by farmers' knowledge gained through social network

Variable	Category/Description	Frequency
Extension contact	No	126 (41.31)
	Yes	179 (58.69)
Conferences, Workshops and Seminars		
	No	227 (74.43)
	Yes	78 (25.57)
Visits to Cocoa demonstration Fields		
	No	242 (79.34)
	Yes	63 (20.66)
FBO membership		
	No	241 (79.02)
	Yes	64 (20.98)
Farmers benefiting from NGO service		
	NO	235 (77.05)
	Yes	70 (22.95)
Number of Observations		305

Source: Field survey (December, 2016).

4.3 Results from the Heckman Two-stage model

4.3.1 Determinants of Adoption of Chemical Fertilizer in Cocoa Farming

Empirical results from estimating the first stage of the Heckman two-stage model are summarized in Tables 4.6. Generally, eight (8) out of the 16 explanatory variables included in the model are significant. It must be noted that all significant variables are interpreted as probability of occurrence.

From Table 4.6, out of the four (4) demographic characteristics, none was significant meaning they had no influence on fertilizer adoption. This could probably be due to the fact that age, sex, marital status and experience were no criteria for benefiting from the cocoa mass spraying programme. Among the 4 institutional variables included in the model, only one (FBO membership) was significant whilst 5 (Farm size, Number of plots, Family labour, farm Assets and distance) out of the 7 farm-specific characteristics significantly explained the variation in farmers' adoption decisions.

FBO membership: This variable was measured as a dummy. Thus 1 if a cocoa farmer belonged to any farmer based organization (FBO) and 0 if otherwise. What this means is that a positive sign goes for those who are members of an FBO and a negative sign will be associated to those who do not belong to an FBO.

From the table, the coefficient of the FBO variable is positive and significant at 10 % level of significance. This means that the variable (FBO membership) plays a very important role in explaining fertilizer adoption decision of cocoa farmers. The implication is that *ceteris paribus* cocoa farmers who belong to an FBO are more likely to adopt fertilizer than their non-FBO members. This finding confirms the *a priori* expectation and the findings of Djokoto et al. (2016) as well as Sodjinou and Henningsen (2012) who argued that farmer based organizations are not only channels for the dissemination of innovations but also institutions where farmers share the innovations and the various problems encountered. The finding also agrees with that of Simtowe et al.

(2016) who in their study noted that while the activities in such groups are not primarily social interactions, they help shape local social norms and networks that kindle the sharing of information and social learning and hence tend to have an influence in technology adoption. As noted by Rogers (2003), diffusion process consists of interpersonal network of interaction between adopters of an innovation and non-adopters of the same innovation who are then influenced to do so. Such a process can be enhanced by farmers' membership in social grouping that also strengthens their social capital. Other studies such as Glin et al. (2012); Nicolay and Baker (2012) and Moumouni et al. (2013) also had similar findings.

Number of plots: This variable positively correlates with the probability of fertilizer adoption at 5% level of significance. This means that an increase in the number of plots of a farmer increases his/her probability of inorganic fertilizer adoption *ceteris paribus*. This means that households with more plots of cocoa are more likely to adopt inorganic fertilizer. The finding is consistent with the *a priori* expectation. This could be attributed to the fact that different plots have different fertility levels and as such some will require the application of fertilizer while others may not depending on the fertility of the plot in question. Cocoa farmers in the study area were of the view that some areas where some of these cocoa farms were located were rich in nutrients and as such could account for owners of these farms not adopting the inorganic fertilizer.

Farm size: The size of cocoa farm cultivated by the household negatively correlates with fertilizer adoption at 5 % significance level. An increase in a household's cultivated land area under cocoa farming on average would decrease the probability of fertilizer adoption. This means that households with larger farm sizes have a lower probability of adopting fertilizer. Some reasons that could be attributed to this finding is the perception cocoa farmers have about their farm lands. Most of the cocoa farmers in the study area felt that their farmlands have between moderate to good soil fertility levels. Moreover, farmers bemoaned the high interest rates charged by credit lenders as one of the major factors credited for their inability to purchase farm inputs such as fertilizer.

The finding is in concurrence with studies conducted by Beshir (2014) and Eghir et al. (2011) though it contradicts that of Ogada et al. (2014). However, Hailu et al. (2014) and Aidoo and Fromm (2015) in their study found no significant effect of farm size on agricultural technology adoption.

Family labour: The coefficient of family labour is positive indicating that cocoa farmers who rely more on family labour for their farming activities are more likely to adopt fertilizer. This conforms to the *a priori* expectation and the findings of Beshir (2014). The possible reason for this finding is that improved practices such as fertilizer application are highly labour intensive and hence households with relatively high labour force, tend to adopt the technology. Other studies such as Egyir et al. (2011) found labour to be negative and significant in explaining the adoption of agrochemicals among plantain farmers in Ghana.

Farm assets: The sign of the parameter of the value of farm assets is positive and statistically significant at 5 %. This probably could be associated with the fact that farmers who have these farm equipment would concentrate on purchasing other inputs such as fertilizer. However, cocoa farmers who have no farm equipment would be compelled to divide their limited capital between renting these farm equipment and purchasing other inputs such inputs as fertilizer.

A study in Malawi conducted by Simtowe et al. (2016), to ascertain the determinants of agricultural technology adoption under partial population awareness revealed that value of assets positively influenced information accessed on improved varieties of pigeon pea. However, in investigating the determinants of adoption of improved pigeon pea, value of assets was found to have no statistical influence on the decision to adopt even though it had a potential of positively influencing adoption.

Mass spraying: This variable was measured as a dummy indicating 1 for beneficiaries of cocoa mass spraying exercise and 0 for non-beneficiaries. The variable positively influenced adoption of chemical fertilizer and was significant at 1 %. The positive coefficient of Mass spraying goes for those who benefited from the mass spraying exercise. Two major reasons could explain this finding. First the mass spraying exercise which focuses on the provision of some agrochemicals to farmers plays a huge role in enabling farmers to save some capital to purchase chemical fertilizer which otherwise would have been used to purchase these agrochemicals. The second reason is that some farmers who had more of the inputs from the mass spraying exercise than they usually needed sold the extra to those who did not benefit since these agrochemicals were not for sale and therefore were not available in shops. The revenue these farmers (beneficiaries) made from the sale of these agrochemicals was used to purchase chemical fertilizers for their farms. Contrary to the finding of this study, Anang (2016) found no significant relationship between cocoa mass spraying exercise and cocoa farmers' adoption decision.

Off-farm income: The coefficient of this variable was found to positively affect fertilizer adoption decision of cocoa farmers. Cocoa farmers who earned more income from their non-farm activities are more likely to adopt fertilizer. The situation could be due to the financial flexibility off-farm income renders to farmers who engage in the activities of cocoa farming. That is, farmers who earn off-farm income have some readily available capital to purchase improved farm inputs such as fertilizer when the need arises.

The finding is in line with that of Diiro et al. (2015), Dirro and Sam (2015), Mmbando and Baiyegunhi (2016) who argued that off-farm income may finance productivity enhancing inputs such as improved seeds and fertilizer purchases. Hailu et al. (2014) measured off-farm income as a dummy and noted that whereas off-farm income positively influenced the decision to adopt fertilizer, it was insignificant in determining the adoption decision of hybrid yam variety.

Distance: This variable measured the distance from the house of the farmer to his/her farm. The regression result reveals that distance from the house of the farmer to his/her farm negatively affects adoption of chemical fertilizer and it was statistically significant at 5% level of significance. The result conforms to that of Gebresilassie and Bekele (2015) who noted that a unit increase in the distance from home to a main road decreases the probability of adoption.

Table 4. 6. Heckman's first stage results estimating determinants of adoption of fertilizer

Variable	Parameter	Co-efficient	SE	T-ratio
Constant	β_0	-0.7241	0.4895	0.139
Age	β_1	0.00458	0.0089	0.616
Sex	β_2	-0.3084	0.2135	0.149
MS	β_3	0.0638	0.2279	0.78
Experience (Years in Cocoa Farming)	β_4	-0.0116	0.0152	0.442
Extension Contact	β_5	0.2063	0.2028	0.309
Training	β_6	-0.4033	0.2574	0.117
FBO membership	β_7	0.4685	0.2734	0.087*
Number of Plots	β_8	0.3183	0.1258	0.011**
Farm Size	β_9	-0.0414	0.0193	0.032**
Average age of Cocoa Farm	β_{10}	-0.0022	0.0135	0.87
Family Labour	β_{11}	0.0016	0.0008	0.036**
Hired Labour	β_{12}	0.0004	0.0003	0.148
Farm Assets	β_{13}	0.1396	0.0686	0.042**
Cocoa Mass Spraying	β_{14}	0.7043	0.1881	0.0000***
Off-Farm Income	β_{15}	0.0003	0.0002	0.081*
Distance	β_{16}	-0.0607	0.0304	0.046**

****, **, * respectively indicate significance level at 1%, 5% and 10%.*
Source: Field survey (December, 2016).

4.3.2 Determinants of the intensity of fertilizer adoption

As part of the first objective of the study, the intensity of fertilizer adoption among cocoa farmers in the Western Region of Ghana was estimated. These factors are discussed separately as reported in Table 4.7 below. As observed in Table 4.7, the Wald chi-square (at degree of freedom 10) is very significant at 1 % (Prob > Chi^2 = 0.0000). This represents the F-statistic of the OLS and Log Likelihood Ratio of the logistic regression and it indicates that, the explanatory variables jointly contribute to explaining the variations in the cocoa farmers' decision to adopt chemical fertilizer. Lambda is significant at 5 % and it confirms Marchenko and Genton, (2012) who noted that a significant lambda suggests that the intensity of adoption depends on the initial discrete decision to adopt fertilizers. Following Sodjinou *et al.* (2015) and Danlami *et al* (2016), some explanatory variables (family labour, hired labour, Age, household size and farm assets) were logged to reduce their variance. This was because there were quite a significant number of outliers among these variables which resulted in larger variances.

Most of the variables are statistically significant with some having positive influence whilst others have negative influence. However, not all the variables maintained their expected signs. Out of the 10 explanatory variables that were hypothesized to influence the intensity of adoption, eight (5) were statistically significant.

Among the characteristics that statistically influence the intensity of fertilizer adoption are hired labour, Number of plots, farm size, Mass Spraying Exercise and off-farm income.

Table 4. 7. Heckman's second stage procedure estimating the determinants of intensity of fertilizer adoption

Variable	Parameter	Co-efficient	SE	T-ratio
Constant	β_0	0.0118	0.0041	0.004***
Ln Family Labour	β_1	-0.0001	0.0002	0.744
Ln Hired Labour	β_2	-0.0004	0.0001	0.005***
Ln Age	β_3	0.0006	0.0010	0.567
Ln Household Size	β_4	-0.0003	0.0004	0.47
Number of plots	β_5	-0.0009	0.0003	0.003***
Farm size	β_6	-0.0003	4.45E-05	0.000***
Mass Spraying	β_7	-0.0014	0.0006	0.018**
Ln Farm Assets	β_8	-0.0003	0.0002	0.108
Off-Farm Income	β_9	1.65E-07	9.65E-08	0.088*
Experience (Years in Cocoa Farming)	β_{10}	6.02E-06	3.16E-05	0.849
N				305
Wald chi^2				131.97***
Sigma		.00345561		
Lambda		-.0032793	.0014081	0.03**

****, **, * respectively indicate significance level at 1%, 5% and 10%.*
Source: Field survey (December, 2016).

Hired Labour: This variable is negative and significant at 1 % level of significance implying its' importance in explaining the intensity of chemical fertilizer adoption. This means that the more hired labour cocoa farmers employ in their farming activities, the less the quantity of fertilizer they are able to apply per acre of cocoa farm. The negative sign of this variable could be attributed to the cost of hiring labour which currently ranges between GH₵20.00 to GH₵30.00 per man-day in the study area. Cocoa farmers heavily relied on hired labour for their farm business. The high cost of employing such labour have the tendency of constraining farmers such that they would be unable to purchase the required quantities of fertilizer and, hence, their intensity of application would be low.

Eghir et al. (2011) found labour to be negative and significant in explaining the adoption of agrochemicals among plantain farmers in Ghana. However, Ouma and De Groote (2011) reported hired labour to be positive and significant in explaining the adoption intensity of improved maize variety and fertilizer. Other studies such as Ben-Houassa (2011) and Aneani et al. (2012) also observed the availability of hired labour to positively affect the intensity of technology adoption.

Number of plots: The number of plots was significant at significant at 1% and positively influenced intensity of adoption. This means that farmers who have more plots of cocoa are more have high intensity of inorganic fertilizer adoption. This is probably because different plots have different fertility levels and as such farmers will intensify fertilizer application for those areas that have poor soil fertility.

Farm size: Farm size was statistically significant at 1 % and negatively influenced intensity of adoption. This means that cocoa farmers with smaller farm sizes have a higher tendency to intensify their use of fertilizer in order to increase their output levels.

This finding is in agreement with that of Amanze et al. (2010), Akpam et al. (2012) and Nunoo et al. (2014). However, the finding contradicts Abera (2008), Beshir (2014) and Oboubisa-Darko (2015).

Mass Spraying: The mass spraying variable was significant at 5 %. Even though the study hypothesized mass spraying to positively influence intensity of fertilizer use, the result revealed otherwise. The negative effect of this variable on the intensity of fertilizer could be ascribed to the ineffectiveness of the cocoa mass spraying for the season under study which farmers largely blamed on the politicization of the exercise. Inadequate funding of the programme could also explain the ineffectiveness of the programme since the farmers who stood the chance of benefiting from the programme could be seen as being too many and as such overstretched the limits of the programme.

Off-farm Income: Income gained from non-farm activities was significant at 10 % with a positive influence on intensity of fertilizer adoption. This may be due to the fact that those cocoa farmers who have extra income from off-farm activities are able to overcome financial constraints with regards to the purchase of chemical inputs easier than their counterparts who depend solely on income from farming.

4.4 Results of the Stochastic Frontier Analysis

4.4.1 Test of Hypothesis

Three Hypotheses were tested for this study: the appropriateness of the model, the existence of inefficiencies, and whether socioeconomic and farm specific factors explain inefficiencies. These tests were individually carried out using the generalized likelihood test ratio- statistic and hence the null hypotheses of each of the three tests were rejected.

From Table 4.8, the null hypothesis that the Cobb-Douglas production function is more appropriate than the Transcendental Logarithm production function (Translog), is rejected at 5 % significance level. Thus, the Translog production function is a more appropriate functional form. The Translog therefore assumes that the coefficients of the squared terms and the interactive terms are statistically different from Zero in explaining the variation in cocoa output in the Western Region of Ghana.

The second null hypothesis test that there is no inefficiency effect indicating that cocoa farmers are operating exactly on the frontier was also rejected in favour of the alternate hypothesis that inefficiencies exist and cocoa farmers might not always be producing at a technically efficient level. This was significant at 1 % and supports the decision to use stochastic frontier estimates instead of the average response model.

Finally, the inefficiency component of the disturbance term (u) is significantly different from zero as indicated by the log likelihood test ratio (chi^2 value of 2.20 with its associate probability of 0.069). Therefore, the null hypothesis that inefficiency effects are not stochastic is rejected implying that the traditional production function is not an adequate representation of cocoa production data used in this study. Thus, inefficiencies are present and they are stochastic.

Table 4. 8. Results of hypothesis test

Test Type	Null Hypothesis	Statistic	P-Value	Decision Rule
Functional form Test	$\mathbf{H_0 : \beta_{ij} = 0}$	28.57	0.0183	Reject H_0:Translog is appropriate
Frontier Test	$\mathbf{H_0 : \delta_1 = \delta_2 ... \delta_{14} = 0}$	71.73	0.0000	Reject H_0: MLE is appropriate, inefficiency effects exists
Inefficiency	$\mathbf{H_0 : \gamma = 0}$	2.02	0.069	Reject H_0: Inefficiency effects are not stochastic.
Effect of Fertilizer Adoption on TE test	$\mathbf{H_0 : \lambda_{ij} = 0}$	9.15	0.01003	Reject $H_{0:}$ Adoption has an effect on TE

4.4.2 Determinants of Cocoa output

This section discusses the results estimated from the stochastic frontier model which included 20 variables in the output model. These variables are made up of five inputs, the squared of each of these inputs as well as their interactions. Mean corrections were made for each of the five inputs included in the output model in order to enable the first order coefficients to be interpreted as partial elasticities. The results are presented in Table 4.9.

It is revealed that out of the five first terms, three (farm size, fertilizer, and fungicide) were significant. Out of the five squared terms, two (farm size and fungicide) statistically contributed to explaining cocoa output levels. The interactive term that was significant in the model was ‘fertilizer and insecticide’. The squared variables in the translog function show the long term effect of the said variable on output of cocoa. An indication of complementarity is when the coefficient of the interaction term is significant and positive whereas a coefficient which is significant and negative indicates substitutability (Abdulai et al., 2013).

Table 4. 9. Maximum likelihood estimates of stochastic frontier model

Variable	Parameter	Coefficient	Std. Error	P-value
Constant	β_0	2.918	0.1216	0.000***
Ln Farm size	β_1	0.7372	0.0703	0.000***
Ln FERT	β_2	0.0604	0.0138	0.000***
Ln INSECT	β_3	0.0059	0.0445	0.894
Ln FUNG	β_4	0.1228	0.0316	0.000***
Ln Labour	β_5	0.0507	0.046	0.28
Ln Farm size square	β_6	0.1081	0.0576	0.06**
Ln FERT square	β_7	0.0018	0.0093	0.849
lnINSECT1_sq	β_8	0.0022	0.00801	0.787
Ln FUNG square	β_9	0.0197	0.0063	0.002***
Ln Labour square	β_{10}	-0.0006	0.0270	0.982
Ln FERT*LAB	β_{11}	-0.0048	0.0165	0.771
Ln FERT*INSECT	β_{12}	-0.0242	0.0093	0.009***
Ln FERT*FUNG1	β_{13}	0.0026	0.0057	0.65
Ln FERT*Farm size	β_{14}	0.0276	0.0182	0.13
Ln INSECT*FUNG	β_{15}	0.0034	0.0069	0.633
Ln INSECT*LAB	β_{16}	0.0280	0.0272	0.302
Ln INSECT*Farm size	β_{17}	0.0345	0.0371	0.353
Ln FUNG*LAB	β_{18}	-0.0335	0.0216	0.121
Ln FUNG*Farm size	β_{19}	0.0025	0.026	0.924
Ln Farm size*LAB	β_{20}	-0.0749	0.0613	0.222
Return to Scale		**0.9770**		

****, **, * respectively indicate significance level at 1%, 5% and 10%.*
Source: Field survey (December, 2016).

All the significant linear terms in the model positively influenced output of cocoa. This implies that a percentage increase in farm size, fertilizer, fungicide and labour, would more likely lead to an increase in cocoa output by 0.74 %, 0.06 %, and 0.12 % respectively holding other factors constant. These findings are consistent with the *a priori* expectations and the findings of some previous studies. For example, the positive effect of farm size on output confirms the finding of Oyewo (2011), Simonyan et al. (2011) and Chiona et al. (2014). Simonyan et al. (2011) examined the gender differences in TE among maize farmers in Nigeria, and observed that for both male and female farmers, farm size positively influenced output levels. Aneani et al. (2011) and Obeng and Adu (2016) further buttress the point of the effect of farm size on cocoa output.

With regard to the squared terms, a positive coefficient indicates that in the long-run more of that variable would be needed to increase output of cocoa. However, a negative sign indicates that more of the variable is needed in the short-run since output would decrease in the long-run with an increase in the said input (Abdulai et al., 2013). Given that farm size squared and fungicide squared are both significant at 5 % and positive; it indicates that for cocoa output to be increased at the latter stage of production, farm size and fungicide use must also be increased, respectively.

The result from Table 4.9 further shows a negative effect between the interaction of fertilizer and insecticide at 1 % level of significance. This means that fertilizer and insecticide are substitutes. This statistically means that holding other factors constant, increasing inorganic fertilizer would require that the quantity of fertilizer should be reduced in order to increase cocoa output by 0.02%

4.4.3 Returns-to-scale

The return-to-scale is a phenomenon that looks at the responsiveness of output to the proportional change in all inputs in the long run. This can be achieved by summing all the coefficients of the first order variables (farm size, fertilizer, insecticide, fungicide and labour). It is shown in Table 4.9 that the estimated returns to scale is 0.98. This indicates a decreasing-returns-to-scale in the study area since the value is less than 1. Thus, a proportionate increase in all conventional inputs would result in a less than proportionate increase in the output of cocoa. This implies that cocoa production in the study area during the 2015/2016 cropping season was in stage II of the production function, an indication that there is still a greater potential for increasing output. This finding affirms that of Oyewo (2011) but contradicts Danso-Abbeam (2012). This could partly be attributed to the investments farmers have made in other sectors of their farms because of the cocoa mass spraying programme.

4.4.4 Determinants of technical inefficiency among cocoa farmers

In explaining the factors that influence technical inefficiency, a significant positive coefficient signifies a negative relationship with technical efficiency and a positive relationship with technical inefficiency. The reverse applies to a significant negative coefficient (Abdulai et al., 2013).

Table 4.10 reveals that sex, years in cocoa farming, farm assets, income from other crops, benefits gained from NGO services, household labour, and fertilizer have negative signs, hence they relate positively to farmers technical efficiency and negatively to their technical inefficiency. However, farm size and propensity score are the only variables that are significant with positive signs and therefore relate positively to their inefficiency.

The negative coefficient of *sex* means that female farmers are more inefficient than their male counterparts *ceteris paribus*. In other words male cocoa farmers are more efficient in their production process than females. This is possible since cocoa production is highly labour intensive and hence male farmers are better placed to offer those services than females. Thus in most parts of the study area, males form labour groups where they work on each other's farms. This to a very large extent helps these farmers to minimize cost on labour and, hence invest in other aspects of the farming activity. This conforms to the results reported by Danso-Abbeam et al. (2012).

Experience of the farmer was found to be significant at 10 % and have a negative influence on farmers' technical inefficiency. This implies that farmers who have more years of experience in cocoa production are more likely to be efficient than their counterparts who have very little or no experience in cocoa cultivation, *ceteris paribus* This result is in line with the *a priori* expectation. The result also conforms to that of Oyewo (2011) and Onumah et al. (2013a).

Farm asset was also estimated to increase farm efficiency. It therefore, means that farmers who acquire more farm assets are inclined to be more efficient than those farmers who acquire fewer or have no farm assets, other factors held constant. This could be explained by the fact that most farmers in the study area own most of these farm assets and as such are more likely to undertake agronomic practices at the right times of the cropping season. However, farmers who have no farm assets may have no choice but to undertake their agronomic practices at the wrong times of the cropping season since they would have to wait and borrow or rent from owners of these assets.

Income from other crops was significant at 5 % and negatively influenced farmers' technical inefficiency. This implies that the higher a farmers' income generated from the cultivation of other crops, the more efficient that farmer becomes. This could be attributed to the fact that farmers who earn more income from such activities have adequate capital resources to adopt new agronomic practices at the right times of the cropping season and hence tend to be efficient in their production process.

The coefficient of *farmers benefit from NGO services* was negative and significant at 10%. Thus, farmers who benefits from NGO services tend to be more efficient than those farmers who do not benefit from any NGO services. This suggests that farmers have access to vital information on production, financial and market information which when utilized effectively has the tendency of improving technical efficiency. This also signifies the important role NGOs are playing in the study area, regardless of the lower proportion of cocoa farmers benefiting from these NGOs services. The result therefore confirms the finding of Chaovanapoonphol et al. (2009) and Asante et al. (2014).

Age of the cocoa farm is another variable that reduces inefficiency. The result deviates from the expectation of the study. A possible explanation that could be attributed to this result may be the fact that farmers knowing that ageing farms yield less output, will be forced to observe agronomic practices effectively in order to get close to the required output. The result affirms the finding of Kyei et al. (2011) but contradicts that of Obeng and Adu (2016).

Also, the coefficient of *hired labour* was negative and significant at 5 % indicating a positive relationship with farmers' technical efficiency. Statistically, this means that farmers who have access to more hired labour, have a higher tendency of increasing their efficiency levels. This could partly be explained by the formation of labour groups that are highly experienced in the study area. This, they do by forming farming groups where they work on each other's farms in rotation. However, a group member who seeks the services of the group is required to pay for the services rendered at a much lower rate than what a non-member would pay. This enables farmers to minimize cost of production and hence can afford to invest into other areas of the farm.

Finally, *farm size* is highly significant at 1 % and with a positive sign. Thus, farmers with larger farm sizes are less efficient than their counterparts with smaller farm sizes. This could partly be attributed to the fact that as farmers increase their farm sizes, management of these farms becomes a problem in the sense that they would require more inputs and farm equipment's to effectively observe agronomic practices. The result is consistent with the findings of Tsimpo (2010). However, it is in sharp contrast to that of Adzawla et al. (2013) who found technical efficiency to be decreasing with larger farms.

Table 4. 10. Inefficiency Variables of output model

Variable	Parameter	Coefficient	Std. Error	P-values
Constant	β_0	0.7047	0.9031	0.435
Household Size	β_1	0.0797	0.0601	0.185
Sex	β_2	-1.3089	0.4047	0.001***
Years in Cocoa Farming (Experience)	β_3	-0.7392	0.3496	0.034**
Farm size	β_4	0.1066	0.0392	0.007***
Farm assets	β_5	-0.001	0.0004	0.003***
Income from other crops	β_6	-0.0008	0.0003	0.02**
Benefits gained from NGO services	β_7	-0.9055	0.5196	0.081*
Age of Farm	β_8	-0.0292	0.0236	0.217
Hired Labour	β_9	-0.001	0.0005	0.045**
Fertilizer	β_{10}	-0.0006	0.0003	0.055**
Propensity Score of Fertilizer	β_{11}	-2.0725	1.1372	0.068*
Variance Parameters				
Sigma Squared		0.6233662	0.1345861	
Lambda		1.459834	0.2095032	
Log-likelihood function		-272.20165		
Mean Efficiency		74.93419		
Log likelihood Ratio test		2.20*		

****, **, * respectively indicate significance level at 1%, 5% and 10%.*

Source: Field survey (December, 2016).

4.4.5 Distribution of Technical Efficiency

In estimating the technical efficiency levels of farmers in the study area, it can be observed from Table 4.11 that whereas the maximum efficiency scores of the farmers in the study area is 0.99 the minimum score is 0.20 with a mean technical efficiency score of 0.75. This is an indication that the most efficient farmer in the study area operates at about 1 % below the frontier while the least efficient farmer operates at about 80 % below the frontier. Given that on the average, a cocoa farmer in the study area operates at about 75 % indicating that farmers in the study area need to close a gap of 25 % to reach the frontier output. This could be achieved by adopting the best agronomic practices in the cocoa production process. However, considering the average efficiency score of farmers it can be concluded that cocoa farmers in the study area are generally efficient. Several studies found farmers to operate below their potential. Among such studies are, Obeng and Adu (2016), who reported a mean efficiency among cocoa farmers in the Twifo Hemang Lower Denkyira area in Ghana to be 54 %; Mukete et al. (2016) who estimated the mean technical efficiency of smallholder cocoa farmers in south-west Cameroon to be 86 % and Olufemi et al. (2015) on technical efficiency of cocoa production in Southern Nigeria, also revealed an average efficiency level of 81 %. Others such as Besseah and Kim (2014) have estimated a mean technical efficiency of about 47.82 % among cocoa farmers in Ghana. This value is far below what has been estimated by this study.

From Figure 4.3 below, it can be observed that the efficiency scores have been categorized into eight (8) groups. The graph shows that about 31 % of the farmers operate in the technical efficiency range of 80- 90 %. This is followed by the efficiency category of 70-79 % which has about 21 % of the farmers. Efficiency range of 90-99 % is the third highest with about 18 % of the farmers falling within this range. While the efficiency range of 60-69 %, 50-59 %, 40-49 %, 30-39 % and 20-29 % have about 12 %, 7 %, 5 %, 3 % and 12 % respectively. Thus, it can be clearly observed that majority of the farmers operate above the mean while a handful of them operate below the mean.

Table 4. 11. Statistical distribution of technical efficiency scores

	Minimum	Maximum	Mean	Std. Deviation
Technical efficiency	0.20	0.99	0.75	0.18

Source: Field survey (December, 2016).

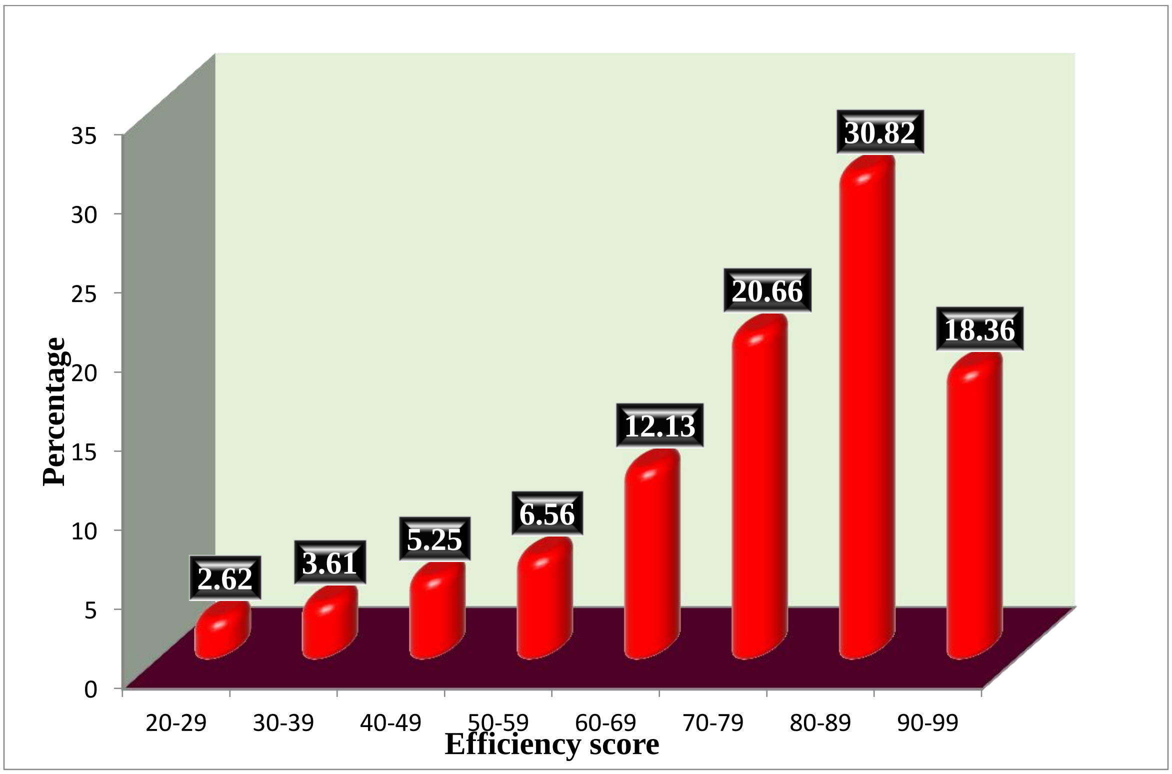

Figure 4. 3. Distribution of technical efficiency among cocoa farmers

Source: Field survey (December, 2016).

4.4.5.1 Farmers' sex and efficiency

Figure 4.4 illustrates the cocoa farmers' technical efficiency level against their sexes. As indicated in Table 4.10, male cocoa farmers are more efficient than their female counterparts. From the graph, efficiency levels of female cocoa farmers are by far lower than that of the male farmers. It is realized that majority (77) of the males fall within the efficiency range of 80-89 % with 53 and 42 of them also finding themselves within the efficiency range of 90-99 % and 70-79 %, respectively.

Meanwhile, majority (21) of the female cocoa farmers operate within the efficiency category of 70-79 % with 17, 15 and 11of them falling within the efficiency range of 80-89 %, 60-69 % and 40-49 %, respectively. Interestingly, there is some sort of even distribution of the proportion of both male and female cocoa farmers across the range categories below the mean efficiency score.

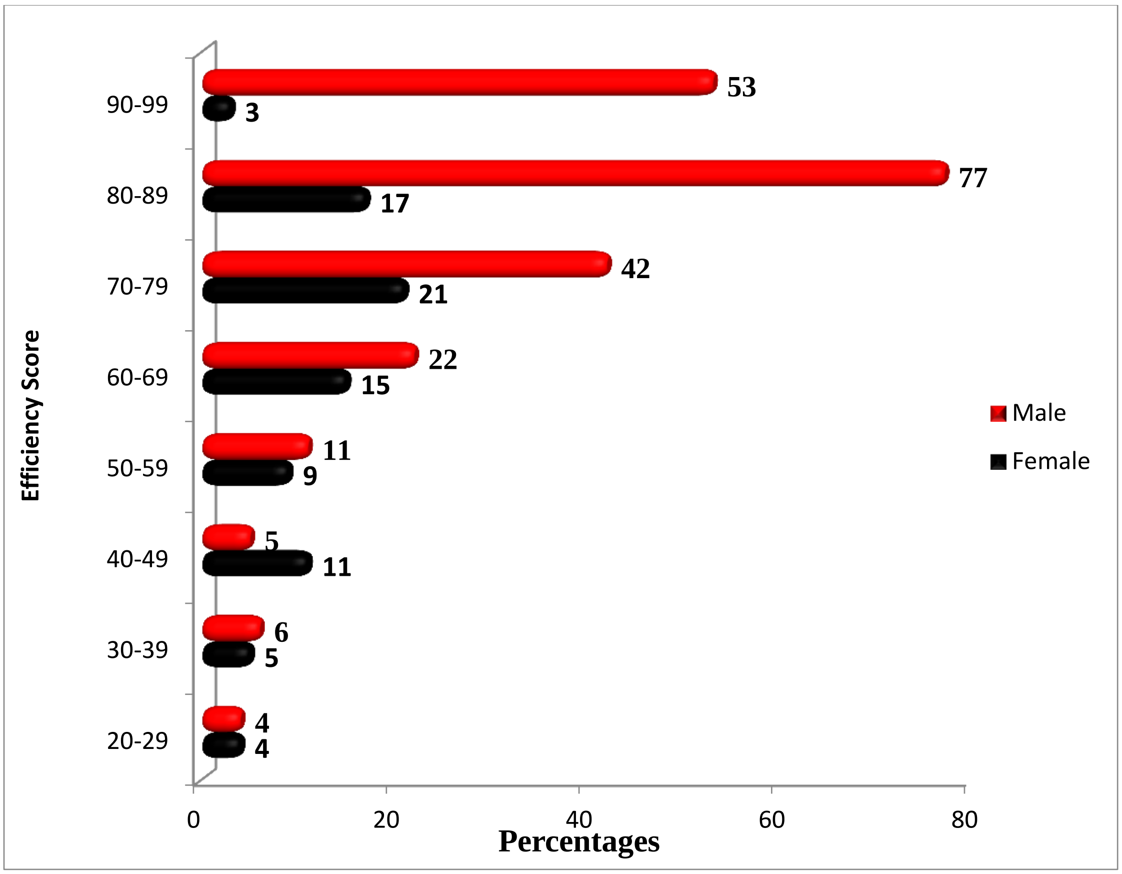

Figure 4. 4. Distribution of technical efficiency by Sex
Source: Field survey (December, 2016).

4.4.5.2 Farmers' efficiency levels by fertilizer adoption

The pictorial view of figure 4.5 clearly shows that indeed those who adopt fertilizer are more efficient than the non-adopters of fertilizer. It can be observed from the graph that, efficiency generally increases for both set of farmers with adopters recording a sharp increase in efficiency than non-adopters of fertilizer. However, in the highest efficiency category (90-99 %), while there was a sharp decrease in the proportion of non-adopters (21 %) that of the proportion of non-adopters was only 10 %. The graph also shows that the proportional distribution of adopters and non-adopters across the various efficiency categories is generally higher for adopters than for non-adopters. For instance, out of the total of 76 non-adopters of fertilizer, only 18 % fall under the 70-79 % category while 46 out of the total of 229 adopters representing 21 % fall within the same group. For the lowest efficiency category (20-29 %), non-adopters dominate with about 3 out of the 79 non-adopters, representing 4 %, while only 5 out of 229 of the non-adopters representing 2 % can be found in the same category.

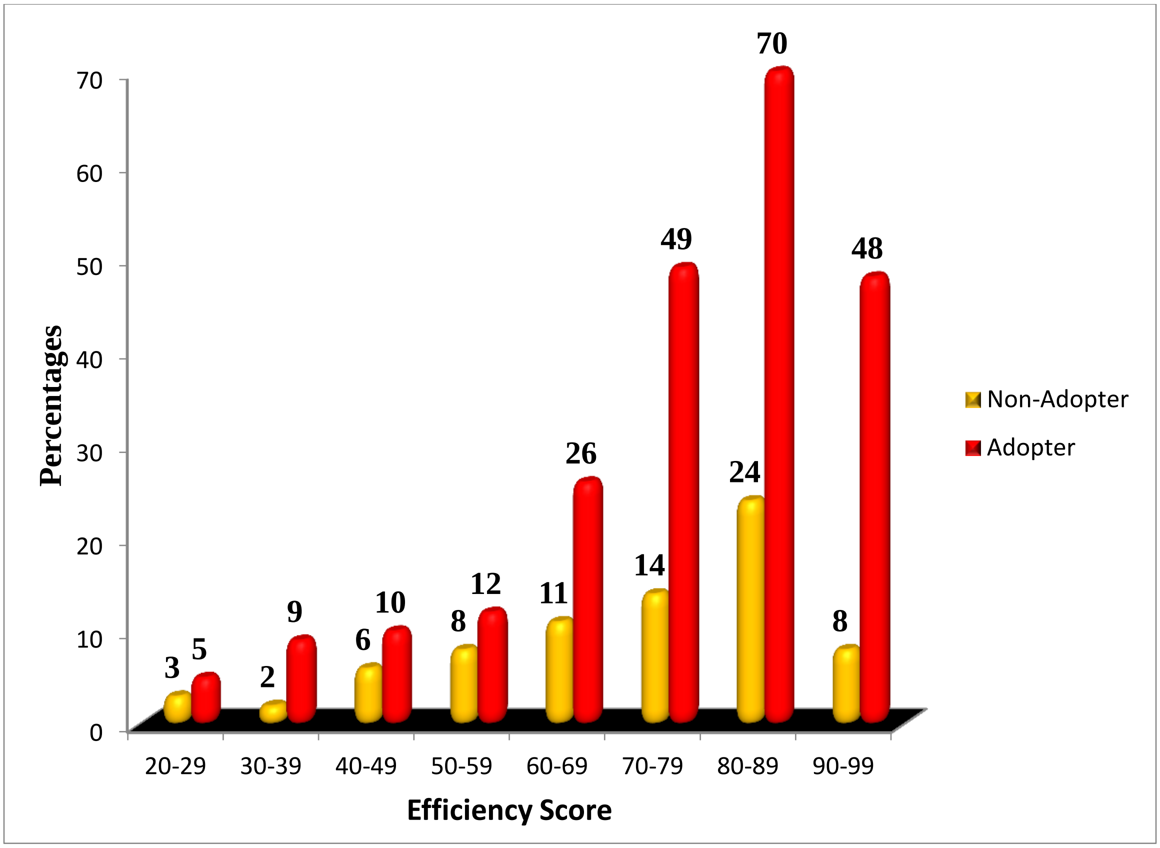

Figure 4. 5. Distribution of technical efficiency by Fertilizer Adoption

Source: Field survey (December, 2016).

4.4.5.3 Farmers benefit from NGO services and Efficiency

From the findings only 22 % of the cocoa farmers in the study area benefited from NGO services. The support was found to significantly reduce their inefficiency levels. The pictorial view of figure 4.8 clearly shows that except for the highest efficiency category, efficiency generally increases for all farmers regardless of whether they benefited from NGO services or not. However, a critical look at the figure shows that compared to beneficiaries of NGO services, the proportion of non-beneficiaries of NGO services who fall below the mean efficiency group is higher (33.6%) than that of the beneficiaries

(18%). Thus, whereas 79 (33.6 %) of the non-beneficiaries of NGO services fall between the efficiency range of 20-69 %, only 13(18 %) of the beneficiaries of NGO services fall within the same range of efficiency. Contrary to that, while majority 57 (81.4 %) of the beneficiaries of NGO services find themselves within the efficiency range of 70-99 %, 156 of the non-beneficiaries representing 61.7 % fall within the same category. This could be as a result of the support received from some NGOs. The support is in the form of finance or physical inputs.

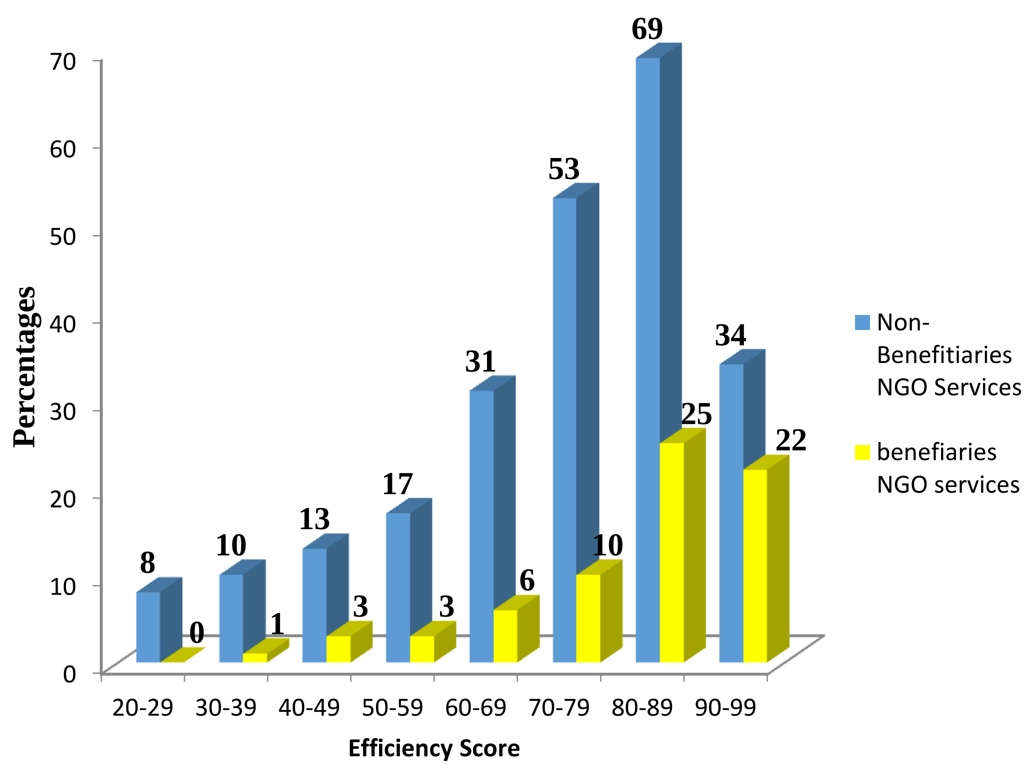

Figure 4. 6. Distribution of technical efficiency by NGO benefits

Source: Field survey (December, 2016).

4.5 Effects of fertilizer adoption on technical efficiency

The last objective of the study was to investigate the effect of fertilizer adoption on technical efficiency. This was done by predicting Propensity Scores from the probit model of fertilizer adoption. The Propensity Score was then included in the inefficiency effect model as a control explanatory variable together with the dummy, fertilizer adoption status, and re-estimated. A log likelihood ratio test was also used to test the hypothesis that adoption has no effect on technical efficiency. This is to assess the robustness of the results with regards to fertilizer adoption on TE.

Result from Table 4.10 shows that fertilizer adopters have a high potential of increasing farmers technical efficiency than non-adopters. This result is further illustrated in figure 4.5 where the proportion of adopters who find themselves within the various efficiency categories keep increasing relative to the proportion of non-adopters who find themselves within the same group.

Also, inferring from Table 4.8 above, it is observed that the Null hypothesis that adoption has no effect on TE is rejected at 5 % significance level in favour of the alternate which states that adoption impacts on TE. This means that adoption of inorganic fertilizer in the study area and the efficient use of this input among other resources available to the cocoa farmer has a high potential of increasing output. Thus, fertilizer has the potential of enabling the farmer operate on the frontier.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the entire work, make conclusions and recommendations from the findings for stakeholders such as investors, policy makers and development partners. Finally, some suggestions are proposed for further studies.

5.2 Summary

The study was aimed at examining inorganic fertilizer adoption and technical efficiency of cocoa farmers in the Western Region of Ghana. The study specifically aimed at determining cocoa farmers' decision to adopt chemical fertilizer, technical efficiency levels and the effect of adoption on technical efficiency.

Data was obtained from a random-sample of 305 respondents analyzed.

Descriptive statistics was used to analyze the farmers' demographic and socioeconomic characteristics. The Heckman two-stage and the stochastic frontier models were used in analyzing farmers' adoption decision and technical efficiency levels respectively. Regression on propensity score was finally used to investigate the effect of adoption on farmers' technical efficiency.

Results from the descriptive statistics indicate that adoption of fertilizer in the study area was very high since a greater percentage (75 %) of the cocoa farmers in the study area applied fertilizer.

The empirical results from the Heckman two-stage model indicated that, membership of FBO, number of plots, farm size, family labour, farm assets, off-farm income, mass spraying, off-farm income and distance from the house to the farm influenced farmers' discrete decision to adopt chemical fertilizer. Again in determining the level of adoption, factors such as hired labour, number of plots, farm size, mass spraying, and off-farm income were found to directly influence farmers' adoption levels.

Furthermore, the results from the SFA showed that whereas the minimum efficiency level of the cocoa farmers in the study area is 20 %, the maximum efficiency level is 99 % with a mean efficiency score of 75 %. Factors that were found to influence cocoa output included farm size, fertilizer, and fungicide.

On the other hand, sex, years in cocoa farming, farm size, farm assets, income from other crops, benefit gained from NGO services and Hired labour were found to significantly influence technical inefficiency.

Finally, results from the regression on propensity score and likelihood ratio test to ascertain the effect of adoption on TE and the robustness of the model revealed that adoption of fertilizer indeed had an effect on TE.

5.3 Concluding Remarks

Based on the findings of the study, the following conclusions were made:

1. Factors such as farm size, number of plots, mass spraying as well as off-farm income affect both the decision to adopt fertilizer and intensity of fertilizer use.

2. On the SFA, it was established that the average efficiency level of cocoa farmers in the study area was 75 %, an indication that technical inefficiency exists among cocoa farmers. Thus 25 % of the output of cocoa is lost to technical inefficiency.

3. The study further established that experience, farm assets, income from other crops as well as support from from NGOs and hired labour all help to reduce technical inefficiency.

4. Adoption of chemical fertilizer has a high potential of increasing farmers technical efficiency.

5.4 Policy Recommendations

5.4.1 Fertilizer adoption and level of use

I. The government through COCOBOD should ensure that fertilizer is made readily available and at affordable prices to farmers at the right time of the cropping season. This can be done by repackaging the fertilizer subsidy programme so as to make it beneficial to all cocoa farmers in the region.

II. Considering the fact that farm size reduces a farmers chances of adoption and intensity of use of fertilizer, stake holders in the sector such as COCOBOD and other concerned bodies should put in place strategies that will enable farmers intensify production rather than the expansion of farmlands under cultivation.

5.4.2 Cocoa output and Efficiency of production

1. Since cocoa farmers in the study area on average operate about 25% below the production frontier, COCOBOD and other NGOs through the cocoa extension agents should educate farmers on the advantages of intensively optimizing production through the efficient use of their resources.

2. The potential of farm size to increase farmers' inefficiency makes it necessary for stake holders to explore the possibility of redistributing farmlands from large farm holders to small farm holders. This would ensure that cocoa farmlands are put to good use and hence efficiency in production can be achieved.

5.4.3 Effect of Adoption on TE

Considering the fact that fertilizer adoption has a potential of ensuring cocoa farmers produce on the production frontier, the government through COCOBOD with the collaboration of the private sector should put in place policies that would ensure that fertilizer is made available at all times of the cropping season and at affordable prizes for farmers. This would ensure that cocoa farmers are able to purchase and also apply them in their right quantities.

5.5 Suggestions for further studies

- Time series or panel data should be employed in studying the efficiency level of cocoa farmers. This would give an in-depth understanding of the trends in efficiency levels over time.

- A more thorough study should be conducted on the impact of agrochemical adoption on TE. This would give a clear picture of the performance of agrochemicals in the cocoa sector for policy interventions.

- A thorough study should be conducted on the impact of fertilizer adoption (organic, inorganic and the combination of both) on cocoa farmers economic efficiency. This would give a better insight into farmers' welfare and as such relevant policy interventions would be made.

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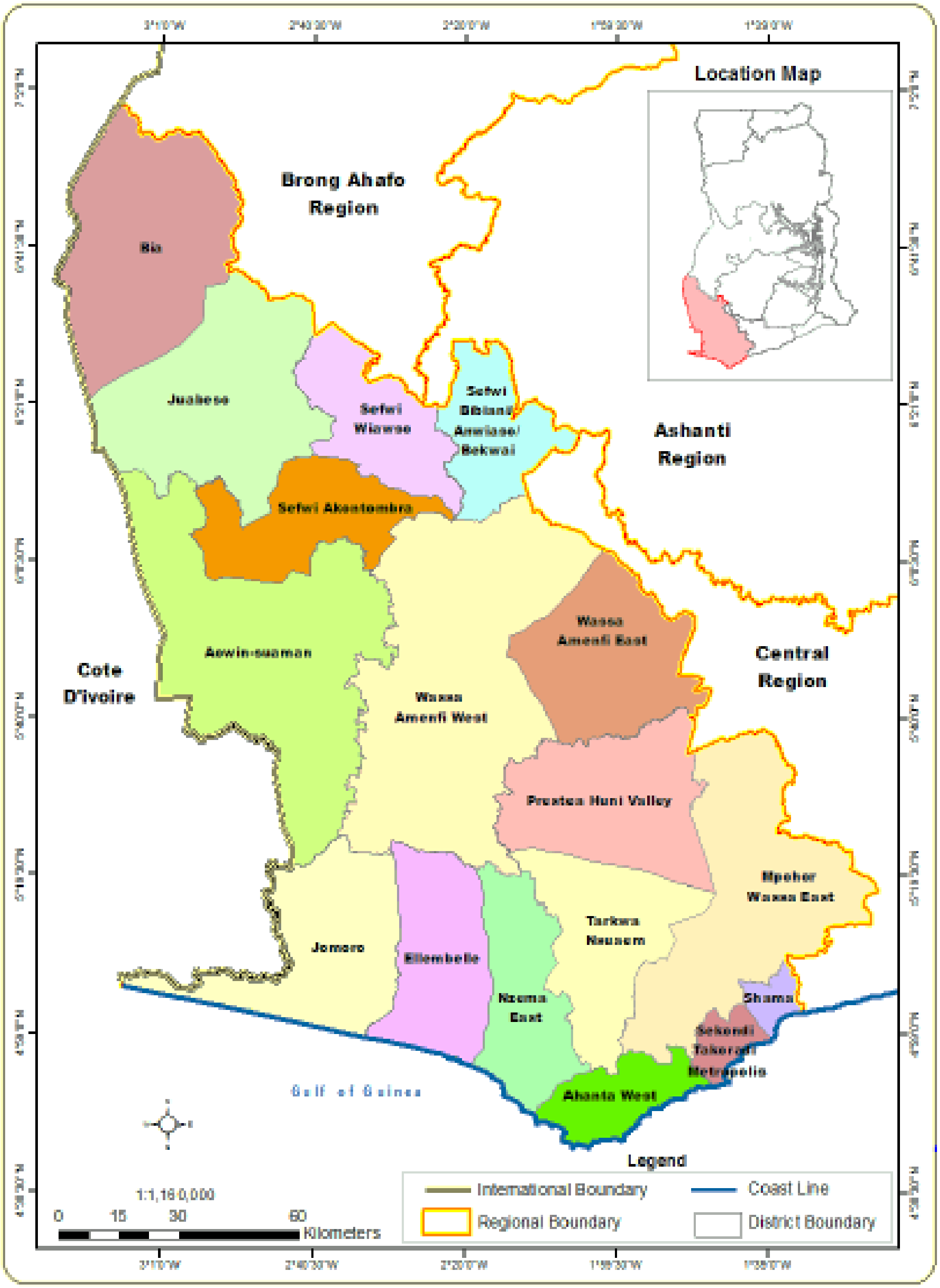
APPENDICES

: Technical Efficiency Scores

NO	[illegible]	[illegible]	[illegible]	NO	TE Scores	NO	TE Scores	NO	TE Scores	NO	TE Scores	NO	TE Scores	NO	TE Scores	NO	TE Scores	NO	TE Scores
1	[illegible]	[illegible]	[illegible]	**63**	0.81	**94**	0.66	**125**	0.92	**156**	0.89	**187**	0.91	**218**	0.89	**249**	0.67	**280**	0.83
2	[illegible]	[illegible]	[illegible]	**64**	0.87	**95**	0.65	**126**	0.84	**157**	0.76	**188**	0.79	**219**	0.86	**250**	0.63	**281**	0.88
3	[illegible]	[illegible]	[illegible]	**65**	0.83	**96**	0.66	**127**	0.71	**158**	0.9	**189**	0.47	**220**	0.9	**251**	0.75	**282**	0.43
4	[illegible]	[illegible]	[illegible]	**66**	0.71	**97**	0.9	**128**	0.78	**159**	0.73	**190**	0.75	**221**	0.89	**252**	0.66	**283**	0.7
5	[illegible]	[illegible]	[illegible]	**67**	0.71	**98**	0.87	**129**	0.83	**160**	0.98	**191**	0.69	**222**	0.29	**253**	0.88	**284**	0.46
6	[illegible]	[illegible]	[illegible]	**68**	0.35	**99**	0.89	**130**	0.36	**161**	0.84	**192**	0.92	**223**	0.31	**254**	0.74	**285**	0.81
7	[illegible]	[illegible]	[illegible]	**69**	0.46	**100**	0.35	**131**	0.82	**162**	0.7	**193**	0.36	**224**	0.91	**255**	0.84	**286**	0.68
8	[illegible]	[illegible]	[illegible]	**70**	0.54	**101**	0.89	**132**	0.35	**163**	0.73	**194**	0.9	**225**	0.36	**256**	0.83	**287**	0.92
9	[illegible]	[illegible]	[illegible]	**71**	0.79	**102**	0.65	**133**	0.94	**164**	0.72	**195**	0.76	**226**	0.8	**257**	0.67	**288**	0.65
10	0.9	**41**	0.9	**72**	0.73	**103**	0.71	**134**	0.88	**165**	0.83	**196**	0.84	**227**	0.97	**258**	0.86	**289**	0.89
11	0.95	**42**	0.82	**73**	0.48	**104**	0.87	**135**	0.87	**166**	0.89	**197**	0.7	**228**	0.55	**259**	0.77	**290**	0.89
12	0.86	**43**	0.42	**74**	0.95	**105**	0.83	**136**	0.93	**167**	0.75	**198**	0.96	**229**	0.36	**260**	0.89	**291**	0.82
13	0.67	**44**	0.7	**75**	0.79	**106**	0.83	**137**	0.89	**168**	0.93	**199**	0.95	**230**	0.68	**261**	0.63	**292**	0.55
14	0.32	**45**	0.91	**76**	0.81	**107**	0.87	**138**	0.98	**169**	0.73	**200**	0.94	**231**	0.85	**262**	0.81	**293**	0.85

15	0.58	**46**	0.54	**77**	0.91	**108**	0.88	**139**	0.32	**170**	0.41	**201**	0.93	**232**	0.73	**263**	0.24	**294**	0.93
16	0	[illegible]	[illegible]	**78**	0.99	**109**	0.75	**140**	0.75	**171**	0.87	**202**	0.62	**233**	0.46	**264**	0.66	**295**	0.82
17	0	[illegible]	[illegible]	**79**	0.92	**110**	0.51	**141**	0.22	**172**	0.73	**203**	0.92	**234**	0.39	**265**	0.44	**296**	0.99
18	0	[illegible]	[illegible]	**80**	0.74	**111**	0.88	**142**	0.77	**173**	0.95	**204**	0.42	**235**	0.99	**266**	0.72	**297**	0.93
19	0	[illegible]	[illegible]	**81**	0.82	**112**	0.75	**143**	0.93	**174**	0.81	**205**	0.81	**236**	0.99	**267**	0.89	**298**	0.81
20	0	[illegible]	[illegible]	**82**	0.86	**113**	0.86	**144**	0.91	**175**	0.84	**206**	0.79	**237**	0.8	**268**	0.96	**299**	0.55
21	0	[illegible]	[illegible]	**83**	0.87	**114**	0.88	**145**	0.95	**176**	0.9	**207**	0.89	**238**	0.79	**269**	0.77	**300**	0.79
22	0	[illegible]	[illegible]	**84**	0.91	**115**	0.96	**146**	0.9	**177**	0.76	**208**	0.82	**239**	0.9	**270**	0.84	**301**	0.2
23	0	[illegible]	[illegible]	**85**	0.22	**116**	0.84	**147**	0.99	**178**	0.57	**209**	0.76	**240**	0.83	**271**	0.83	**302**	0.25
24	0	[illegible]	[illegible]	**86**	0.62	**117**	0.62	**148**	0.63	**179**	0.65	**210**	0.62	**241**	0.87	**272**	0.88	**303**	0.9
25	0	[illegible]	[illegible]	**87**	0.88	**118**	0.39	**149**	0.89	**180**	0.82	**211**	0.82	**242**	0.95	**273**	0.52	**304**	0.49
26	0	[illegible]	[illegible]	**88**	0.88	**119**	0.84	**150**	0.93	**181**	0.74	**212**	0.64	**243**	0.76	**274**	0.83	**305**	0.3
27	0	[illegible]	[illegible]	**89**	0.9	**120**	0.78	**151**	0.84	**182**	0.78	**213**	0.83	**244**	0.68	**275**	0.92		
28	0	[illegible]	[illegible]	**90**	0.7	**121**	0.47	**152**	0.99	**183**	0.75	**214**	0.44	**245**	0.73	**276**	0.85		
29	0	[illegible]	[illegible]	**91**	0.84	**122**	0.85	**153**	0.72	**184**	0.91	**215**	0.89	**246**	0.98	**277**	0.75		
30	0	[illegible]	[illegible]	**92**	0.97	**123**	0.83	**154**	0.97	**185**	0.85	**216**	0.73	**247**	0.92	**278**	0.83		
31	0.84	**62**	0.74	**93**	0.97	**124**	0.69	**155**	0.65	**186**	0.97	**217**	0.91	**248**	0.7	**279**	0.93		

Appendix 2: Map of Ghana showing Western Region



Appendix 3: Survey Questionnaire

RESEARCH QUESTIONNAIRE

UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE, GHANA

RESEARCH TOPIC: FERTILIZER ADOPTION AND TECHNICAL EFFICIENCY OF COCOA FARMERS IN THE WESTERN REGION OF GHANA

Serial Number of Questionnaire …………………..

Introduction and Consent

Please introduce yourself to respondent: My name is ______________________ I am an enumerator collecting data on behalf of Ernest Baba Ali, an M. Phil student of the institution named above. This research aims at examining **Fertilizer adoption and Technical Efficiency of Cocoa farmers in the Western Region of Ghana**. Before I begin, I would like to assure you that your responses will be strictly used for academic research and will be treated anonymous and confidential. Your name would not be mentioned anywhere in the research work. Therefore, try as much as possible to be accurate and objective in your responses.

In the process of the interview, you are free to interrupt me and ask for any clarification. You have the liberty or legal right to call the principal researcher (**Mr. Ernest Baba Ali**) on the mobile number **+233247267762/505844415** and ask for any clarification at any point in time. I respect all the responses you give and appreciate your cooperation.

A. CONTACT INFORMATION ON ENUMERATORS AND RESPONDENTS

Enumerator's Information		Respondent's information			
Name of enumerator		Phone #		Community Name	
Contact mobile number		House #		Name of district	
Enumerator's Code		Date:		Name of region	

SECTION A. SOCIOECONOMIC CHARACTERISTICS OF RESPONDENTS

1. Household Basic Characteristics

Questions	Responses
1.1 Are you the household head?	(1) Yes [ ] (2) No [ ]
1.2 If no, state your relationship with the household head	(1) Spouse [ ] (2) Child/House-help/Farm care-taker [ ]
1.3 Age of household head	
1.4 Gender of household head	(1) Male [ ] (2) Female [ ]
1.5 Marital status of household head	(1) Married [ ] (2) Single/divorced [ ]
1.6 Household (HH) size	
1.7 Household composition by Gender	(1) # of males ………. (2) # of females …………..
1.8 # of years in crop farming	
1.9 # of years in cocoa farming	

HH are people who usually eat from the same pot and sleep under the same roof. Include also members who are absent for less than two months

2. **Educational Status (Human Capital)**

Questions	Responses
2.1 Can the household head (HHH) read, construct and write a simple sentence?	(1) Yes [ ] (2) No [ ]
2.2 Highest level of education completed by the household head	(1) Primary school [ ] (2) JHS/MSLC [ ] (3) SHS [ ] (4) Tech/Voc. [ ] (5) Training/Poly/Univ. [ ]
2.3 Number of years of schooling by household head	…………………..

3. **Other Knowledge Gained Through Social Network**

Training attended/Membership of organization for the past 5 years	**Household head**	
	Yes = Y **No = N**	**# of times**
3.1 Agricultural extension services		
3.2 Farmer seminar/workshop/conference		
3.3 Farmer field school		
3.4 Cocoa demonstration farms		
3.5 Membership of any cocoa related NGO’s		
3.6 Farmer-based-organization		

4. SECTION B: FARM INPUT AND OUTPUT

5 ... ific Characteristics (Matured fruit bearing cocoa farms: >5 years)

#	Age of Farm	Variety cocoa	# of shade trees	# of cocoa trees/acre	Cocoa Output (bags or Kg)			Farm manager	Trees planted in row	Distance to the plot (km)
					Main crop	Light Crop	Total			
1										
2										
3										
4										
5										
6										
7										
8										

N ... ties, write 1 for Tetteh Quashie; 2 for Amazon (I and II) and 3 for Hybrid. For trees planted in row, write Y if trees cocoa trees are in rows. 2: Write S for spouse if the specific farm plot is managed by the wife, “shared” is a shared cropping system of management and HHH if it is managed by the household head himself who is usually the man.

6 … about the Farmland

F…	Soil fertility		
	1. Poor	**2. Medium**	**3. Good**
1			
2			
3			
4			
5			
6			
7			
8			

7 …rochemical Management Practices

6.1 Did you benefit from the cocoa mass spraying exercise? Yes [ ] No [ ]

6.2 Apart from the mass spraying exercise, kindly answer the following

I #	**r Application: Y [ ] N [ ]**			**Insecticide Application: Y [ ] N [ ]**			**Fungicides Application: Y [ ] N [ ]**		
	y	**Frequency**	**Price/ unit**	**Quantity**	**Frequency**	**Price/ unit**	**Quantity**	**Frequency**	**Price/ unit**
1									
2									
3									
4									
5									
6									
7									
8									

Note: Tick Yes (Y) with respect to each plot if farmer applied the agrochemical and fill the column according to each plot appropriately. Farm plots in table 5 should be in the same order as arranged in table 4 above.

7 … ets/Wealth

Farm assets (Intermediates Inputs)					
T…	**Yes = Y** **No = N**	**Quantity**	**Value**	**Life span**	**Year** **Bought**
C…					
C…					
H…					
J…					
M…					
H…					

N… otes motorized spraying machine, 2: HSM denotes hand held spraying machine

8 [illegible] ructure - Hired

I [illegible] es	**No. of labourers Hired**		**Number days hired**		**Wage per day per person**		**Other Cost of input application**	
	Male	**Female**	**male**	**Female**	**Male**	**Female**	**Fuel**	**Machine**
8 [illegible] ing								
8 [illegible] ication								
8 [illegible] plication per f [illegible]								
8 [illegible] plication per f [illegible]								
8 [illegible] coa beans								
8 [illegible] cocoa beans								
8 [illegible] coa pods								
8 [illegible] of cocoa beans								
8.9 Transportation of cocoa beans								
8.10 Drying of cocoa beans								

Note: T & T denotes the transportation cost of labourers from the community to the farm.

9 tructure - Family

I es	**Number family labourers**		**Number of days worked**	
	Adults (18 years and above)		**Adults (18 years and above)**	
	Male	**Female**	**Male**	**Female**
9 ing				
9 ication				
9 plication per frequency				
9 plication per frequency				
9 coa beans				
9 coa beans				
9 ocoa pods				
9 n of cocoa beans				
9 oa beans				

SECTION C: AGRICULTURAL CREDIT ACCESSIBILITY

10. Credit Access

10.1 Have you received credit for the past 24 months? Yes [ ] No [ ]

S F-FARM ACTIVITIES, ACCESS TO SOCIAL AMENITIES AND INSTITUTIONAL FACILITIES

1 vities

(s comprise the following **[nployment (e.g. nurse, teacher, doctor, agric. officer, driver etc.) [2] Self-employed (e.g. carpenter, r uto mechanic etc.)** **[Retailing (e.g. kiosk or store operator, buying and selling at road side or market etc.)**											
I	**day**		**Days/week**		**Weeks/month**		**Farm income (GH¢)**		**Off-Farm income**	**Remittances (Abroad and Home)**	**Off-farm income**
		Off-farm	**Farm**	**Off-farm**	**Farm**	**Off-farm**	**Other crops**	**Live-stock**	**Non-farm business**		**Wages**
F											
S											
1											
2.											
3.											

Note: Write the number of hours worked per day (e.g. 8hrs/day), number of days per week (e.g; 3 days/wk), week per month (2 wks/month) and income earned for the year (GH¢500 from livestock last year).

THANKS FOR YOUR TIME