EFFECT OF CLIMATE CHANGE AND VARIABILITY ON COCOA OUTPUT IN THE WESTERN REGION OF GHANA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ADMINISTRATION

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DECLARATION

I, Emmanuel Okyere, author of this MPhil thesis do hereby declare that the work presented in this thesis titled, "***Effect of Climate Change and Variability on Cocoa Output in the Western Region of Ghana***" was done entirely by me in the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon from August

2015 to July 2016.

This work has never been presented either in whole or in part for any other degree in this University or elsewhere.

All works used are duly cited.

Attached to this is the plagiarism report

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This thesis has been presented for examination with our approval as supervisors:

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DEDICATION

To God be the Glory. This work is dedicated to my wonderful wife, Eunice Agyare Okyere and daughter, Praise Emmanuella Okyere

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ABSTRACT

The main objective of this study was to analyze the effects of climate change and variability on cocoa output. The multistage sampling techniques were used to select the respondents (cocoa farmers). The first and second objectives of the study described smallholder farmers' perception on climate change and variability and examined any empirical evidence of climate change and variability in the study area respectively. The third objective primarily analyzed the effect of these climatic variables (rainfall, temperature, bright sunshine duration and relative humidity) on cocoa output. The study also described the adaptation strategies employed by the small scale cocoa farmers in mitigating the effects of climate change and variability within the study area in the fourth objective. The final objective addressed the determinants of choice of an adaptation strategy. Most farmers (77.1%) were aware of climate change and variability however, more men (65%) observed changes and variation in temperature and rainfall than women (35%). Climate has changed with varying levels of variation over the past 40 years in the Western Region. However, most of the climatic variables were not statistically significant. Bright Sunshine Duration was found to be statistically significant at 5% with P-values of 0.0369 and 0.0274 for the mean decades 1975-1985 and 1985-1994 and 1985-1994. There were greater than average rainfall, but no significant difference among the decades. Temperature, rainfall, and extreme temperature had no significant effect on cocoa output but previous year's output and extreme rainfall had significant effect on the output of the small-scale cocoa farmers. A 1 mm increase in extreme rainfall amount resulted in a 0.24 MT/ha decrease in cocoa output whilst a unit change in technology resulted in a 0.86 MT/ha increase in cocoa output from the regression results. Almost 50.2% of the farmers adopted on-farm adaptation strategy while 32.9% adopted non-farm adaptation strategy and the remaining 16.9% did not adopt any strategy beside cocoa farming. In all, age, gender, education and membership of FBOs were statistically significant determinants of choice of adaptation strategies to climate change and variability. Membership of FBO makes a farmer 29.82 percent more likely to adopt On-farm adaption strategies. Men were 23.16% more likely to choose non-farm adaptation strategies than their female counterparts while females were 13.24% more likely to choose on-farm strategies. In conclusion, Bright Sunshine duration and extreme rainfall, had significant effect on cocoa production. It is recommended that COCOBOD, MoFA and NGOs should design improved technology such as cocoa seeds/seedlings that can withstand extreme climatic events as well as boost yields.

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ABBREVIATIONS

AEAs	Agricultural Extension Agents
CEEPA	Centre for Environmental Economics and Policy in Africa
CERSGIS	Centre for Remote Sensing and Geographic Information Systems
COCOBOD	Ghana Cocoa Marketing Board
CRIG	Cocoa Research Institute of Ghana
GDP	Gross Domestic Product
ICCO	International Cocoa Organization
IMF	International Monetary Fund
IPCC	International Panel on Climate Change
ISSER	Institute of Statistical, Social and Economic Research
LCBs	Licensed Cocoa Buyers
MLGRD	Ministry of Local Government and Rural Development
MoFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework on Climate Change

CHAPTER ONE

INTRODUCTION

1.1 Background

The contribution of agriculture to the economy of Ghana over the years has been phenomenal. Since 2010 however, there has been a consistent decrease in its share to GDP though the sector still remains an integral part of the economy, contributing about 21.3% to GDP in 2013 (ISSER, 2014). The sector employs about 56% of the total labour force (MoFA, 2014). In the year 2012, agriculture contributed 22.7 percent to the GDP which was the biggest foreign exchange source, accounting for nearly 40% of Ghana's total foreign currency earnings; and the principal producer of two-thirds of the domestic food need (ISSER, 2013).

In addition, about 70 percent of the manufacturing value-added is based on agricultural raw materials, and it also employs about 56 percent of the workforce, with about 80 percent being in the rural areas with small landholdings (GSS,2014; FAOSTAT, 2010). In recent years however, the contribution of agriculture to GDP continues to decline though agriculture is experiencing gains in annual growth rate resulting primarily from the cocoa sub-sector (ISSER, 2013). This has been the trend since the sector peaked at 31.8% share of GDP in 2009 to 22.7% and 22.0% in 2012 and 2013 respectively.

This has been largely attributed to the rapid expansion of the industrial and service sectors, which shrinks the contribution of agriculture in relative terms (ISSER, 2013). Comparatively, the agricultural sector is also highly bedeviled by the adverse impacts of climate change and variability and these also account for its low share to the Ghanaian GDP (Akudugu, 2012). The influence of the climate on crop development can come through through pest and disease infestation, resulting in heavy losses, poor outputs and ultimately reduction in income.

Cocoa, *Theobroma cacao* is an international cash crop belonging to the family, sterculiaceae and the genus, Theobroma. With the help of the application of molecular marker, it has recently been reassigned to the family Malvaceae (Ofori-Boateng & Insha, 2011). The lower storey of the evergreen rainforest has been its natural habitat. Even though there are over twenty species in the genus, the only one cultivated widely is *Theobroma cacao*. Since its discovery in the 18th century in the Amazon basin, cocoa has continued to spread to other tropical areas of South and Central America and West Africa, which became a major producer in the mid 1960's (Opeke, 1987).

The importance, popularity and earnings from the crop to the Ghanaian economy has made it a specialty crop with huge interest to policy makers mainly because of its share to GDP and foreign exchange earnings. Earnings from cocoa constituted approximately 16.48% of total export receipts in 2013, a decrease in cocoa percentage share of the total export when compared with 2012 figure of 20.47%. This notwithstanding, within the crop sub-sector; cocoa was still the highest contributor (ISSER, 2013).

In terms of the agricultural contribution to foreign exchange earnings, the sector yielded US$ 2709 million to the economy (sum of earning by cocoa, timber and non-traditional export. In percentage terms, the sector's contribution to Ghana's total foreign exchange earnings in 2013 made up 20% of the total. Compared to what the sector earned in 2012, there was a decline of 16.48%. Agriculture yielded US$ 3225 million in 2012.This huge fall was mainly as a result of the drop in the revenue from the export of cocoa (ISSER, 2013). This goes to show the importance of cocoa's earnings to the crop sub sector and the agricultural sector as a whole.

Cocoa contributes 70 - 100 percent to the annual household income of most Ghanaian farmers (Ntiamoah & Afrane, 2008). Poverty rates have declined from 60.1 percent in

1991/92 to 23.9 percent in 2005/6 for the Ghanaian (Coulombe & Wodon, 2007). Additionally, stakeholders made up of chemical companies, input suppliers and licensed cocoa buying companies (LBCs) depend mainly on the sector for income and employment (Anang & Asamoah, 2013).

Climate variability and change are among the most pressing issues on the developmental agenda. While mankind has always had to live with, deal with and adapt to environmental challenges, the challenges posed by climatic change are however believed to be of such a magnitude as to exceed historical experiences. This is likely to result in unprecedented challenges to local communities and the global community at large (Christoplos *et al.*, 2009; Schipper, 2007).

According to Anim-Kwapong and Frimpong (2005), climate change and variability and erosion are two major factors affecting crop yield. Therefore, there is the need to understand the climatic parameter like, rainfall, temperature, humidity and sunshine which impact on the agricultural output of any region to be able to improve on the production of any crop (Anim-Kwapong & Frimpong, 2004).

The crop is highly sensitive to the change and variations in the climate, most especially to temperature, primarily because of its effects on evapotranspiration (Anim-Kwapong & Frimpong, 2005). Changes in the climatic variables could greatly affect the rate and development of pest and pathogens, modifying host resistance and ultimately resulting in crop losses which in the end affect output and has a spiral effect on income, livelihood and farm level decision making (Oyekale *et al.*, 2009). Therefore, the climate plays a critical role in the output of cocoa

1.2 Problem Statement

Cocoa is a climate sensitive crop, cultivated mainly in Ghana under the mercy of the weather. Irrespective of the level of adoption of output enhancing measures which are socially sound, economically rewarding, ethically embraced and environmentally friendly among others, the climate which is the average weather conditions in a particular area for long period of time, decade and more still remains an important exogenous variable in the equation which can simply not be overlooked.

Weather related events like longer drought periods, erratic rainfall and floods are on the increase in terms of both magnitude as well as frequency in Ghana (FAO, 2008). Such events have been creating natural hazards and adversely impacting on smallholder farmers' livelihoods (Yaro,2002; Hesselberg & Yaro, 2006; Akudugu, 2012). The negative consequences of natural hazards hamper crop outputs and livelihoods of the rural poor who build their lives on this climate sensitive sector.

Over the years, climate change and variability have been impacting most agricultural activities and cocoa, a major cash crop of the Western Region of Ghana and to the nation at large has not been spared. Even though the region continues to provide the highest output of 51.3% to the national output according to (COCOBOD, 2015), the impact of the climate in the region should be a matter of great concern as climate impacts heavily on cocoa production taking all other things to be constant.

While small scale cocoa farmers in the region have and continue to battle with a litany of conventional production and post-harvest challenges confronting the sector, they are now faced with a much bigger issue and the challenges associated with the changes in climatic elements which ultimately affect cocoa production and outputs.

According to Fosu-Mensah et al. (2012), the semi-deciduous and evergreen rainforest zone which plays host to major cocoa producing areas of Ghana are experiencing varied changes in climate and extreme weather events of which temperature increase and rainfall amount decline are the foremost. These assertions were also confirmed by Sagoe (2006) and Codjoe and Owusu (2011) in their respective studies. Invariably, the changing climate affects the farmers and the cocoa plants as well. The crop calendar then changes which affect various interventions like spraying, fertilization, postharvest handling and most importantly output.

Farmers become highly distressed as results of the changing climate affecting the establishment, production and postharvest phases of the crop production as well as increase in pest activity with certain extremes of these climatic variables. Furthermore, the incidence of these pests and diseases destroy cocoa seedlings and fruits, leading to reduction in yields, income and foreign exchange earnings are adverse effects of climate change (Anim-Kwapong & Frimpong, 2005).

However, the adaptation strategies used by most farmers have been inadequate. The challenge is further aggravated by the absence of well planned agro-meteorological information communication systems, financial constraint to address most of the adaptation strategies, lack of knowledge and the appropriate technology as well as the high illiteracy rates in the Western Region impedes against them in their quest to control and enhance their adaptation strategies to this pressing challenge of climate change and variability. The research therefore seeks to empirically investigate the effects of the variability and change of the climate and impact on cocoa outputs as well as the adaptation strategies employed by the farmers in adapting to the impacts of climate change and variability.

From the foregoing, the following research questions becomes pertinent:

1. What is the level of awareness of climate change and variability by small-scale cocoa farmers in the Western Region of Ghana?
2. Have there been any significant changes in climate variable (rainfall amount, temperature, relative humidity and sunshine duration) in the Western Region over the period 1975 to 2015.
3. What are the effects of climate change and variability on cocoa output?
4. In the face of this changing climate and variability, what are the adaptation strategies employed by the small-scale cocoa farmers in the Western Region?
5. What determinants influence a farmers' choice of adoption of an adaptation strategy in their bid to increasing resilience to the changing climate in the Western Region?

1.3 Objectives of the Study

The main objective of the study is to analyze the effects of climate change and variability on cocoa outputs in the Western Region.

Specific Objectives

1. To determine the perception of small-scale cocoa farmers on climate change and variability in the Western Region.
2. To describe the trends in the climatic variables over the period 1975 to 2015
3. To analyze the effect of climatic variables on the outputs of small-scale cocoa farmers from 1975 to 2015.
4. To describe the adaptation strategies employed by the small-scale cocoa farmers in the face of climate change and variability.
5. To estimate the determinants of the choice of adaptation strategies employed by the small-scaled cocoa farmers.

1.4 Relevance of the Study

One of the several reasons for social science based research is to provide empirical support for understanding human behavior. In recent times, climate change and variability has become a subject of global concern. Developing countries like Ghana are most vulnerable to changes in climate because of our low level of adaptation techniques and technology compared to the advanced countries. In the Western Region, large proportions of the labour force are engaged in cocoa farming and most of these communities are in remote areas and may not be fully aware of the current issues of climate change.

The study therefore endeavors to understand the perception of cocoa farmers to climate change and variability. In knowing their level of awareness to these changes, policy makers and related stakeholders in the sector will gain insight into designing and implementing policies and programmes that are specific and well tuned in addressing the challenges. To empirically establish any trend of climate change and variability over the period 1975 to 2015 in the region as good as knows how to address the challenges related to climate change and variability in whatever direction the trend turns out.

The specific climatic variable change will provide us with the appropriate remedial action to embark on. The study will further analyze the effect of these changes and variability on cocoa output and what strategies are farmers adopting in dealing with these constraints. A farmers' choice of adoption of a particular strategy may be influenced by a number of factors in any particular field of operation which may vary from one crop to the other. Therefore the study will estimate the key determinants of farmers' choice of adoption of any adaptation strategy and how this ultimately influences output.

The study would provide relevant findings to help address climate change and variability and its effect on the cash crop, which many farmers depend on thereby increasing yield, boosting economic growth, reducing poverty and enhance national development.

1.5 Organization of the Thesis

This study is organized into five chapters. The first chapter is the introductory aspect of the thesis and it gives a brief discussion of the background, explains the problem, the objectives and justifications of the study. The second chapter reviews literature relevant to the objectives of the study. The third chapter presents the various methods employed to analyse the specific objectives of the study. The fourth chapter presents the findings and the discussion of results of the study whilst the final chapter, chapter five presents the conclusions drawn and recommendations of the study.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

This chapter presents a review of literature relevant to the study. First part of this chapter reviews literature on the origin and spread of cocoa in Ghana, its production and the determinants of cocoa production in Ghana. The second part consists of the concept of climate change, climate change evidence in Ghana, small-scale cocoa farmers' perception on climate change, climate change and cocoa production as well as its effect on cocoa yields. Adaptation strategies employed by small-scale cocoa farmers to safeguard their yields against the adverse effects of climate change as well as studies done on climate change effects on cocoa yields are also presented in this chapter.

2.2 Origin and Spread of Cocoa in Ghana

Cocoa (*Theobroma cacao)* is an international crop belonging to the family of sterculiaceae and genus, Theobroma. With the help of application of molecular marker, cocoa was reclassified to belong to the family Malvaceae (ICCO, 2010). The natural habitat for the crop is the lower storey of the evergreen rainforest. The value of cocoa made its cultivation spread in ancient times throughout Western and Central Amazonia and northwards to Central America.

The Spanish pioneered large scale production of cocoa mainly in the 16th Century in Central America after which it expanded to British, French and Dutch West Indies (specifically, Jamaica, Surinam and Martinique) and to Brazil in the 17th and 18th centuries respectively. From Brazil, it was taken to Sao Tome and Fernando Po in 1840 (COCOBOD, 2000). Thence, its spread to other West African countries, of which the then Gold Coast, now Ghana, Cote d'Ivoire and Nigeria were well noted for. Records indicate that as early as 1815 and 1857 both the Dutch and the Basel missionaries planted cocoa in the coastal and Aburi areas respectively (COCOBOD, 2000). These however, did not lead to the spread of the cultivation of the crop until Tete Quashie, a native of Osu, Accra in 1879 brought in Amelonado cocoa pods on his return from Fernando Po where he worked as a blacksmith. He established a cocoa farm in Akuapem Mampong, a small town in the Akuapim North District of the Eastern Region of Ghana. Cocoa then spread to other parts of the country where agro-ecological conditions supported its growth mainly in the Eastern, Western, Ashanti, Brong Ahafo and Volta regions.

The zeal and enthusiasm that accompanied cocoa farming in Gold Coast was astonishing. According to Acheampong (2012) for instance, it was observed that the enthusiasm and seriousness with which cocoa was cultivated by the natives, demonstrated to the whole world that they were not lazy as it was made to be believed and as such very capable of taking their own initiatives of building a strong industry for a resilient economy. As a result of its high demand in the European and American countries, it quickly became the main traditional export commodity in Ghana.

2.3 Cocoa Production in Ghana

2.3.1 The Structure of Cocoa Production in Ghana

In the hope of sustaining the production of the crop, one of the best known varieties which was also early bearing was introduced for the first time in Ghana, *Amelonado* cocoa. The variety takes less than 5 years to bear fruit and was welcomed by all. According to COCOBOD (2000), the Amazonian variety which has early maturity of three to four years was introduced in 1950). Varieties between 1960 and 1970 were all the Amazonian breed till the new hybrid variety otherwise known as “akokora bedi” (in Akan, the old man shall enjoy) was introduced. The hybrid is an improved breed which is not only high yielding but early maturing and resistant to many pests and diseases and is what is currently been cultivated by many farmers. The economic life-cycle of cocoa is between twenty-five to thirty years. In its initial cultivation stage (depending on the variety used, mostly two to three years from planting), for the purpose of providing shade for the young and fragile cocoa seedlings, annual crops mostly plantain, cocoyam, cassava and maize and used to intercrop.

The crops then serve the farmer for his food needs. Cocoa typically takes between three to six years (primarily depending on the variety used) to start to produce the first pod and continues to produce until it reaches its complete production capacity after ten years (ICCO, 2000). The tropical rainforest is the optimal climatic zone where cocoa is mostly cultivated.

The crop performs better under optimum shade mostly characterized by a climate with relatively high temperatures (between 18-32 ^{o}C) and good volumes of precipitation. However, cocoa depends to a large extent on the rainfall pattern. The monthly rainfall distribution is more significant to the crop than the mere annual totals because of the crop cycle and its pest and diseases infestations issues. An annual rainfall in excess of 2500mm may heighten the incidence and spread of fungal diseases (phytophtora pod rot being the most common and caused by the devastating black pod disease) and Cocoa Swollen Shoot Virus Disease (CSSVD) (ICCO, 2000; ICCO, 2001).

The cocoa crop thrives well in deep, well-drained soils, well supplied with moisture and nutrient with very little or no coarse materials (CRIG, 1987). There is no difference in approach to preparing land for cocoa and/or other foodstuffs. First and foremost, the forest vegetation is cleared with some of the trees left standing for shade. The litter is mostly burnt, however very few farmers allow the litter to decay to mulch the soil. Farmers take advantage of the rains to cultivate simultaneously annual food crops and the cocoa seedling in March to maximize shade provision to the seedlings by the crops. Cocoa farm does not need extensive weeding because of the closed tree canopy which reduces sunlight to the weeds for chlorophyll synthesis and hence growth. There are two cropping season for cocoa, the main crop and the light or mid crop with the crop calendars, in October till March and May through August respectively (COCOBOD, 1998).

Harvesting, depending on the size of the crop (personal communication with experienced cocoa farmers in Sefwi-Bekwai and Akontombra cocoa districts) starts from about September and may continue till late December or mid-January. It is done by means of a cutlass or a Go-to-hell (metal hook which is so constructed that it severs the pod neatly from the stem by a thrust or a draw). Labour is mainly supplied by family. The women collect the harvested pods into heaps and carry them in baskets to a spot selected for breaking which is done communally.

The men cut open the pots with cutlass and women and children scoop out the wet cocoa with their hands. The beans are fermented for a period of 6 -7 days in the wrapped, airtight container made of banana or plantain leaves. Sometimes, it is heaped under the multi-storey canopy of cocoa trees and well covered with broad leaves, usually plantain leaves. The fermented beans are then transferred to raised drying platforms made of sticks and covered with mats of split bamboo (COCOBOD 1998).

The dried cocoa beans are then filled into jute sacks and sent to the local representatives of the numerous licensed buying companies which are then bought at the price fixed by COCOBOD. The bean are further sorted and graded to the standards of the quality control division of the regulating authority. Evacuation of the produce are then made to the various depots and ports of export.

2.3.2 The Role of Cocoa in Ghana's Economy

Abekoe et al. (2002) aptly paint a picture of the sector's performance in recent times as an example of what "favorable external conditions and internal reforms" could bring to bear in revolutionalising Ghana's traditional exports. Ghana enjoyed a comfortable lead overtime among the origin countries. Irrespective of the view held by most economic pundits on the risk of entrapment into a dependency trap of raw material exporter because of the country's over-reliance on the sub-sector, cocoa continued to be huge foreign exchange earner to the economy of Ghana.

Research findings clearly show that cocoa production has been largely driven by land expansion and intensive labor use, rather than by increase in the productivity of land, raising concerns of its sustainability (Gockowaski, 2007; Vigneri, 2005). The contribution of cocoa to annual income of farmers is about 70 percent and a vital fulcrum to Licensed Cocoa Buyers (LCBs) and other stakeholders operation (Anim- Kwapong & Frimpong, 2004). Bulíř (2002) demonstrates strongly a household's total income is greatly influenced by income from cocoa and by extension greatly determines investments in the non-farm sector.

Researchers have shown that small scale farming serves as a significant demand structure for other sectors in the economy as well as reducing greatly unemployment in the rural areas thereby defending its desirability (Amos, 2007; Bateman, 1990).The cocoa industry also provides employment to many Ghanaians,55 percent of farm families are either directly or indirectly actively engaged by the sector. The sector takes a little over a third of all cultivated lands in Ghana (COCOBOD, 2004). It engages over 800,000 farm households in addition to the other support service providers like agro- input suppliers, licensed buying companies (LBCs) haulers etc.

A decline in the agricultural sector, particularly cocoa would inadvertently affect the economy as a whole because the sector has and continue to be one of the driving forces of the economy. In the late 1980s, Ghana produced one-seventh of world's cocoa dropping from from the one-third recorded in 1965. This phenomenal decrease was attributed in part to inadequate support system for credit, inappropriate management of pests and diseases and the poor macroeconomic policy, are just but few examples (Opoku *et al.*,1999). Further decline in cocoa output in 1986 and 1992 consequently led to a massive 41% drop in earnings from foreign exchange to US $302.5million from US $503.3 million (Compton Interactive Information Guide, 1995).

The producer price was then increased as a measure to boost cocoa production, however this could not be sustained due to huge inflation (ICCO, 2010). Ghana's Gross Domestic Product (GDP) recorded a decrease of 0.5 percent per annum, between 1970 and 1982, while real export earnings also plummeted to 4 percent in 1989 from 21 percent GDP in 1970 (UNCTAD, 2004).This, was one of the prime reasons that necessitated the government to signing on to the Economic Recovery Programme (ERP) to competitively reposition the country's economy.

The programme, among other things, was intended to incentivize most players of the economy to increase outputs be it farmers in general, exporters and industry.

Traditional and raw material export was highly encouraged of which cocoa was a critical component. Throughout the years, the sales from cocoa beans have contributed immensely to foreign exchange earning to the country. For instance, in the year 2002, 22.4 percent (US $ 463 million) of the Ghana's entire foreign exchange earnings came in from cocoa (ISSER, 2003) and the of the total foreign exchange earnings from agriculture, the crop contributed 63% to the sector (ISSER, 2003).

According to ISSER (2000) Cocoa happens to be the only traditional export crop whose earning is taxed. Its contribution to the country's total tax revenue in 1992 for instance was 14.5 percent of overall tax earnings. ISSER (2002) reported that the year 2002 saw an 17.8% increase in total export receipts from cocoa compared to the previous year's figure (US$ 463.4 million in 2002 compared to US$ 381.1 million in 2001). The sub-sector in recent times has shown outstanding performance. In 2002, the sector grew by a phenomenal 16.4 percent; attributed mainly to increase in the crop output and relatively better border price the commodity enjoyed (ISSER, 2003).

2.4 Major Determinants of Cocoa Production in Ghana

2.4.1 Pest and Diseases

The high incidence of pest and disease infestation is considered by many farmers to be the major cause for low cocoa yields (Anim-Kwapong & Frimpong, 2004). There are three major diseases and pest of economic significance exist: (i) swollen shoot caused by virus, (ii) black pod caused by fungus and (iii) capsid, which feed on plant tissues (shoot and pods), eventually killing them. The cocoa crop is affected by many diseases most notable among them are black pod disease caused by *Phytophtora megakaya* or *palmivora*, tree canker, Cocoa Swollen Shoot Virus Disease (CSSVD), seedling blight, *Theilaviopsis* pod rot, *Charcoal* pod rot, *Cherelle* wilt and *Collar* crack disease (Blecowe & Wharton, 1961).

Black pod disease probably appeared as soon as cocoa was introduced in Ghana and it is considered to be the most destructive among all cocoa diseases. The disease is caused by a soil-borne fungus *phytophtora* and accentuated by heavy rain. It is very predominant mostly in the wet season. Areas of heavy rainfall are the worst hit as the disease can cause huge economic losses through destruction of pods of various categories. Pest and disease of cocoa are area and variety dependent as some areas are relatively dry and some varieties do not have the same level of resistance.

There are two known species of phytophtora that cause the disease in Ghana; palmivora and megakarya (Opoku *et al.*, 1999). Generally, losses resulting from *Phytopthora megakarya* can be quite high, 60-80 percent in newly affected farms to 100 percent during the season of great infestation (May to mid June). Losses from *Pyhtophtora palmivora* are estimated to be comparatively low, 4.9 percent to 19 percent (Dakwa, 1984). The Black Pod disease is highly correlated to the weather and climate and much predominant in years where the July to August is very wet. This deadly disease, through yield reduction, also reduces farmer's revenue and the country's export earnings. The recommended method of control was to remove the affected pods and also to harvest the matured pods at short intervals.

Another important disease of cocoa is the mired/capsids attack, caused by the capsid pest and vectored by the mealy bug. It was first identified as serious cocoa pests in the early part of the cocoa beans industry's history in 1910 (Asomaning *et al.*, 1971). These piercing and sucking insects destroy the soft tissues of the trees by injecting poisonous saliva into the young shoots with their mouthparts, and sucking out from the wounds, the liquid mixture which is food to them. The wounds mostly become infected with a fungus (Anim- Kwapong & Frimpong, 2005). The affected shoots in young trees rapidly begin to die as results of the die back affecting the establishment of the entire farm in time.

Mostly the few infected trees start in localized pockets which then spread in what is called capsids blast in mature farms. In years of extreme temperature, the pest activity intensifies and covers a wide area, culminating into what is known as in 'capsid blast' by killing off the terminal shoots of the affected trees (Anim-Kwapong & Frimpong, 2004).The insects are usually most active and destructive in dry seasons mostly between September through to March and ably aided by increasing intensity of light (WACRI, 1951). Chemical control agents, mostly synthetic pesticides can be used to control yield losses associated with capsids because of their efficacy, ease of storage, transport and application, however they have short shelf life according to Opoku et al. (1999).

2.4.2 Fertilizer Application

One of the major causes of yield decline in cocoa has been identified to be the low soil fertility (Acheampong, 2012). Therefore, the importance of fertilizer in ameliorating this challenge is key in increasing output. One of the surest means of soil nutrient replacement after years of mining these nutrients through annual harvest is through the application of fertilizer. Output has been found to have increased through adequate fertilizer application (Acheampong, 2012). Ghana's cocoa has traditionally been grown with minimum purchased inputs, however, it has been well recognized that nutrient reserves in the soils would eventually become depleted (Anim-Kwapong & Frimpong, 2004).

A double yield increase was reported in 1997 in Ghana through the application of 4.94 bags of triple superphosphate and 2.47bags of muraite of potash per hectare over a four-year period according to Appiah et al. (1997). A 50-percent food production increase could be achieved by the application of fertilizer according to Vigneri (2007). While a tremendous increase in fertilizer use has the highest potential of increasing cocoa productivity, the lack of the fertilizers and the inappropriate dosage of application is having a crippling effect on the yields of cocoa in Ghana. Acheampong (2012)

2.4.3 Producer Price Index

According to Anim-Kwapong and Frimpong (2004), in arriving at the annual cocoa producer price in Ghana, huge economic considerations are made, taking into account an array of key indicators like, estimated cost of production of farmers, expected FOB price, expected exchange rate, explicit duty determined by the governments' revenue needs and COCOBOD's cost (COCOBOD, 1998). Price is an important is an important indicator of how farmers tend their farms. Farmers' response will be to greatly relax on farm maintenance and new planting when their normal variable cannot be sufficiently covered by the price (Anim-Kwapong & Frimpong, 2004). Additionally, when prices are such that basic activities like, harvesting, fermenting and drying, are not covered, then harvesting of the pods for the bean will even stop. Conversely farmers will intensify farm management and input application if prices are good enough to cover their variable cost.

According to COCOBOD (1998), the short-run price elasticity of supply, estimated at 0.3 and the price elasticity of production for period 5 and 10 years later, 0.9 and 1.8 respectively result in a 3% increase in production in the short term and 18% increase after 10 years from new planting. Ghana's cocoa, in recent years has seen some significant gains in export volume following several years of decline and mediocre recovery (ICCO 2005; IMF, 2011). In both nominal and real terms, prices paid to cocoa farmers in Ghana have also improved significantly. The Ghana Cocoa Marketing Board (COCOBOD) paid the nominal price per bag of cocoa of GH¢7 in 1995, GH¢90 in 2004, GH¢350 in 2014 and GH¢420 by 2015 (MoFA, 2011; World Cocoa Foundation, 2014). In summary, Ghanaian farmers respond to producer price increase by supplying more cocoa beans in the short and long run (World Cocoa Foundation, 2014).

2.4.3.1 Rainfall

Rainfall distribution has always guided the pattern of cocoa production. The crop is very susceptible to draught. A year of huge crop harvest have been found in Ghana to be closely correlated to a year with high rainfall even though that is not application in all years (Anim-Kwapong & Frimpong, 2005; Brew, 1991). Brew (1991) again reported positive and negative association between rainfall and yield of the main crop in certain months. In the cocoa growing regions of Ghana, the total annual rainfall is less than 2000m with a bi-modal pattern of rainfall distribution from April to July and then September to November.

There is however, a high relative humidity from April through July and September through November where the weather becomes dry (Anim-Kwapong & Frimpong, 2005). The main dry which is typified by November through where soil moisture content is low and many cocoa seedlings die during their establishment phase because irrigation is not part of our farming system. If the dry season is sufficiently severe, bean size largely becomes affected for bearing trees. The almost six months of dry weather, reduces soil moisture greatly resulting in high mortality for seedlings and young cocoa. Pod filling likewise becomes affected in mature trees which consequently results in small beans as the situation becomes retrogressive. Further, lower yields are recorded as a results of the water deficit which favours capsids. (Anim-Kwapong & Frimpong, 2005).

A key criteria considered in arriving at the suitability of soils for cocoa production is not the quantity of water in the soils but rather its rate of release to the trees which is important. Because there are varied conditions on the field, which to a large extent affect available moisture content in the soils during dry seasons like shade, air movement, vigour and age, distribution of active roots and their depth as well as the soil texture and structure, no established upper limits of adequate moisture in the soils have been defined (Ahenkorah, 1981).

2.4.3.2 Solar Radiation

The light saturation point (LSP) and the maximum photosynthetic rate for cocoa is quite low 400 μ E m^{-2} s^{-1} and (7mg dm^{-1} h^{-1}) respectively (Anim-Kwapong & Frimpong, 2005). However, light intensity in excess of 60% of full sunlight, 1800 μ mol m^{-2} s^{-1} causes the photosynthetic apparatus to have a reduced photosynthetic rate for the crop according to Galyuon *et al.* (1996). At the same time, the mechanism of photosynthetic apparatus of the leaves is also destroyed at high light intensities (Anim-Kwapong & Frimpong, 2004). Light intensities lower than 1800 hours $year^{-1}$ have a remarkably damaging results on cocoa production by impeding the rate flower production (Asomaning *et al.*, 1971).

The total solar radiation captured during the growing season has been identified to be a key determinant of crop growth and yield when soil water, nutrient, temperature and pest and diseases losses are generally not a challenge (Ofori-Boateng & Insah, 2011). Where fertilizers are applied, yield potential of cocoa from trials in West Africa were shown to have doubled when permanent shading, intercepting 30-50% incident radiations were removed (Ofori-Boateng & Insah, 2011).

2.4.3.3 Temperature

Tropical crop as it is, cocoa grows profitably under varying temperatures in 30-32^{o}C and 18-21^{o}C mean maximum and mean minimums respectively with absolute minimum of 10^{o}C (Ojo & Iyanda, 2010). According to Ofori-Boateng & Insah, 2011), temperature lower than 24^{o}C results in decreasing effect on light saturated photosynthetic rates as temperature is closely associated with light use efficiency. Leaf temperature greatly affects the resistance of stomata to photosynthesis as temperature below 10^{o}C inhibits photosynthetic rates. Stomata of non-chilled leaves are open and more receptive to photosynthesis than chilled ones. The effect however, of vapour pressure deficits (VPD) may override increase in temperature as the increasing temperature and higher vapour pressure often move together (Ofori-Boateng & Insah, 2011). According to (Anim-Kwapong & Frimpong, 2005), the high temperature periods have been observed to meet flushing incidence in Ghana.

2.5 Concept of Climate Change

Basically, climate is defined as an average weather conditions spanning over an extended period of time. Climate is seen as a composite of daily weather conditions that describe the average and variability typically over 30 year (CGIAR, 2009). The major elements weather are rainfall, solar radiation and ionization, sunshine, humidity, atmospheric pressure, wind direction and wind speed.

According to IPCC (2007), “Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer. Further, it can also refer to any change in climate over time, whether due to natural variability or as a result of human activity”. There is a contrary view from the position of the United Nations Framework Convention on Climate Change (UNFCCC), which defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Operationally, climate change has been understood and defined from the perspective of any change in the mean and or the variability of the climatic variables for an appreciably long periods, from decades onwards by statistical means (IPCC, 2007).

2.5.1 Causes of Climate Change

According to Jan and Anja (2007), there are two main causes of climate change. Artificial or human activities and natural processes or disasters can cause climate change. The notable natural causes of climate change are volcanoes, earth tilt, ocean currents, earthquakes, comets and meteorites (Pidwirny, 2006). IPCC (2007) report stated that there is 90 percent likelihood of human activities being the major cause of the warming of the climate system. These activities include burning of fuels in automobiles, industrial emissions, deforestation, and land degradation through land use cover and land use change, which release Green House Gases (GHGs) into the atmosphere.

The rate of change of climate emanating from natural causes is not a worry to the inhabitance of this planet as compared to climate change emanating from human activities because the rate at which climate is changing due to human activities far exceeds that caused by nature. It is expected that the velocity of the change will increase more than what is occurring today. More often than not, causes of climate change are always attributed to intentional and unintentional economic activities of human (IPCC, 2007).

2.5.2 Evidence of Climate Change in Ghana

Ghana is a tropical country which experiences changes in weather elements. Ghana was documented to have completed its first National Communication to the United Nations Framework on Climate Change (UNFCCC) in 2000, which predicted the impacts of climate change. Furthermore, findings from Centre for Environmental Economics and Policy in Africa (CEEPA) studies carried out in 2006 revealed changes in some of the climatic elements such as temperature, rainfall and sea levels in Africa, including Ghana. According to Daze (2007), the temperature in Ghana was expected to increase by 2.5^{O}C to 3.2^{O}C by 2100. This increase in temperature would however differ according to the agro-ecological zones in Ghana. Daze (2007) further documents that Sudan savannah zone in the Upper East Region is predicted to experience the maximum temperature of 3^{O}C by 2100, followed by the Guinea savannah in the Northern Region of 2.5^{O}C.

In contrast, the Sudan Savannah is however predicted to experience the least minimum temperature with the Transitional zone found in the Brong-Ahafo Region of Ghana expected to experience the highest minimum temperature of 2.7^{O}C by the year 2100 (Anim-Kwapong & Frimpong, 2005). Anim-Kwapong and Frimpong, (2004) further documented predictions in the changes in rainfall to be expected by 2100 mainly due to human activities. Evidently rainfall amount and distribution in Ghana has fluctuated over the years.

A study conducted by Anim-Kwapong and Frimpong (2005) indicated that there has indeed been a 10 percent increased and 15 percent decreased in the seasonal rainfall pattern and distribution globally especially in the south coastal regions of West Africa between the years of 1931-1960 and 1961-1990. These changes were however reported to have been caused by changes in land cover in the region, change in global ocean circulation due to changes in the surface temperatures of seas and finally changes in global atmospheric composition (Hulme, 1992). In Ghana, the rainfall amount and runoff have been reported to decrease by 20 percent and 30 percent respectively within the past 30 years (Daze, 2007).

Again, Daze (2007), reported that the annual rainfall in the country is projected to decrease between 9-27 percent by the year 2100. Notwithstanding, the Sudan savannah agro-ecological zone is however predicted to experience the highest decline in the amount of rainfall of 170.0mm by that year, followed by Deciduous Forest, Transitional zone and Guinea savannah, by 99.0mm, 78.0mm and 74.0mm respectively by the year 2100 with rainforest predicted to experience an increase of 110.0mm in the amount of rainfall by the year 2100. Contrary to this, Daze (2007) reported that although the amount of rainfall has decreased over the years and expected to decrease more in the coming years in Ghana, the level of sea has been reported to have increased by 2.1mm per year over the past 30 years. And this has been estimated to further increase by 1mm by the year 2100.

2.6 Small-Scale Farmers' Perception on Climate Change

Perception of small-scale farmers on climate change is very important in the sense that it accord them the opportunity to adapt and minimize its effect on agricultural production. There had been a lot of researches on perception on climate change in the developed countries and resulting in more encounters the scientific community and the people (Jan and Anja, 2007). Though many researchers in African continent have looked at farmers' perception on climate change, it is not enough. Ishaya and Abaje (2008) and Fosu-Mensah et al. (2012) have examined the indigenous people's perception on climate change and adaptation strategies in Kaduna State of Nigeria and the Sekyere District of the Ashanti Region of Ghana respectively.

The result of their study revealed that indigenous people perceived that climate had changed and still continues to change due to human activities. Literature revealed that most smallholder farmers are aware that the climate has changed. Centre for Environmental Economics and Policy in Africa (CEEPA, 2006) highlighted that a high percentage of farmers in Africa have realized that the climate had change significantly. That study indicated that majority of farmers in Africa believe that precipitation had decreased considerably. It is an undeniable fact that a significant number of smallholder farmers also perceived temperature had increased over the years.

Deressa et al. (2008) indicated that smallholder farmers along the Nile Basin were aware that temperature was increasing and the level of precipitation was decreasing and this corresponds with meteorological evidence. Most literature established that it is well experienced farmers who perceived that climate has changed and continues to do so due to unfair treatment of the environment by humans (Deressa *et al.*, 2008). It is therefore convenient for a researcher to look at the perception of farmers on climate change based on the respondents' years of farming experience.

According to Maddison (2007), as experience increases farmers are more likely to perceive changes in rainfall. To him, frequency of drought changes in the timing of rains increase with the number of years in farming.Also, there are other factors that affect smallholder farmers' perception on climate change. These factors range from social to economic. Maddison (2007) indicated that there is the likelihood that smallholder farmers' perception on climate change may be determined by gender, marital status, years of education, whether the farmer is engaged in off-farm work or not, whether he or she is the head of a household or not. Distance from ones farm to the market centre, access to extension advice and access to weather information could also affect farmers' perception on climate change (Maddison, 2007).

2.7 Climate Change and Agriculture

The dependence of Sub-Saharan Africa on agriculture, a climate sensitive sector, is a major source of livelihood that cannot be overlooked. Research has shown evidence of climate variability and changes globally in terms of temperature, precipitation as well as sea levels (Jones & Mann, 2004; IPCC, 2007). According to Alley et al. (2007), climate models have also been used to confirm changes in climatic factors to be a result of the decline in rainfall, extreme temperatures, among other observations. Thus climate change would adversely affect production and productivity of the resource rural poor farmers in the region.

These changes in climatic factors have been reported to cause both positive and negative effects. However, in developing countries, studies have indicated more negative effects that cut across crops, livestock as well as fisheries within the agricultural sector. Nelson et al. (2009) posited that variation in temperature caused adverse decline in crop production through increase in pest infestation. According to Ludi (2009) and FAO (2008), fluctuations in precipitation and prolonged drought negatively affect crop productivity.

Besides these effects of climate change on crop productivity, there is also evidence of adverse effects on fishery production as well as livestock productivity. Kabubo-Maria

(2008), reports the effect of climate change on the quality of feed available for livestock production and productivity. Recent studies also claimed climate change directly affect the physiology, reproductive capacity, behaviour, growth, mortality and distribution of fisheries and also indirectly affect the productivity, structure and composition of the marine ecosystems which serve as food for the fisheries (Brander, 2010; Okunishi *et al*., 2012).

The economy of Ghana has been mostly agrarian with about 60 percent of the populace engaged in the growing of crops and rearing of animals at the subsistence level as a means of survival (Alhassan & Dio, 2007). This implies that majority of land in the country is mainly used for agricultural cultivation (Benneh, 1994). Agricultural production in Ghana is still highly dependent on rainfall although initiatives have been put in place with the introduction of irrigation farming in recent years (MoFA, 2008). By implication, Ghana's agriculture is rainfall dependent; the production of crops and animals is entirely at the mercy of the weather. Highlighting the effects of changing climate on crop productivity, Stutley (2010) confirms extreme temperature in Ghana to be the source of low yields in the crop production. Similarly, Mendelsohn et al. (2006) contended that extreme temperatures and prolonged drought periods in Ghana were the major causes of low crop productivity.

According to Tonah (1993), Mensah-Bonsu (2003) and Fosu-Mensah (2013), planting periods for crops in Ghana have changed over the years from early April in the 1960's to late April or early May. These changes were attributed to unpredictable nature of rains and the changing environmental conditions especially in the amount and distribution of rains. These changing rainfall regimes affected cereal, root and tuber crop productions (Daze, 2007; Sagoe, 2006 and Mabe, 2011). However, climate change does not only reduce crop productions thereby causing food insecurity at local or national levels but also increases the incidence of pests and diseases in crops posing serious threats to human health and the attainable of livelihoods (Daze, 2007; Ampaabeng & Tan, 2012).

Climate Change and Cocoa Production

Climate change affects cocoa production, a major export of Ghana and the largest contributor to the country's GDP (ISSER, 2010). It affects the life cycle of pest and diseases which determines the productivity of cocoa. According to Anim-Kwapong & Frimpong (2004) reported that a survey conducted among farmers in the southern cocoa growing areas of Ghana acknowledged declining rainfall and rising temperatures which appears to threaten the Ghanaian cocoa industry.

Oyekele et al. (2009) explained that high rates in climate change have greater influence on cocoa, affecting the various phases like seedling, establishment and processing phase in cocoa production. The climate to a large extent influence cocoa production activities as the various elements therein impact on the crop significantly with different impact. This can be felt in rainfall amounts and intensity, temperature or solar radiation and or spill-over effect of some of the variables like rainfall resulting in erosion, increasing pest infestation among all affect the crop growth. Rainfall to a large extent determines the planting date of cocoa beans.

By drying the cocoa beans in the sun, the moisture content of the beans thereby making it easier to process. Furthermore, changing climatic conditions could lead to modifications in the way(s) in host plant resistance and an alteration in development stages and rates of cocoa pests and pathogens and ultimately a subsequent effect on yield and socio-economic variables (Anim-Kwapong & Frimpong, 2005). High cocoa seedling mortality is also intensified by protracted dry season which goes on further to affect cocoa output. Climate continuous to affect cocoa production in diverse ways by the impact of the various climatic variables during both wet and dry periods by either increasing black pod diseases or favouring capsids respectively (Anim-Kwapong & Frimpong, 2005).

2.8 Adaptation Strategies to Climate Change

IPCC (2001) defined adaptation as interventions, which are embarked upon so as to manage the losses or take advantage of the opportunities presented by a changing climate. Adaptation can be viewed from different perspectives; the anticipatory type, where there is an initial preparedness systems in place to arrest and to mitigate any impact that may arise or reactive type, which is only a response mechanism to an only instituted at the beginning or at a point where impact are felt (International Union for Conservation of Nature *et. al*., 2004). It has to do with improving society's ability to cope with changes in climatic conditions over the short term and/or longterm (IPCC, 2001).

According to Anim-Kwapong and Frimpong (2005), climate change adaptation implies taking action to minimize the adverse effects or to exploit the positive effects of climate change. IPCC (2001) holds the view that adaptation can potentially minimize the negative impacts of climate change and enhance the beneficial impacts but will incur cost and will not prevent all damages. Adaptive actions are instituted to forestall any imminent or impending effect that may likely results from climate change. Some adaptive actions may be taken however to rather deal with situations when actual impacts on climate change do occur. The ultimate goal of adaptation measure should be to increase the capacity of a system to cope with adverse shocks.

Oyekele *et al.* (2009) suggested that agricultural adaptations primarily consist of two (2) types of modification in production systems. The authors argued that the first strategy is increased diversification which comprises engaging in production activities that are resistant to temperature stress and drought tolerant. This strategy also includes activities that take full advantages and makes efficient use of prevailing temperature and water conditions. Crop diversification in cocoa and non-cocoa sub-sectors act as insurance against unreliable rainfall parttern. The second strategy primarily dwells on crop management practices directed at ensuring that critical crop growth stages do not coincide with extremely harsh climatic conditions.

The adaptation strategies to climate change reported in literature include livestock farming system, mixed cropping, crop diversification, cultivating different varieties of crop, changing planting and harvesting dates, market based insurance products which allow farmers to insure their crops against weather variability and other market uncertainties, blending cultivation of low yielding drought resistant varieties and high yielding water sensitive crops (Jagtap, 1995).

Hassan and Nhemachena (2008) also explained that the use of fertilizers and pesticides and insuring agricultural crops are potential adaptation strategies to climate change. Adaptation strategies specific to tree crops, such as cocoa, include shade management strategies; crop diversification; farm size strategies; soil fertility management; land preparation strategies; and lining and pegging strategies (Codjoe *et al.*, 2013).

2.9 Barriers of Adaptation to Climate Change

Barriers facing adaptation to climate change are the constraints that farmers encounter as they try to adjust to the effect of climate change. Deressa (2007) and CEEPA (2006) outlined the following barriers to adaptation:

- Lack of information about the weather
- Shortage of labour
- Lack of access to appropriate seed
- Poor potential for irrigation
- Inadequate financial resource

Adaptation is costly as most barriers to it are often associated with poverty. Most farmers do not have financial means to adapt at all. Adaptation requires farmers' capacity to adjust and cope with climate change. Some farmers may lack the capacity to use any adaptation strategies to reduce the effects of the change. According to Mabe (2011), the strategies may be available for use, but it may not be accessible because of factors influencing farmers' decision to adaptation ; education, gender, non- farm income, access to credit, farm size and free extension advice. Access to weather information and experience in farming can also influence the ability of farmers to adapt to climate change (Deressa *et al.*, 2008).

2.10 Empirical Economic Impact Studies on Climate Change

For the past 30 years, there have been many researches on climate change. Most researchers have looked at the impact of climate change on agricultural production. Some researchers have tried to develop an Integrated Assessment Model (IAMs) for the assessment of the impact of climate change (Amiraslany, 2010). According to Ringuis (2002), the other group of researchers looked at the development of local and regional quantitative indicators for assessing the impact of climate change.

Manne et al. (1995) categorised climate change impacts into two, namely; market damages and non-market damages (ecological damages). To Manne et al. (1995), the market damages affect the agricultural, forestry, fishery, energy, transport, tourism and water sectors. Air pollution, drought, migration, hurricanes etc. results from global warming through non-market damages. There are controversies on the number of methodologies (approaches) available for assessing the impact of climatic changes on agriculture. Amos (2007) indicated that there are two approaches and these are the Production Function Approach and the Ricardian Model Approach. However, Schlenker et al. (2006) and Ofori-Boateng and Insha (2011) grouped climate change impact assessment approaches into three broad categories. These are Computational General Equilibrium (CGE) model, Agronomic Simulation Model (agro-economic analysis and Ricardian Cross-sectional Hedonic Model.

2.10.1 Computational General Equilibrium (CGE) Model

Darwin et al. (1995) developed the Computational General Equilibrium (CGE) model to analyze potential impact of climate change on agriculture, bearing in mind the interactions with non-agricultural sectors and other global regions. The assumption underlying this model is that the impact of climate change is exogenous (Bosello & Zhang, 2005). The strength of this model is that structural changes and farmer responses are implicit in the analysis, freeing the analyst from the burden of estimating the effects of climate change on particular region-specific crops and farmers responses (Darwin *et al.,* 1995).

Secondly, the model is assumes spatial adaptation as initial responses to changes in climate and to the availability of spatially disaggregate data on present agricultural production, land values and climate. Despite the above strengths, the model is bedeviled by some weakness. One of the weaknesses of the spatial-analogue approach is that it assumes a long-run equilibrium that ignores short and medium-run adjustment costs.

Also, the model ignores likely changes in input prices and output that results from changes in production at the global level and affects farm-level decisions (Bosello & Zhang, 2005).

Lastly, the approach also assumes that farmers will inevitably know when and how to respond to changes in climatic variables. This model is also called production function or yield response model. It is based on the assumption that crop yields are functions of exogenous environmental or climatic factors such as rainfall, temperature, wind speed etc. (Lobell *et al.*, 2007). It uses a controlled physiological changes approach of crop growth to stimulate yields based on uncontrollable climatic factors (Amiraslany, 2010). As noted by Environmental Economist, climatic factors are important inputs in production but they are usually unaccounted for. This model deals with this omission.

This model was used by some researchers like Adams et al. (1990), Rosenzweig and Parry (1994), Chen and Chang (2005), Mainardi (2010) and Mabe (2011) to measure the impact of climate change on certain agricultural crops. According to Amos (2007), the advantage of this model is that it enables the researchers to isolate the impact of climatic factors on crops from other factors.

Despite it advantage, it has certain disadvantages. However, the effect of climate change on yield has made many farmers to adopt some adaptive strategies. These adaptive strategies are intended to mitigate the negative impact of climate change on crop yield. The adaptive strategies can increase production thereby leading to insignificant negative impact of climate change on crop yield. Agronomic-Simulation Model (production function model) is deficient in accounting for these adjustments on the part of farmers (Snaghi *et al.*, 1998). Another drawback of this model is the uncertainty of the functional form to give the best coefficient of determination. It also lacks the ability to link agricultural sector with other sectors in the economy.

2.10.2 Ricardian Cross-Sectional Hedonic Models

This model can simply be called Ricardian model. It was named after a classical economist called David Ricardo (1772-1823). As the name of the model implies, it uses cross-sectional data to regress net revenue or land value on the explanatory variables (Kabubo-Mariara, 2008). David Ricardo in his time made a crucial observation that the rent of land would reflect its productivity in a perfectly competitive market. The perfectly competitive assumption ensures that excess profit is zero.

The Ricardian model is a hedonic approach which tries to price land and regress it on exogenous inputs (purchased inputs, climate, socio-economic and soil variables). Schlenker et al. (2006) noted that the model operates under the assumption that land value is equal to the stream of discounted value of future rent. The basic concept of the model is that land productivity is a function of climatic variables like rainfall, relative humidity and temperature (Kurukulasuriya & Mendelson, 2007). As such, variation in climate and other inputs affect net revenue or land value. It determines the impacts of climate change on crop yield by noting that a farmer maximizes net revenue by choosing inputs that are controllable and those that are uncontrollable (environmental factors). In stating empirically the Ricardian model (climate response function), temperature and rainfall enter as both linear and non-linear factors.

The Ricardian Cross-Sectional Hedonic Model has a number of merits, in estimating the effect of climate variables on net revenues; the model takes the individual farmer's adaptation strategies into account. The adjustment that a farmer makes can minimize the effects that climate change has on productivity. Kurukulasuriya and Mendelson (2007) indicated that the Ricardian model has the ability to deal with overestimation of the damage that other models are likely to cause. This is an advantage over the two models mentioned above.

However the model has certain demerits. The model has a limitation of not being able to take price changes into consideration in the advent of climate change (Quiggin & Horowitz, 1999). The assumption underlying Ricardian model is that price changes are netted out. Thus, an increase in price in some areas due to reduction in crop production neutralizes the effects of a decrease in prices due to expansion in crop production. This is not entirely true. The model usually underestimates damages or overestimates benefits of land productivity by assuming that prices are constant (Amiraslany, 2010).

Also, another limitation of this model is its inability to quantify the effects of variables which are constant across space (Kurukulasuriya & Mendelson, 2007). Thirdly the model assumes that farmers can easily adjust to climate change by adaptation. It notes that adaptation to climate change is less expensive and hence farmers adjust rapidly. It was observed by many researchers that adaptations are expensive and farmers slowly adjust to climate change. Another limitation is that it does not consider past and future agricultural policies.

Additionally, the explicit inclusion of irrigation in Ricardian model's analysis is a limitation. Furthermore, it is not applicable in the situation when farmers switche from one production industry to another. This is because it does not quantify the transition cost. Even though the model has a lot of criticism, Kurukulasuriya and Mendelson (2007), Kabubo-Mariara (2010) used it to assess the impact of climate change on crops and animal production.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The first part of this chapter presents the study area, types of data collected, data collection methods, sampling methods as well as sample size. The second part presents the methods of analysis for each objective. The scope of the study is also presented in chapter three.

3.2 Description of Study Area

The study was conducted in the Western Region of Ghana, the cocoa belt of the country. The region is geographically divided into 2 broad regions under the COCOBOD demarcation zones; Western North and Western South respectively. There are a total of 23 cocoa districts in the Western Region out of the 40 scattered in the 5 remaining cocoa regions. The Western North has 12 cocoa districts while the south is made up of 11 districts. One district each was selected from the North and South i.e. Sefwi Bekwai and Akontombra respectively.

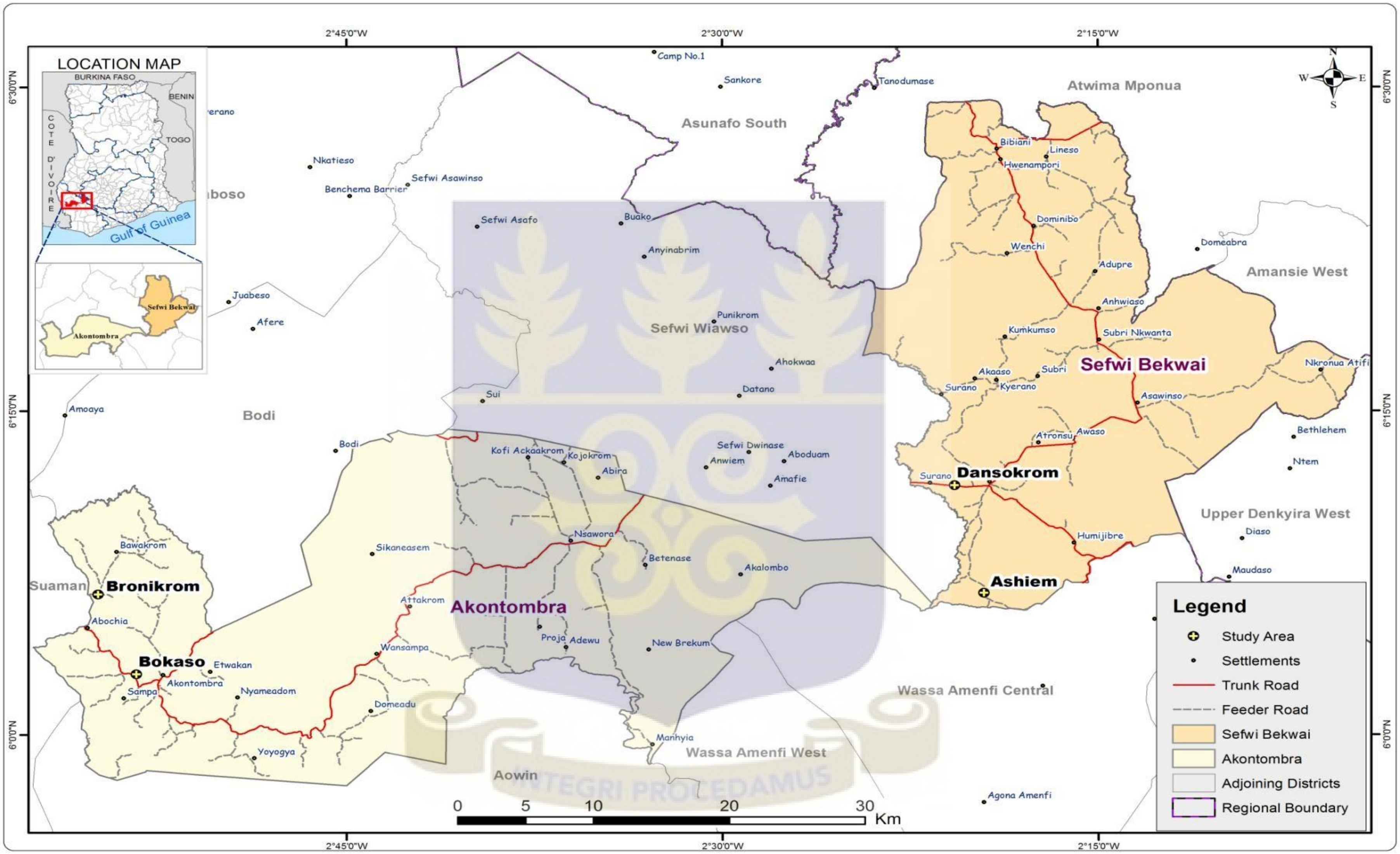
The Sefwi Bekwai cocoa district which is located in the Western north is found between Latitude 6.1980° N and longitude 2.3246° as shown in Figure 3.2. The district is bounded to the North by Boako cocoa district, South by Sefwi Wiawso cocoa district and to the East by Diaso district. The District is characterized by bimodal rainfall pattern with annual rainfall average between 1200mm in March-August and 1500mm in September-October and an annual average temperature of about 26 ^{O}C (Ministry of Local Government and Rural Development (MLGRD), 2006).

There is a high relative humidity, averaging between 75 percent in the afternoon and 95 percent in night and early morning. Dansokrom and Ashiem were the communities where the study took place within the Western North, shown in the map of the study area.

The Akontombra cocoa district located between longitude 6.0418° N, and Latitude 2.8752° W in the Western South of the Western Region was the other district where the study took place. It is the second leading producer of cocoa in the Western Region. It produces nearly 6,000 metric tons of cocoa annually. It shares boundaries with Dadieso A, B, and C cocoa districts on the West, to the South with Aowin District, to the North with Sefwi Wiawso and to the East with Wassa Amenfi West district.

The District is known to have a wet-semi equatorial climate with annual temperatures averaging 26 ^{O}C. The hottest months are March and April months of the year. There is a bimodal rainfall pattern with June and October being the peak seasons and an annual rainfall range of 1700mm-2100mm. On the average, relative humidity is usually and ranges between 75 percent to 80 percent in the wet season. This further decreases to nearly 70 percent for most part of the year.

Figure 3.1: Map of Study Area



Source: CERSGIS (2014)

3.3 Data Collection

3.3.1 Sources of Data

In order to gather reliable and valid data, the study employed two methodological approaches in which the primary data collected from the field was complimented by secondary data obtained from Ghana Meteorological Agency (GMA) and the Ghana Cocoa Board (COCOBOD).

Data collected included farm-level and demographic information; cocoa farmers' perception on climate change and variability, as well as climate change effects on cocoa yields. Data on barriers influencing cocoa farmers' ability to adapt to climate change and variability were also collected. In all, the study interviewed men and women smallholder farmers, key informants, government representatives at community levels, Assembly Persons as well as Agricultural Extension Agents (AEAs).

In addition to the primary data, the study collected secondary data. These included data on cocoa output for the region; climatic variables such as, rainfall, temperature, sunshine hours and relative humidity from the Ghana Meteorological Agency; review of available literature and statistics on the topic areas, such as reports and working documents prepared by government agencies and NGOs as well as other official publications.

3.3.2 Data Collection Method

The selected method for primary data collection was under the form of semi-structured and in-depth interviews by using a questionnaire. Saunders (2003) opined that aside providing first-hand and new information regarding the topic under study, the use of interviews and questionnaires help to collect valid and reliable data that are of relevance to the research questions and objectives.

In addition, focus group discussions were conducted to solicit in-depth information from both small-scale farmers and relevant cocoa research institutions in the region concerning the effects of climate change on their livelihoods. As suggested by Barbie & Mouton (2007), this kind of research brings a rather in-depth understanding of events or actions which can help the researcher to gain insight into how and why actions or events take place rather than merely presenting a phenomenon.

3.3.3 Sampling Method

A multistage sampling approach was employed in this study. The Western Region was purposively selected because it is the largest cocoa growing region with the single biggest contribution to the national output. It is the wettest part of Ghana with a double maxima rainfall pattern averaging 1600mm per annum, characterized by moderate temperatures ranging from 22 ^{0}C at nightfall to 34 ^{0}C during the day creating an optimum condition for cocoa production.

The region is not exempted from the current global change and variability in the climatic variable (Rainfall amount, Temperature, Relative humidity and Bright Sunshine duration) which invariably affect cocoa crop output. Hence the region was purposively selected.

One (1) cocoa district each was then randomly selected, from the Two(2) broad regions, Western North and South Akontombra.

Finally, Two (2) communities each from the Two (2) cocoa districts were again randomly selected from each cocoa district for the data collection. The communities where the list of farmers were drawn with the help of COCOBOD's Agricultural Extension Agents (AEAs) were Ashiem and Dansokrom (Sefwi Bekwai Cocoa District); and Bronikrom and Bokaso (Akontombra Cocoa District).

A stratified random sampling method was used to separate female small-scale cocoa farmers from their male counterpart. A gender-based stratum is justified in this study on the grounds that most women in the districts tended not to be heads of households, have smaller farm sizes as well as have limited access to resources such as inputs and extension services (USAID & MFCS, 2014). Hence if women were not purposively targeted, their number would be small and their opinions will not be given proper attention in this study

To give each farmer equal chance of being selected for the study, a simple random sampling method was used where households were randomly selected to form part of the survey and questionnaire was then administered to them.Broadly, all the smallholder cocoa farmers face the same weather, have common livelihood assets, market and soil conditions. They also have similar socioeconomic characteristics. Hence this sampling approach provided the farmers equal chances of being part of the study (Saunders, 2003).

3.3.4 Sample Size

In the determination of sample size for the study, this formula was used

$$n = \frac{N}{1 + N(e)^2}$$

Where n= sample size, N= population size of cocoa farmers and e= level of precision (0.05) was used. Using the above formula, a sample size of 312 was computed from the population of 1426 cocoa farmers in the Two (2) cocoa districts. The study however used 231 farmers as the final sample size due to financial constraints, time and lack of responses from the farmers. Based on the proportion of farmers in the Two (2) cocoa districts, 120 out of 741 farmers were selected from Sefwi Bekwai whilst 111 out of 685 farmers from Akontombra cocoa district were selected for the study. Again, 60 farmers each were selected from Ashiem and Dansokrom which are key cocoa growing communities in the Sefwi Bekwai based on the proportion of farmers within each community. The same was repeated for the Akontombra cocoa district: 70 and 40 farmers each were selected from Bronikrom and Bokaso respectively.

This formula requires a sample size of 400 but due to resource constraints (financial and time), 231 smallholder farmers were selected and interviewed. Out of these 231 respondents, 120 were selected from Sefwi Bekwi district and 111 selected from Akontombra cocoa district as well as 60 respondents from each community within Sefwi Bekwai, Donkrokrom and Ahiem respectively. A total of 71 and 40 respondents (farmers) from each of the 2 communities within Akontombra cocoa district, Bronikrom and Bokaso respectively were also used.

Only adults (of 40 years and above) were targeted for sampling because it is generally understood that farmers who are less than 40 years old would not be able to identify their experience of climate changes in the region, since climate change is a long-term shift in weather variables.

3.4 Conceptual Framework for Climate Change and Variability and Cocoa Yield

A conceptual framework on climate change and variability and cocoa yield interactions is adapted from FAO (2008) to highlight the climatic and non-climatic variables affecting cocoa yield. The framework depicted in Figure 3.2 shows how climate change and variability in addition to non-climatic factors affect cocoa yield. Climate change and variability is fundamentally caused through two mediums; human induced causes and natural causes. This occurs through the action of man, which in this case is primarily by deforestation (cocoa production) and naturally through changes in sea level temperature, changes in solar radiation which then affect climate change indicators like rainfall, temperature, bright sunshine duration and relative humidity.

Changes in these climatic variables then results in output changes. The establishment, production and post harvest phases are all affected through increased cocoa seedlings mortality, increased diseases and pest infestation and even quality of the harvested beans through post-harvest challenges with drying etc. The agro-ecological zones change and land becomes unsuitable for cocoa production. Cocoa crop suffers huge losses from Blackpod diseases caused by *Phytophtora megakarya* and *Phytophtora palmivora* when rainfall amounts are high and the increased humidity serves as precursor the fungi attack.

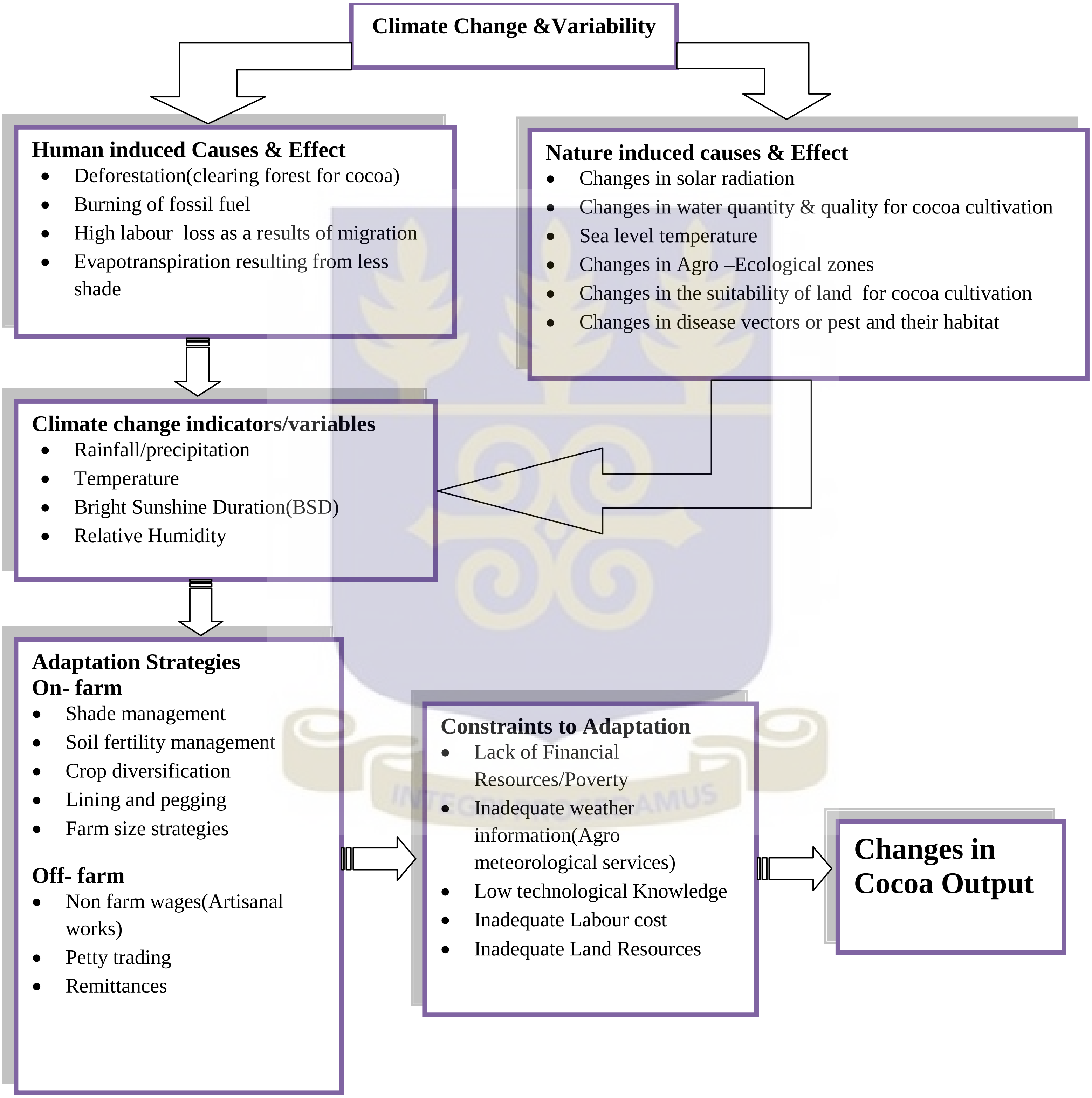
In the event of extreme heat, capsids or mired attack increases as well whereas Bright Sunshine Duration (BSD) affects the photosynthetic apparatus ultimately impacting on output. Climate change variables, such as temperature, rainfall, sunshine duration and relative humidity, can influence biophysical factors, such as land, cocoa plant growth, water quantity and quality as well as cycles, biodiversity and nutrient cycling. Indirectly climate change induces loss of labour for cocoa production through these among others results in most farmers adapting to strategies aimed at mitigating the impact of climate change and variability which requires funds for shade tree management, soil fertility management, crop diversification.

More land is therefore required for expansion, labour cost is increased and access to information then becomes a challenge. However, non-climatic variables, such as soil characteristics, technology and management also tend to affect cocoa yield. Chang (2009) noted that the type and quality of soils as well as the slope of the land that are used in cocoa cultivation tends to affect its yield. According to Calpe (2002), the type of technology (agricultural machines and inputs) that are used and the agronomic practices that practiced on the cocoa fields has a part to play in affecting it yields.

The climate variables considered in this framework are:

- Increase in global mean temperatures
- Gradual changes in precipitation
- Changes in degree of humidity and extreme weather events

Figure 3.2: Conceptual Framework



Source: Adapted from FAO (2008)

3.5 Theoretical Framework

The theoretical framework for the study leans on the crop yields response. The crop response theory allows for weather influence upon crops in agricultural production analysis. According to Mabe (2011), Lobel et al. (2007) Chen and Chang (2005), and Chang (2001), the yearly effects of climate change and variability can be linked to the respective year's crop yield. Crop yield response model in this study uses a production function approach to quantify the effects of climate change indicators on cocoa yield for the past 40 years (1975 to 2015). The basic concept of this model is that the trend of cocoa yield is affected by climatic variables especially temperature, rainfall, relative humidity and sunshine. Nonetheless, non-climatic variables such as socioeconomic factors, technology and soil conditions also affects crop yield (Lobell *et al*., 2007). Crop yield response (production) function is given as:

$$\text{Yield} = f\,(\text{Weather, Technology, Labour, Land}) \qquad (1)$$

Where yield denotes output of cocoa measured in metric tonnes per hectare (mt/ha),

Weather denotes climate input variables (rainfall, temperature, relative humidity and sunshine duration) as posited by Martonne (1920, Lang (1920) and strengthened by Oury (1965) who used Cobb-Douglass production function where Weather entered the production process an additional input. Technology denotes innovative management practices, while Labour and Land denote the labour provision and the soil conditions respectively.

Primarily, the production function model is specified as"

$$y = f\,(xi) \qquad (2)$$

where Y denotes the output of cocoa i and x are the vector of inputs variables

The theory conceives that output is generally through a production function to Land, labour and capital among others. The direct application of such general function to agriculture disregards the presence of weather as a significant exogenous factor. Hence the theory considers rainfall and temperature fundamentally as well as other weather factors as non-cost input into the production process especially when taken as deviation from the average. In assuming the log-normal distribution of W such as in Cobb-Douglass specification, the equation is written as:

$$P = aL\ N^{n} K^{k} W \qquad (3)$$

$$\ln P = \ln\beta_0 + \ln\beta_1 L + \ln\beta_2 N + \ln\beta_3 K + \ln\beta_4 T + \ln\beta_5 R + \ln\beta_6 Edu + \ln\beta_7 Age + \beta_8 Ext + V_i$$

Where a is a constant term, P =Output , L =land, N =Labour, K =Capital, R =Rainfall, T=Temperature, Edu= Education of farmer, Age= age of cocoa farm, Ext= Number of extension visits per year and βi are the coefficients of constant elasticity of output each input factor are the coefficients of constant elasticity of output each input factor and Vi is the random error term.

Dell et al. (2010) and Guan (2006) argue that climatic effects especially rainfall and temperature may not have instantaneous effects on perennial tree crops like cocoa. However, climatic variables on tree crops have growth effect which is not the case in arable crops where shocks in the weather level effect such that as soon as the shock is normalized, crop yield is restored. Therefore, climatic effect plays a key role on cocoa growth and consequently, its output.

$$InP = \alpha + \sum \beta_i Inx_i + \sum_i \sum_j \delta_y (Inx_i)(Inx_j \qquad (4)$$

Where P is output, x_i and x_j are the set of inputs including weather variables

However, climatic variables (rainfall, temperature, relative humidity and sunshine duration) are not controlled by the decision makers (farmers) and hence are exogenous factors. At individual level, each farmer tries to maximize yield by choosing endogenous variables inputs such that the resulting yield becomes a function of exogenous variables such as weather in this case represented by the climatic variables, rainfall, temperature, relative humidity and sunshine duration, technology used and soil conditions (Mendelsohn *et al*., 1994).

$$Yield = f \text{ (rainfall, temperature, relative humidity and sunshine duration)} \quad (5)$$

3.5.1 Determining the Effects of Climate Change Indicators on Cocoa Yield

According to Lobell et al. (2007), the contribution of climate change to crop yield trends can be estimated by modelling the crop yield data without removing trend factor as a function of both time and climatic variables. Mainardi (2010) assumed that the effect of the previous year's yield on the current year's yield measure the technological changes. Soil conditions can be proxied by the slope of the land in the study area. The slope of the land depends on the area that each farmer cultivates. Following Chang (2001) and Mabe (2011), management of farms can be measured as the ratio of full-time farm household to total farm households' area.

Since cocoa yield data is not taken at the farmer level but at the regional and district level, the soil conditions and management variables were excluded in the model.

The corresponding difference in annual minimum and maximum temperature and rainfall are included in the model in order to measure the influence of departure from normal climatic conditions on cocoa yield (Chang, 2001). These variables also capture the extreme events on cocoa yield. According to Mendelsohn et al. (1996) omitting variation term of temperature or rainfall biases the estimation of the effects of global warming on crop yield.

Temperature and rainfall have a non-monotonic effect on cocoa yield. According to Chang (2001), the actual yield response model is given as:

$$Y^R_t = \delta_0 + \delta_t Y^R_{t-1} + \delta_1 T_t + \delta_2 T^2_t + \delta_3 R_t + \delta_4 R^2 + \delta_5 VarT_t + \delta_6 VarR_t + \varepsilon_t \quad (6)$$

Where δ_0 is the intercept of equation, δ_t, δ_1, δ_2, δ_3, δ_4, δ_5, and δ_6 are the slope coefficients of the explanatory variables Y^R_{t-1}, T_t, T^2_t, R_t, R^2_t, $VarT_t$, and $VarR_t$ respectively. Y^R_t, Y^R_{t-1}, T_t, and R_t denotes cocoa yield (metric tonnes per hectare) in year t, previous years cocoa yield (metric tonnes per hectare), average annual temperature (^oC) in year t and total annual rainfall amount (mm) in year t respectively. $VarT_t$, and $VarR_t$, represent differences between monthly minimum and maximum average temperatures (^oC) and rainfall amount (mm) in year t respectively. The nonlinear temperature, rainfall and sunshine amount variables are shown by T^2_t and R^2_t, respectively. Lastly, ε_t is the stochastic error term which satisfies the classical normal regression assumption.

Chang (2001) used linear log functional form to estimate crop yield response model based on the fact that temperature and rainfall have a non-linear relationship with crop yield. In this research, several functional forms were estimated in equations (7), (8) and the best one equation(9) chosen, the log-log functional form

Equation (7), (8) and (9) represent, the log-linear, linear-log and log-log functional forms respectively.

$$In(Y^R_t) = \delta_0 + \delta_t Y^R_{t-1} + \delta_1 T_t + \delta_2 T^2_t + \delta_3 R_t + \delta_4 R^2 + \delta_5 VarT_t + \delta_6 VarR_t + \varepsilon_t \quad (7)$$

$$Y^R_t = \delta_0 + \delta_t Y^R_{t-1} + \delta_1 In(T_t) + \delta_2 In(T^2_t) + \delta_3 In(R_t) + \delta_4 In(R^2_t) + \delta_5 In(VarT_t) + \delta_6 In(VarR_t) + \varepsilon_t \quad (8)$$

$$In(Y^R_t) = \delta_0 + \delta_t In(Y^R_{t-1}) + \delta_1 In(T_t) + \delta_2 In(T^2_t) + \delta_3 In(R_t) + \delta_4 In(R^2_t) + \delta_5 In(VarT_t) + \delta_6 In(VarR_t) + \varepsilon_t \quad (9)$$

3.6 Methods of Analysis of other Objectives

This section presents the various methods that the study used to achieve each of the specific objectives.

3.6.1 Determining the Perception of Small-Scale Cocoa Farmers' on Climate Change and Variability in the Western Region

The first objective of the study sought to describe the perceptions small-scale cocoa farmers on climate change and variability in the Western Region. In this study the Likert scale ranking was adopted to rank the perceptions of the farmers on climate change. Based on the question asked example; 'Weather conditions have changed over the last 10 years'. The responses were ranked as: 1= strongly agree, 2= can't tell, 3= strongly disagree. Data obtained from this objective was further analysed by the use of Statistical Package for the Social Science (SPSS) software and findings presented using descriptive statistics (e.g. mean, mode, median, graphs, percentages, pie charts etc.)

3.6.2 Determining the trends in Climate Change and Variability of the climatic variables in the study area

Data on the above mentioned indicators were obtained from the Ghana Meteorological Agency (GMA) and the mean values of the variables (Rainfall, Temperature, Relative humidity and Bright Sunshine Duration) were computed. The paired t-test analysis was used to establish significance difference in means between the decades for each of the climatic variables for the period 1975 to 2015.

Paired t-test for Comparing Decade Means of Climate Variables

Testing the differences between two means can be done by using different methods. Stephens (1996) used analysis of variance to test for significant difference between monthly maximum temperatures of 1931-60 and 1961-90. The Intergovernmental Panel on Climate Change (IPCC) (2007) defined climate change as a change in the state of the average weather conditions which can be identified by changes in the mean and/or the variability of its properties which persist for an extended period, typically decades or longer. This study used paired t-test to compare the decadal means (presented in the table 1.0) of the entire climatic variable to establish whether the difference is significant or not.

Table 3.1: Decadal Mean for comparison

Number of Decades	Decades Ranges	Decadal Pairing	Inter-decadal
1	1975-1984	1 & 2	**1975-1984** **1985-1994**
2	1985-1994	1 & 3	**1975-1984** **1995-2004**
3	1995-2004	1 & 4	**1975-1984** **2005-2014**
4	2005-2014	2 & 3	**1985-1994** **1995-2004**
		2 & 4	**1985-1994** **2005-2014**
		3 & 4	**1995-2004** **2005-2014**

Source: Author (2016)

The hypotheses tested are:

$H_0: \bar{X}_{2i} = \bar{X}_{1i}$

$H_A: \bar{X}_{2i} > \bar{X}_{1i}$ for temperature and bright sunshine duration

$H_A: \bar{X}_{2i} < \bar{X}_{1i}$ for rainfall and relative humidity

The t-calculated was arrived as follows:

$$T\text{-}calculated = \frac{\bar{X}_{2i} - \bar{X}_{1i}}{SE_i} \quad (10)$$

Where $\bar{X}_{2i}$ and $\bar{X}_{1i}$ are the means for the current and the previous decades compared for *i*th climate variable respectively and SE_i is the standard error for *i*th climate variable.

The 1-tailed significance test was used to test for the equality of means between all the climatic variables, rainfall, temperature, relative humidity and bright sunshine duration (results presented in Table 4.3, Table 4.4, Table 4.5 and Table 4.6).

The test was conducted at 0.05% significance level. The decision rule was that if the 1-tailed significance value from the test was greater than 0.05, then there was no statistical difference between the mean decadal climatic variable in question hence, any difference in means could be due to chance. If on the other hand the significance value (1-tailed)was found to be less or equal to 0.05, then the conclusion would be that there was a statistically significant difference between the mean climatic variables of the 2 decades been compared and the difference observed between the means was not merely due to chance.

Table 3.2: A priori Expectation of Cocoa Yield Response Model

Variables	Parameters	A priori Expectation
Previous years cocoa yield	δ_t	Positive
Temperature	δ_1	Negative
Temperature Square/extreme high Temperature	δ_2	Negative
Rainfall	δ_3	Positive
Rainfall Square/ Extreme high rainfall	δ_4	Negative
Maximum – minimum temperatures (extreme)	δ_5	Negative
Maximum – minimum rainfall (extreme)	δ_6	Negative

Statement of Hypotheses

A. H_0: Extreme variations in temperature have no effect on cocoa output

H_A: Extreme variations in temperature have negative effect on cocoa output.

Extreme variations in rainfall amounts, extreme level of temperature and extreme level of rainfall amount follow similar hypotheses stated above

B. H_0: Normal rainfall amount have no effect on cocoa output.

H_A: Normal rainfall amount have positive effect on cocoa output.

Validation of Hypotheses

The student t-statistic test was used to test the null hypotheses stated above. It was used to determine whether the estimated parameters are significantly different from zero.

3.6.3 Determining the Adaptation Strategies Employed by Small-Scale Cocoa Farmers in the Face of Climate Change and Variability.

In order to fulfill this objective, a semi-structured questionnaire containing open-ended questions was used. Questions such as "what adaptation strategies do you adopt on your cocoa farm in managing the effects of climate change indicators?" A list of adaptation strategies that the small-scale cocoa farmers use in minimizing the effects of climate change and variability on cocoa outputs was obtained from such question. Descriptive statistics such as chart and percentages was used to present the findings.

3.6.4 Estimating the determinants that Influence the Adoption of Adaptation Strategies.

3.6.4.1 Theoretical framework of the multinomial logistic regression

The Random Utility model was used for the basis for determining the factors that influence the choice of farmers' adaptation process. The model assumes the choice of an adaptation strategy is to maximize farmer's utility. Following Fontana et al.(2006) and assuming a farmer *n* has to make a choice among *J* different adaptation strategies. Let U_{nj} j= 1... J represent the utility that farmer *n* obtains from choosing adaptation strategy *j*. The farmer will choose strategy *i* if and only if he derives a relatively higher utility from that strategy.

This can be represented as $U_{nj} > U_{nj}$, $V_j \neq i$. From Random Utility Theory, the utility (U_{nj}) a farmer derives from using strategy j has two components V_{nj} and ε_{nj} . V_{nj} is the properties of the adaptation strategy labeled X_{nj} and some household characteristics of the farmer, H_n, with a random error term ε_{nj} which represents innately random choice behaviours, specification or measurement error as well as attributes of the alternatives that affect the utility (U_{nj}) that are unobserved but are not captured in V_{nj}. The utility function can be represented as:

$$\left.\begin{aligned} U_{nj} &= V_{nj} + \varepsilon_{nj} \forall j \\ &= V(X_{nj}, H_n) + \varepsilon_{nj} \end{aligned}\right\} \qquad (10)$$

Since the outcomes or choices of adaptation strategy involved in this study are three, the multinomial Logit model can be used to estimate the probabilities associated with choosing each adaptation strategy. With the assumption that the error term associated with each utility being identical and independent, the multinomial Logit be expressed as:

$$P_{nj} = \frac{e^{(\beta' X_{nj} + \gamma' H_{nj})}}{\sum_{j=1}^{4} e^{(\beta' X_{jj} + \gamma' H_{nj})}} \qquad (11)$$

Setting the β*'s* and γ*'s* to zero for a strategy (let's say No-adaptation strategy) which was used as the base category, the Multinomial Logit for each strategy (j≠ strategy R) can be represented as

$$P_{nj,j\neq 1} = \frac{e^{(\beta' X_{nj} + \gamma' H_{nj})}}{1 + \sum_{j=2}^{4} e^{(\beta' X_{nj} + \gamma' H_{nj})}} \quad (j=2,3) \qquad \text{and} \qquad (13)$$

$$P_{n1} = \frac{1}{1 + \sum_{j=1}^{4} e^{(\beta' X_{nj} + \gamma' H_{nj})}} \qquad (14)$$

The above equation can be estimated using The maximum likelihood method can be used to estimate the above. The H_n and X_n are the 'asset-based' variables.

Model Specification

$$P_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_9 X_9 + \varepsilon \qquad (15)$$

Where P_i= Probability of a farmer choosing income strategy j; β_0= constant; β_k =

coefficients; X_i =Explanatory variables; ε = random error term

3.6.4.2 Description of Variables used in the Model

Age

The age variable was measured using the years of the farmer nearest to a whole number. It is expected that age will be related to investment into capital intensive adaptation strategy positively. From a study by Hassan and Nhemacha (2008) age had no significant effect on choice of adaptation strategy to climate change. However other studies have found otherwise, Deressa et al. (2010) found a positive effect on choice of livestock (On farm) adaptation.

Household size

Household size represented the number of people who shared the same resources for basic up keep with the farmer. Larger households are expected to engage in labour intensive On-farm activities. Such households could also have members who will engage in Non-farm activities and making good gains prompting the farmer to partake in such activities as a means of mitigating the effect of climate change if the means of adapting to certain on-farm strategies like soil fertility management, shade management etc which are mostly capital intensive is not there.

Farmer Based Organizations (FBOs)

Farmer Based Organizations are associations of farmers where information, new technology and other resources are introduced to farmers. In most cocoa growing areas, FBO's help provide information and training on Good Agricultural Practices(GAP),Integrated Pest Management(IPM) and even input schemes among others. Information are disseminated through Farmer Field Schools (FFS) with the help of demonstration plots or look-see farms which makes adoption and its benefit easier to comprehend. These organizations are formed to promote farming and agriculture hence they are expected to increase the probability of choosing an On-farm adaptation strategy.

Farm size

Farm size was measured in Hectares. Farmers with larger farms were expected to choose On-farm adaptation strategies because they had invested a lot into their farms and modify them to mitigate the effect of climate change and variability. Investment in land clearing, farm maintenance including pest and disease control management, soil fertility management (fertilization) among others is enormous cost to the cocoa farmer. Therefore to safeguard his investment, a farmer is more likely to adapt to climate change strategies to be able to off-set investment made. The larger the farm size, the bigger the investment

Output

Output which was measured as production of a farmer could be a measure of how well a farmer is adapting to climate change. Farmers with higher outputs are expected to invest into On-farm practices such as fertilizer application, pest and disease managment to help increase their output and yield as a whole.

Gender

Gender was measured as a dummy, 1 for male and 0 for female in the study. Climate change adaptation studies have diverse opinions on gender and adaptations. Some have found that males were more likely to adapt because they had more access to resources both on the farm and off the farm. Hence females were rather less likely to adapt. This study expects males to adapt for than their female counterparts as found by Mandleni and Anim (2011).

Education

According to Maddison (2007) educated farmers had a higher probability of adopting livestock as an adaptation strategy. This study measured education as years, this was captured as number of years spent in formal education by the farmer.

Extension Services

The extension services considered for this study was the formal extension service provided to farmers by the agricultural extension agents. The informal farmer-farmer extension service was received by all farmers. Extension service was measured as a Yes=1 and No=0 dummy in the model. The study expects farmers who receive extension service to be aware of new the appropriate adaptation strategy to employ and new and innovative farming systems that holistically address challenges with output with regards to climate change and variability and more importantly information on how to improve their farming in the face of climatic challenges. So such farmers are expected to practice On-farm adaptation strategies.

Source of Labour

Source of labour which was either family or hired about was measured as a dummy were ‘family labour’=1 and ‘hired labour’=0. Source of labour is important characteristic where a farmer who invests into hired labour will have a higher probability of choosing On-farm strategy. This was the expectation of the study.

Table 3.3: Exogenous Variables

Description	Measurement	A priori Expectation
Age of farmer	Years	+
Gender of farmer	Male=0 Female=1	+/-
Household size	Head	+/-
Output	MT	+
Educational	Years	+
FBO member	Yes=1 No=0	+
Source of Labour	Family=1 Hired=0	+
Extension service	Yes=1 No=0	+/-
Farm size	Hectare	+/-

Source: Author (2016)

Hypothesis test (T-test)

The null hypothesis (Ho) is tested against the alternate hypothesis (Ha) as follows

Ho: gender does not affect a farmers' choice of an adaptation strategy.

Ha: gender affects a farmers' decision to choose an adaptation strategy

The same for all variables

The Kendall's coefficient of concordance (*W*) was also used in ranking the constraints the farmers face from among the numerous methods for test ranking, such as the Friedman's and Garrett's test. Adaptation strategies were identified from pre-trials and literature and presented to farmers to rank from most used strategies to the least used adaptation strategies.

The focus of Friedman's test is on the items being ranked rather than the rankers themselves while the Garrett's ranking test uses average score of the rankers and then arrange them in either ascending or descending order. The limitation of this method however is that it involves a couple of steps and does not test the level of agreement among rankers (Kuwornu *et al.*, 2013). The Kendall's was chosen because unlike Friedman's and Garrett's tests, it provides the test of agreement of rankers (respondents), among their rankings.

The Kendall's coefficient of concordance (*W*) ranges from zero (0) to one (1). It is one when the mark assigned by each respondent/farmer is exactly the same as those assigned by the other respondents/farmers and it will be zero when there is maximum disagreement among the respondent's/farmer's rankings. If T represents the sum of ranks for each adaptation strategies ranked, the variance of the sum of the ranks would be found by the formula:

$$W = \frac{12[\sum T^2 - (\frac{\sum T)^2}{n})]}{nm^2(n^2-1)} \qquad (16)$$

Where;

T= sum of ranks for each adaptation strategies m= number of rankers (respondents)

n= number of adaptation strategies being ranked.

Statement of Hypotheses and Significant Test

H_0: There is no difference in the barriers that influence the adoption of adaptation strategies by small-scale cocoa farmers.

H_A: There is a difference in the barriers that influence the adoption of adaptation strategies by small-scale cocoa farmers.

Where **H_0** is the null hypothesis and the **H_A** is the alternate hypothesis. Significance in agreements in the adaptation strategies was tested by the use of the chi-square test.

$$X^2 = \sum \frac{(O-E)^2}{E}$$

This is stated as: (17)

Where;

X^2 = Chi-square

$\sum$= Sum of the above frequencies across all cells

O=Observed frequency

E= Expected frequency

Statistical Application

STATA and Microsoft Excel were the applications used for the data analysis. Results are presented in tables and graphs in Chapter 4.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study. It first describes the socio-economic characteristics of the small-scale cocoa farmers interviewed. The second part of this chapter determines the trends in climate change and significant variables among the climate change variables from 1975 to 2014. The evidence of climate change is also presented. The effects of climate change on cocoa output, the adaptation strategies adopted by the small-scale farmers as well as the factors that influence the adoption of these strategies are presented in this chapter.

Table 4.1: Summary of Socio-economic Characteristics of Farmers in the Study Area

Description						**Cocoa Districts**
Frequency	**Akontombra**		**Sefwi Bekwai**		**Total**	**Total Percentage**
	Frequency	**Percent**	**Frequency**	**Percent**		
Gender						
Male	77	69.4	73	60.8	150	65
Female	34	30.6	47	39.2	81	35
Age						
40-49	79	71.2	76	63.3	155	67.11
50-59	22	19.8	17	14.2	39	16.88
60-69	6	5.4	18	15	24	10.39
70-79	1	0.9	7	5.8	8	3.46
80-89	3	2.7	1	0.8	4	1.73
>90	0	0	1	0.8	1	0.43
Educational Level						
None	17	15.3	14	11.7	31	13.42
Primary Edu	37	33.3	16	13.3	53	22.94
Middle/JSS	41	36.9	74	61.7	115	49.78
SSS/Tech/Voc	10	9	10	8.3	20	8.66
Tertiary Educ	6	5.4	6	5	12	5.2
Farming Experience						
Min(1-10)yrs	52	46.8	24.2	31	76	35.1
Mean(10-20)yrs	32	28.8	50	60	82	39.8
Max(>20)yrs	27	24.3	25.8	31	53	25.1
Origin of Farmers						
Indigenes	77	69.4	96	80	173	74.9
Settlers/Migrants	34	30.6	24	20	58	25.1
Income Sources						
Other farming	84	47.7	91	**52.3**	**176**	76.2
Petty Trading	22	47.8	24	**52.2**	**46**	19.9
Remittances	3	42.9	4	**57.1**	**7**	3.0
Formal Occupation	1	50.0	1	**50.0**	**2**	0.9
Adaptation Strategies						
No adaptation	18	46.2	21	**53.8**	39	16.9
On- farm	52	44.8	64	**55.2**	116	50.2
Non-farm	41	53.9	35	**46.1**	76	32.9
TOTAL	**111**	**100**	**120**	**100**	**231**	

Source: Field survey (2016)

4.2 Sample Distribution among the Communities

Table 4.1 summarizes the actual sample sizes from the various communities. In all, the study made use of 231 respondents from the two districts taken from four communities.

4.2.1 Age and Gender of Respondents

Table 4.1 shows the frequency and percentage of age and gender of the respondents. The table indicates that majority of the respondents are aged from 40-49 years. This represents about 67% of the total small-scale cocoa farmers. Out of the 231 cocoa farmers interviewed, about 17% were aged 50-59 years. The least percentage (about 0.4%) of the respondents was in the age ranges of 90 years and above. The age distribution of the study further confirms the existing concern of ageing cocoa sub-sector. In a study by Vigneri (2007), the author attributed this to the continuous exodus of the young farmers from the hinterlands to the urban centers in search for greener pastures.

Also, the table indicates that out of 231 respondents interviewed, majority of them (65%) are males whiles 35% are females. The male dominance in cocoa farming can be attributed to the traditional land tenure systems in Ghana which generally favour land ownership by males compared to their female counterparts. This very opinion is held by Onumah et al. (2014).

4.2.2 Marital Status of Respondents

Majority (about 92%) of the small-scale cocoa farmers interviewed were married. About 2% were widowed whiles those divorced and single were 2% and 4% respectively.

4.2.3 Educational Levels of Respondents

The modal educational level attained by the cocoa farmers was the Middle School; nearly half of them reached this level. Around 13 percent of the farmers had no formal education. A little over 5% of the cocoa farmers had attained tertiary education. The generally low level of education amongst the cocoa farmers is consistent with what Vigneri (2007) reported.

4.2.4 Farming Experience of Respondents

According to Deressa et al. (2008), it is the well-experienced farmers who perceived that climate has changed. Therefore it is convenient for a researcher to look at the perception of farmers on climate change based on the respondents' years of farming experience (Maddison, 2007). The results presented in Table 4.1 shows that 50 men smallholder farmers representing 54 percent and 42 women smallholder farmers (46 percent) had 11-21 years of farming experience. Similarly, 72 percent of men and 28 percent women smallholder farmers had 1-10 years farming experience. From the study it is evident that men smallholder farmers have more farming experience than their women counterparts. This implies that men smallholder farmers are likely to perceive changes in climate than the women smallholder farmers (Deressa *et al.*, 2008; Maddison, 2007).

4.2.5 Income Sources of Respondents

Table 4.1 highlights the sources of income for the small-scale cocoa farmers in the study area. Among the 231 small-scale cocoa farmers, 76% derived their income from agricultural activities such as primary crop production (mainly from cocoa and other crops such as cassava, plantain etc.) and/or animal rearing; working as laborers on people's farm, trading in agricultural commodities; as well as processing of agricultural produce.

Aside the agricultural production providing income for some respondents, non- agricultural activities such as petty trading (20%); formal occupation (such as teaching and nursing) (1%) and remittances from family and friends also served as a source of income for the respondents in the study area. This finding supports the argument by Ruf et al. (2015) who reported that climate change has compelled cocoa farmers to practice crop diversification among other adaptation strategies.

4.2.6 Origin of Respondents

The study found out that out of the 231 respondents interviewed, 173 representing 75 percent were indigenous/native dwellers whiles the remaining 58, representing 25 percent were migrant settlers as depicted in Table 4.1 above. In their study, Aneani et al (2012) expected some differences in the attitude of farmers toward carrying out recommended agronomic practices between settlers and natives. They expected cocoa farmers who were migrant settlers to introduce new technologies and best practices into their respective farming communities which will intend drive the natives to also adopt same.

4.2.7 Output, Area Cultivated and Cocoa Yields

Table 4.2 reports the percentage of farmers, total cocoa output obtained, total land area of cocoa cultivated and cocoa yields in the Sefwi-Bekwai and Akontombra Districts of the Western Region. Out of 231 respondents interviewed, 52% from Sefwi-Bekwai Districts obtained 325.97 metric tons of cocoa on 122.07 hectares of land cultivated. Also, the table indicates that about 48% of the interviewed in the Akontombra Districts cropped 100.27 hectares of land and produced 258.58 metric tons of cocoa.

Table 4.2: Summary of Output, Cultivate Hectarage and Yields of Cocoa

Study Area (n)	Frequency	% of Respondents	Total Output	Mean Output	Yield (mt/ha)	TFS	AFS	Cocoa Yield(Mt/ha)
Sefwi Bekwai	120	52	325.97	2.72	2.67	122.1	2.34	0.37
Akontombra	111	48	258.58	2.33	2.58	100.3	2.08	0.38
Total	231	100	584.55	2.53	2.63	222.3	4.42	0.75

TFS=Total Farm Size AFS=Average Farm Size

Test for difference in means conducted indicates no difference in means of cocoa yields from the two districts
Source: Authors computation from field data (2016)

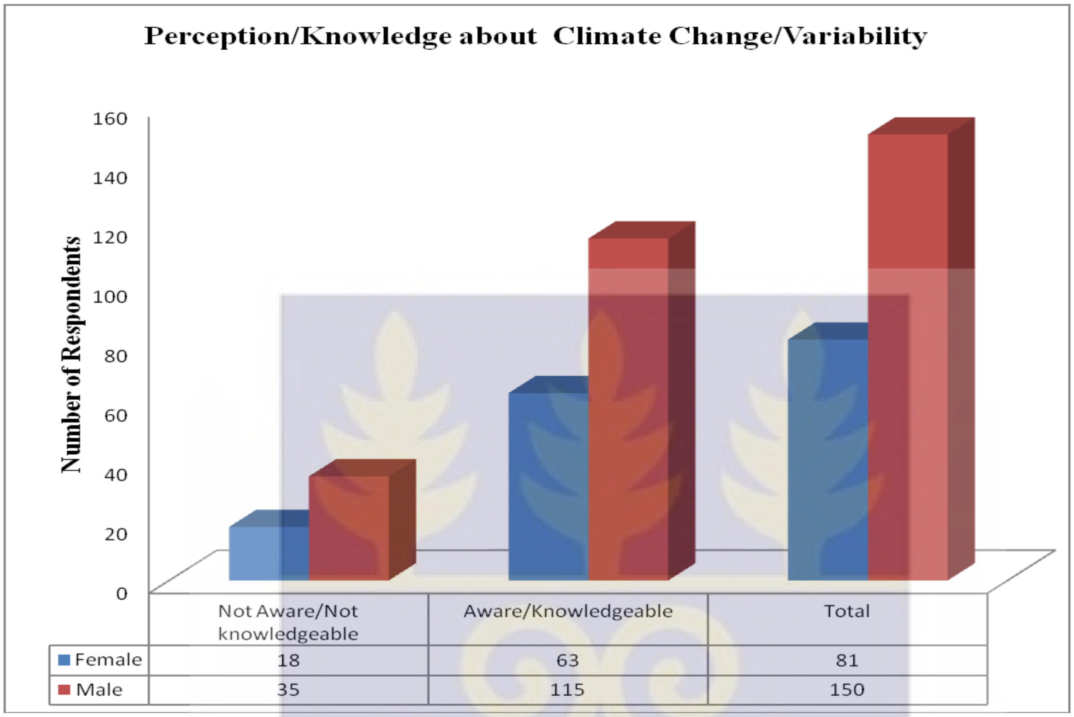
Farmers from Sefwi-Bekwai District have higher cocoa yield than those in Akontombra District. The small-scale cocoa farmers interviewed in the Sefwi-Bekwai and Akontombra Districts obtained cocoa yields of 0.37 metric tons per hectare and 0.38 metric tons per hectare respectively. A difference in means test was conducted to ascertain whether there is a difference in the mean yields from the two districts.

The test revealed no significant difference in the yields from both districts and that the apparent difference could be due to chance. On average, farmers interviewed had cocoa yield of 0.375 metric tons per hectare. This yield figure is slightly lower than the national figure of 0.4 metric tons per hectare in 2014. The average farm size of farmers in Sefwi-Bekwai and Akontombra Districts were 2.34 hectares and 2.08 hectare respectively.

4.3 Perception of Small-scale farmers on Climate Change

The study assessed small-scale farmers' perception on climate change variables (mainly rainfall, temperature and extreme events) over the past 5-10 years.

Figure 4.1: Farmers Perception and Knowledge about Climate Change



Source: Field data (2016)

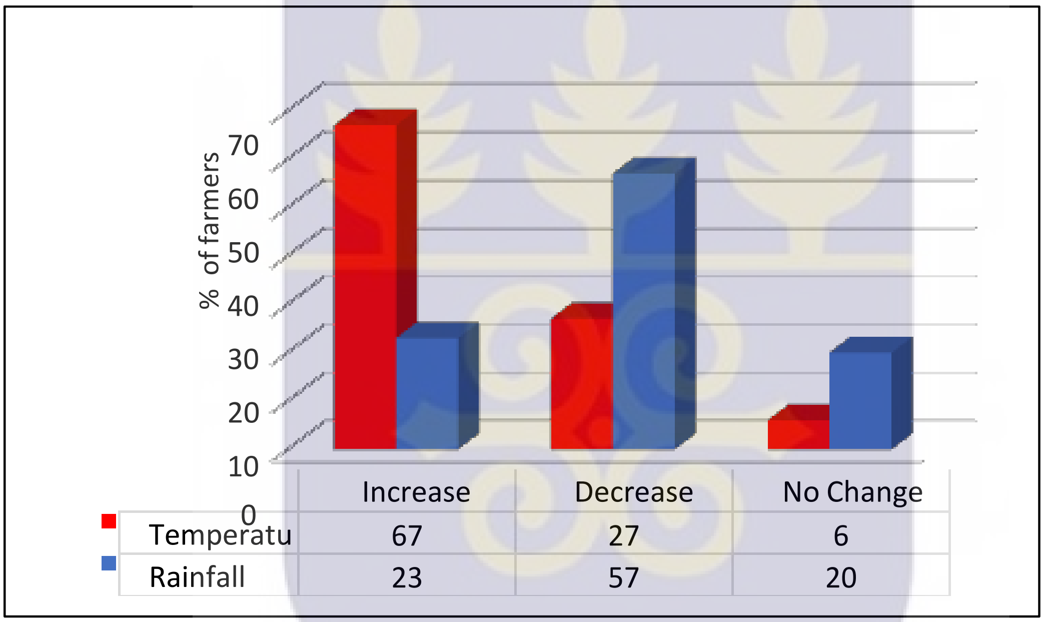
Household survey results shows that a total of 178 respondents representing 77 percent are knowledgeable of the term "climate change", mainly through radio, television, agricultural extension agents and loudspeakers. However, many could not explain what climate change was, therefore there was need to explain this in other words.

Findings is in line with the findings of Fosu-Mensah et al. (2012), who argued that male farmers are more informed about climate change happening than the females because of their easy access to information due to their frequent participation in training and educational programs. It appeared that more men small-scale farmers, representing 65 percent, were knowledgeable about climate change than women farmers, who represented 35 percent (See Table 4.1).

4.4 Perception of Farmers on Climate Change Indicators

Figure 4.2 illustrates the percentage of farmer's perception on changes in temperature and rainfall. Majority of the farmers (67%) perceived that the amount of average annual temperature had increased over the past ten years.

Figure 4.2: Perception of Farmers on Temperature and Rainfall Change



Source: Field data (2016)

About 6 percent perceived that the amount of average annual temperature had not changed over the past ten years. Sixty two (27%) out of the 231 respondents perceived that amount of average annual temperature had decreased over the past ten years.

Also, a greater percentage of the respondents (57%) had the perception that total amount of annual rainfall had decreased over the past ten years. Only 20 percent farmers out of the 231 interviewed perceived that the total amount of rainfall had remained unchanged over the past ten years. Meanwhile, 23 percent farmers thought that total amount of annual rainfall had increased over the past ten years. The findings of this research is consistent with the work of Deressa et al. (2008) who concluded that farmers were aware that temperature was increasing and the level of precipitation was decreasing.

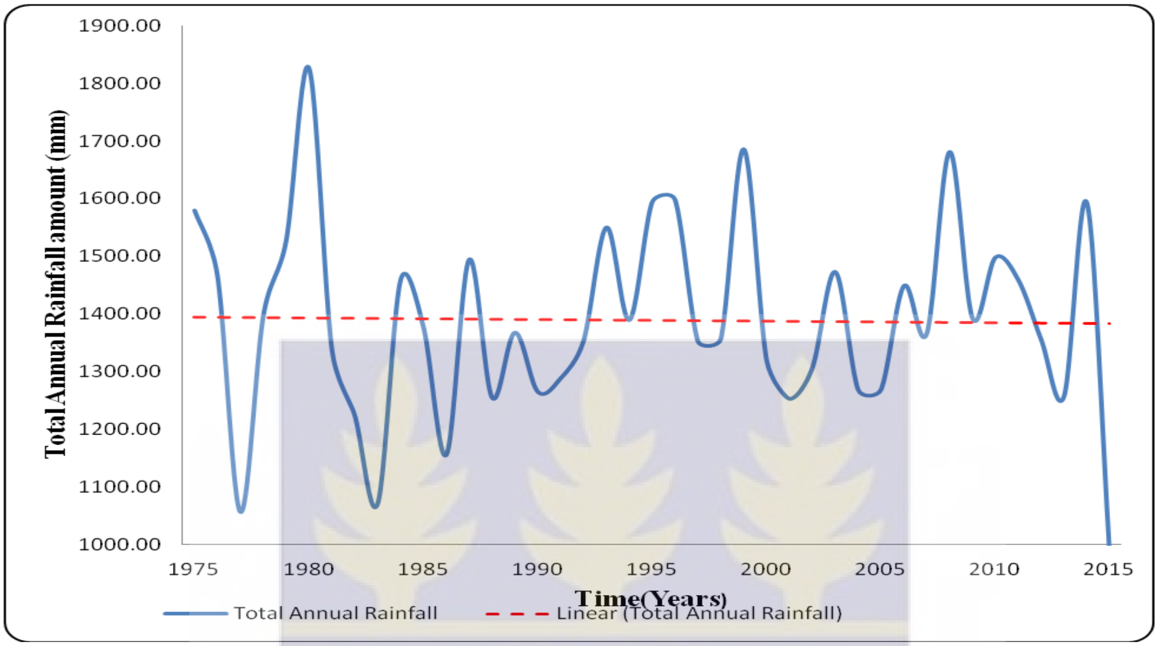
4.5 Trend and Variability of Climatic Variables

This section estimates the annual growth rate of climate change variables from 1975-2014. The trend of variability estimated in this section are total annual rainfall, average annual temperature, average annual relative humidity and average annual bright sunshine duration.

4.6 Trend of Annual Total Annual Rainfall in the Western Region

Fig 4.3 is a graph which shows the trend and direction of change of total annual rainfall recorded over the period 1975 to 2015 in the Western Region of Ghana. There were extremely high and low rainfall amounts recorded between 1997 through 1985 but a much more greater than average rainfall occurring in the 1990 through 2010.The linear trend line shows an upward climb meaning on the average, there has been increase in the level of rainfall over the long run for the period 1975-2015. This supports the argument by Daze (2007) who reported a decline in rainfall amount in Ghana over the past 30 years and further predicted a further decline in precipitation in the years to follow.

Figure 4.3: Trend of Annual Total Rainfall in the Western Region from 1975-2015



Source: Authors computation based on GMA data (2016)

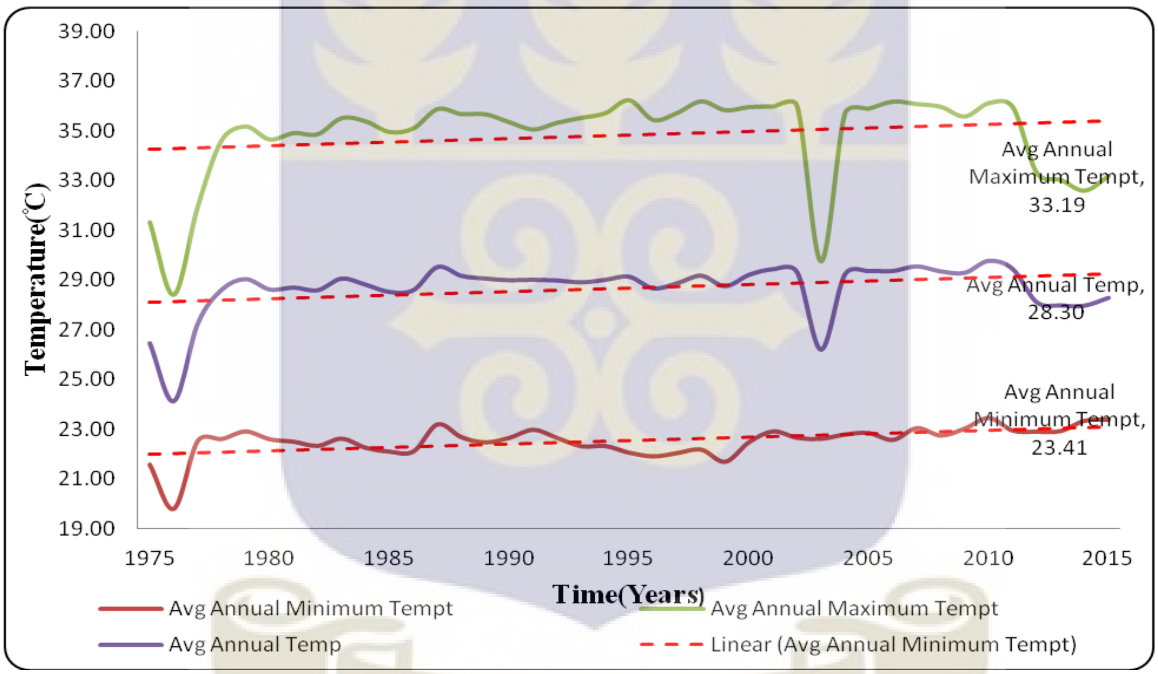
4.7 Trend of Average Annual Temperature

The graph shown in Figure 4.4 illustrates how the trend in average annual temperature fluctuates over the period 1975 to 2015. The variation in average annual temperature is not constant but rather fluctuates mildly each year about the mean. In the long run, there is a steady rise in temperature in the region, consistent with study by Daze (2007) who predicted a steady rise in temperature across the different ecological zones in Ghana Daze (2007).

What extremely high temperatures does to cocoa production is that it intensifies the spread of capsid pests. Temperature is a precursor for mirid attacks. It also reduces soil water reserves via evapotranspiration with resultant effect on yield by reducing the pod set and ultimately, bean sizes. There were not too much departure from the mean generally; however the maximum temperature experienced stronger variation than the minimum temperature over the past 40 years.

A sharp drop in temperature readings were recorded at two data point, 1976 and 2003 but on the average there was a much stable temperature. Over the past 5 years, there has been a decrease in temperature which could be partly attributed to the effect of the policies such as Reducing Emissions from Deforestations and Forest Degradation (REDD) and Afforestation/tree planting programs being carried out in the region for some years.

Figure 4.4: Trend of Average Annual Temperature in the Western Region



Source: Authors computation based on GMA data (2016)

It was evidenced that in the case of the average maximum temperature (Tmax), the rate of variation showed a much higher fluctuation than the minimum temperature (Tmin) over the same period. The departure from the mean was much positive representing upward trend implying there is greater than average temperature variation in the maximum temperature readings than the case of the minimum.

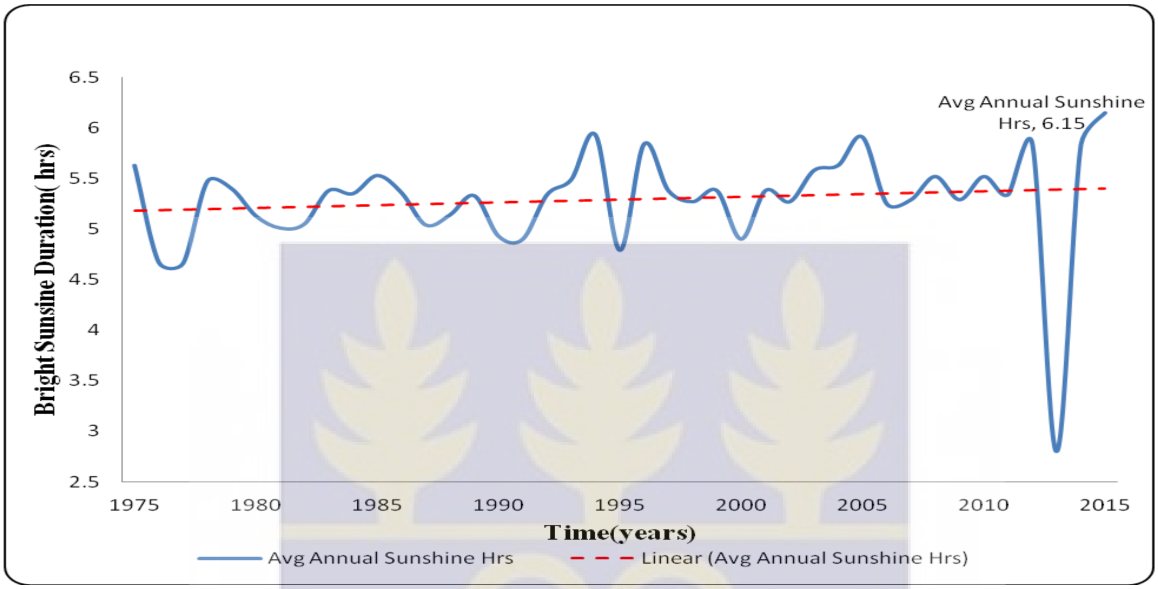
The average maximum and minimum temperature readings were 33.19 and 23.41^{0}C with a mean annual temperature being 28.3^{0}C The results of this study further indicates that the region is becoming warmer which confirms the assertion of the farmers that temperature in the study area has been rising and also corroborates Daze (2007). This further shows that but for the forest policies such as Reducing Emissions from Deforestations and Forest Degradation (REDD) and Afforestation/tree planting programs being carried out in the region for some years, there would have been much warmer than it is at present.

4.8 Trend of Annual Bright Sunshine Duration

Figure 4.5 illustrates growth in bright sunshine duration (BSD) against time in years. The trends in bright sunshine duration fluctuated over the past 40 years with stronger variation above the mean observed between 1992 through 1995,1996-1998 and somewhere around 2005 and 2006. Generally, there had been an increasing trend in the annual bright sunshine duration over the period 1975 to 2015. The steepest fluctuation was recorded in 2014, and peaking strongly in 2015.

This notwithstanding, BSD has the most extreme variations in both directions but on the long run there is more upward trending with positive departure from the mean implying that over the 40- year period, there has been greater than average BSD recorded over the time span. Long Bright Sunshine Duration promotes photosynthetic activity for the crop. In other words, the longer the BSD, the more synthesis of chlorophyll which is the energy source for plant growth and also the higher the flower production (Giraldo et al., 2014).

Figure 4.5: Trend of Average Annual Bright Sunshine Duration in the Western Region



Source: Authors computation based on GMA data (2016)

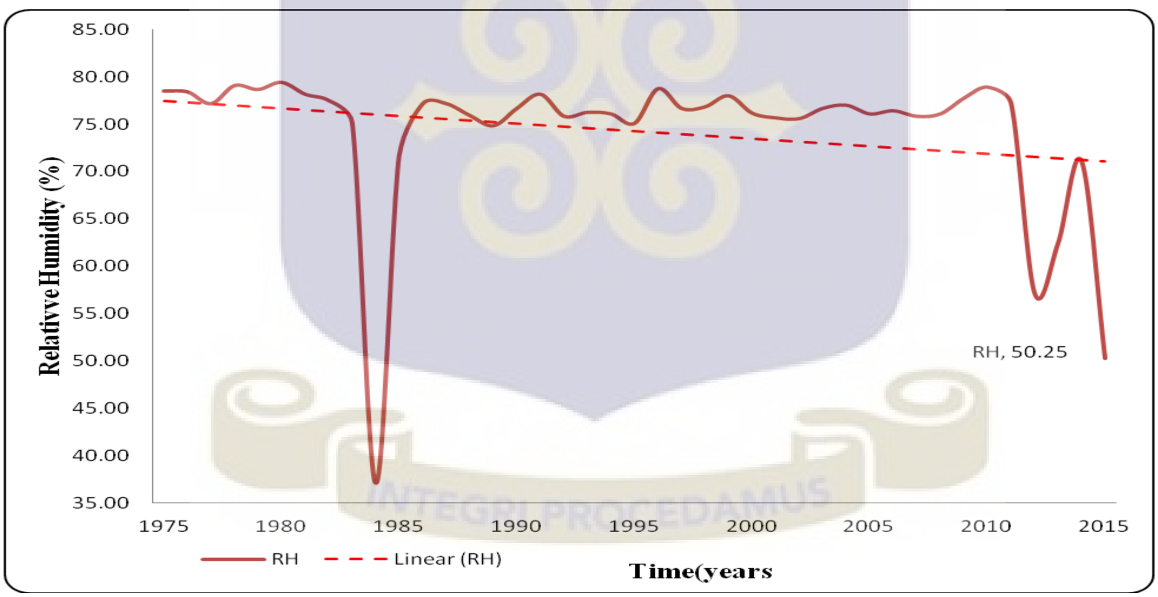
4.9 Trend of Average Annual Relative Humidity

Growth rate in average annual relative humidity (RH) is illustrated in Figure 4.6. The pattern of average annual relative humidity changes yearly with variation that does not depart too much from the mean. The pattern of the growth in average annual relative humidity fluctuates steadily each year. However, over the period 1982-1989 and 1996-2013, there has been downward departure, representing growth rates.

This means this period experienced lower than average relative humidity for those protracted periods. There were sharp decline and rise in the annual growth rates in 2013-2014 and this period record the highest single negative departure for the period. The slope coefficient value for the equation is 0.0001. This value signifies that the percentage change in annual relative humidity is 0.01%. This implies that the average relative humidity decreases by 0.01% each year.

The t-value of 1.02 however implies that the growth rate is not statistically significant. When the following years 1984 and 2014 were controlled, the direction of the change and variation remained the same as seen in the second graph. The decreasing relative humidity recorded in the Western Region over the period is good for the crop. This is because high humidity promotes pests and disease infestation in general and specifically blackpod as reported by Jacobi et al. (2015).

Figure 4.6: Trend of Average Annual Relative Humidity in the Western Region



Source: Authors computation based on GMA data (2016)

4.10 Trend in Climate Change and Variability in the Western Region of Ghana

This section tests the evidence of climate change by comparing means of any two decades' rainfall amount, temperature, relative humidity and bright sunshine duration.

4.10.1 Empirical Evidence of Changes in Rainfall

Table 4.3 indicates the paired t-test for comparing decades' means of total annual rainfall to establish whether there is significant change in the means. For evidence of climate change and variability, the paired t-test between the decades being compared must be statistically significant with respect to the climatic variable in question. The t-statistics and the p-values shown in the table indicate that none of the two decades' means of total annual rainfall values compared is statistically significant. This implies that though there were changes in rainfall between 1975-1984 and 1985-1994; 1975-1984 and 1995-2004;

1975-1984 and 2008-2014, none of these observed changes were statistically significant. Hence, there were no climate change and variability with respect to rainfall between 1975 and 2014. This contradicts the report of IPCC (2014) which suggests evidence of variability in rainfall.

Table 4.3: Paired t-test for Comparing Decade's Means of Annual Rainfall

Decades	Mean Rainfall	n	Df	t-statistics	t-critical (one tail)	P-Value (one tail)
1975-1984	1394.41	10				
1985-1994	1349.72	10	9	0.4414	1.8331	0.3347
1975-1984	1394.41	10				
1995-2004	1420.83	10	9	-0.3254	1.8331	0.3761
1975-1984	1394.41	10				
2005-2014	1431.92	10	9	-0.5188	1.8331	0.3082
1985-1994	1349.72	10				
1995-2004	1420.83	10	9	-1.1391	1.8331	0.1420
1985-1994	1349.72	10				
2005-2014	1431.92	10	9	-1.1774	1.8331	0.1346
1995-2004	1420.83	10				
2005-2014	1431.92	10	9	-0.1424	1.8331	0.4449

Source: Authors computation based on GMA data (2016).

Also, the decades' means between 1985-1994 and 1995-2004; 1985-1994 and 2005-2014; and 1995-2004 and 2005-2014 are much closed to each other that none of them shows significant differences. This can be concluded that for the past four decades, annual rainfall amounts in the study area have changed but not significant based on the P- values. Though, none of the test is significant, the difference in means between 1975- 1984 and 1995-2004; 1975-1984 and 2005-2014; 1985-1994 and 1995-2004; 1985-1994 and 2005-2014; and 1995-2004 and 2005-2014 were inconsistent with *a priori* expectations, rainfall levels have increased over the decades but not statistically significant. Comparing the decadal means in total as seen in Figure 4.5, Mean Decadal Annual Rainfalls (1975-2014) over the long run, shows a steady increase in rainfall in the region with a Mean Total annual rainfall amount of 1431.92 mm

4.10.2 Empirical Evidence of Changes in Temperatures

The paired t-test results in table 4.5.2 show the empirical evidence of changes in the decades' means average annual temperature. The t-statistics and the p-values shown in the table indicate that only one of the two decades' means of total average temperature values compared is statistically significant. The difference between 1975-1984 and 1985-1994 means of decade temperature is statistically significant at 10% and inconsistent with the *a priori* expectation. This means there is significant difference between decade mean temperature of 26.40 ^{O}C and 27.52 ^{O}C. The difference in decades' means between 1975-1984 and 1995-2004; 1975-1984 and 2005 and 2014 are not statistically significant but also inconsistent with the *a priori* expectation. They show the average annual temperature for the study area is falling, contradicting the report by IPCC (2007) that global temperatures are rising.

Table 4.4: Paired t-test for Comparing Decades' Means of Annual Temperature

Decades	Mean Temperature	N	df	t-statistics	t-critical (one tail)	P-Value (one tail)	
1975-1984	**26.4008**						**10**
1985-1994	**27.5183**	**10**	**9**	**-2.1618**	**1.8331**	**0.0589***	
1975-1984	26.4008						10
1995-2004	27.2550	10	9	-1.2497	1.8331	0.1215	
1975-1984	26.4008						10
2005-2014	26.5833	10	9	-0.1658	1.8331	0.4360	
1985-1994	27.5183						10
1995-2004	27.2550	10	9	0.8809	1.8331	0.2006	
1985-1994	27.5183						10
2005-2014	26.5833	10	9	1.1937	1.8331	0.1316	
1995-2004	27.2550	10					
2005-2014	26.5833	10	9	0.8867	1.8331	0.1992	

Source: Authors computation based on GMA data (2016)

4.10.3 Empirical Evidence of Changes in Relative Humidity

Table 4.5 depicts paired t-test for comparing decadal means of relative humidity. The t-test value of 1.66 implies that the difference between 1995-2004 and 2005-2014 means of relative humidity is statistically significant at 10%. This difference between the mean is not consistent with the *apriori* expectation as the test does not support that relative humidity is decreasing. Even though difference in decade means between 1975-1984 and 1985-1994; 1975-184 and 1995-2004; and 1985-1994 and 1995-2004 are not statistically significant, they are consistent with the *a priori* expectation. They show that relative humidity had decreased over these decades with the mean bean 72.9%, supporting the assertion of IPPC (2014) that there has been variability in precipitation across the African continent.

The best fit trend line was the polynomial which confirms the declining trend.A decline in relative humidity means less pest and disease infestation to the cocoa crop particulary to blackpods, caused by phytopthera palmivora or megakaya which is known to cause significant losses in the regions of 20-30% annually and in some plantation where humidity is high,losses up to 90% have been recorded Vanegtern (2015).

Table 4.5: Paired t-test for Comparing Decades' Means of Relative Humidity

Decades	Mean Relative Humidity	n	df	t-statistics	t-critical (one tail)	P-Value (one tail)
1975-1984	73.9167	10				
1985-1994	75.9667	10	9	-0.4917	1.8331	0.3174
1975-1984	73.9167	10				
1995-2004	76.6417	10	9	-0.6547	1.8331	0.2645
1975-1984	73.9167	10				
2005-2014	72.9000	10	9	0.2309	1.8331	0.4111
1985-1994	75.9667	10				
1995-2004	76.6417	10	9	-1.1913	1.8331	0.1320
1985-1994	75.9667	10				
2005-2014	72.9000	10	9	1.2911	1.8331	0.1144
1995-2004	**76.6417**	**10**				
2005-2014	**72.9000**	**10**	**9**	**1.6640**	**1.8331**	**0.0652***

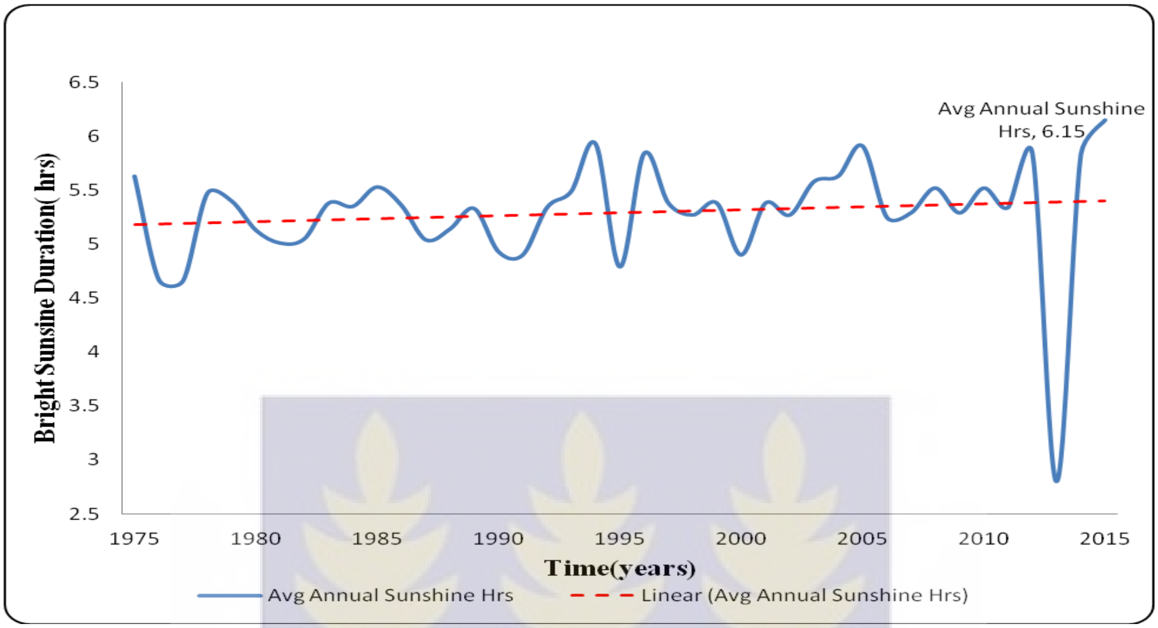
Source: Authors computation based on GMA data (2016)

4.10.4 Empirical Evidence of Changes in Bright Sunshine Duration

The empirical evidence of climate change caused by changes in decades' means of bright sunshine duration is depicted in table 4.5 The paired t-test for the difference in bright sunshine duration between 1975-1984 and 1985-1994 is statistically significant at 5%. This is supported by the p-value of 0.0369. This implies that there is a significant difference between the mean decadal bright sunshine values of 7.4 hours and 7.1 hours. The difference between the mean is not consistent with the *apriori* expectation as the test does not confirm that bright sunshine duration is increasing. The finding however corroborates that of Mabe et al. (2013) for the same period. Hence, the average bright sunshine duration had decreased from 7.4299 hours (1975-1984) to 7.1.83 hours (1985-1994).

Also, there is a significant difference between the decades' means of bright sunshine duration of 1985-1994 and 2005-2014. The p-value of 0.0274 indicates that the test is significant at 5%. The positive figure for the difference in the decadal means compared here supports the assertion by Mabe et al. (2013) who reported significant difference and increasing bright sunshine duration between 1980-1989 and 2000-2009 decades.

Figure 4.7: Empirical Evidence of Changes in Bright Sunshine Duration



Source: Authors computation based on GMA data (2016)

Table 4.6: Paired t-test for Comparing Decades' Means of Bright Sunshine

Decades	Mean Sunshine Duration	N	df	t-statistics	t-critical (one tail)	P-Value (one tail)
1975-1984	**7.4299**	**10**				
1985-1994	**7.1083**	**10**	**9**	**-2.0269**	**1.8331**	**0.0369****
1975-1984	7.4299	10				
1995-2004	7.2045	10	9	-1.2924	1.8331	0.1205
1975-1984	7.4299	10				
2005-2014	7.3585	10	9	-0.9654	1.8331	0.1819
1985-1994	7.1083	10				
1995-2004	7.2045	10	9	0.9511	1.8331	0.1929
1985-1994	**7.1083**	**10**				
2005-2014	**7.3585**	**10**	**9**	**1.2911**	**1.8331**	**0.0274****
1995-2004	7.2074	10				
2005-2014	7.3558	10	9	1.0424	1.8331	0.1639

Source: Authors computation based on GMA data (2016)

***Significance at 5%*

4.11 Effects of Climate Change Indicators on Cocoa Output

Table 4.6 represents regression results on the effects of climate change indicators on cocoa output in the study area. The log-log model was used because it gave better estimators and goodness of fit than the other models. The coefficient of determination (R^2) shown in the table indicates that 94% of the variations in cocoa output is explained by the variation in the previous years' cocoa output *(Y^R_{t-1})*, temperature *(T_t)*, rainfall *(R_t)*, variations between maximum and minimum temperatures *($VarT_t$)* and rainfall *($VarR_t$)*. The F-statistics also shows that the explanatory variables jointly and significantly affect cocoa output. The Durbin-Watson value of 2.2 implies that there is no linear relationship between any of the explanatory variables (no multicolinearity).

Table 4.7: Cocoa output Response to Climate Change Variables

Dependent Variable: Cocoa Output (YR)
Method: Least Square
Sample: 1975-2015
R-squared = 0.9414
F-statistics = 98.91
Prob > F = 0.0000***
Durbin-Watson Stat=2.1630

Variable	Coefficient	Robust Std Error	T stat	P value
lnEdu	0.1312**	0.0672	1.9500	0.0510
lnAge	-0.4019***	0.0830	-4.8400	0.0000
Ext	0.0073	0.0071	1.0200	0.3060
In(YRt-1)	0.8559***	0.0615	13.9100	0.0000
In(Tt)	0.6101	1.0567	0.5800	0.5680
In(Rt)	0.0880	0.4491	0.2000	0.8460
In(VarTt)	0.1100	0.1986	0.5500	0.5830
In(VarRt)	-0.2380***	0.0836	-0.2850	0.0070
constant	0.3594	4.2866	0.0800	0.9340

***** represents 1% levels of significance respectively.*

Source: Authors computation based on data from COCOBOD & GMA (2016)

From Table 4.7, the coefficient of previous years' cocoa output *(Y^{R}_{t-1})* which measures effects of technological changes and management practices on cocoa output falls in line with *a priori* expectation. It is also significant at 1% implying that technological changes and management practices significantly affects cocoa output. This means that enhancing technology by 1 unit will lead to a corresponding increase in cocoa output by 0.86mt/ha.

Worth noting in the findings is the consistency of the variation in rainfall amount *($VarR_t$)* with the *a priori* expectation. It is significant at 10% meaning that variation in rainfall (extreme rainfall) has significant effects on cocoa outputs in the study area. From the table above, it can be concluded that a 1mm extreme increase in rainfall amount will result in a 0.24mt/ha decrease in cocoa output. In this study, temperature, rainfall amount and extreme temperatures do not have significant effects on cocoa output. These results are inconsistent with the finding of the work of Oyekale et al. (2009) and Anim-Kwapong and Frimpong (2005) whose studies concluded that total rainfall, average annual temperature and extreme temperatures significantly influence the output of crops.

For every additional year increase in a cocoa farmer's education will lead to a corresponding 13.12% increase in cocoa yield. Education of the cocoa farmer (lnEdu) was found to be significantly associated with yield because more educated farmers can make more prudent decisions with respect to appropriate production technologies and input use which will translate into higher yields. Aneani and Ofori-Frimpong (2013) found this to be the case for cocoa farmers in 6 different districts in Ghana.

Age of cocoa farm (lnAge) had a significantly inverse relationship with the yield of cocoa because older cocoa farms have old trees which have likely outgrown their economic lifespan and therefore have begun to decline in yield. The higher yields associated with younger cocoa farms could also possibly be due to the fact that these younger farms have younger plants that are newly improved varieties and therefore have better yields. Edwin and Masters (2005) also held similar views in their study on genetic improvement and cocoa yields in Ghana.

4.12 Adaptation Strategies of the Small-Scale Cocoa Farmers

The study categorized the adaptation strategies adopted by the cocoa farmers to mitigate the negative effect of climate change on cocoa production into three main groups, namely on-farm, off-farm and non-farm. On-farm adaptation strategy was the most (about 50.2%) used strategy adopted by the cocoa farmers' whilst` the least used strategy was the non-farm strategy. The detailed activities embedded in each of these strategies are discussed below.

4.12.1 On -Farm Adaptation Strategies

On-farm adaptation strategies were the most employed strategy by the majority (116) representing 50.2% of the small-scale cocoa farmers. These strategies include shade management, farm size strategies, soil fertility management, land preparation strategies, crop diversification and lining and pegging strategies.

It was revealed from the study that most farmers (111), representing 87% of the farmers in this grouping mainly adopted shade management as an on-farm adaptation strategy which further depict the benefits of Farmer Based Organizations(FBO's), Farmer Field School(FFS) and largely the crucial role extension plays in disseminating good agricultural practices with respect to the optimal level of shade requirement for an acre eg 5-8 beneficial trees like glyrecidia which is not host to pest and diseases as well as playing key role in recycling the nutrient in the soil.

A varied number of reasons such as lack of access to recommended seedlings, finance among others accounted for about 15 farmers, representing 13% who did not adopted shade management. It also came to the fore, that majority (68%) of the farmers strongly relied on organic materials eg cocoa leaf-litter, pod husk, crop residue and cleared weeds as soils fertility management practice. Inorganic fertilizers such as Asaase Wura , Sidalco liquid fertilizer etc formed the remaining were what the remaining 32% of farmers relied on to improving soil fertility.

The high cost associated with these inorganic fertilizers accounted for the difference in percentage. As part of land preparation, respondents who slash , gather and burn were in the majority(65%).The logic is that the released potassium serves as rich nutrients for plant growth. To the farmers, dangerous animals are killed by this practice as well. Quite interestingly, a great number of farmers 35% allow the slashed bush to rot and mulch the farm soil increasing the soil organic matter content and consequently improves soil water conservation

Majority (72%) of the farmers practice farm extension with the new and improved seedlings and also replanting existing farms and moribund one not only with cocoa but other food crops as a result taking advantage of diversifying their crops as a way of mitigating against the varying climatic conditions. Crop diversification in essence involves farmers using production activities that make optimum use of the prevailing temperature and water conditions as well as using drought tolerant and or temperature stress resistant varieties.

28% of the farmers, being the remaining number were engaged in increasing intensification practices specifically through replanting missing stance.

In order to adapt to crop failure, 53% of the cocoa farmers adopted lining and pegging strategy whereas the remaining 47% were not practicing lining and pegging. The farmers who subscribed to lining and pegging were of the view that the practice prevent rapid pest and disease infestation and easy to control when they exist. It also helps maintain the required number of plants thus overcoming the problem of over- estimating or under-estimating the input requirement thus preventing financial loss and crop nutrient loss or under optimal control of pest and disease. It was revealed that lack of technical knowledge was the main reason for the non-adopters to subscribe to this strategy.

4.12.2 Non-farm Adaptation Strategies

Aside on-farm adaptation strategies being the most used strategy; small-scale cocoa farmers also adopted non-farm adaptation strategies. These strategies broadly include alternative livelihood sources for the cocoa farmers in the face of climate outside of the farm sector. Out of the 32.9% who adopted non-farm strategies, 24% were engaged in working on other people's farms, 8% were involved in trading in agricultural commodities whiles the remaining 2.6% were into agricultural processing.

Wage employment from non-agricultural sources (mainly from petty trading, masonry and carpentry) (7%), migration to the cities (4%) and remittances from family and friends (1.6%) were the most used non-farm adaptation strategy used the cocoa farmers in the study area. The above findings are consistent with the work of Anim-Kwapong and Frimpong (2005) whose study concluded that non-farm adaptation strategies are anticipatory adaptive measures (insurance) against loss of livelihood as a result of loss of income from cocoa production caused by climate change.

4.13 Determinants of Adaption strategies to climate change and variability

Multinomial logit was run using the Maximum Likelihood Estimation method. The results for the determinants of choice adaptation strategy are presented in Table 4.8. The number of farmers used as the data points were 231 cocoa farmers sampled from the study. The overall model recorded a log likelihood (-224.10) ratio which is statistically significant (P<0000) presented in appendix 3. This shows the model has a strong explanatory power of the choice of adaptation strategy used by the farmers. The estimates presented in Table 4.8 are the marginal effects with their corresponding standard errors in parenthesis. For a multinomial logit, the coefficient estimates can only be used to predict the direction of effect of the independent variables but not the probabilities. The problem of heteroscedasticity was addressed in the model by estimating a robust model that computes robust variance of the error term. This generated error terms which were homoscedastic. The study checked for multicollinearity by fitting an Ordinary Least Square model and checking the Variance Inflation Factor (VIF). The VIF generated were all less than 10 as presented in Appendix 3

In all age, gender, education and membership of FBOs were statistically significant determinants of choice of adaptation strategies to climate change and variability. Age was found to be statistically significant when it came to adopting both On-farm and Non-farm farm adaptation strategy. An increase in age increased the probability of a farmer adopting On-farm. This finding is consistent with the findings of Etwire et al. (2013), who found that older people were more probable to adopt the use of chemical and fertilizers which are On-farm adaptation strategies. This could be attributed to the fact that older farmers had more access to resources to invest into their farming activities as compared to younger ones. These resources could be the reason they could easily get involved into other Non-farm activities than rather not adopt any adaptation strategies.

Membership of FBO makes a farmer 29.82 percent more likely to adopt On-farm adaption strategies. The FBO's identified in the study area were organizations that were privileged to get access to basic training on modified and advanced farming practices which will help farmers increase their yield. These FBO trained farmers on adaptation strategies to help them mitigate the negative effect of climate change. Due to the fact that members of these FBO had information on farming practices which will increase their yield they channeled their efforts into On-farm adaptation strategies. They undertook good agricultural practices at the right timing such as chemical and fertilizer application at the right time and dosage, shade management practices timing of the seasons as well as agro forest practices.

Males are 13.24% less likely to choose on-farm adaptation strategies. Bryan et al. (2009) found similar results in their study which revealed that males were more likely to rare animals on their farms as adaptation strategies as compared to females. In rural African settings where males have dominance in resources that females. Males, are easier for males to adapt compared to females where resources are needed to carry out a strategy. It was found in the study also that males were 23.16% more likely to choose non-farm adaptation strategies than their female counterparts. Clearly this can confirm the pattern that males had more access to resources and could invest as compared to females who will not invest.Education makes a farmer more likely to choose both on farm and non-farm adaptation strategy. Educated farmers had easier access to information as to adaptation strategies as compared to uneducated farmers. These educated farmers could easily monitor weather forecast. These added advantages makes it easier for them to pick up practices both on and off the farm which will help them in mitigating losses which they might have incurred due to the weather or climate failure. Instead of not adapting, they engage in practices such as timing the weather, application of fertilizer, diversifying the crops they cultivate as well as addition of animal farming to their livelihood sources.

Table 4.8: Multinomial logit for determinants1 of adaptation strategies

Number of observation	231	
Wald chi2(18)	1586.5700	
Prob > chi2	0.0000	
Pseudo R2	0.4140	
Log pseudo likelihood	-224.0949	
Variables	Adaptation Strategies	
	On-Farm	Non-Farm
Age	-0.0009*	-0.0009*
	(-1.8900)	(-1.7)
Household size	0.0120	-0.0114
	(-0.5700)	(-0.63)
FBO	0.2982***	-0.2378
	(-13.01)	(-0.29)
Farm size	0.0001	-0.0001
	(-0.27)	(-0.64)
Output	0.0000	0.0000
	(-0.38)	(-0.48)
Gender	-0.1324***	0.2316***
	(-23.65)	(-23.78)
Education	0.2240***	0.0436***
	(-13.24)	(-9.21)
Extension	-0.0094	0.0025
	(-1.06)	(-0.52)
Source of labour	0.0000	-0.0000
	(-0.52)	(-1.06)

* and *** denote statistical significance at 10% and 1% significance levels respectively
(Values in bracket are the z-values)
No adaption category was used as base
Source: Field survey, 2016

[1]Marginal effects reported

4.14 Barriers to Climate Change Adaptation

Barriers facing adaptation to climate change are the constraints that farmers encounter as they try to adjust to the effect of climate change on their cocoa production. In this study the farmers were presented with some constraints (observed from pre-trials, literature and confirmed from the recognisance survey) and allowed to ranked. In ranking, the barrier that assumes the largest number in the sum of ranks is taken as the least important among the barriers identified. Table 4.9 shows the collated source and the mean ranks.

Table 4.9: Constraints to Climate Change and Variability

Constraints to Adaptation	Mean Rank	Rank
Inadequate Financial Resources/Poverty	2.17	1
Inadequate Weather Information	2.69	2
Low Technological Knowledge	2.84	3
Inadequate Labour Resource	3.38	4
Inadequate Land Resource/Farmland	3.91	5

Source: Authors' computation from field data (2016)

The small-scale farmers in the study area ranked poverty/lack of financial resources as the major barrier to adapting to climate change challenges. The small-scale farmers complained that their lack of financial resource was hindering their adoption of appropriate adaptation strategies/technology that could reduce the climate change challenges on their cocoa production. This study confirms the study of Mabe (2011) whose study concluded that most farmers do not adapt to climate change challenges because they do not have adequate financial means.

Inadequate weather information was ranked the second most pressing barrier influencing adaptation to climate change. Majority of the small-scale cocoa farmers lamented that limited weather information in the study area brought about not knowing what adaptation strategy to adopt. That is to say, their adoption of a particular adaptation strategy (whether on-farm, off-arm or non-farm) was highly dependent on weather information in the study area. Low technical knowledge on the use of available technology (such as improved seed, fertilizers and pesticides) was ranked the third most pressing barrier affecting the small-scale farmers' adaptation. The farmers were of the view that although there were appropriate technology that could improve their adaptation, they lacked the knowledge and expertise as to when and how to use these technologies. This supports a study by Moser and Ekstrom (2010) who reported availability of information and access to the various options as barriers to adaptation to climate change.

Inadequate farm labour was also hindering these small-scale farmers adaptation. This was ranked forth. Most on-farm adaptation strategies requires high amount of labour and this the farmers complained that despite the high cost involve in hiring labour, the youth who mostly hire out their services on the farms have migrated to the cities and neighbouring villages to look out for better income earning opportunities. The least ranked barrier was availability of farm land. This might be due to the fact that most the small-scale farmers in the study area were household heads and as a result had enough lands which could be used for expansion (on-farm adaptation strategy).

The Kendall's Coefficient of Concordance was used to test the agreement among the farmers' ranking of barriers. The estimated Kendall's Coefficient, *w*, was 0.179 implying that there was 17.9% agreement among the farmers ranking of barriers. The computed wald chi-square value of (166) was significant at 1% level. Decision rule is to reject the null hypothesis in favour of the alternative hypothesis and conclude that there is agreement among the farmers' ranking of barriers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this chapter, the summary and conclusion of the results are presented in section 5.2 and 5.3 respectively. The chapter also presents policy recommendations of the study and suggestions for future research.

5.2 Summary

Climate change and variability is a major concern for the small-scale cocoa farmers. The main objective of this study was to analyse the effects of climate change and variability on cocoa outputs. The study employed the use of both primary and secondary data. Multistage sampling techniques were used to select the respondents. Primary data was collected from cocoa farmers in the Sehwi Bekwai and Akontombra districts in a survey. Secondary data on climate in the Western Region was obtained from the Ghana Meteorological Agency. The data was analysed using Microsoft Excel and STATA softwares.

The first and second objective of the study described farmers' perception on climate change and variability and the trends for their variables (rainfall, temperature, relative humidity and bright sunshine duration) with the help of paired t-test statistical analysis. The decadal means for all the variables were compared for the period 1975-2015 differences which were significant. The study determined the major adaptation strategies employed by the small scale cocoa farmers in the face of climate change and variability and finally the determinants that influences the adoption of an adaptation employed by the small-scale cocoa farmers in reducing the effects of climate change on cocoa production.

This was done by asking farmers to choose the adaptation strategies they use. The study also used the Kendall's coefficient of concordance to estimate the magnitude in the rankings of the barriers facing the farmers' adaptation to climate change.

Majority of the farmers (67%) perceived that the amount of average annual temperature had increased whiles 57% perceived rainfall had decreased over the past ten years. The paired t-test revealed that climate has changed over the past 40 years in terms of significant changes in only 1975- 1984 and 1985-1994 decade's temperature and no other decades was significant. It was realized in the study that climate change and variability has not taken place in the study area with respect to significant changes in the decadal mean rainfall for the period since there is no extended change in the mean properties and or variability of rainfall for more than one decade. Rainfall had not significantly change during the period 1975-2014.The same can be said of temperature and relative humidity. However, bright sunshine duration revealed significant changes in the means for the decades, 1975-1984 and 1985-1994 with a P value 0.0369 and 1985-1994 and 2005-2014 giving a P-value of 0.0274. Since these two decades were statistically significant, we can infer that climate change and variability has occurred in the study area with respect to Bright Sunshine Duration(BSD) because the change was statistically established in more than one decade.

The study identified that previous year's output and extreme rainfall had significant effect on the output of the small-scale cocoa farmers. Temperature, rainfall, and extreme temperature had no significant effect on cocoa output. A 1mm increase in extreme rainfall (Rainfall square) will results in a 0.24mt/ha decrease in cocoa output while a unit increase in technology(coefficient of previous years cocoa output, representing technology and management practices will results in a 0.86mt/ha increase in cocoa output.

In all, age, gender, education and membership of FBOs were statistically significant determinants of choice of adaptation strategies to climate change and variability Membership of FBO makes a farmer 29.82 percent more likely to adopt On-farm adaption strategies. The study revealed that majority (about 52.8%) of the small-scale cocoa farmers were practicing on-farm adaptation strategies such as shade management, soil fertility management, land preparation strategies, crop diversification/farm size strategies and lining and pegging strategies. The remaining were into off (34.6%) and non-farm (12.6%) adaptation strategies. Finally, the study shows that among the barriers hindering the small-scale farmers' adaptation to climate change, inadequate financial resources/high level of poverty was the most pressing barrier whiles the least barrier was lack of land resource/farm land.

5.3 Conclusions of the study

This sub-section provides the conclusion to study. The thesis has centered on the effects of climate change/variability on cocoa output, their perceptions on climate change, their responses to climate change impacts and the barriers hindering the adaptation to climate change challenges. From the results of the study, the following conclusions can be drawn:

- Most of the small-scale cocoa farmers in the study area had noticed and were aware of climate change and variability but more men considered changes and variation in temperature and rainfall than women. Deforestation, bush burning and increased in population were the main cause of climate change in the study area.

- Climate has changed with strong variability over the past 40 years in the Western Region in terms of significant changes in decade temperature, relative humidity and bright sunshine duration. However only changes observed in Bright Sunshine Duration is statistically significant at 5% with P-values of 0.0369 and 0.0274 for the decades 1975-1998 and 1985-1994, and 2005-2014 decades respectively Rainfall had not significantly changed during the period 1975-2014.

- Temperature, rainfall, and extreme temperature had no significant effect on cocoa output. Whereas previous year's output and extreme rainfall had significant effect on the output of the small-scale cocoa farmers.

- On-farm adaptation strategy was the most employed strategy by the small-scale cocoa farmers, whiles the least used strategy was non-farm adaptation strategy.
- Finally, lack of financial resources/poverty was the main barrier facing the small-scale cocoa farmers' adaptation to climate change. The least barrier was inadequate land resources/farm land.

5.4 Policy Recommendations

From the key findings of this study, a number of policy intervention and recommendations are identified. These are:

- Climate change awareness programmes should target both sexes, in order to build their capacity to cope with climate change stresses and uncertainties on local livelihoods as few women were aware about climate change than men.

- Since extreme rainfall and technology (previous years' yield) significantly affect cocoa output, it is recommended that COCOBOD, MoFA and NGOs should design improved technology such as cocoa seeds/seedlings that can withstand extreme climatic events and boost yields.

- Also Government and existing NGOs in the study area should try as much as possible to design policies and programs to improve upon the identified adaptation strategies. Based on the findings that majority of the farmers were involved in on-farm adaptation strategy, they should be empowered in order to attain high adaptive capacity status. Policy makers should design policies to train the farmers on the use of the identified on farm adaptation methods to help them adapt well to the changing climatic conditions. When this is done output would be boost output and cocoa farmers would not diverse to other sources of livelihood.

- Lastly, based on the findings that lack of financial resources/high level of poverty was the major barrier affecting the small-scale cocoa farmers adaptation to climate change, it is recommended that government and NGOs should empower the small- scale cocoa farmers financially so as to adequately adapt to the changing climate.

5.5 Suggestion for Future Research

It is suggested that future researchers should look at income differential between small-scale farmers who adapt to climate change and those who do not adapt to climate change.

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APPENDICES

Appendix 1:Sample Questionnaire

SAMPLE QUESTIONNAIRE FOR FARMERS

EFFECTS OF CLIMATE CHANGE/VARIABILITY ON COCOA YIELDS: A CASE OF THE SEFWI BEKWAI & AKONTOMBRA COCOA DISTRICTS OF THE WESTERN REGION OF GHANA

This questionnaire seeks to obtain information on the effects climate change and variability is having on the yields of both male and female small-holder cocoa farmers, their adaptation strategies in the face of climate change, as well as their perceptions on climate change and variability

This interview is purposively for academic work and entirely anonymous. No one will know your name and so you may speak quite freely to the interviewer. Thank you for your time and assistance in our work.

Reference Information

Name of Respondents…………………… Serial Number…………….

Mobile Number………………………… Date of Interview …./…./2016

Name of Community………………….. Name of District……………..

A. Demographic Information

1. Age of respondent: [ ] yrs
2. Gender of respondent: 0. Male [ ] 1. Female[ ]
3. Education of respondent: 1. None [ ] 2. Primary Education [ ] 3. Middle/JSS [ ] 4. SSS/Tech/Voc[ ] 5. Training College [ ] f. Tertiary [ ]
4. Marital Status: 0. Single [ ] 1. Married [ ] 2. Divorced/Separated [ ] 3. Widowed[ ]
5. Religion: 1. Traditional religion [ ] 2. Christian [ ] 3. Muslim [ ] 4. Other, specify…………………
6. Ethnicity: 1. Akan[ ] 2. Fante[ ] 3. Sefwi[ ] 4. Ewe [ ] 5. Ga 6. Dagomba 7. Other, specify……
7. Place of Origin of respondent: 1. Native [ ] 2. Settler/Migrant [ ] 3. Other, specify…………….
8. How often do you stay/reside in the community/village: 1. Stay during the farming season [ ] 2. Stay throughout the year.[ ]
9. Years of farming experience of respondent: [ ]years
10. Is the respondent the head of household: 0. No[ ] 1. Yes[ ]
11. If no, provide name of household head: …………………………………………..
12. Sex of Household Head: 0. Male [ ] 1. Female[ ]
13. Age of Household Head: [ ] years
14. Household Size [ ]

15. Type of land ownership: 1. Own land (purchased/Inherited) [ ] 2. Rented[ ]
3. Shared holding[ ]
16. Do you belong to a Farmer Based Organizations (FBOs) or any Cooperative: 0. No[ ] 1. Yes[ ]
17. If yes to question 16, name the organization/cooperative……………………………………………
18. Sources of Income(Please complete the table below)

Source of Income	Amount in GHS
1. Farming (sales from last harvest)	
2. Off-farm activities (e.g. laborer)	
a. Wage	
b. kind (estimate in monetary terms)	
3. Petty trading	
4. Formal Occupation (e.g. teacher, nurse etc.)	
5. Remittances	
6. Pension / government transfers	
7. Other, specify	

19. What is the Size of your cocoa farm [ ] acres
20. How long have you being in this enterprise/business [ ] years
21. What was your yield for the past Two(2) years

Plot/Farm	Size(Acres)	Variety	Yield(bags)			
			2013 / 2014		2014 / 2015	
			Light	Main	Light	Main

a) Total yield 2013/14[ ] b) Total yield 2014/15 [ ]

22. In your view, which were the most critical factors that influenced these yields
a) Rainfall [ ] b) Sunshine [ ] c) Relative Humidity [ ]
d) Inputs [ ] e) Others[ ] if yes please specify

B. Perception on Climate Change

23. How knowledgeable are you about climate change and variability
a) Cannot tell [ ] b) Know a bit [ ] c) Very knowledgeable [ ]
24. How do you access climatic information?
a) Radio Programs [ ] b) Television [ ] c) Government Extension Officer(s) [ ]

d) Private Extension Officer(s) [ ] e) Farmer Field Schools [ ] f) NGO Projects [ ]
25. Do you think the weather conditions have changed over the past 10 years?
0. No [ ] 1. Yes [ ] 3. Do not know [ ]

26. What do you think is the cause of this changes?
1. God/gods [ ] 2. Deforestation [ ] 3. Bush burning [ ] 4. Increased population[ ] 5. Others (specify)…………………………

27.Temperature has changed over the past 10 years?
1= Strongly disagree [ ] 2= can't tell [ ] 3= Strongly agree[ ]

28. How has it changed over the past 10 years?
0. Decreased [ ] 1.Increased [ ]

29. Rainfall amount has changed over the past 10 years
1= Strongly disagree[ ] 2= do not know[ ] 3= Strongly agree[ ]

30. How has it changed over the past 10 years?
0. Decreased [ ] 1.Increased [ ]

31. What do you think is the cause of this changes?
1. God/gods[ ] 2. Deforestation [ ] 3. Bush burning [ ] 4. Increased population [ ] 5. Others (specify)…………………………

32. Temperature has changed over the past 10 years?
1= Strongly disagree [ ] 2= Can't tell [ ] 3= Strongly agree [ ]

33. How has it changed over the past 10 years?
0. Decreased [ ] 1.Increased [ ]

34. Rainfall amount has changed over the past 10 years
1= strongly disagree [ ] 2= do not know [ ] 3= strongly agree [ ]

35. How has it changed over the past 10 years?
0. Decreased [ ] 1.Increased [ ]

C. Effect of Climatic Variables on Yield C.1 Rainfall /Precipitation

36. Does the rainfall follow the timing?
a) Yes [ ] b) No [ ] c) Sometimes [ ]

37. Have you noticed any long-term changes in the mean rainfall over the past 10 years
a) Yes [ ] b) No [ ]

38. How has the rain impacted on your cocoa yield?
a) Increased [ ] b) Decrease [ ]

39. What Pest & Diseases are normally associated with this weather condition a) Blackpods [ ] b) Capid[ ] c) Stemborer [ ]

C.2 Sunshine Hours/Duration

40. In your estimation has the sunshine duration/hours changed?
a) Yes [ ] b) No [ ]
41. How has it changed?
a) Increased [ ] b) Decreased[ ] c) Constant/Stayed the same[ ] d) Cannot tell [ ]

C.3 Temperature

42. Have you noticed any long –term change in the mean temperature over the past 10yrs ?
a) Yes [ ] b) No [ ]
43. Has the number of hot days changed?
a) Increased [ ] b) Decreased [ ] c) No changes [ ]
44. How has increase in Temperature impacted on your cocoa crop ?
a) Increased [ ] b) Decreased [ ] c) No changes [ ]
45. How has decrease in Temperature impacted on your cocoa crop ?
Increased [ ] b) Decreased [ ] c) No changes [ ]
46. What Pest & Diseases are normally associated with this weather condition?
a) Blackpods [ ] b) Capsid/Mirids[ ]

C.4 Humidity

47. In your estimation has the relative humidity been changing?
a) Yes [ ] b) No [ ]
48. How has it impacted on the health of your cocoa pods?
a) Positive [ ] b) Negative [ ]

49. What Pest & Disease is normally associated with this weather condition a) Black Pods [ ] Mirids[ ] CSSVD [ ]

D. **Coping strategies**

50. Have you adapted to or try to adapt to current climatic variation?
a) Yes [ ] b) No[ ]

51. If yes, what are some the adaptation strategies you have so far adopted?

Adaptation Strategies	Rank
A. **On-Farm Strategies**	
Crop diversification (including switching from crops, usage of improved crop variety etc.)	
Switching to livestock production	
Integration of crop and livestock production	
Agronomic practices (changing planting date, intercropping, irrigation, agroforestry, mulching, etc.)	
B.Non -Farm Strategies	
i) Wage from agricultural activities other than own farm (laborer on other farms, processing of agricultural produce, sales of agricultural produce, etc.) ii) Wage employment other than from agriculture (petty trading, carpentry, masonry, teacher, etc.)	
C. Non-Adaptation Strategies	
Wage employment other than from agriculture (petty trading, carpentry, masonry, teacher, etc.)	
Migration to cities	
Remittances (e.g. from relatives and friends)	
Property income (such as houses, stores, land, etc.)	
Government grants and transfers (pension)	

52. If no why?

a) Financial constraints [ ] b) Lack of information[ ] c) Resource Constraints [ ]

b) Others please specify

……………………………………………………………………………………

E. **Adaptation Constraints**

53. What constraints do you face in adapting to Climate change and variability?

a) lack of information [ ]
b) Financial constraints/ Poverty [ ]
c) Low level of technology [ ]
d) Inadequate Labour [ ]
e) Poor soils [ ]
f) Lack of water [ ]
f) Inadequate land [ ]

54. Which adaptation strategy would you recommend for policy considerations?

Please select from list A. B. C. D. E. F.

INTERVIEW QUESTIONS FOR INSTITUTIONS

A. Institutional Background

Position of interviewee…………………… Date …. /…/16

Name of Institution……………………………………

Type of Institution (i) Public (ii) Civic (iii) Private

Its vision:

…………………………………………………………………………………….....

Its mission:

……………………………………………………………………………………..

How many years has the organization been in existence?...

How many years has the organization been operating in the community?..........................

B. Climate Change Impacts

1. Do you perceive climate is changing in the community?
2. What do you think might be the causes?
3. Can you describe how the changing climate affects the livelihoods of the community members (including smallholder farmers).
4. How does your institution contribute to support the community address the climate change challenges? (e.g education and training; cash aid, food aid and credit; infrastructure improvement; technology transfer; business advice)
5. Does every member of the community benefit from these support services?
6. If no, state target group of beneficiaries
7. What are the challenges your institution is facing in supporting the community address climate change challenges?

INTERVIEW GUIDE FOR FOCUS GROUP DISCUSSION

1. Has there been a significant change in weather variables over the last 10 years? (Such as temperature, rainfall amount, duration and distribution, sunshine, heat spell etc.)

2. How has the changes been like?

(i) For temperature

(ii) For rainfall

(iii) Other weather variables

3. Has there being change(s) in the agricultural production output (crop yields/livestock production) for both men and women in the community? Yes/No/May each with reason

   ……………………………………………………………………

4. What accounted for these changes? (i) Extreme weather/climate change events (floods, droughts, heat spell etc.) (ii) Pest/diseases (iii) soil infertility issues
5. If extreme weather/climate change events were a factor, what was the main problem caused by such events. (ask of effects on both men and women)……………………………………………

6. What are the effects of climate change on cocoa production:…………………………………

7. In the face of extreme weather events/climate change what are the strategies employed to safeguard your livelihoods?
………………………………………………………………………………
8. Are the members of the communities (specifically smallholder cocoa farmers) assisted by any institution to help address the climate change impacts?
....
9. State the institutions involve………………………………………………………………
10. What type of services do these institutions provide?
………………………………………………………………………………………
11. Do every member of the community benefit from such services?
12. State the beneficiaries of the support services. (e.g. women only, men only, children, the aged, large scale farmers, small scale farmers, etc.

Appendix 2: Coefficients of the multinomial logit output for determinants of climate change adaptation strategy

	On-farm		Non-farm	
	Coefficient	P-values	Coefficient	P-values
Age	-0.0289* (0.0153)	0.0590	-0.0310* (0.0183)	0.0900
Household size	0.0276 (0.0483)	0.5680	-0.0358 (0.0565)	0.5260
FBO	1.3814*** (0.1062)	0.0000	-0.0109 (0.0383)	0.7750
Farm size	-0.0004 (0.0014)	0.7910	-0.0010 (0.0015)	0.5230
Output	0.0000 (0.0000)	0.7020	0.0000 (0.0000)	0.6340
Gender	15.6646*** (0.6624)	0.0000	16.5745*** (0.6969)	0.0000
Education	4.5284*** (0.3419)	0.0000	4.3789*** (0.4756)	0.0000
Extension	-0.1222 (0.1151)	0.2880	-0.0987 (0.1911)	0.6060
Source of labour	0.0000 (0.0001)	0.6010	-0.0001 (0.0001)	0.2890
_cons	0.9472 (0.6779)	0.1620	1.9002 (0.7274)	0.0090

*,*** denote statistical significance at 10 percent and 1 percent respectively

Values in parenthesis are robust standard errors

Appendix 3:Variance Inflation Factor for the independent variables used in the multinomial model

VIF		
Variable	**VIF**	**1/VIF**
Age	1.17	0.851856
Household size	1.15	0.866806
FBO	1.15	0.870259
Farm size	1.14	0.875714
Output	1.13	0.884668
Gender	1.07	0.935653
Education	1.05	0.95602
Extension	1.03	0.973225
Source of labour	1.02	0.98386
Mean VIF	**1.1**	

Appendix 4: Plagiarism report

10507133:Finalized_Thesis_Work_Plagiarism_Checked.doc

ORIGINALITY REPORT

%10	%5	%6	%3
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Handbook of Climate Change Adaptation, 2015. Publication	%1
2	www.nlcap.net Internet Source	%1
3	www.medwelljournals.com Internet Source	%1
4	Submitted to Kwame Nkrumah University of Science and Technology Student Paper	<%1
5	agriscience.ru Internet Source	<%1