UNIVERSITY OF CAPE COAST

VULNERABILITY OF COCOA PRODUCTION TO CLIMATE CHANGE: A CASE OF THE WESTERN AND CENTRAL REGIONS IN GHANA

DAVID NII BAAH BUXTON

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BY

DAVID NII BAAH BUXTON

Thesis submitted to the Department of Geography and Regional Planning of the Faculty of Social Sciences, University of Cape Coast in partial fulfilment of the requirements for the award of Doctor of Philosophy Degree in Geography.

AUGUST 2018

DECLARATION

Candidate's Declaration

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

Candidate's Signature: ……………….. Date: ………………………

Name: David Nii Baah Buxton

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: ………………… Date: ………………….

Name: Dr. Benjamin Kofi Nyarko

Co-Supervisor's Signature:…………………… Date: ……………………

Name: Dr. Benjamin Lamptey

ABSTRACT

This research work focused on the effect of climate change on cocoa yield in some selected cocoa districts in the Eastern, Ashanti, Western and Central Regions of Ghana. For sustainable cocoa production, weather, which is an uncontrollable variable, is an important factor whose effect on cocoa is difficult to quantify in a field environment. This research has two components; effects of climate change on cocoa production in Ghana and coping strategies of cocoa farmers. The Heckman's probit model and multinomial logit regression were used to measure the level of vulnerability and determine the factors that influence farmers' choice of coping strategies. The effects of two major weather parameters – rainfall and temperature – on cocoa yield were evaluated over thirteen years. The study revealed that there is a weak positive correlation with rainfall, that is, increase in rainfall results in an increase in yield. A relatively stronger positive correlation was established for maximum temperature. About seventeen percent (17.2%) of the variations in yield can be explained by the predictor variables. A one unit increase in temperature will result in a 2593.67 unit in yield and a one unit increase in rainfall will result in a 11.76 unit increase in yield. Cocoa production is thus vulnerable without adaptation. It was observed that adaptation could be behavioural, institutional and technological, and may differ from one locality to another.

KEY WORDS

Climate change

Adaptation

Coping Strategies

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DEDICATION

To my family

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
AOGCM	Atmosphere-Ocean General Circulation Models
ARIMA	Autoregressive Integrated Moving Average
CEC	Cation Exchange Capacity
CERES	Crop Environment Resource Synthesis
CGE	Computable National Product
CIESIN	Center for International Earth Science Information Network
CIRAD	Centre de Cooperation Internationale en Researche
CO_2	Carbon dioxide
COCOBOD	The Ghana Cocoa Board
CODAPEC	Cocoa Disease and Pest Control Programme
CSM	Crop Simulation Models
CSSVD	Cocoa Swollen Shoot Virus Disease
ENSO	El Nino Southern Oscillations
EPA	Environmental Protection Agency
EPA-NCAP	Environmental Protection Agency – Netherlands Climate Assistant Programme
EPIC	Erosion Productivity Impact Calculator
FAO	Food and Agricultural Organization
GCM	General Circulation Model
GDP	Gross Domestic Production
GHG	Green House Gas
GIS	Geographic Information Systems
HYV	High-Yielding Variety

ICCO	International Cocoa Organization
IDW	Inverse Distance Weighted
IPCC	Intergovernmental Panel on Climate Change
ISSER	Institute of Statistical, Social and Economic Research
ITCZ	Inter-Tropical Convergence Zone
ITD	Intertropical Discontinuity
LSP	Light Saturation Point
LUT	Land Utilization Type
MOFA	Ministry of Food and Agriculture
NCAP	Netherlands Climate Assistance Programme
NGO	Non-Governmental Organization
ORS	On-set of Rainy Season
SPSS	Statistical Package for the Social Science
UNCTAD	United Nations Conference on Trade and Development
UNDP- NSCP	United Nations Development Programme – National Communication Support Programme
UNFCCC	United Nations Framework Convention on Climate Change
VPD	Vapour Pressure Deficit
WACRI	West African Cocoa Research Institute
WMO	World Meteorological Organization

CHAPTER ONE

INTRODUCTION

Researchers and policy makers now agree that the world’s economy is facing a big threat from global warming. The degree of its impact and distribution is still being debated. The current evidence suggests that countries in temperate and polar locations may reap some small economic advantages because additional warming will benefit their agriculture. On the other hand, countries in the tropical and sub-tropical regions are expected to be at a disadvantage, because additional warming will affect their marginal water balance and harm their agricultural sector (Mendelssohn, Dinar & Sanghi, 2000a).

The effect of climate change is expected to be particularly severe in Tropical Africa which, according to research (Mendelssohn, Dinar & Dalfelt, 2000b; Boko et al., 2007; Intergovernmental Panel on Climate Change, 2013), is the poorest and has the slowest technological change, and where domestic economies have depended heavily on rain-fed agriculture. Midgeley, Davis and Chesterman (2011) conducted vulnerability assessments for southern Africa to highlight “hotspots” of current and future (2050) vulnerability to climate change. This study showed that areas that relied significantly on rain-fed agriculture, and were characterised by high population growth, were more vulnerable.

Some regions in Africa are highly populated, and most of the people live below the poverty line. This, together with climate change, is expected to increase food insecurity throughout Africa. Evidence from the world, particularly in Africa, has shown that climate is changing and its effects are being felt in the agricultural sectors of countries. Zimbabwe, Kenya and South Africa have been found to be the regions that suffer most seriously from the effects of drought. Intra-seasonal and inter-annual variability of rainfall also creates a high-risk environment for agriculture in some zones (Food and Agriculture Organisation, 1997). Sivakumar (1992) focused on changing rainfall patterns to assess the impact on the production of pearl millet, which is a staple food in Niger and found out that, at several locations in Niger, a significant decline in the annual and August rainfall has occurred since 1966, with negative impacts on the production of pearl millet.

Reilly and Schimmelpfennig (1999), showed the adverse effects of agricultural damage on the wellbeing of consumers in Africa. All forecasts indicate that climate change will result in the deterioration of living conditions on the continent (Department for International Development, 2006). A report from the United Nation Conference on Trade and Development 2009 showed that prices of tropical beverages have been propped up by crop shortages in major producing areas due to adverse weather conditions. For example, coffee in Colombia, Central America and Brazil, cocoa in Côte D'Ivoire and Ghana, and tea in India, Kenya and Sri Lanka, all show evidence of climate shocks.

Traditionally, export crops have played an important role in the development of many African countries through the generation of foreign exchange, government revenues, and household incomes. Dependence on a few export commodities has often made these countries vulnerable to international price volatility such that a continued deterioration of the commodity terms of trade of agricultural producers has reinforced the need for diversification in economic development from primary-commodity-producing countries to manufacturing and service exporters (Wilson, 1984; United Nations Conference on Trade and Development, 2005).

Muchinda (1994) conducted an agro-economic study on the effects of rainfall changes on agricultural production in Zambia. Recurring droughts were found to have detrimental effects on agriculture in the country in such a way that, the southern zones of Zambia would be less able to support the variety of maize grown in these parts, which would necessitate large imports of basic foods. However, for Kenya, climate change assessment results by Fischer and Van Velthuizen (1996) show that, with higher carbon dioxide and temperatures as a result of climate change, there will be an increase in maize yield in higher altitude regions.

In Ghana, a study conducted by the Environmental Protection Agency under the Netherlands Climate Assistance Programme (NCAP) on 'climate change impacts, vulnerability and adaptation assessment' reveals that climate was indeed changing and the impacts were already being felt on the production of some crops. Root crops in Ghana were found to be highly significantly positively correlated to total rainfall, giving a highly significant correlation coefficient value between 0.89 and 0.92. Although mean temperatures were positively correlated to yield, the level of correlation was below 0.05 indicating a low degree of association (EPA, 2008). Cereals and some export crops are also likely to be affected by climate change.

Ghana's economy was once led by the agricultural sector. However, its contribution to the economy continues to decline, with its share reducing from 35.0 per cent of GDP in 2007, to 23.0 per cent of GDP in 2012, and to 22.0 percent in 2013 (COCOBOD, 2007; Ghana Statistical Service, April 2014).

Agricultural crops which are produced for export include cocoa, coffee, bananas, pineapples, palm nuts, copra, limes, kola nuts, shea nuts, rubber, and cotton. However, cocoa is the dominant export crop. The cocoa industry alone employs close to 60 percent of the national agricultural workforce in the country (Asuming-Brempong, Sarpong, Asenso-Okyere, & Amoo, 2006).

In Ghana, cocoa has historically been a key economic crop and a major source of export and fiscal earnings (Bulir, 1998; McKay & Aryeetey, 2004). Hence, there is great dependence on the export of cocoa for economic growth and development in Ghana. In 2009 for instance, the cocoa sector contributed 84.9 percent (US$ 1.865 billion) out of the US$ 2.197 billion of the foreign exchange earnings of the agricultural sector (Institute of Statistical, Social and Economic Research, 2011).

Ghana has regained its position among the world’s leading cocoa producers and exporters, and the crop has played an important role in the nation’s recent economic growth (McKay & Aryeetey, 2004; Bogetic, Noer, & Espina, 2007). For instance, during the 2002 season, cocoa accounted for 22.4 percent of the total foreign exchange earnings for Ghana. This represented 63 percent of the export earnings from the agricultural sector. Also, the outstanding performance of the country’s economy in 2003 was due mainly to an exceptionally strong output growth in the agricultural sector which raised the overall growth rate from a projected 4.7 percent to 5.2 percent. An examination of the sector’s performance showed that this remarkable growth was achieved exclusively on account of cocoa production and marketing, with output rising from a slight decline of 0.5 percent in 2002 to 16.4 percent in 2003. The agricultural sector is still said to be a major contributor to Ghana’s economy, contributing about 45 percent to the country's Gross Domestic Products [GDP], with cocoa alone producing almost 25 percent of this total amount (Ghana Statistical Service, 2015).

Currently, Ghana is rated as the world's leader in premium quality cocoa beans production, ahead of major competing countries such as Cote d'Ivoire and Indonesia (Osei, 2008).

Several factors account for Ghana's success in cocoa production. Among them are the relatively good cocoa purchasing prices, improved farm husbandry practices due to research, proper disease and pests control, good government policies such as loan schemes, the Akuafo cheque system, free spraying of cacao trees, subsidies on fertilizers and check-points to stop the smuggling of dried cocoa beans, favourable changes in land tenure systems and good planning to limit the effect of urbanization on cocoa farming (Environmental Protection Agency of Ghana, 2008; Owusu-Achaw, 2012; Ghana Cocoa Board, Press Release, 11th November, 2013).

The measures that have been employed to ensure high yields of the cacao plant in Ghana have not taken into consideration the effects of climate change and variability. However, it is generally acknowledged that climate change and variability also affect the production of agricultural crops. Climate is a critical factor influencing the production of crops in any region. The climate, like other inputs such as land, labour, high-yielding variety (HYV) seeds, fertilizers, pesticides, and so on, is also a direct input into agriculture. While both sets of factors are crucial, some measurable inputs are controllable, but the climate is not (Paltasingh, Goyaria & Mishra, 2012).

Understanding the precise linkage between the weather and crop yield could provide potential implications of the effects of climate change on food security; and consequently, it can facilitate some kind of interventions for securing crops from the vagaries of weather. The extent of the vulnerability of the cacao plant to climate change and variability, if well established, will help in forecasting production, and hence, ensure reliable production data for planning.

Statement of the Problem

In Ghana, cocoa has traditionally been an important source of foreign exchange earnings, and therefore the engine of growth and a means to reduce poverty. Cocoa's share of the income from agriculture has been increasing rapidly, and the existing yield gaps and prospects of continuing high world commodity prices suggest a further growth potential (Breisinger, Diao, Kolavalli, & Thurlow, 2008).

However, there have been doubts about the sustainability of cocoa production in Ghana due to the fact that, as in other parts of Africa, the increase in production has been mainly due to expansion in the land area for cocoa production (Gockowski**,** Nkamleu, & Wendt, 2000; Nkamleu & Ndoye, 2003). This method of expanding production is no longer sustainable, taking into consideration the increase in population and land-use demands, and the fact that the cocoa crop, like many other crops, thrives best only in certain agro-climatic regions where temperatures range between 18 and 32^{o}C with rainfall ranging between 1,500 and 2,500 mm annually. There is evidence that former cocoa growing areas have now become marginal, not supporting cocoa production like it did in the past. Farmers in old cocoa production areas, who found that selling prices barely covered their costs, increasingly turned from cocoa to food production (Amanor, 2005). There may not always be new areas favourable to cocoa production as some old areas become marginal due to climate change. Ghana’s agriculture is predominantly smallholder, traditional and rain-fed; and changes in rainfall patterns, frequency, distribution, duration and intensity affect production levels greatly (Statistics Research and Information Directorate, 2010).

Several direct factors including the climate, type of cacao variety, the fertility of the soil, farm maintenance practices, and indirect factors such as the price of the commodity and government policies affect the yield of cacao. Man has some level of control over all the factors that affect cocoa yield except the climate which sets some limitation on the crop in terms of where it can thrive and its potential yield.

Cacao is highly sensitive to changes in climate. Climate change may alter the stages and rates of development of cocoa pests and pathogens, modify host resistance and result in changes in the physiology of host-pathogen/pests interaction, and altering crop yields and losses (Anim-Kwapong & Frimpong, 2008). These changes impact socio-economic variables such as farm income, livelihood and farm-level decision making.

The effect of climate change on cocoa production has not been given the attention it deserves, even though it plays an important role in determining the yield of the crop. Knowledge of the possible yield of cocoa is essential for economic planning, especially since the contribution of cocoa to the national output is very significant. Changes in climate has the potential of making the cocoa sector vulnerable, therefore the need to study the effects of climate change on cocoa production, and the potential for adaptation to climate change, in order to ensure sustainability of the livelihood of cocoa farmers and their dependants, as well as the foreign exchange which is so necessary for the country's development.

Purpose of the Study

The purpose of the study was to assess the effects of climate change on cocoa production in Ghana.

Objectives

The objectives of the study were to:

1. Examine the impact of climatic variables (i.e. rainfall and temperature) on cocoa yields;
2. Assess the perception of cocoa farmers to changes in the climate;
3. Develop a model that can be used to predict future cocoa production in Ghana; and
4. Explore the adaptations of cocoa farmers to changes in the climate.

Research Questions

The following questions guided the study:

1. What are the impacts of climatic variables (rainfall and temperature) on cocoa yields?
2. How do cocoa farmers perceive the effects of climate change on their yields?
3. How can future cocoa production be predicted in Ghana?
4. What are the adaptation and coping strategies of cocoa farmers?

The Study Areas

Cacao, as a tropical crop, is specific in its climatic and soil requirement. Thus, in Ghana, cacao is profitably grown in the forest belt (Figure 1).

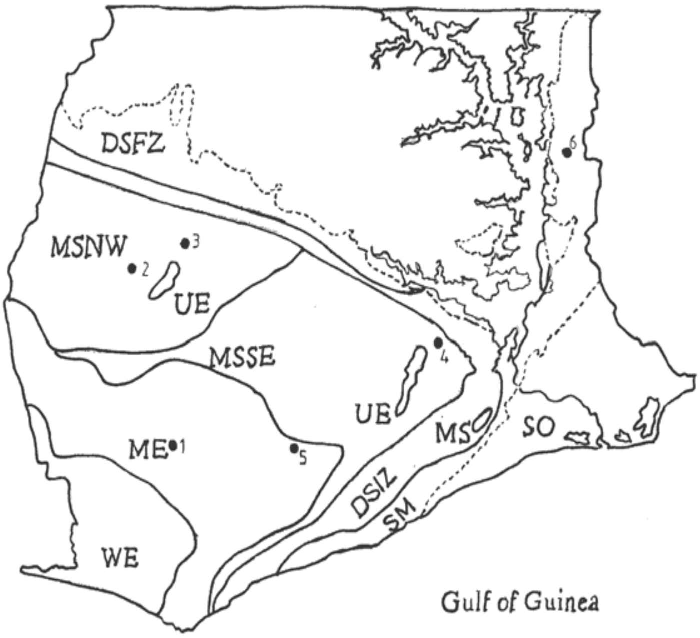


Figure 1: Forest Zones which Support Cocoa Production in Ghana

Source: Anim-Kwapong and Frimpong, (2005)

KEY

Forest boundaries shown by broken line (-----). Forest-type abbreviations: WE=Wet Evergreen; UE=Upland Evergreen; ME=Moist Evergreen; MS=Moist Semi-deciduous (NW=Northwest subtype; SE=Southeast subtype); DS Dry Semi-deciduous (FZ=Fire Zone subtype; IZ=Inner Zone subtype; SM=Southern Marginal; SO = Southern Outliners

Ghana’s cocoa belt lies in the south of the country. The Central and Western Regions were covered in the survey. These areas represent a cross-section of the geographical variation in the cocoa belt. Tafo with its environs in the Eastern Region, as well as the Central Region, has been the traditional cocoa-growing area, whilst Western Region is a new area of production. The soils in these areas fall under the suitable to highly suitable cocoa soil classification of Adu and Mensah-Ansah (1969). From the Central Region, the Assin Foso and Twifo Praso Cocoa districts were used for the study whilst the Sefwi Boako and Sekondi-Takoradi Cocoa districts were selected from the Western Region (Figure 2).

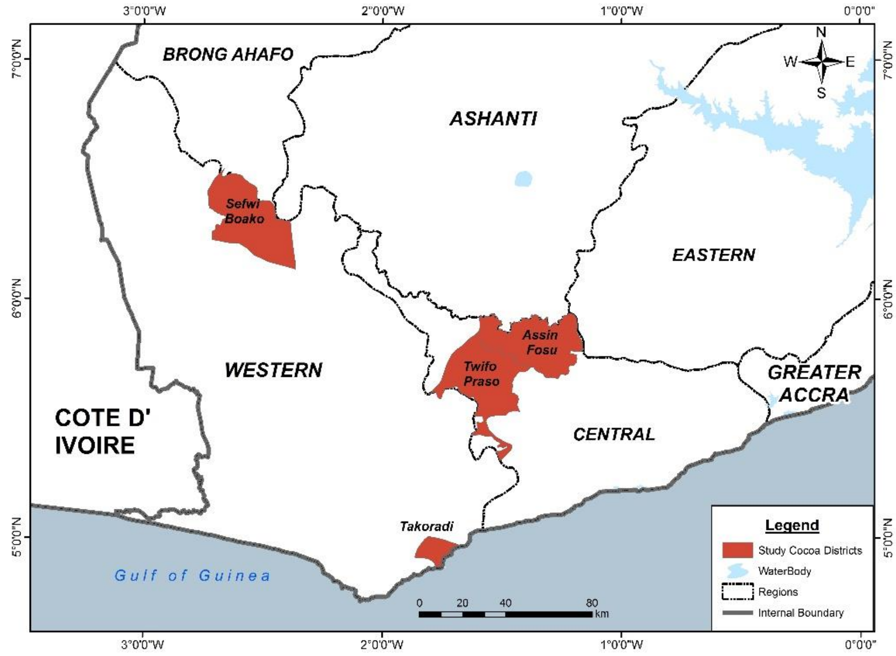


Figure 2: Map Showing the Study Cocoa Districts

Source: GIS, Department of Geography and Regional Planning, UCC

The Assin Fosu cocoa district (Central Region)

The Assin North Municipality is among the twenty (20) metropolitan, municipalities and districts in the Central Region of Ghana. It lies within Longitudes 1° 05’ East and 1° 25’ West and Latitudes 6 ° 05’ North and 6° 40’ South. The municipality covers an area of about 1,500 sq. km., and it is made up of about 1,000 settlements, including Assin Foso (the municipal and administrative capital), Assin Nyankumasi, Assin Akonfudi, Assin Bereku, Assin Praso, Assin Kushea and others. The administrative capital is Assin Fosu (Ghana Districts, 2015).

Topology and drainage

The district is characterized by an undulating topography, and has an average height of about 200 m above sea level. Flood-prone plains of rivers and streams lie below sea level. The district has numerous small rivers and streams. The main rivers include the Pra, Offin, and Betinsin; and some swamps in the district provide a potential for fish farming and dry season vegetable and rice farming (Ghana Districts, 2015).

Climate and vegetation

The Assin North District falls within the moist tropical forest, mainly deciduous forest. The area has an annual rainfall between 1,500 and 2,000 mm. Annual temperatures are high and range between 30°C in March/April and about 26°C in August. Average relative humidity is high, ranging from 60% to 70% (Ghana Districts, 2015).

The ecological balance allows for a variety of food, cash and non-traditional export crops to be grown. The district comes under the relatively cool and moist South-West monsoon winds that blow from the Atlantic for most part of the year, however, the dry harmattan or North-East Trade Winds blow in from the North between December and February and its desiccating effect, however is greatly reduced by its long passage over the forest zone. The rainfall pattern is bi-modal. The major rainy season is from April to July, corresponding with the major farming season; and the minor rainy season occurs from September to November (Ghana Districts, 2015).

The Assin North District has about six Forest Reserves which include the Bimpong Forest Reserve, the Supong Forest Reserve, the Assin Forest Reserve, Wawahi Forest Reserve, Krochua Forest Reserve and Baku Forest Reserve. These reserves serve as protective cover to some of the major rivers that drain the district, and also provide the shade necessary for establishing cocoa farms (Ghana Districts, 2015).

Geology and soil

The land area is underlain by geological strata of the Cape Coast Granite Complex belonging to the pre-Cambrian Platform and comprises basically granites, grandiosities and adamellites. It is schistose in some communities and very massive in others with several components, ranging in composition from grandiorites to granites and their migmatitic varieties. The predominant mica minerals are muscovite and biotite. About 60% of the communities, however, are underlain by the lower Birrimian Phyllites, which are often associated with extensive decomposition basins and thick weathering mantles (Ghana Districts, 2015).

The Sekondi –Takoradi cocoa district

Location and size:

Sekondi-Takoradi is the administrative capital of the Western Region. The Sekondi-Takoradi Metropolitan Area has a land area of 385 square kilometers and is strategically located in the South-Western part of Ghana, about 242 km to the West of Accra, the capital city of Ghana. It is also approximately 280 km from the La C'ote d'lvoire border in the West.

The Secondi –Takoradi Metropolitan Area forms part of twenty two metropolitans, municipalities and districts in the Western Region of Ghana. The administrative capital of the Metropolitan Area is Sekondi. The Metropolitan Area shares boundaries with Shama District to the east, Mpohor District to the north, Ahanta West District to the west and the Gulf of Guinea to the south (Ghana Districts, 2015).

Topology and drainage

The metropolis is of varied topography, with the central area of Takoradi being low-lying and occupied by muddy lagoons interspersed with ridges and hills. The metropolis is bordered to the west by the Whin River, with its main tributary, the Ayire, joining the Whin lagoon before entering the sea; while on the east flows the Pra River (Ghana Districts, 2015).

Climate and vegetation

Sekondi-Takoradi is characterized by an equatorial climate. Temperatures are high, with an average of 22^0 C. It has a mean annual rainfall of 2,350 mm, which is experienced heavily in May and June, with the minor rains occurring between September and October. The climate offers opportunities for varying agricultural production (Ghana Districts, 2015). Vegetation is highly woodland in the northern and central parts. In areas where there are no permanent crops, especially along the coast, thickets are interspersed with tall grass species.

Geology and soil

The geology of the metropolis consists of faulted shoals and sandstone of various types resting on a hard basement of granites, gneiss and schist. The land surface is well watered (Ghana Districts, 2015).

The Sewfi-Boako cocoa district

Sefwi Boako is part of the Sefwi-Wiawso District, which forms part of twenty two metropolitans, municipalities and districts in the Western Region of Ghana. The administrative capital of the district is Wiawso. Sefwi Boako is about 21km from Sefwi Wiawso. The district shares boundaries with Bibiani-Anhwiawso-Bekwai to the east, Bodi District to the west, Asunafo South in the Brong Ahafo Region to the north and Aowin District to the south. The municipality falls within the tropical rainforest climatic zone, with high temperatures between 25^{o}C and 30^{o}C throughout the year. It has a moderate to heavy rainfall between 1,524 mm and 1,780 mm per annum, with double maxima characteristics in June to July and September to October. Humidity is relatively high, about 90 per cent at night, falling to 75 per cent during the day. There are two long wet seasons, separated by a short relatively dry season (Ghana Districts, 2015).

Soils

The most widespread is the forest Ochrosols, which covers most of the Northern and Western parts of the district. The forest Ochrosols and Oxysols support the cultivation of cash and food crops, such as cocoa, the oil palm, cola, coffee, cashew, plantains, cocoyam, cassava and maize, with high yields in the Municipality (Ghana Districts, 2015).

Vegetation and forest reserve cover

The Sefwi Wiawso Municipality falls within the moist semi-deciduous forest zone of Ghana, which covers most of Ashanti, Western, Brong-Ahafo and Eastern Regions. The forest type consists of the *Celtis - Triplochiton* association. Common species found are Onyina, Odum **(***Milicia excels*)**,** Wawa (*Triplochiton scleroxylon*), Mahogany (*Khaya ivorensis*), Emire (*Terminalia ivorensis*) and Red cedar, among others (Ghana Districts, 2015).

There is a high degree of depletion of the original forest; and large sections of the forest are now secondary due to improper farming practices and logging although a large section of the forest, totaling 612.22 km^2, has been put under reserves. The Municipality has three (3) forest reserves which include Muro in Boako (167.8 km^2), Suhuma in Old Adiembra/Amafie (359.8 km^2) and Tano Suhien in Punikrom (84.6 km^2).

Justification of the Study

Despite the discovery of oil in Ghana, cocoa production remains an important contributor to economic growth and development. Several yield gaps exist and there is a potential for increased productivity in the cocoa industry. In spite of the various policies put in place by the government to increase the yield of the crop, the effect of climate seems to be ignored although it is the one factor that man has little control of.

Existing research by the EPA of Ghana suggests that climate is changing and some crops are already experiencing the effects. If cocoa production will continue to contribute significantly to the growth and development of the country, there is the need to examine the nature and extent of its vulnerability to climate change.

Significance of the Study

The findings of this research would add to the existing body of knowledge on the effects of climate on agriculture. The study would be useful for planning in the cocoa sector. Knowing farmers' perception of the effects of climate on cocoa production and their coping strategies would help stakeholders design effective measures to reduce to the barest minimum the effects of climate change on the cocoa sector.

Organisation of the Study

This research is organised into eight chapters. The first chapter gives an introduction, the statement of problem, objectives, research questions, a description of the study area, significance of the study, organisation of the study, some ethical consideration and limitations of the study. Chapter Two presents a review of pertinent theoretical literature on climate change and its effects on cocoa production. This chapter discusses the effects of climate change on crop production in general and on cocoa production in particular. Some key concepts used in this thesis are discussed. The chapter ends with a brief history of cocoa production in Ghana and its role in Ghana's development. Chapter Three, presents a discussion of the empirical literature on climate change and cocoa production. A section of this chapter discusses climate trends in Ghana and some projections made for the future with regard to climate change. It also describes and discusses some models for predicting the effects of climate change on crop yield. Chapter Four describes the methodology used for the study. The research philosophy and design are presented; this is followed by the description of the data employed in the study and their sources; and the statistical techniques employed in the study.

Chapters Five to eight present and discuss the results of the study. Chapter Five looks at the climatic data and tries to establish the magnitude of climate change. It gives a summary of future climate change predictions made for Ghana. Chapter Six presents a summary of the socio-economic background of cocoa farmers and assesses their perception of climate change and factors influencing their perception. Cocoa farmers' adaptive strategies in a changing climate, factors affecting adaptation and alternative livelihoods are discussed in Chapter Seven. Chapter Eight gives a summary of the findings, related policy implications and recommendations for further study.

Ethical Considerations

Social science research often involves the study of real people in real situations, and this raises ethical questions regarding the relationship between the researcher and the respondents. Where care is not taken in conducting social science research, the validity of the research may be questioned.

The researcher, therefore, must take responsibility for all procedures and ethical issues related to the project. The research must be conducted in such a way that its integrity would be maintained, and any negative after-effects which might diminish the potential for future research would be avoided. Again the research must be conducted as an objective scientific project and without bias. The research took into account the issues of informed consent, anonymity and confidentiality.

To this end, all the research personnel used in the study were selected from agricultural extension officers who were already experienced in dealing with farmers. They were trained in all the procedures used in the study, and they took part in pre-testing the instruments used.

The research was carried out in full compliance with local customs, standards, laws and regulations. Proper community entry procedures were followed. In particular, permission was obtained at the regional, district and community level. The Chief Cocoa Farmer in each community selected was visited, and all issues related to the research were discussed. Local customs – the days on which farming activities were prohibited, for example, were observed.

Undue intrusion into the lives of respondents was avoided. Hence, questions relating to personal issues of farmers were not asked and farmers had the freedom not to answer any question they deemed to be personal. The welfare of the informants was considered important and their dignity, privacy and interests were protected. Questionnaires were only administered during periods which were favourable to the respondents, and effort was made not to significantly affect their daily routines. Therefore, farmers were often accompanied to their farms, and questionnaires were administered when they were on break.

Freely given informed consent was obtained from all respondents. Potential participants were informed (in a manner and in a language they could understand) of the context, purpose, nature, methods, procedures, and sponsors of the research. Verbal consent was obtained from participants who could not sign their names or read the information sheets (in which cases, the sheets were read out to them). Participants were made aware that their involvement in the research was voluntary. Participants were given the opportunity to ask questions that might be bothering them before signing the consent form.

Neuman (2007), states that researchers must not coerce anyone into participating in research and participation must be voluntary at all times. Hence, coercion was not used, and participants were fully informed of their right to refuse and to withdraw at any time during the research. They were informed of any potential consequences of their participation.

To avoid misinterpretation of responses, questions were asked in the local dialect of the respondents, and the responses given were repeated to them after writing. Full confidentiality of all information and the anonymity of participants were maintained. Anonymity protects privacy by not disclosing a participant’s identity after the information is gathered. Hence, names of respondents were not noted in the study. Farmers were assured of confidentiality; the information they provided was not to be divulged to any third party other than its intended purpose, which was an academic exercise.

Participants were offered access to the research results, presented in a manner and language they can understand. Limits of reliability and applicability of the results were made clear to all stakeholders. Lastly, unpublished as well as published works of other scholars used in the study have been properly acknowledged.

Delimitation of the Study

The focus of this study was on the effect of climate (rainfall and temperature) on the yield of the cacao tree. The research work considered only the effects of climate change and variability on the yield of the cacao tree in selected cocoa growing areas in Ghana and not on the growth of the tree. This study does not distinguish between climate change and climate variability. The working definition is a noticeable change in the prevailing weather condition in an area over a long period of time, irrespective of the cause of change, be it natural variability or human activity. The study again does not consider whether the observed changes have been permanent or temporary.

Limitation of the Study

Some selected cocoa growing areas (which are important in terms of their contribution to the total output of cocoa in Ghana) did not have meteorological stations as required for the study. Data from meteorological stations nearby were therefore used for such areas through interpolation. This method, however, may not produce the best results, because of possible errors. Gaps in the data were also bridged through interpolation and results obtained may not be exactly accurate compared with a consistent trend data set.

Chapter Summary

Chapter One discussed the introduction of the study. It presented a background of the study, statement of the research problem and the objectives of the study. Some questions guiding the study as well as the significance of the study were also discussed. Finally, the organisation of the study was outlined and some limitations of the study were identified.

CHAPTER TWO

REVIEW OF THEORETICAL LITERATURE ON CLIMATE CHANGE AND COCOA PRODUCTION

Introduction

This chapter presents a review of relevant theoretical literature relating to the effects of climate change on crop production in general and on cocoa production in West Africa in particular. The first section describes the climate system and how it influences climate variability and climate change. The difference between climate variability and climate change is explored. Vulnerability, adaptation and perception as concepts are defined in relation to climate change and crop production. Some interpretations of vulnerability assessments are discussed in addition to a conceptual framework used for assessing vulnerability. Also discussed are scales and levels of adaptation to climate change and variability. The difference between coping and adaptive capacities, barriers to adaptation are also presented in this chapter. The cacao tree is introduced and factors affecting its growth and production are discussed. The chapter ends with a brief history of cocoa production in Ghana and its role in Ghana’s development.

Climate Systems

A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere (IPCC, 2008). The climate of a location is affected by its latitude, terrain and altitude, as well as nearby water bodies and their currents. Weather and climate are the result of a complex series of interactions between all elements of the earth system (hydrosphere, atmosphere, biosphere, solid earth) but are largely controlled by the interaction between the earth and the sun. Weather represents the state of the atmosphere at a given time and place. In contrast, the climate is the average weather conditions for a site measured over a long time period (years).

The climate system of a place influences the on-set of rainfall, its cessation and the potential of the occurrence of drought in an area. Most of the flow characteristics in West Africa are linked with the Intertropical Discontinuity (ITD), which separates humid maritime air masses from dry continental air masses from the Sahara. The monsoon of western sub- Saharan Africa is the result of the seasonal shifts of the Intertropical Convergence Zone (ITCZ) and the great seasonal temperature differences between the Sahara and the equatorial Atlantic Ocean (Laux, 2009).

According to Sultan and Janicot (2000; 2003) and Sultan, Baron, Dingkuhn, Sarr, and Janicot (2005), the West African Monsoon onset dynamics follows two distinct phases, the pre-onset and the onset phase. The pre-onset occurs in late spring when the ITCZ establishes itself at 5° (~ May 14th), whereas the actual onset occurs when the ITCZ shifts abruptly northwards (~ June 24th). Afterwards, the ITCZ moves from 5° to 10° N, where it stays for the whole of August.

The date of the start of the wet season is a crucial factor in planning farming activities such as preparing the land, planting, weeding and harvesting (Sivakumar, 1988 as cited in Laux, 2009; Mugalavai, Kipkorir, Raes, & Rao, 2008). Planting too early may lead to crop failure, whereas planting too late may reduce the growing season and hence crop yield. Recognising when the wet season has actually started is, therefore, important, and any reliable guidance on this is of great value. According to Walter (1967), the agriculturist is only interested in a high probability that, at a certain point in time: (i) the rains will become fairly continuous and sufficient to ensure enough moisture in the soil at the time of planting and (ii) this level will be maintained or even increased as the season advances. The rainy season's onset seldom occurs abruptly with the movement of the ITCZ; it is often preceded by short isolated showers with intermittent dry spells of various lengths, which are often misinterpreted as the start of the rainy season (Laux, 2009).

The wet season is described by three parameters: its onset, end, and rain rate. All three are important from meteorological and societal perspectives (Liebmann et al., 2007). The spatial and temporal variability of the onset of the rainy season has been an issue of interest for researchers (Kousky, 1988; Liebmann & Marengo, 2001; Ati, Stigter, & Oladipo, 2002). One type of strategy examines past climatic records for relevant weather stations and finds the first date by which the wet season has started in a specified high proportion of previous years. More sophisticated variants of this approach have been proposed (Stern, Dennett, & Dale, 1982); but most researchers still rely mainly on previous years' data in making decisions about wet season onset.

Although the timing and quality of the wet season are of importance to agriculture, the ecosystem and forest are more sensitive to the length of the dry season (Sombroek, 2001). Thus, the ending date is of interest as well.

The cessation of the rainy season is of lower importance compared to the onset of the rainy season (ORS). The withdrawal of some monsoon systems is often more abrupt, and hence better organized than the onset

(Odekunle, 2004a&b; Segele & Lamb, 2005). The most common definition of the cessation is the month in which rainfall stops (Simelton et al., 2011). In years when it occurs too early, agricultural production suffers. Long periods with an absence of necessary moisture for agricultural production will lead to drought.

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It is not an anomaly; rather it is part of the natural variability in the earth system (Laux, 2009). It is significantly one of the two prevailing extremes of rainfall variability; and it is the most significant threat to rain-fed agriculture (Usman, Archer, Johnston, & Tadross, 2005). Probably, a drought is the most complex natural hazard, because it develops slowly, it is difficult to detect and has many facets in any single region (Morid, Smakhtin, & Bagherzadeh, 2007).

Palmer (1965) defined drought as an interval of time, generally of the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply. McMahon and Diaz Arenas (1982) state that drought is a period of abnormally dry weather, sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance, and carries connotations of a moisture deficiency with respect to man’s usage of water. According to Beran and Rodier (1985), the principal characteristic of a drought is a decrease of water availability in a particular period and over a particular area. Agricultural drought may be defined in terms of the sensitivity of crops at different stages to water requirements in terms of rainfall, irrigation, soil moisture content and evapotranspiration. Agricultural drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time (Brown & Magary, 1998). Long dry periods affect the establishment phase of cocoa farms.

Climate Change versus Climate Variability

Climate change can be defined as any change in climate over time, whether due to natural variability or human activity (IPCC, 2001). The reports by the United Nations Framework Convention on Climate Change (UNFCCC) define it as “a change of climate, 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”. Whether, by natural or human means, it is generally believed that climate is changing more rapidly in recent years than it did in the past.

According to Lambrou and Nelson (2010, 11), “Climate variability refers to variations in the mean state of the climate and variations in other statistics (such as the occurrence of extremes) on all temporal and spatial scales beyond that of individual weather events. The average range of temperature for a location, as indicated by minimum, maximum and average temperature values, is an example of a measure of climate variability”.

Perhaps, the most well-understood occurrence of climate variability is the naturally occurring phenomenon known as the El Niño-Southern Oscillation (ENSO), an interaction between the ocean and the atmosphere over the tropical Pacific Ocean that has important consequences for the weather around the globe. The ENSO cycle is characterized by coherent and strong variations in sea-surface temperatures, rainfall, air pressure, and atmospheric circulation across the equatorial Pacific. El Niño refers to the warm phase of the cycle in which above-average sea-surface temperatures develop across the east-central tropical Pacific. La Niña is the cold phase of the ENSO cycle. The swings of the ENSO cycle typically occur on a time scale of a few years. These changes in tropical rainfall affect weather patterns throughout the world.

Ghana’s climate is dominated by the interaction of the Inter-Tropical Convergence Zone (ITCZ) and the West African Monsoon. The principal feature of the climate of Ghana is the alternate wet and dry seasons caused by the movements of the ITCZ and West African Monsoon. The rainfall seasons of Ghana are controlled by the movement of the ITCZ, which oscillates annually between the northern and southern tropics following the position of the sun with a lag of 1-2 months. The dominant wind direction in regions south of the ITCZ is southwesterly, blowing warm, moist air from the Atlantic Ocean onto the continent. North of the ITCZ, the prevailing winds (the Harmattan) come from the northeast, bringing dry, hot, and dusty air from the Sahara Desert. At the northern summer solstice, the ITCZ lies near the Tropic of Cancer and wet maritime winds produce a rainy season north of the Equator. When the ITCZ moves south and the sun is over the Tropic of Capricorn, most of West Africa comes under the influence of the continental, hot, dry Harmattan. As the ITCZ migrates between its north and south positions over the course of the year, the regions between the northern and southernmost positions of the ITCZ experience a shift between the two opposing prevailing wind directions (i.e., the south westerlies and the north easterlies) (McSweeney, New & Lizcano, 2008).

The earth has always experienced climate variability on time scales ranging from seasonal to inter-annual to hundreds and thousands of years. Variability in climate leads to uncertainties about the on-set of the rainy season, rain cessation, occurrence of drought and dry-spells and the extent of their effect on agricultural productivity.

Definition of Terms

In the climate change literature, there are no universally agreed definitions for terms such as vulnerability, perception and adaptation. Given that definitions of these terms and concepts are often contested, working definitions are provided here and applied throughout this thesis. Justifications for the chosen definitions are provided to frame the analysis and discussions.

The Concept of Vulnerability

Vulnerability, according to the 2007 IPCC Report (pp 883), "is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change, including climate variability and extremes." It is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.

Santiago (2001) stated that vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change. According to Okunmadewa (2003), vulnerability is the likelihood of a shock causing a significant welfare loss and that vulnerability depends on exposure to risks and on risk management actions taken in response, which may be ex-ante or ex-post.

The extent of vulnerability can vary from one geographical area to another and even within the same location considering the differences in socio-economic variables within. Vulnerability is context-specific and what makes one region or community vulnerable may be different from another (Brooks, Adger, & Kelly, 2005; Füssel, 2010). There are certain generic determinants of vulnerability including developmental factors that are likely to influence the vulnerability of a particular region or community even in a diverse socioeconomic context (Brooks *et al.*,). Thus, one of the key features of vulnerability is its dynamic nature that may change as a result of alterations in the biophysical as well as the socioeconomic characteristics of a particular region or community (Cutter, Emrich, Webb, & Morath, 2009; Smit & Wandel, 2006). The dynamic nature of vulnerability means that assessments should be on-going processes, in order to highlight the spatial and temporal scales of the vulnerability of a particular region or community (Luers, 2005; Eriksen & Kelly, 2007).

The extent of vulnerability of individuals and societies to the impact of climate change will depend on the availability of, and accessibility to, assets and resources. Thus, systems (or communities) that have more adaptive capacity are less vulnerable than those that are characterised by lower levels of adaptive capacity (Smit & Wandel, 2006). Also, the entitlements of individuals to capital assets including social, financial, human, physical and natural capitals could affect the individual's ability to cope with the impacts of climate change (Sen, 1999).

The vulnerability of cocoa production in Ghana can be viewed in terms of the problems encountered by cocoa farmers that hamper increased production and their capacity to cope. The problems can be grouped into shocks and trends. Shocks include damage due to drought, pests and diseases, and floods, while trends are fluctuations in prices, inconsistencies in policies, inadequate access to credit, marketing problems and inadequate labour during the growing season.

Competing Interpretations of Vulnerability Assessments

In the literature, two competing interpretations of vulnerability to climate change include an ‘end-point’ approach and a ‘starting-point’ approach (Füssel & Klein, 2006; Kelly & Adger, 2000). In the end-point approach, the “assessment of vulnerability is the end-point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options” (Kelly & Adger, p. 327). In this case, vulnerability is defined as the residual consequence of such assessment after feasible adaptation has been taken into consideration (Füssel, 2007). In the starting-point approach, the vulnerability of a system or individual refers to the current state or the pre-existing incapacity to withstand shocks imposed by climate variability and change (O'Brien, Eriksen, Nygaard, & Schjolden, 2007). Starting point analyses consider vulnerability as an interplay of multiple factors within the socio-ecological systems (Kelly & Adger,; O'Brien *et al.*,). One characteristic difference between the two approaches is the way they view adaptations. Whilst the end-point analyses maintain that adaptive capacity of the particular system determines its vulnerability, the starting-point approach considers that it is rather a vulnerability that determines the adaptive capacity and adaptation of a particular system (Füssel & Klein,).

This thesis adopts the end-point approach by assessing the vulnerability of the cocoa sector considering its capacity to adapt to climatic changes. The sequence of analysis begins with projections of future trends in climate change, climate change scenarios development, impact studies and identification of adaptive options. This can inform policies aimed at reducing the vulnerability of such farming communities and households. Farming communities have coped with climatic variability as part of their farming systems for centuries (Vogel, 2005). Moreover, to be able to properly characterize the vulnerability of a given system, it is vital that the adaptive capacity of that particular system be identified or explored because every system has some inherent adaptive capacity to environmental change (Gbetibouo, Ringler, & Hassan, 2010). Exploring these coping and adaptive capacities in an attempt to determine the extent of vulnerability of such communities to climate variability is indeed vital.

Frameworks for Assessing Vulnerability to Climate Change

Assessing vulnerability has always been difficult because of its dynamic nature relating to its spatial and temporal dimensions (Cutter *et al.*, 2009; Eriksen & Kelly, 2007; Antwi-Adjei, 2012). Nevertheless, several scholars (e.g. Turner et al., 2003; Luers, Lobell, Sklar, Addams, & Matson, 2003; Fraser, Mabee, & Figge, 2005) have proposed different theoretical frameworks for the assessment of vulnerability to climate change and variability. This study uses that of Turner et al. as a conceptual framework for assessing the vulnerability of the cocoa sector to climate change and variability and calls for clearly defined framework.

Conceptual Framework for Assessing Vulnerability

The conceptual framework that relates climate change and variability to the adaptation responses of smallholder farmers, as well as the theoretical framework employed by the study is presented in this section. The conceptual framework, adopted from Turner et al. (2003), focuses on drawing linkages and explaining how climate change and variability affect smallholder farmers.

Climate change and variability arise as a result of factors both internal and external to the smallholder farmer. The activities of the smallholder

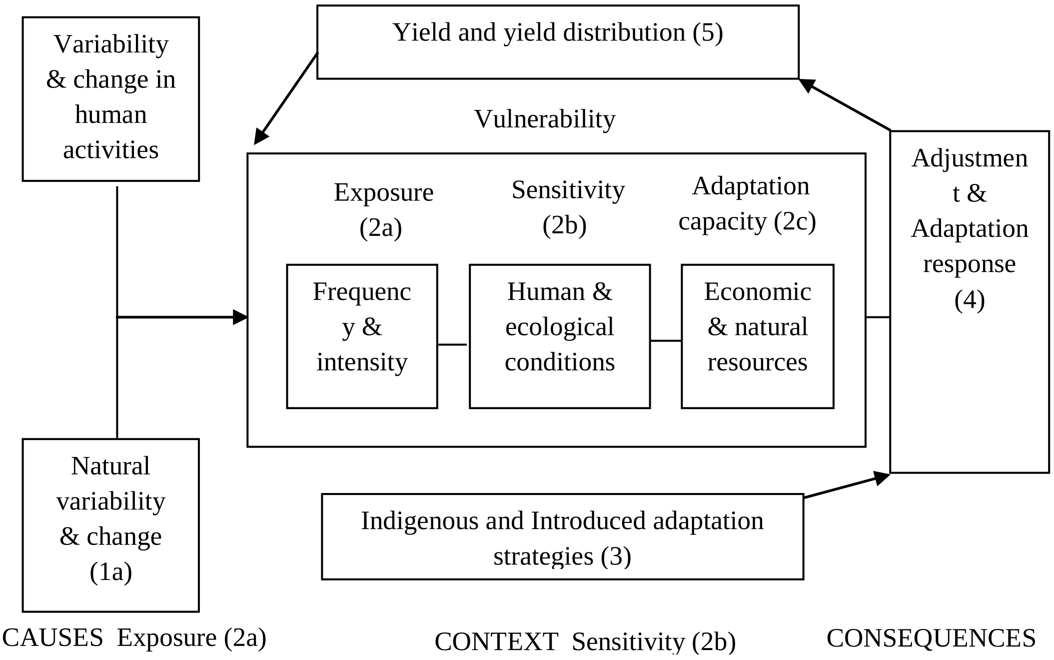


Figure 3: Conceptual Framework for Assessing Vulnerability

Source: Adopted from Turner et al., (2003).

As shown in the figure above, the extent of exposure depends on the frequency and intensity of the climatic shocks; sensitivity depends on the prevailing human and ecological conditions; and the ability to adapt depends on the economic and natural resources at the disposal of the smallholder cocoa farmer. Thus the yield in a favourable year will provide the needed resources which will reduce the vulnerability of a cocoa farmer. The study considers the IPCC definition of vulnerability in assessing the level of vulnerability of smallholder cocoa farmers to climate change. This definition takes into account exposure, sensitivity and systems capacity to adapt. The decision of smallholder cocoa farmers to adjust their behaviours in order to adopt an adaptation strategy depends on several factors that are both internal and external to the smallholder farmer. The study also determines the factors that influence the decision of smallholder cocoa farmers to adopt a climate-related strategy. Before any strategy will be adopted, farmers must perceive a change in climate which threatens their livelihood.

The Concepts of Perception and Adaptation

Bartley (1969), states that perception is the immediate discriminatory response of the organism to energy activating sense organs. To Fieandti (1966), it is the response of an experienced sensation that is a phenomenal impression resulting functionally from certain inputs. Forgus (1966), also adds that perception is the process by which an organism receives or extracts certain information about the environment.

Similarly, Barnhart (1988), explains that perception is the state of being aware of something through the senses, that is: to see, hear, taste, smell and feel. It also involves insights, apprehension, discrimination and comprehension.

Therefore, the word perception as used in this thesis is the reaction of people to a phenomenon in their environment. It is the way people use their senses to discern ideas and concepts that confront them. Those who perceive a phenomenon are in the position to think of adaptation where the phenomenon threatens them.

Adaptation is not new to farming communities, as there have been many instances where societies have adapted to changes in climate, in order to survive, by altering settlements and agricultural patterns (Antwi-Adjei, 2012). However, climate change and its associated impacts add a new dimension to this challenge (Burton, 2009). The specific definition given to adaptation depends primarily on the researcher's discipline.

This thesis, as in Antwi-Adjei (2012), adopts Smith *et al.*'s (2000), definition of adaptation to climate change as the process by which stakeholders reduce the adverse effects of climate on their livelihoods. This conceptualization allows a better understanding of how households and communities use their adaptive capacities and various assets in reducing the adverse impacts of climate variability on food systems and livelihoods. This will help in assessing how such households and communities could be assisted by various stakeholders to withstand climatic stresses.

In the context of climate change research, various definitions of adaptation abound. The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is accepted as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv, 1993). This is the ability to respond and adjust to actual or potential impacts of changing climate conditions in ways that cause moderate harm or takes advantage of any positive opportunities that the climate may afford (Santiago, 2001). According to Santiago, adaptation involves adjustment to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events, as well as longer-term climate change.

Adaptation can be anticipatory, where systems adjust before the initial impacts take place, or it can be reactive, where change is introduced in response to the onset of impacts. The extent to which an agricultural system is affected by climate change depends on its capacity to adapt.

A clear distinction is made between actual adaptation and potential adaptation. According to Brooks (2003), adaptive capacity is the potential to reduce social vulnerability by realising adaptations that, in turn, decrease biophysical vulnerability. Indeed, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, take advantage of opportunities, or cope with the consequences (IPCC, 2001).

Reidsma, Ewert and Oude Lansink (2007) differentiate between potential and actual impacts of climate change on a particular system or community in relation to climate exposure and sensitivity. According to them, the potential impact of climate change is a function of the exposure and sensitivity of the given community without taking into consideration its adaptive capacity, whilst the actual impact is what obtains when adaptation has been considered.

Füssel (2007) states that the distinction between potential adaptation (adaptive capacity) and actual adaptation must be made to reflect the temporal dimension of climate change. Adaption is said to rely on information about the vulnerability to climate change.

Adaptation to climate change includes many possible responses, such as changes in crop management practices (for example, choice of fields, planting dates, planting densities, crop varieties, etc.), livestock management practices (e.g., feeding and animal health practices, transhumance timing and destinations, etc.), land use and land management (e.g. fallowing, tree planting or protection, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management, etc.), livelihood strategies (e.g., mix of crops or livestock produced, combination of agricultural and non-farm activities, temporary or permanent migration, etc.)(Füssel, 2007).

Adaptation can greatly reduce vulnerability to climate change by making rural communities better able to adjust to climate change and variability, moderating potential damages, and helping them cope with adverse consequences (IPCC, 2001). It should include local actions taken by the poor people themselves in response to changing market or environmental conditions (Codjoe, Owusu, & Burkett, 2014).

Adaptation will require the involvement of multiple stakeholders, including policy makers, extension agents, NGOs, researchers, communities and farmers. According to Codjoe et al., (2014), adaptation activities can be of different types; from the purely technological (such as sea defence construction), through behavioural (such as shifts in choice of food or recreation), managerial (such as changes in farming methods) and policy (such as planning regulations)

The contemporary discourse of adaptation to climate change poses two quite distinctive questions. First, how can adaptation to climate change be facilitated and enhanced, given that there are several generations in the twenty-first century which will experience progressively changing climates? Second, given that efforts at mitigating further global climate change are disputed with respect to desirability, effectiveness and feasibility, are there limits to adaptation by society, beyond which politically or ethically undesirable outcomes occur? This latter question has been discussed in a sub-theme termed ‘dangerous climate change’. The implication here is that adaptation by society is limited, in some way, once climate change crosses some dangerous threshold (Stern, 2007).

Schellnhuber, Cramer, Nakicenovic, Wigley, and Yohe (2006) and Stern (2007) in recent years have followed this line of reasoning. An important policy discourse, at least in Europe, suggests that such a threshold is 2°C of global warming above pre-industrial levels (Adger et al., 2007). This target is, in effect, chosen to induce urgent action, given the high likelihood that this threshold will be crossed in coming decades (Schellnhuber et al.,). Questions that remain unanswered include the following: “Are limits immutable, imposed on society by physical reality, a form of environmental determinism?” Or, “are limits purely social constructions, infinitely renegotiable by each generation?” And “what is adaptation to climate change seeking to accomplish, for whom, by what means and at what cost?”

Considering that uncertainties still abound as to the exact nature of climate change – how it will manifest in various local and regional places at different times – approaches are being sought to take account of these uncertainties through the adaptation actions to be adopted. Africa’s agriculture faces varying climate change impacts which mainly worsen production conditions and adversely affect its economies (Mendelssohn, 1998). Adaptation methods thus need to build resilience into farming systems. Farmers will be able to cope with some changes in climate more easily than with others, and this will depend on what they produce, when they produce, where they are located, and the extent of the change.

Scales and Levels of Adaptation to Climate Change and Variability

The terms “scales” and “levels” are used interchangeably, even though some people have distinguished between them. Gibson, Ostrom, and Ahn (2000, p. 218) defined scale as “the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon, and levels as the units of analysis that are located at different positions on a scale.” Hence, the spatial scale can be divided into different levels, whilst the temporal scale can be divided into different time frames (Gibson, et al.,). In terms of scale, Kandlikar and Risbey (2000) differentiate farm-level adaptation from regional and national level adaptation. Regional- and national-level adaptation involves changes in infrastructure as well as support systems whereas farm-level adaptation covers the range of farm management practices undertaken at the farm or field level by the farmer in an attempt to moderate the adverse impacts of climate variability (Kandlikar & Risbey,). Adaptation may also be characterized by timing (reactive or anticipatory), duration (short or long term), as well as its spatial occurrence (i.e., whether it is localized or widespread) (Smit, Burton, Klein & Street, 1999). However, the success of agricultural adaptation to climate variability should not be measured only by economic outputs in terms of yields but also by ethical considerations relating to distributional and social issues such as equity and fairness (Kandlikar &

Risbey,). Central to the understanding of climate adaptation in agricultural systems and rural livelihoods are coping capacity and adaptive capacity. Adaptive capacity and coping capacity are widely used terms in climate adaptation literature (Yohe & Tol, 2002; Engle, 2011).

Coping Capacity versus Adaptive Capacity

Coping capacity has been used interchangeably with adaptive capacity in the climate change literature. Coping capacity and adaptive capacity are mostly distinguished between, with reference to time scale. Engle (2011) is of the view that adaptive capacity generally connotes some positive attributes of a system that enable it to reduce the adverse impacts (vulnerability) associated with climate change. Adaptive capacity is linked to long-term strategies whilst coping may include short-term strategies (Smithers & Smit, 1997). In this thesis, coping capacity refers to short-term strategies taken by cocoa farmers to counteract the immediate negative impacts of climate variability (Campbell, Barker, & Mcgregor, 2011; Antwi-Adjei, 2012).

Coping capacity may be applied when attempts are made to manage current stresses/stressors and may be reactive in nature, whilst adaptive capacity refers to preparing in anticipation of future uncertain changes, thereby reducing vulnerability (Ericksen, 2008). Coping responses are taken within the existing institutional structures of the system under consideration whilst adaptive capacity demands some transformation of structures and the functioning of the existing structures (Eriksen, Brown, & Kelly, 2005). Moreover, to be able to properly characterise the vulnerability of a given system, it is vital that the adaptive capacity of that particular system be identified or explored, because every system has some inherent adaptive capacity to environmental change (Gbetibouo et al., 2010).

Adaptive capacity can change over time and depends on several factors, including technology, access to economic resources, access to information, infrastructural development, appropriate institutions, kinship network, literacy levels, skills, equity and political influence (Smit, Burton, Klein & Wandel, 2000; Brooks et al., 2005). These determinants of adaptive capacity are “not independent and may function differently in different contexts” (Smit & Wandel, 2006, p. 288). Adaptive capacity may differ from one country, region or community to another, and it is considered dynamic in nature (Smit & Wandel, 2006). Adaptive capacity and coping strategies are situated within wider socio-cultural and religious processes occurring within such communities (Nielsen & Reenberg, 2010; Jones & Boyd, 2011). Therefore, efforts should be made by governments and policy makers to take cognisance of such processes and factors when designing climate change adaptation strategies aimed at increasing the capacities of rural communities to survive the negative impacts of climate variability on their livelihoods. This calls for application of appropriate analytical methods for assessing adaptation.

Analytical Methods for Accessing Adaptation

Several methods have been used in different subject areas to study how a system adapts to a phenomenon. This fact limits the ease of comparing methodologies and debating the appropriateness of any given model. Despite this, methodological similarities could be traced between agricultural technology adoption, climate change adaptation methods and other related models involving decisions to adopt or not to adopt a given course of action (Deressa, 2008).

Agricultural technology adoption models are based on farmers’ utility or profit maximizing behaviours (Norris & Batie, 1987; Pryanishnikov & Katarina, 2003). These models are based on the assumption that farmers adopt a new technology only when the perceived utility or profit from using this new technology is significantly greater than that of the traditional or the old method. While utility is not directly observed, the aims of the actions of economic agents are indirectly observed through the choices they make (Deressa, 2007).

Commonly used in agricultural technology adoption research are the Probit and Logit Models. These models are employed when there are two choices available to a farmer (whether to adopt or not). When the number of choices available is more than two, extensions of these models, most often referred to as Multivariate Models, are employed. These models have been employed in climate change studies because of the conceptual similarities between agricultural technology adoption research and climate change studies. For instance, in 2007, Nhemachena and Hassan analysed factors influencing the choice of climate change adaptation options in Southern Africa using the multivariate probit model. Kurukulasuriya and Mendelssohn (2006) also employed the multinomial logit model to see if farmers’ are climate sensitive in their choice of particular crops.

When a decision by farmers as to whether to adopt a new technology or not requires more than one step, models with two-step regressions are employed to correct for the selection bias generated during the decision-making processes. For example, Yirga (2007) employed Heckman’s selection model to analyze the two-step process of agricultural technology adoption and the intensity of agricultural input use. Maddison (2006) also argued that adaptation to climate change is a two-step process which involves perceiving that climate is changing in the first step and then responding to changes through adaptation in the second step. Thus, the current study adopts the Heckman’s two-step procedure (Heckman, 1976) to analyze the perception and adaptation to climate change in the cocoa sector of Ghana. According to Heckman, adaptation to climate change involves a two-stage process: first perceiving that there is climate change and then deciding whether or not to adapt by taking a particular measure. This leads to a sample selectivity problem since only those who perceive climate change will adapt. Thus, the Heckman probit selection model is employed to analyse the perception of cocoa farmers regarding climate change and their adaptation to it in the cocoa belt of Ghana.

Adger et al. (2007) identify two potential limits to adaptation: thresholds and barriers. A threshold refers to a state in sensitive ecological or physical systems beyond which change becomes irreversible. Some thresholds identified in the ecological literature refer to habitat ranges, ecosystem functions and threats of extinction of particular species (Parmesan & Yohe, 2003; O’Neill & Oppenheimer, 2002; Fischlin & Midgeley, 2007). A barrier to adaptation, on the other hand, exists because of the way a society is organised or because of the values it upholds (Adger et al.,).

Over time, these social values are likely to vary widely within and between societies. Values in this context refer to the personal or societal judgement of what is valuable and important in life (Adger et al., 2007). Values thus, affect the willingness to adapt, depending on the available alternatives. Values translate into action because they determine how societies develop rules and institutions to govern risk, social change and the allocation of scarce resources (Ostrom, 2005). A limit to adaptation implies an absolute barrier, one that is unsurpassable.

Barriers to Adaptation

Present understanding of the processes of adaptation to climate change suggests that actions occur when risks are known and when resources are available to minimise these risks or reduce vulnerabilities. There are several reasons why actions to build resilience to future climate change are not being implemented more widely. Despite a high degree of certainty that most, if not all, businesses, local authorities, and communities will be affected by changes in climate, the willingness and ability to adapt are often impaired by both real and perceived social, financial, political and psychological barriers.

An analysis of the barriers to adaptation to climate change in the Nile basin of Ethiopia indicates that there are five major constraints to adaptation. They are a lack of information, lack of money, shortage of labour, shortage of land and poor potential for irrigation (Deressa, 2007). Most of these constraints are associated with poverty. For instance, lack of information about adaptation options could be attributed to the fact that research on climate change and adaptation options have not been strengthened in the country; and thus, information is lacking in this area.

Adaptation to climate change is costly, and this cost could be seen in terms of the need for intensive labour use. Thus, if farmers do not have sufficient family labour or the financial means to hire labour, they cannot adapt. Shortage of land has been associated with high population pressure. High population pressures force farmers to intensively farm a small plot of land (Onyeneke & Madukwe, 2010). Where adaptation involves using new farming techniques which make use of larger farm sizes, farmers cannot easily adapt due to a shortage of land as a result of high population pressure.

Given the fact that the Nile Basin in Ethiopia is considered very rich in water resources (FAO, 1997), the poor irrigation potential can most probably be associated with the inability of farmers to use the already existing water, due to technological incapability. Farmers in Ethiopia, in general, are very poor and cannot afford to invest in irrigation technology, not only to adapt to climate change but also to sustain their livelihood during harsh climatic extremes such as drought, which often causes famine.

The Cacao Plant

Linneaus (1753) named the cacao tree *Theobroma cacao*. Cacao (*Theobroma cacao* L.) - which literally means "food of the gods" is one of 22 species that constitute the genus *Theobroma*, a member of the family Sterculiaceae, and the principal commercially important member of the genus. Botanically, the term 'cacao' refers to the tree and its fruit, whilst 'cocoa' describes the dried fermented beans, as well as the powder produced from the beans. Cacao, in its natural environment, occurs as an under storey plant in the lower canopy.

Theobroma cacao comprises a large number of highly morphologically variable types. Three main varieties of cacao have been identified. They are the c*riollo*, the f*orastero* and the t*rinitario* (Cheeseman, 1944). The f*orastero* constitutes the largest cacao population; and even though it has less flavour than the *criollo*, it constitutes the bulk of the cocoa produced in West Africa and the world at large. The *Trinitario* is believed to have been hybridised from the c*riollo* and f*orastero,* initially from Trinidad (Coe & Coe, 1996). The c*riollo* is the best in terms of cocoa flavour, but it is difficult to establish and prone to attacks by diseases and pests.

Factors Affecting Cacao Growth, Development and Yield

Several factors are known to affect the growth, development and yield of cacao. These factors can generally be classified under two broad categories, namely the genetic factors peculiar to the crop and environmental factors.

Genetic factors

The availability of good varieties is a basic feature of sustainable production of any crop. However, it has been estimated that only about 30% of the total cultivated cacao acreage is under selected varieties (Paulin & Eskes, 1995). These varieties consist mostly of mixtures of bi-parental crosses (hybrids) between local and introduced clones. The unselected cultivated cacao varieties consist mostly of traditional populations (Trinitario, Amelonado, F3 Amazon) and open-pollinated populations derived from selected hybrid varieties. Some high yielding clonal cacao varieties with effective resistance to diseases have been selected during the last 25 years. In other crops, genetic modification has sometimes been targeted at benefiting the farmer, and at other times, the consumer. Currently, most applications relate to the correction of only those genetic weaknesses of the crop that are controlled by one or a few genes (*e.g.* susceptibility to pests, diseases or stress conditions). An efficient genetic transformation system in cacao is required for significant breeding perspectives in the long term. However, it is essential that any such work is carried out in conjunction with appropriate studies of the impact of the genetically modified organism on the environment, and with due consideration to consumer opinion.

Environmental factors

The environment plays a major role in the development, growth and yield of cacao. Among the environmental factors that affect the production of cacao are climatic elements – moisture availability (rainfall), temperature, solar radiation, humidity – and soil.

Climatic Elements that Significantly Affect Cacao Production

Some of the climatic elements that are known to significantly affect cacao production are discussed below.

Rainfall

Cacao is highly susceptible to drought, and the pattern of cropping of cacao is related to rainfall distribution. Significant correlations between cacao yield and rainfall over varying intervals prior to harvest have been reported. It has been found that in Ghana a year with high rainfall is followed by a year with a large crop, though the correlation is not true in all years (Smellie, 1925; Skidmore, 1929, Brew, 1991). Ali (1969) reported both positive and negative correlations between rainfall in certain months and the yield of the main crop in Ghana.

Values defining the limits of soil moisture for cacao cultivation during the dry season in Ghana are variable and, under field conditions, depend on many factors such as shade, air movement, soil texture and structure, age and vigour of the cacao tree, volume and distribution of active roots and root depth. In considering the suitability of a soil for cacao in relation to soil moisture, it is not the quantity of available soil moisture *per se* which is important; it is rather the rate of release of the available water from the soil to the tree which matters (Wessel, 1971; Ahenkorah, 1981).

Temperature

Cacao as a tropical crop can be profitably grown in temperatures varying between 30-32 ^{o}C mean maximum, 18-21 ^{o}C mean minimum and an absolute minimum of 10 ^{o}C (Wood & Lass, 1985). Temperature has been related to light-use efficiency, with temperatures below 24 ^{o}C having a decreasing effect on the light saturated photosynthesis rate (Hutcheon, 1977). Temperatures below 10 ^{o}C cause severe inhibition of photosynthetic rate. The stomata of chilled leaves never open as wide as the stomata of non-chilled plants. Thus, leaf temperature affects stomatal resistance, with increasing temperatures decreasing the resistance. However, since the increases in temperature may often go together with higher vapour pressure deficits (VPD), the effect of VPD may override the effect of temperature (Harun & Hardwick, 1986).

In Ghana, the period of high temperatures (when the widest range in the maximum and minimum temperatures occurs) has been noted to coincide with flushing (Hurd & Cunningham, 1961; Asomaning, Kwakwa, & Hutcheon, 1971).

Solar radiation

It is well established that, in general, where soil nutrients, water and temperature are not limiting, and losses from pests and diseases can be avoided, crop growth and yield are dependent on the total solar radiation intercepted during the growing season (Monteith, 1978). Trials in West Africa have shown that potential yields of cocoa can be doubled by removing permanent shading (intercepting 30-50% incident radiation), provided fertilizers are applied (Lechenaud & Mossu, 1985).

Thus, the amount of sunlight on the cacao tree affects its growth and yield (Ojo & Sadiq, 2010). Cacao has a low light saturation point (LSP) of 400 μ E m^{-2} s^{-1} and a low maximum photosynthetic rate (7mg dm^{-1} h^{-1}) at light saturation (Hutcheon, 1981). The photosynthetic rate of the crop decreases if the crop is exposed to light intensities exceeding 60% of full sunlight, that is, 1800 μ mol m^{-2} s^{-1} (Galyuon, McDavid, Lopez & Spence, 1996), while prolonged exposure to high light intensities damages the photosynthetic mechanism of the leaves (Harun & Hardwick, 1988). Low light intensities, however, suppress flower production with light levels less than 1800 hours $year^{-1}$, having a considerable depressing effect on production (Asomaning *et al.*, 1971).

Humidity

Relative humidity is uniformly high in cacao-growing areas, often 100% at night, falling to 70-80 % by day, sometimes lower during the dry season. Its most marked effect is on leaf area (Ojo & Sadiq, 2010). Plants growing at low humidity (50-60%) have larger leaves and greater leaf area than plants growing at medium (70-80%) and high (90-95%) humidity. Under the latter conditions leaves are small and tend to be curled and withered at the tip. Other effects of high humidity concern the spread of fungal diseases and the difficulties of drying and storage of the beans (Ojo & Sadiq,).

The variability of these climatic elements determines the suitability of a place to grow cacao and even the overall output from the crop.

Soils

Cacao is grown on a wide range of soil types, and the standards of soil suitable for cacao vary considerably. Cacao trees are more sensitive to moisture stress than many other tropical crops. In addition, cacao trees are sensitive to water-logging (Anim-Kwapong & Frimpong, 2005). While they can withstand flooding, they will not tolerate stagnant, water-logged conditions. The depth of the soil that supports cocoa is at least 1.5 m. The best soil for cocoa is forest soil, rich in humus. Suitable soils allow easy penetration of roots, are capable of retaining moisture during dry periods, and allow circulation of air and moisture. Clay loams and sandy loams are suitable. A minimum requirement of 3.5% organic matter, with about 2% carbon in the top 15 cm is ideal for growing cacao. Cacao thrives on soils with pH ranging from 6 to 7.5 within which major nutrients and trace elements are available (Anim- Kwapong & Frimpong,).

Field and profile examination of soils suitable for cocoa indicates that deep, friable loam to clay loams and sandy loam soils are about the most important physical properties of good cacao soils. These soil profiles are characterised by low cation exchange capacity (CEC), with the exchange capacity highest in the top soil as a result of the high accumulation and consequent decomposition of organic matter. The nitrogen content is concentrated within the top 10 cm layer and decreases sharply below this layer (Appiah, 1992).

Adu and Mensah-Ansah (1969) have categorized soils in Ghana into cacao suitable and unsuitable soils, on the basis of textural and depth analyses. The model profile of a good cacao soil is deep and characterized by a well-drained non-gravelly top soil over a sandy clay loam layer, which usually contains both iron oxide concretions and quartz gravels. This layer overlies sedentary mottled clay, which merges with the incompletely weathered parent material (Ahenkorah, 1981). Soils carrying cacao in Ghana are shown in Figure 4.

The unsuitable soils are highly de-saturated ferrallitic soils, primarily Forest Oxysols and Oxysol-Ochrosol intergrade. These soils cover the south of the Western Region. It is on these soils that the move to extend the area under cocoa in recent years has taken place. Without fertilizer application, their lack of necessary minerals results in limited yields and to premature tree aging. For trees grown in full sunlight, yields tend to fall from around year 10 onwards (Ahenkorah, 1981).

The suitable soils are moderately de-saturated ferrallitic soils (dystropepts/Forest Ochrosols). They are primarily found in the old cocoa growing areas of the Eastern and Ashanti Regions. On them it is possible, without fertilizer application and with light permanent shading, to achieve potential yields of about 1500 kg per hectare for over fifteen years (Ahenkorah, 1981).

The highly suitable soils are only slightly de-saturated ferrallitic soils (tropical eutrophic brown soils/ Forest Ochrosol - Rubrisol intergrade) with a high exchange capacity. These soils respond better to mineral fertilizers. They are generally well-drained deep soils, occurring in limited areas in Ashanti and in the North of the Western region (Ahenkorah, 1981).

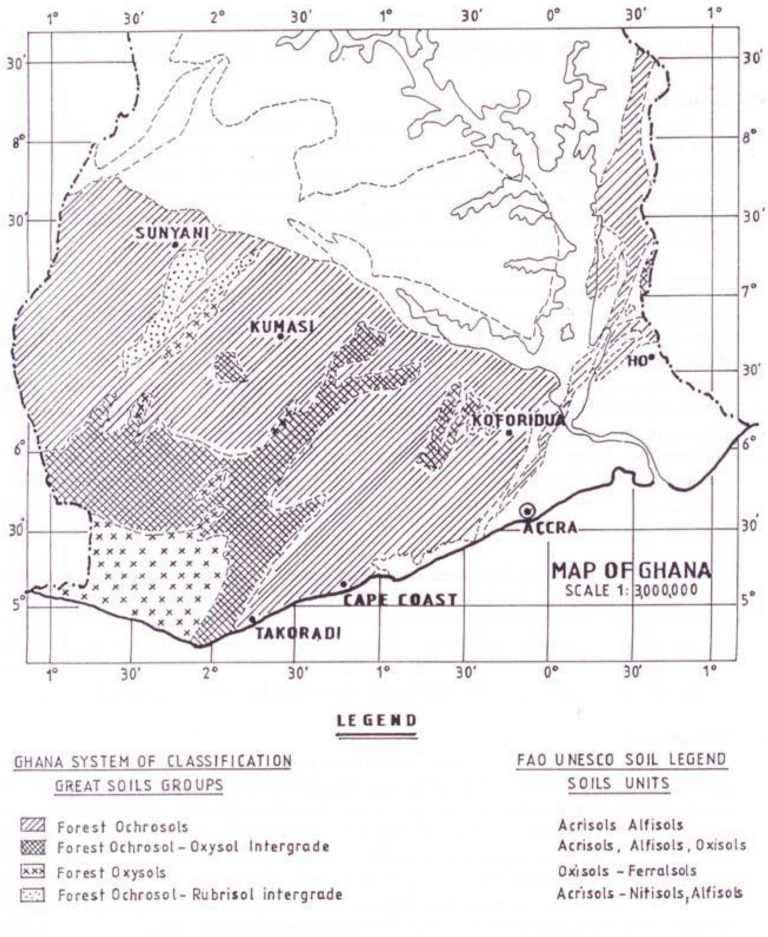


Figure 4: The Major Soil Groups within the Cacao Growing Regions in Ghana.

Source: Anim-Kwapong and Frimpong, (2005)

Area expansion contributed to output growth from 2002 to 2004, but the area planted then declined, from two million hectares in 2004 to 1.8 million hectares in 2006, about 25 percent of cultivated land in Ghana

(COCOBOD, 2007). A comparison of land currently devoted to cocoa production with land that is suitable for the production of cocoa indicates that future growth in production through area expansion will be limited (Anim-Kwapong & Frimpong, 2005). Currently, cocoa production is concentrated in areas that are “very suitable” or “suitable”, but it also extends to areas only “moderately suitable.” Even then, the moderately suitable land is limited, and the larger proportion of remaining land, especially in the North, is not suitable for cocoa production.

Other Factors Affecting Cocoa Production in Ghana

A wide range of other factors affect the production of cocoa in Ghana. They include the economic status of farmers, cocoa purchasing price, land tenure system, smuggling, government policies, diseases and pests and husbandry practices such as spraying, weeding, fertilizer application, pruning and harvesting. The age of the tree is also important when considering production levels.

Economic status of farmers and cocoa purchasing price

The income levels of cocoa farmers in Ghana affect their ability and willingness to invest in response to high world prices. Coupled with the fact that most trees are aging, cocoa farmers’ low incomes make it nearly impossible to invest in fertilizers, regular spraying and the hiring of labour, among other costs.

Ghana is a price taker in the international cocoa market; and the world price and supply conditions of cocoa have a powerful impact on the country’s cocoa sector (Bulir, 1998). Nevertheless, the supply of cocoa is ultimately a function of relative producer prices, even though short-term production capacity is constrained and output may fluctuate because of weather conditions (Bulir,). As the purchasing price for cocoa beans increases, there is an incentive for cacao farmers to increase their production through proper husbandry practices. Weeding and spraying, for example, are done more regularly; and where credit is available, fertilizers are used to ensure high yields in anticipation of a favourable purchasing price.

Land tenure systems under cocoa

Land is the source of wealth in any nation. Land tenure defines access to land resources and considers the ways in which land is held or accessed (Bugri, 2008). It can be said that access to land has limited the cocoa sector, since most of the increases in output have been due to expansion in the area under cocoa. In Ghana, migrant cocoa farmers can gain access to land under three main tenurial arrangements. These are share-cropping, of which there are the ‘abunu’ and ‘abusa’ systems, an outright purchase and gifts.

There can be no doubt that security of land tenure would engender more investment of resources in the cocoa sector. In the era of climate change where some old cocoa growing areas are likely to be vulnerable to its effects, moving to areas more favourable to the cacao plant will be necessary. Unfavourable land tenure systems in plausible new areas will limit farmers and hence affect the cocoa sector. Land related issues in cocoa farming must, therefore, be tackled with the urgency they deserve if cocoa is to continue its role as a mainstay of the Ghanaian economy.

Smuggling and government policies

Smuggling has the tendency to render projections of cocoa beans production erroneous. As contended by Armah (2008) in his report, the current boom in cocoa exports from Ghana is primarily the result of the reversal of price incentives to smuggle Ghana cocoa to Cote D’Ivoire and not due to gains in the Ghana cocoa supply chain. The official COCOBOD estimates of smuggling were between 5-10 percent of the officially recorded crop (May, 1985).

The Government of Ghana has over the years been committed to implementing policy measures within the cocoa sub-sector such as increased producer prices, an effective diseases and pests control programme (CODAPEC), bonus payment, a hi-tech programme (subsidized fertilizer for application) and replanting of denuded areas to enable the sub-sector contribute significantly to the growth of agriculture’s share in the GDP, foreign exchange earnings, employment generation and poverty reduction in the country (Naminse, Fosu, & Nongyenge , 2011).

In recent years, Ghana has been the most successful of all cocoa exporters. Higher producer prices, partial liberalization of internal marketing, the establishment of a price stabilization system, government-backed rehabilitation programmes, spraying programmes, fertilizer credits, improvements in extension systems, and the privatization of input distribution may have contributed to growth in the cocoa sector (ICCO, 2007; Laven, 2007).

Diseases and pests of cocoa

The length of time that a cocoa farm remains productive and financially viable is determined by the application of good maintenance practices; in particular, pest and disease control (ICCO, 2008). Some common diseases that affect cocoa plantations are discussed below.

Of all the diseases that affect the cacao tree, Black pod or *Phytophthora* pod root causes the largest loss to cocoa production. The p*hytophthora* species is typically found in tropical or warm, temperate countries with high rainfall. In Ghana, the disease is caused by two *Phytophthora* species: *P. palmivora* and *P. megakarya* (Opoku, Akrofi & Appiah, 1999). Generally, losses from *P. palmivora* are estimated at 4.9-19% (Blencowe & Wharton, 1961; Dakwa, 1984). Losses due to *P. megakarya* range from 60-80% in newly affected farms to about 100% in farms which have been affected for a long time. This is especially the case during the black pod season (May to mid-June).

The Black pod disease is closely related to the weather and climate. It is more prevalent in damp situations, and it is most destructive in years when the short dry period from July to August is very wet (Anim-Kwapong & Frimpong, 2005).

The Cocoa Swollen Shoot Virus Disease (CSSVD) is a disease transmitted by infectious mealy bugs and infected budwood that occur in all the main cocoa producing countries of West Africa. In affected plants, red vein-banding occurs in young leaves (Posnette, 1941). Other symptoms of the disease include swellings in stems and roots, reduction in yield, die-back and complete death of affected plants (Domfeh, Dzahini-Obiatey, Ameyaw, Abaka-Ewusie & Opoku, 2011). This disease has serious constraints to the production of cocoa in West Africa, particularly in Ghana. The Amelonado cocoa varieties are particularly susceptible to infection (Dzahini-Obiatey, Domfeh & Amoah, 2010). The CSSVD continues to spread in Ghana despite many years of the cutting-out of infected trees.

Cocoa pests include capsids which are sucking insects that damage the soft, young tissues of the tree by piercing the young shoots with their mouth, injecting poisonous saliva and then sucking liquid food out of the wound so made. These wounds often become infected with a fungus. As a result, the affected shoot dies out. In young cacao, the whole plant may be killed. Capsids thus make cocoa difficult to establish. The insects are usually most active and destructive from September to March, particularly when moisture deficit is severe. They are favoured by high light intensity and humidity in the cocoa micro-environment (WACRI, 1951).

Another serious and major parasitic pest that attacks mature cacao trees is the mistletoe. If it is not removed early, it destroys the young branches of the cacao trees and affects the potential of the trees to bear healthy and good fruits (Naminse et al., 2011).

It has been noticed that one of the challenges to high yields of the cacao in Ghana over the years is the ineffective control of pests and diseases such as the swollen shoot, black pod and capsid bug (Naminse, et al., 2011).

Husbandry practices that affect cocoa production

The husbandry practices that are important in cocoa production include regular spraying, weeding, fertilizer application, pruning, mistletoe control and proper harvesting procedures. It has further been observed that, planting improved cocoa seeds from designated gardens used for planting, regular spacing, regular weed management, shade management, frequent disease and pest control, and fertilizer application once a year among other improved cultural practices could give a yield as much as 22 bags/ha or 9 bags/acre or more (Naminse et al., 2011).

Controlling weeds in young cocoa farms is one of the most expensive and time-consuming cultural operations during cocoa farm establishment. Farmers have to weed their farms between four to six times per annum to enhance growth and early yield of young cocoa (Oppong, Osei-Bonsu, Amoah & Acheampong, 1998). In older farms, however, it is recommended that weeding is done at least twice in a year: one during the rainy season and the other after the short dry season.

Where soil fertility is lost, fertilizer usage has been encouraged to ensure increased productivity of the cacao trees. It has been observed that the yield of cocoa can be increased by 30% by applying fertilizer (Naminse et al., 2011).

Cocoa pods are harvested as soon as they are ripe. Harvesting is usually done every week during peak periods and fortnightly if there are not many ripe pods. Over-ripe cocoa pods are more likely to become infected with diseases, and the beans inside them will germinate. Correct harvesting will reduce the possibility of transferring diseases from one tree to another and increase yield (Naminse et al., 2011).

Age of cacao tree

The age of the cacao tree is another important determinant of the yield of the crop. The older the tree, the bigger it is, hence the greater its ability to support more fruits. However, the yield behaves like the marginal product curve. It rises, reaches a maximum and begins to fall. This means that, very old trees yield less compared with mature younger trees, all other things being equal. In other words, as a cocoa farm ages, output begins to decline (Baah, Anchirinah, & Amon-Armah, 2011). The economic life span of the cacao tree is not known; but under the best conditions of weather, soil and management, it can be kept almost in indefinite bearing (Kishore, 2010).

The History of Cocoa and its Production in Ghana

Cocoa originated from around the headwaters of the Amazon in South America (Opeke, 1987). Its cultivation and value spread in ancient times throughout Central and Eastern Amazonia, and northwards to Central America. Large-scale cultivation of cacao was started by the Spanish in the 16th century in Central America. It spread to the British, French and Dutch West Indies (Jamaica, Martinique and Surinam) in the 17th century, and to Brazil in the 18th century. From Brazil it was taken to Sao Tome and Fernando Po (now part of Equatorial Guinea) in 1840; and from there, to other parts of West Africa, notably the Gold Coast (now Ghana), Nigeria and the Ivory Coast (Cote d'Ivoire).

Dutch Missionaries planted cacao in the coastal areas of the then Gold Coast as early as 1815, whilst in 1857 Basel Missionaries also planted cacao at Aburi. However, these efforts did not result in the spread of cacao cultivation until Tetteh Quarshie, a native of Osu, Accra, who had travelled to Fernando Po and worked there as a blacksmith, returned in 1879 with the Amelonado cocoa pods and established a farm at Akwapim Mampong in the Eastern Region (Adjinah & Opoku**,** 2010). Farmers bought pods from his farm to plant; and cultivation spread from the Akwapim area to other parts of the Eastern Region. In 1886, Sir William Bradford Griffith, the then Governor of the Gold Coast, arranged for cocoa pods to be brought in from Sao Tome, from which seedlings were raised at the Aburi Botanical Gardens and distributed to farmers (Asuming-Brempong et al., 2006).

The first cocoa beans left the shores of Ghana in 1891. Since then, the crop has remained the major export crop and a ready source of domestic revenue and foreign exchange to the nation. By dint of hard work, Ghana became the world’s leading producer of cocoa. From 1910 to 1977, Ghana’s market shares ranged between 30 and 40 percent. Production increased from 36.3 metric tonnes in 1891 to a peak of 591,031 metric tonnes in the 1964/65 season, giving the country a global output share of about 33 percent (Adjinah & Opoku, 2010).

Although Ghana was the world's largest cocoa producer in the early 1960s, by the early 1980s Ghana’s production had dwindled almost to the point of insignificance. The drop from an average of more than 450,000 tons per year to a low 159,000 tons in 1983-1984 was attributed to aging trees, widespread disease, low producer prices and bad weather. In addition, bush fires in 1983 destroyed some 60,000 hectares of cocoa farms, so that the 1983-84 crop was barely 28 percent of the 591,031 tons recorded in 1964-65. Output recovered to 228,000 tons in 1986-87. Revised figures show that production amounted to 301,000 tons in 1988-89, 293,000 tons in 1990-91, and 305,000 tons in 1992-93 (COCOBOD, 1998).

To rescue the cocoa industry, the Government of Ghana, in collaboration with COCOBOD instituted a number of policy interventions to control the challenges facing the cocoa sector. Though some of these interventions could not hold for long, others were embraced by the farmers. For example, the Akuafo cheque payment system which was introduced in 1986 to pay for farmers' produce collapsed a few years after its inception. Also the policy of cutting out diseased cacao trees, enacted by the colonial Government upon the recommendations of the Cocoa Research Station at Tafo, had its share of hitches at the beginning when most of the farmers refused to cooperate with the workers who were mandated to cut out all the affected cacao trees (COCOBOD, 1998).

Recently, the Government, through COCOBOD, has initiated two intervention programmes geared towards reviving and booming the cocoa industry. A nationwide cocoa diseases and pests control programme, commonly known as "Cocoa Mass Spraying", was started in the 2001/2002 cocoa season. This aimed at assisting farmers to fight the black pod and mirid/capsid diseases (COCOBOD, 2007).

The timely introduction of the Cocoa Hi-technology programme in the 2002/2003 cocoa season also reduced the effects of soil nutrient deficiency and pest attacks on cocoa production (COCOBOD, 2007). All these programmes have helped to revamp the cocoa sector.

Role of Cocoa in Ghana's Development

In Ghana, like many other African countries, export crops continue to play an important role in its development although over dependence on these export crops has often made the country vulnerable to international price volatility (Wilson, 1984; UNCTAD 2005). In Ghana, the cocoa sector continues to play an important role. There has been a consistent increase in cocoa production from 2007 to 2010 when the country earned approximately $2.285 billion from cocoa exports, which constituted 28.9% of the total foreign exchange earnings (ISSER, 2011).

In recent years, cocoa production more than doubled, from 395,000 tons in 2000 to 740,000 tons in 2005, constituting 28 percent of agricultural growth in 2006, up from 19 percent in 2001 (Bogetic et al., 2007). Cocoa accounts for about half of agricultural exports, including forestry and fishery. In comparison, the two major non-traditional agricultural export commodities, palm oil and fruits, together account for only about 4 percent of total agricultural exports.

Sales of cocoa beans have been one of the major foreign exchange earners to Ghana over the years. In 2001, cocoa export contributed 16% ($246.7 million) to total exports (Agric Education and Training in Africa, 2011). In 2002, cocoa made up 22.4 per cent (463 million US$) of the total foreign exchange earnings. Cocoa constituted 63% of the export earnings from the agricultural sector, compared to 25% and 12% contribute by timber and the non-traditional export sectors respectively (ISSER, 2003).

According to Dwinger (2010), cocoa contributed 9% to GDP in 2008. In 2010, the Ministry of Food and Agriculture (MOFA) also reported that the agricultural sector contributed about 37.3% to Ghana’s GDP that year. It further stated that the cocoa sub-sector contributed 15% of that year’s GDP (MOFA, 2010). In view of such sturdy performance of the cocoa industry, it is quite reasonable to surmise that the growth of the cocoa industry is the engine propelling the country’s recent impressive economic growth (Armah, 2008).

There are several indications that cocoa can continue to play an important role in Ghana's economic growth. The indications are that, international cocoa prices are likely to remain high (World Bank, 2007). Secondly, cacao yields in Ghana are well below international averages, suggesting potentials for production driven growth (FAO, 2005; ICCO, 2007). Thirdly, new scientific evidence emphasizes health benefits for cocoa consumers which will potentially boost demand further (ICCO,). Finally, the Government of Ghana is expected to continue its support to the cocoa sector, and there are indications that the partial liberalization of Licensed Buying Companies will continue to contribute to output (Varangis & Schreiber, 2001; Zeitlin, 2005).

Synthesis and Conclusions

This theoretical literature review has shown how climate systems can influence variability and change in the local climate, leaving farmers with difficult decision making on what, when and how to produce. Increasing temperatures and rainfall variability associated with climate change and variability could have a devastating effect on livelihoods especially in countries that depend heavily on agriculture. However, these impacts will vary spatially in nature and magnitude. Hence, understanding the complexity of climate impacts on agricultural systems requires further investigation through more detailed assessments of key regions in West Africa.

An attempt has been made to explain the concepts of vulnerability to climate change, noting that the extent of vulnerability to climate change of individuals and societies will depend on the availability of and accessibility to assets and resources. Again, the extent of vulnerability to climate change differs from one scale to the other. Hence studies conducted on global, regional or national scales, though allowing for comparison, do not always reflect household level vulnerability. Adopting a multi-scale approach to drought vulnerability assessments provides a significantly richer understanding of the different dimensions of the problem, through its exploration across scales (Antwi-Adjei, 2012). However, a bottom-up approach will be more appropriate in ensuring that issues discussed in vulnerability assessments will increase resilience of households to climate change.

The concept of adaptation to climate change has also been discussed. Adaptation can be anticipatory, where systems adjust before the initial impacts take place; or it can be reactive, where change is introduced in response to the onset of impacts. An attempt is made to distinguish between actual impact of climate change (considering the system's adaptive capacity) and potential impact (which is a function of the exposure and sensitivity of the given community) (Reidsma *et al.*, 2007). Limits and thresholds to adaptation are reviewed; and some adaptive responses to climate change have been discussed. These responses, according to Gibson, Ostrom & Ahn (2000), can be on different levels (farm-level, regional-level, and national-level) and scales (the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon). A distinction has also made between coping capacity (short-term strategies) and adaptive capacity (long-term strategies). Some barriers to adaptation in the literature are also reviewed.

The last section of the literature looked at the cacao plant, its history and role in Ghana’s development and some factors that influence its growth, development and yield.

CHAPTER THREE

REVIEW OF EMPHIRICAL LITERATURE ON CLIMATE CHANGE AND COCOA PRODUCTION

Introduction

This chapter presents a review of relevant empirical literature relating to the effects of climate change on crop production in general and on cocoa production in West Africa in particular. The first section discusses climate trends in Ghana and some projections made for the future with regards to climate change. The effect of climate change on some crops such as maize, sorghum and wheat and on cocoa production follows in the next section. Finally, some models used for estimating crop production in a changing climate are examined as the justification for the methodology used in the study.

Climate Trends in Ghana

Temperature

Since 1960, for Ghana as a whole, mean annual temperature has risen by 1.0°C, an average rate of 0.21°C per decade and the rate of increase has been most rapid in April through June (about 0.27°C/decade) (McSweeney et al., 2008). According to Minia (2008) and McSweeney et al., (2008), the rate of increase generally has been more rapid in the northern than southern regions. Five-year moving averages from 1961 to 2000 indicate about a 1°C increase in the Sudan Savanna and Guinea Savanna zones and <1°C in the Deciduous Forest (~0.8°C), Rain Forest (~0.4°C), and Coastal Savanna (~0.6°C) zones (interpolated from graphs in Minia,). Ghana's cocoa belt lies in the South where, there is the needed forest canopy for establishing cocoa farms. The soils here are classified Very Suitable or Suitable, made up of the forest ochrosols and oxysols with their intergrades (Ahenkorah, 1981). Temperature increases here are predicted to be less than 1^{o}C. No obvious upward or downward trends in temperature were indicated in graphs from 1961 to 2000 for the Transitional Zone (Minia,).

A notable increase in mean annual air temperature of about 0.9°C occurred between 1960 and 2001 along the coast of Ghana; the maximum and minimum temperatures increased by 2.5 and 2.2°C, respectively, during this time (Dontwi, Dontwi, & Buabeng, 2008).

Precipitation

Annual rainfall in Ghana is highly variable on inter-annual and inter-decadal timescales, making identification of long-term trends difficult (Stanturf et al., 2011). In the 1960s, rainfall in Ghana was particularly high and decreased to particularly low levels in the late 1970s and early 1980s. This caused an overall country-wide decreasing trend in the period 1960 to 2006 of an average 2.3 mm per month or a 2.4 percent per decade (McSweeney et al., 2008).

For most eco-climatic zones, five-year moving averages also indicate a trend toward decreased total annual precipitation from 1961 to 2000 (Minia, 2008). Over this period, mean decreases occurred in the Guinea Savanna Zone (~120 mm decrease), Deciduous Forest Zone (~240 mm), and Rain Forest Zone (~750 mm) (interpolated from graphs in Minia,). Inspection of graphs (Minia,) did not indicate upward or downward trends in total annual precipitation for the Sudan Savanna or Transitional zones. Along the coast of

Ghana, total annual precipitation showed a significant linear decrease from 1961 to 2000 (a decrease of about 1000 mm) with a marked cycling of high and low rainfall years with an apparent six-year lag (Dontwi et al., 2008).

Comparison of the mean annual rainfall differences between 1951-1970 and 1981-2000 at meteorological stations across Ghana also indicated less rainfall (Owusu & Waylen,). Significantly less rainfall occurred in the latter period in the Deciduous Forest and Rain Forest zones (mean decreases ranged from 136.9 to 335.3 mm) and the coast (Accra station, mean decrease of 260.5 mm). As a percentage of total annual rainfall, southwestern Ghana (i.e., ~Rain Forest Zone) experienced reductions in rainfall as high as 20 percent (300 mm), twice the proportion experienced in the savanna zones (Owusu & Waylen,). Rainfall decreased, though not significantly, for most stations in the Transitional Zone (mean decrease of 115.1-169.8 mm) and combined Sudan and Guinea savanna zones (77.3-93.3 mm) (Owusu & Waylen, 2009). Another analysis based on comparison of annual rainfall data between 1950-1970 and 1971-1990 showed significant decreases in rainfall in the Sudan and Guinea savanna zones (1.5 percent reduction at Tamale, 2.3 percent at Yendi, 7.2 percent at Navrongo, and 11.3 percent at Wa) (Gyau-Boakye & Tumbulto, 2000).

Climate Scenarios for Ghana

Climate Projections

Generally, climate models cannot project changes in regionally driven climate phenomena, such as ENSO. Thus, for Ghana climate models show a wide range of projected changes in the amplitude of future El Niño type of events. As the climate in Ghana is strongly influenced by ENSO, this contributes to uncertainty in climate projections (Global Facility for Disaster Reduction and Recovery, 2011).

In predicting future climatic conditions, assumptions must be made about how the human component of the climate system will evolve over the course of the forecast period (Stanturf et al., 2011). This is typically accomplished by developing different scenarios of anthropogenic influences, basically different rates of GHG emissions. These scenarios do not represent predictions, but are instead alternative views of how the future may unfold. The IPCC developed four different families of scenarios. This work will focus on three of those families described in various IPCC documents (IPCC, 2007).

A2 - The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

A1B1 - The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system.

B1 - The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The first set of projections of potential changes in temperature and precipitation presented are the result of averaging 16 atmosphere-ocean general circulation models (AOGCMs) that have been downscaled to a horizontal grid size of ~50 km following the statistical methodology described in Maurer, Adam, and Wood (2009). The use of an ensemble of models helps limit the influence of any bias present in any one model (Stanturf et al., 2011). As noted by some authors, generally, most GCMs have difficulty correctly reproducing a number of key features of the atmospheric circulation patterns over West Africa, which contribute to uncertainty in estimates of future rainfall (Douville, Me'lia, & Tyteca, 2006; Joly, Voldoire, Douville, Terray, & Royer, 2007; Caminade & Terray, 2009). Neither the Third nor Fourth Assessment Report of the IPCC reached a consensus regarding the sign or magnitude of predicted changes in precipitation over West Africa during this century (Hulme, Doherty, Ngara, New, & Lister, 2001; Bernstein et al., 2007). The West African Monsoon is difficult for coarse resolution GCMs to describe, considering the wide range of mechanisms for variability, acting at various time and space scales from global teleconnection patterns related to the El Nĩno-Southern Oscillation ENSO (Caminade & Terray,) or the Atlantic Multi-Decadal Oscillation (Shanahan et al., 2009) to the coupling of soil moisture to intra-seasonal variability (Lavender, Taylor, & Matthews, 2010).

Druyan (2011) provides a convincing argument for the need of more detailed (higher resolution) modelling to properly capture critical processes in this region. For this reason, the focus is on the changes predicted by an ensemble of climate models, as this provides a means of examining not only the projected change in temperature and precipitation but also provides a measure of confidence in these projections.

Several studies have been undertaken to reveal overall climate trends for Ghana in the future. These include the World Bank study of the Economics of Adaptation to Climate Change Study (looking at the 2010-2050 period) and the 2000 UNDP Climate Profile of Ghana (looking at the 2060-2090 period). Some of their findings are discussed below.

Temperature Projections

In a country-wide projections for Ghana (McSweeney et al., 2008), the mean annual temperature is projected to increase by 1.0 to 3.0°C by the 2060s and 1.5 to 5.2°C by the 2090s. The range of projections by the 2090s under any one emission scenario used in the UNDP-NSCP work is about 1.5-2.5°C. The projected rate of warming is more rapid in the northern inland regions of Ghana than the coastal regions (McSweeney et al.,). Although the projected mean temperature increased more rapidly in the interior regions of Ghana than near the coast, the projected changes in the daily temperature extremes ("Hot" and "Cold" days and nights) in Ghana were largest in the coastal areas, and smaller inland (McSweeney et al.,).

The eco-climatic zone projections of the EPA-NCAP work also indicated continued increases in temperature (Minia, 2008); but the projections do not appear to be scaled to the level of the eco-climatic zones. An increase of 0.6, 2.0, and 3.9-4.0°C for 2020, 2050, and 2080, respectively, was uniformly applied to the mean annual baseline temperatures of each eco-climatic zone to produce the 30-year mid-range projections (upper boundary projected increases of 0.8, 2.5, and 5.4°C, for respective 30-year periods) (Minia,). For all but one zone (Sudan Savanna) the projected increases in monthly temperatures applied to each 30-year projection in each zone are identical and tended to be highest in February to- May. However, using this approach, the annual and monthly "projection" patterns follow the baseline mean annual (and monthly) temperature patterns, and simply add a constant increase across most eco-climatic zones for each 30-year period.

Projections of changes in temperature for meteorological stations across Ghana by Stanturf et al., (2011) also indicated continued increases for 2050 and 2080. Notably, regardless of emission scenario, the AOGCMs are consistent in predicting slightly warmer conditions, with only minor differences between the wet and dry seasons.

Perhaps, the best estimate of the impact of future climate conditions on temperature is provided by the overall ensemble of 16 climate models across the three emission scenarios which suggest the increases in temperature as shown in Table 1.

Table 1- *Predicted Temperature Changes in the Wet and Dry Seasons*

Station/Eco-climatic Zone	Dry Season	Wet Season
Accra (Coastal Savanna Zone)	1.74 ± 0.60°C by 2050; 2.71 ± 0.91°C by 2080	1.68 ± 0.38°C by 2050; 2.54 ± 0.75°C by 2080;
Kumasi (Deciduous Forest Zone):	1.81 ± 0.68°C by 2050; 2.83 ± 1.04°C by 2080	1.71 ± 0.39°C by 2050; 2.60 ± 0.77°C by 2080
Tarkwa (Rain Forest Zone)	1.76 ± 0.67°C by 2050; 2.76 ± 1.01°C by 2080	1.69 ± 0.37°C by 2050; 2.56 ± 0.75°C by 2080
Techiman (Forest-Savanna Transition Zone):	1.95 ± 0.79°C by 2050; 3.05 ± 1.20°C by 2080	1.77 ± 0.43°C by 2050; 2.71 ± 0.85°C by 2080
Tamale (Guinea Savanna Zone)	2.05 ± 0.75°C by 2050; 3.18 ± 1.18°C by 2080	1.84 ± 0.46°C by 2050; 2.83 ± 0.91°C by 2080
Wallembelle (northernmost Guinea Savanna Zone)	2.10 ± 0.71°C by 2050; 3.27 ± 1.11°C by 2080	1.92 ± 0.52°C by 2050; 2.96 ± 0.98°C by 2080
Bawku (Sudan Savanna Zone)	2.11 ± 0.68°C by 2050; 3.25 ± 1.08°C by 2080	1.92 ± 0.53°C by 2050; 2.97 ± 0.98°C by 2080

Source: Stanturf et al. (2011)

Precipitation Projections

Projections of mean annual rainfall averaged over the country (UNDP report) from different models in the ensemble indicate a wide range of changes in precipitation for Ghana with about half the models projecting increases and half decreases (McSweeney et al., 2008). Seasonally, the projections tend towards decreases in January through June rainfall and increases in July through December rainfall.

At the eco-climatic level (Minia, 2008), rainfall is projected to decrease by 2020, 2050, and 2080 in all regions. Percentage decrease in rainfall at each projection period tend to increase from north to south from -1.1, -6.7,-12.8 percent in the Sudan Savanna Zone to -3.1, -12.3, -20.5 percent in the Coastal Savanna Zone for 2020, 2050, and 2080, respectively. Absolute change in rainfall is projected to be highest in the Deciduous Forest and Rain Forest Zones (243 and 423 mm decrease by 2080, respectively). Upper boundary projections indicate an annual decrease of 32.6 percent in annual precipitation in the Sudan Savanna Zone and a 26.8 percent decrease in the remaining eco-climatic zones.

However, AOGCM modeling projections of rainfall among seven representative meteorological stations by Stanturf et al. (2011) gave mixed and inconclusive results. AOGCM predictions of precipitation lack any consistency, predicting both decreases and increases in rainfall at each station. The results (Table 2) are summarized for each station as follows:

Table 2- *Predicted Precipitation Changes*

Station/ Eco-Climatic Zone	**Forecast**
Accra (Coastal Savanna Zone)	Changes in precipitation range from 52% decreases to 44% increases in wet season rainfall by 2080. The overall ensemble prediction across emission scenarios gives a slight increase in wet season rainfall of 2.65 ± 13.96 percent by 2050 and 3.88 ± 19.41 percent by 2080. The variability among the models' precipitation changes is not very different from the inter-annual variability currently experienced in the region.
Kumasi (Deciduous Forest Zone)	Changes in precipitation range from 48% decreases to 45 % increases in wet season rainfall by 2080. The overall ensemble prediction across emission scenarios gives a slight increase in wet season rainfall of 1.73 ± 13.42 percent by 2050 and 3.19 ± 18.98 percent by 2080. The A2 scenario, which generally shows the largest greenhouse gas impact, predicts the weakest increase in wet season rainfall by 1.13 percent.
Tarkwa (Rain Forest Zone)	Changes in precipitation range from 45% decreases to 31% increases in wet season rainfall. The overall ensemble prediction across emission scenarios gives a slight increase in wet season rainfall of 2.58 ± 12.83 percent by 2050 and 2.98 ± 16.45 percent by 2080.
Techiman (Forest-Savanna Transition Zone)	Changes in precipitation range from 46 % decreases to 36 % increases in wet season rainfall. The overall ensemble prediction across emission scenarios gives a slight decrease in wet season rainfall of -1.06 ± 14.25 percent by 2050 and -0.83 ± 19.71 percent by 2080. The A2 scenario, which generally shows the largest greenhouse gas impact, predicts the largest

Table 2, continued

	decrease in wet season rainfall, -2.94 percent.
Tamale (Guinea Savanna Zone)	Changes in precipitation in this zone range from 36 % decreases to 32 % increases in wet season rainfall. The overall ensemble prediction across emission scenarios gives a decrease in wet season rainfall of -1.46 ± 10.35 percent by 2050 and -2.19 ± 15.25 percent by 2080. The Northern Region where Tamale is located is the southern-most region of this zone in Ghana and shows a consistent trend toward decreased rainfall.
Walembelle (Northern Guinea Savanna Zone	Here, changes in precipitation range from 25 % decreases to 24 % increases in wet season rainfall. The overall ensemble prediction across emission scenarios gives a slight decrease in wet season rainfall of -0.42 ± 8.93 percent by 2050 and -1.06 ± 11.79 percent by 2080.
Bawku (Sudan Savanna Zone)	Changes in precipitation range from 28 % decreases to 30 % increases in wet season rainfall. The overall ensemble prediction across emission scenarios gives a slight decrease in wet season rainfall of -0.10 ± 9.63 percent by 2050 and - 0.69 ± 12.94 percent by 2080.

Source: Stanturf et al. (2011)

Impacts of Climate Variability and Climate Change on Crop Production

The day-to-day changes in the amount, duration, intensity and frequency of precipitation and other elements of the weather pose a significant challenge to farmers, especially in making farm level decisions on what to grow, when to grow and how to grow. The availability of water for crop production greatly depends on the onset, cessation, and length of the rainy season. The most important factor affecting agricultural productivity is the high spatial and temporal variability of rainfall. This variability is experienced during dry spells and recurrent droughts and floods (Laux, Jäckel, Tingem, & Kunstmann, 2010). When the rains start in a growing season directly affects farm management practices, especially planting. Planting dates significantly affect crop yield and the probability of agricultural droughts (Kumar, 1998). For sowing, it is important to know whether the rains will continue and will be sufficient to ensure enough soil moisture during planting, and whether this level will be maintained or even increased during the growing period in order to avoid total crop failure (Walter, 1967). The variability that exists within and between the planting season is often given as the reason for crop failure and food shortages (Usman et al., 2005; Sultan et al., 2005; Mishra et al., 2008). Climate variability, therefore, is expected to worsen food supply and hence exacerbate the widespread poverty in many regions.

There are both positive and negative impacts on crop production as a result of increases in temperature due to climate change. For example, in the middle and higher latitudes, it is suggested that global warming will extend the length of the potential growing season, allowing earlier planting of crops in the spring, earlier maturation and harvesting, and the possibility of completing two or more cropping cycles during the same season (Rosenzweig et al., 2004).

While it is anticipated that the temperate and polar regions stand to gain in terms of productivity increase because of additional warming, several developing countries, especially those in the tropics, are expected to be the worst affected, suffering significant agricultural production losses and increased ecological and economic stress (Lwandel, 2005; Kurukulasuriya & Rosenthal, 2003; FAO, 2001; Mendelssohn et al., 2000a; Rosenzweig & lglesias, 1994; Downing, 1992).

Hulme (1996), for example, used a crop simulation model and constructed an index of vulnerability based on national food balances, food production and dependence on food imports and food aid. The results showed four ways in which climate change will physically affect crops. These effects include changes in temperature and precipitation, carbon dioxide, water availability and increased frequency in extreme events such as droughts and floods. Changes in temperature and precipitation are again expected to alter the distribution of agro-ecological zones, leading to changes in soil moisture and the timing and length of growing seasons.

Boote and Sinclair (2006) also found out that high temperature reduces yield by accelerating physiological development (hastening maturation), thereby not allowing the crop to progress slowly through the season so as to maximize time for the capture of resources. Therefore, under warming conditions, yields are expected to decrease.

Different growth and development processes of plants, it is suggested, will be affected by climate change (Fosu-Mensah, 2012). An important process that will be affected by climate change is photosynthesis. The direct effect of CO_2 enrichment on plants is that an increase in CO_2 concentrations increases the rate of photosynthesis and water-use efficiency (the efficiency with which plants use water to produce a unit of biomass or yield).

In addition, an increase in CO_2, particularly in the temperate regions, may stimulate photosynthesis rates and sometimes result in higher yields

(Kimball, 1983). Changes in temperature and precipitation may also affect crop photosynthesis, and plant development rates, as well as water and nutrient budgets in the field (Long, 1991). However, in Africa where nutrients often are a limiting factor and leaf temperatures are high, the effect of CO_2 on crops remains highly uncertain (Watson, Zinyowera, & Moss, 1998).

Deressa (2003) used the Ricardian approach to investigate farmer adaptations to different environmental factors in an attempt to analyse the impact of climate change on South African sugarcane production. Results from this study indicate that sugarcane production in South Africa is more sensitive to future increases in temperature than in precipitation expected from climate change.

Gbetibouo (2004) also conducted a study using the Ricardian model to measure the impact of climate change on South African field crops (maize, wheat, sorghum, sugarcane, groundnut, sunflower and soybeans) and analysed potential impacts of further changes in the climate. This study indicated that the production of field crops is more sensitive to marginal changes in temperature than precipitation. Also, an increase in temperature was found to positively affect net revenue whereas the effect of a reduction in rainfall was found to be negative. An important finding of the study was that season and location were vital considerations in dealing with climate change. The study showed that the spatial distribution of the impacts of climate change, and consequently, the needed adaptations, will not be uniform across agro-ecological regions.

Smith and Tirpak (1989), Kane, Reilly, and Tobey (1991) and Mendelssohn and Neumann (1998) conducted studies in which they assessed the economic impacts of climate change on agriculture in the United States. Although these studies used different methodologies, which included mainly regional crop simulations and global circulation models, the results, nonetheless, all showed a decrease in agricultural production. In all these studies, extreme climate conditions (including droughts and floods) were found to have detrimental effects on agricultural production, leading to reduced agricultural output.

In view of these effects of climate variability in both developed and developing countries, it can be said that in Ghana, cocoa (like other crops) may be under threat from climate variability. Also, given that the results of the above researches clearly indicate an urgent need for farmers to adapt to climate change, there is a need to know the possible adaptations among farmers in the cocoa sector.

Studies by Antle (1995) and Dinar et al. (1998) for instance, focused on finding both adaptation and mitigation techniques to withstand the changing climate for farmers in developing countries. Different agronomic approaches specific to each region and country were used in these studies. The findings showed that changing seed varieties through both advanced technological research and management practices, creating new water-harvesting strategies and government-farmer interventions were the major adaptation and mitigation techniques. However, these studies show that without government policy and interventions, these adaptation techniques fail because most farmers simply cannot afford the measures involved.

Easterling (1994) did a review study of the adaptability of North American (U.S and Canada) agriculture to climate change. The work showed that adjustments to climate at the farm level, international trade policies which recognise the impacts of climate change, government policies that assist farmers to adapt to climate change and introduction of new crops and resource substitutions are among the most efficient agronomic and economical adaptation strategies.

West Africa has a high vulnerability profile in terms of its natural, economic and social systems; and due to this, climate change is expected to affect all means of livelihood of the populations. Heinemann and Kasozi (1991) emphasised Africa's high vulnerability to climate change because of its heavy dependence on agriculture and its limited capacity for adapting.

The crisis brought about by the spiralling prices of agricultural commodities throughout the world has recently been intensified by the vulnerability of tropical regions to climate hazards. According to CIRAD, a Paris-based research institution, global prices of cocoa have risen in part because Côte D'Ivoire, which usually grows 1.3 million metric tonnes per annum, endured a torrid 2008/09 season (Duguma, Gockowski & Bakala, 2010).

The utmost concern, therefore, should be to gain a better understanding of the potential impact of the current and projected climate changes on Africa's agriculture and to identify ways and means to adapt to and mitigate any detrimental impact.

Although agriculture may contribute to climate change, it can also be a solution to climate change if adequate sustainable production measures are adopted that hold substantial mitigation potential. These measures must help to adapt agriculture and food production systems to extreme events, rising temperatures, and increasing CO_2 concentration (FAO, 2009).

Although there are differences in the ways climate change will be experienced among regions, the majority of the regions will face increased temperatures, particularly in minimum levels, changes in precipitation and higher concentrations of carbon dioxide (CO_2) in the atmosphere (Meza, Silva, & Vigil, 2008).

Effects of Climate Change on Cocoa Production

Climate affects the three phases of cocoa production – the seedling, establishment and processing phases (Oyekale, Bolaji, & Olowa, 2009). Most of the processes involved in cocoa production are influenced by climate. For example, solar radiation produces energy for warming the soil, plants, air and metabolic processes. The characteristics of rainfall in terms of its amount, intensity, reliability and distribution influence crop growth (Oyekale et al.,). The planting date of cocoa is determined by the start of the rains. The survival of the crops and their performance are also affected by evaporation. After harvesting of the cocoa pods, the intensity of heat from the sun helps in drying the beans. The heat reduces the water content of cocoa seeds and makes their processing easier. A prolonged wet season and windy or cloudy days, on the other hand, slow down the drying and processing of cocoa beans. This reduces the value of the beans and increases the cost of processing.

Cocoa is highly sensitive to changes in climate, from hours of sunshine to rainfall. It is also very sensitive to the soil moisture condition and, particularly, to temperature due to effects on evapotranspiration (Oyekale, Bolaji, & Olowa, 2009). Climate changes also alter stages and rates of development of cocoa pests and pathogens. They also modify host resistance and cause changes in the physiology of host-pathogen or pest interaction. These happenings affect cocoa yields and result in harvest losses and their effect on socio-economic variables such as farm incomes, decision-making at the farm level, marketability and, more especially, the livelihoods of farmers (Oyekale, Bolaji, & Olowa, ; Anim-Kwapong & Frimpong, 2005; Ojo & Sadiq, 2010).

Cocoa is also highly susceptible to drought, and the pattern of growing cocoa correlates to rainfall distribution. Reports have shown a significant correlation between cocoa yield and rainfall over varying intervals prior to the harvesting of cocoa pods (Anim-Kwapong & Frimpong, 2005; Oyekale, et al.). A prolonged dry season encourages cocoa seedling mortality, and the short dry season during the main crop pod filling can also affect the bean size if it is significantly severe on bearing plants. Mirid (capsid) is an insect which makes cocoa difficult to establish. In mature plants, water deficits lead to low yield and increase the level of mirid damage. Also related to the climate is the blackpod disease which is the most destructive disease that affects the ripening of cocoa pods. It is prevalent in damp conditions and most destructive during the wet season.

With proper cocoa husbandry practices, the increased effects of diseases and pests as a result of climate change can be mitigated. When farmers are equipped with the skills and resources, the negative effects of climate change can be reduced to the barest minimum.

Crop Models for Predicting Climate

Crop models predict the response of crops to weather, soil, and management by simulating the growth and development of plant organs such as leaves, roots, stems and grains (Fosu-Mensah, 2012). Crop models provide a means of evaluating possible causes of changes in yield over time within a given location (Keating & McCown, 2001). In addition, they serve as research tools for evaluating optimum management of cultural practices, fertilizer use and water use, and for appraising the impact of climate change on agricultural production (Fosu-Mensah, 2012).

In recent years, crop growth models have become state-of-the-art research tools and are an important component of agriculture-related decision-support systems (Jame & Cutforth, 1996; Stephens & Middleton, 2002). Modelling the response of crop yield to management options and prevailing environmental conditions can be done through several approaches, and each approach has its merits and limitations.

Measuring the Climate Sensitivity of Agriculture

Sensitivity determines the response of a given system to climate change and may be influenced by socioeconomic and ecological conditions of the system (IPCC, 2007). Hence, sensitivity is determined by the function of the inherent characteristics of the system being exposed, as well as the extent of stress on that particular system (Smit & Wandel, 2006).

Assessing the climate sensitivity of agriculture has increasingly become important, especially in the face of climate change. Two main approaches have been developed to assess the climate sensitivity of the agricultural sector. The first, Structural Modelling of agronomic responses, is based on theoretical specifications and controlled experimental evidence. The second approach relies on the observation of the responses of crops and farmers to climate variations. Both approaches seek to measure how agriculture will be affected, if the particular components that make up the general climate of a region change by a certain amount (FAO, 2000).

Structural Modelling of Agronomic Responses

This approach is based on controlled experiments where detailed data are needed on the responses of specific crops and crop varieties to different climatic conditions. The main advantage of this approach is that it helps to improve the understanding of how crop management can be undertaken under different climatic conditions. With this approach, representatives of farms or crops are modelled in a very basic way. The approach also includes the modelling of farming decisions by implicitly incorporating a crop response function. However, a major setback of this approach is that such modelling and representation of crops and farm operations tend to give results that differ from the actual experiences on farms operating under real world conditions (Lwandel, 2005).

Broadly, there are two main types of structural modelling of agronomic responses – Integrated Assessment Models and Crop-Growth Simulation Models. The latter, furthermore, include agro-ecological zone analysis and agro-economic approaches. Agro-economic approaches are sometimes also referred to as production function approaches.

Integrated Assessment for Climate Change Analysis

The IPCC defines “integrated assessment” in its Third Assessment Report (IPCC, 2001) as “an interdisciplinary process that combines, interprets, and communicates knowledge from diverse scientific disciplines (which include natural and social sciences) to investigate and understand causal relationships within and between systems” (IPCC,).

It is generally agreed that there are two main principles of integrated assessment: Firstly, the integration of information obtained through a range of relevant disciplines, and secondly, the provision of information suitable for decision-making.

The Integrated Assessment approach is used for climate change analysis for the following reasons: It has the advantage of compiling available knowledge in order to evaluate what has been learned from various disciplines. It also assesses policy implications and research needs, and promotes a better understanding of how countries and regions contribute to climate change, and how they are affected by it.

Figure 5 illustrates a basic integrated assessment model of climate change, which begins with the assessment of GHG emissions and its future concentrations, the identification of the effects of these concentrations on global warming, the determination of climate change patterns, the climate sensitivity of an ecosystem and, lastly, the determination of future impacts on agriculture, for example.

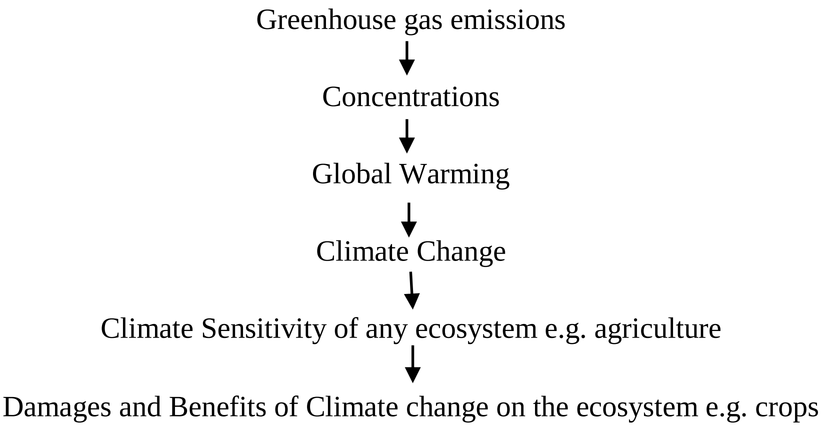


Figure 5: A Basic Integrated Assessment Model of Climate Change

Source: FAO (1999).

The main research activity in the integrated assessment model involves the development of methods for linking knowledge across various disciplines, whilst emphasizing the importance of feedback mechanisms, nonlinearities and uncertainties to climate change (Easterling, Crosson, Rosenberg, McKenney, Katz and Lemon, 1993). Integrated assessment is thus a primary tool for studying climate change impacts. It takes into consideration the anticipated impacts of climate change, current and future patterns of climate variability, current and future non-climatic developments and the anticipated interactions which may occur between climate related impacts and non-climatic developments. Finally, it considers the likely autonomous and planned adaptation measures to both climatic and non-climatic impacts (Mendelssohn, 2000).

According to Mendelssohn, Nordhaus and Shaw (1994), this approach has also been able to account for adaptation and welfare impacts, which other approaches have failed to account for. In the area of agriculture, the integrated assessment of climate change remains a key link in measuring the climate sensitivity of agriculture. It plays an important role in enhancing our understanding of the range of possible future climatic changes, their impacts and the interactive effects with respect to agriculture.

The basis for such assessments has mainly been an understanding of the climate system, its relation to climate change and its impacts on the atmosphere, the oceans, the terrestrial biosphere, glaciers, ice sheets and land surface. In order to project the impact of human disturbances on the climate system, it is necessary to calculate the effects of all the key processes operating in the components of these climate systems and the interactions between them.

Integrated assessment models for climate change have also been used to evaluate the costs and benefits of controlling climate. However, there remains a great deal of uncertainty about many of the components of these models, and one of the most uncertain phenomena is the impact of any specific climate change on human welfare (Mendelssohn, Nordhaus & Shaw, 1996).

The integrated assessment approach, despite its great benefits, has some outstanding challenges which have been widely recognized. These challenges include the challenge of supplying methods that represent and assess policies as implemented in reality rather than in an idealized form and its ability to improve our understanding of the biggest long-term driving factors – technological change and population growth.

In addition, a number of serious unresolved questions still exist that are more general in character, with regard to the appropriate scope and disciplines needed for assessments, the relationship between assessments and policymakers, and the extent to which assessment tools can be generalised across issues (CIESIN, 1995).

Crop Simulation Models

Certain models have been developed and calibrated by Agronomists which forecast yield for specific crops and for different weather patterns (Poonyth, Hassan, Gbetibouo, Ramaila, & Letsoalo, 2002). Crop Simulation Models (CSM) are computerized representations of crop growth, development and yield, simulated through mathematical equations as functions of soil conditions, weather and management practices (Hoogenboom et al., 2004). Crop simulation models arise primarily from the understanding of processes rather than from statistical relationships (Willmott, 1996). They can be used to quantify potential yield gaps between prevailing management options and potential yields of different crops. They also provide a means of quantifying possible dynamics in crop yield responses over a given time within a given location (Fosu-Mensah, 2012).

Crop simulation models that have been widely used include the Crop Environment Resource Synthesis (CERES) and the Erosion Productivity Impact Calculator (EPIC). Climate prediction models form the basis of simulation models and are thus able to simulate short-and long-term biophysical processes in agro-ecosystems (Downing, Harrison, Butterfield, & Lonsdale, 2000).

Crop simulation models that use Global Circulation Models are also closely linked to agronomic science and hydrological conditions, and they are currently the only methods capable of including carbon dioxide fertilisation in agronomic analyses. They are thus able to impose climate change scenarios on current agricultural systems, whilst including a variety of planting times, crop varieties, harvest dates and tilling and irrigation methods (Sanghi, Mendelssohn & Dinar, 1998).

Soil-crop-climate interactions are considered in detail in crop simulation models, as they are able to predict crop growth as a function of genetics, climate, soils and management practices (Dhakhwa, Campbell, LeDuc & Cooter, 1996; Rosenzweig & Parry, 1993; Muchena, 1994; Du Toit, Prinsloo, Durand & Kiker, 2001). These complex climate predictions are mathematical representations of atmospheric, ocean and land surface processes, involving interactions between mass, momentum, energy and water. Thus, the use of crop simulation models further allows the user to include weather factors (through climate prediction models) and to evaluate the effects of alternative scenarios on crop development and yield.

Crop models are only an approximation of the real world, and many do not account for important factors such as weeds, diseases, insects, tillage and phosphorus (Jones, Keating, & Porter, 2001). Again, even though these models are based on agronomy, they still fail to incorporate crop growth in relation to the actual behaviour of farmers. Nevertheless, CSM have played important roles in the interpretation of agronomic results; and their application as decision support systems for farmers is increasing. The two approaches commonly used for analysing the impacts of climate change on agriculture, based on this group of crop simulation models, are the Agro-ecological zone analysis and the Agro-economic approaches.

Agro-ecological Zone Analysis (AEZ)

The Food and Agricultural Organisation (FAO) in 1992 developed the eco-physiological process method to measure the climate sensitivity of crops in different agro-ecological zones (AEZ) in developing countries.

This AEZ approach provides a standardised framework for characterising climate, soil and terrain conditions relevant to agricultural production, whilst its matching procedures are used to identify crop-specific limitations in terms of the prevailing climate, soil and terrain resources, under assumed levels of input and management conditions. It also provides a framework for various applications, which include productivity, the extent of land with rain-fed or irrigated cultivation potential, estimates of the population-supporting capacity of land in particular areas, and multi-criteria optimisation of land resource use and optimisation (Deressa, 2003).

In this approach, a yield biomass simulation model is used to simulate crop yield for each of the assessed agricultural zones. A land resources inventory is used to assess all feasible agricultural land-use options for specific management conditions, and the levels of input required to quantify the expected production of relevant cropping activities.

The inventory includes information on climate, soils and land reform, since this is important for the supply of water, energy, nutrients and physical support to crops. The availability of a digital global database of climatic parameters, topography, soil, terrain, and land cover has also allowed for revisions and improvements in the calculation procedures for this methodology.

The revisions and improvements include a selection and definition of additional crop or land utilization types (LUTs) relevant to temperature and boreal climates, and the expansion of crop-ecological adaptability inventory. It also adds an application of soil-specific moisture regimes to calculate the lengths of growing periods. There is also an extension of land utilisation definitions to cover irrigated conditions, which makes it possible to apply FAO's digital soil map, among other applications. Finally, an assessment of agro-climatic crop suitability grid cells and the expansion of land suitability assessment procedures for irrigated crop production can be made (Deressa, 2003).

Adaptation to and technology adoption in respect of impacts that are specific to climate change can be captured in the AEZ model by generating static scenarios with changes in technological parameters.

Mendelssohn and Tiwari (2000) however, argue that the large temperature categories reflected in the climate zones in the AEZ approach make it difficult to capture subtle changes within a zone.

Reliance on the Observed Response of Crops and Farmers to Varying Climate

Methodologies, which rely on the observed response of crops and farmers to climate variations, are very important in the assessment of climate sensitivity, as they provide thoroughly explained variables to estimate the potential impacts of climate change. These methodologies include the following; Ricardian approaches (cross-sectional approaches), and Economy-wide models (Computable General Equilibrium (CGE) approaches.

The ricardian approach

This method, developed to account for farmers' adaptations to global climatic change, called 'Ricardian' by Mendelssohn, Nordhaus, and Shaw (1994), econometrically estimates the impact of climatic and other variables on the value of farm real estate. It examines farm performance as measured by land values (rents) and crop revenues across different agro-climatic zones, assessing how long-term farm profitability may vary in response to local climate, while controlling other factors. The influence of economic, climatic and environmental factors on farm income or land value is captured, thus further incorporating adaptation techniques by farmers (Mendelssohn et al.,).

This cross-sectional model analyses farm performance across climate zones by assessing the observed responses of both crops and farmers to climate variations (Mendelssohn & Tiwari, 2000; Kumar & Parikh, 1998). Poonyth, Hassan, Gbetibouo, Ramaila, and Letsoalo (2002), Deressa (2003), and Gbetibouo (2004) have used a similar approach for some crops in South Africa.

This approach easily incorporates private adoption and freedom of choice with regard to methods and technologies, which allows the farmer to modify his operational environment to increase profits. For example, a farmer can change his crops in response to climatic conditions. As it does not depend on controlled experiments, it thus makes it possible to measure the direct impact of climate changes on farm income or revenue. It is also useful for evaluating country level and regional level impacts (Lwandel, 2005).

The fact that the farms are not controlled, as in the case of scientific experiments, becomes a disadvantage. Thus, the impact of important uncontrolled variables, which could explain ultimate variations in farm incomes, is not properly captured. Another disadvantage with this approach according to Mendelssohn (2000) is that, this approach has also not been able to take into account water usage in crop production and the magnitude of the water supplies on which crops depend.

Many analysts have regarded these assumptions as the main drawbacks of this approach, as they may result in the underestimation of damages and the overestimation of benefits, as crop prices are treated as constant values. This is because, firstly, farm-level adaptations made by farmers in response to global climate change would possibly generate supply changes that, in turn, would affect output prices. Furthermore, the supplies of crops may increase or decrease, whilst their prices decline or rise, respectively. Also, supply changes could be accompanied by changes in inputs and input prices as well (Rosenzweig & Parry, 1994; Darwin, Tsigas, Lewandrowski & Raneses, 1995).

The agro-economic branch takes the loss in yields as inevitable, but assumes the loss to be smaller through crop switching. The Ricardian model measures final net impacts by looking at actual adaptation made by the farmers. Kurukulasuriya and Mendelssohn (2008) argue that the problem with the agronomic and panel data model is that it overestimates negative impacts of climate change by neglecting future adaptation. In the agro-economic model, one of the problems is that the researcher has to determine what adaptation could be made. According to Maddison (2007), the advantage with the Ricardian model is that it can calculate climate change responses with almost indefinite adaptation. However, the need to control many variables in relation to climate change is a weakness; and the model is not able to incorporate the CO_2 fertilization effect (Kurukulasuriya & Mendelssohn,).

Another problem that is not accounted for is that the model has an equilibrium in the long-run; but it is not certain that the farmers know what strategy is the best in the short-run; and it might take a long time before farmers perceive changes in climate as permanent. Maddison also notes that this is a problem and says that most analysis of the impact of climate change on agriculture compares equilibrium outcomes to a baseline and a climate change scenario, disclosing no facts regarding transitory losses (Maddison, 2007).

A new model called the Structural-Ricardian model was created by Kurukulasuriya and Mendelssohn (2008) in which a simple model of the farm is created. The farmers choose what crops are grown, one or several, and a certain income is set to every crop. Using this model, existing adaptation is shown and the sensitivity to climate change for existing crop varieties and for shifting crops can be quantified.

Challinor, Wheeler, Garforth, Craufurd and Kassam (2007) called for increased realism and relevance in predictions of crop in relation to climate change. This, according to them, is achieved by including adaptation strategies. The assessments made, therefore, must seek to combine the predictions of crop yield with socioeconomic scenarios, to be able to see the real impacts of climate change. Both the market and change in GNP affect the impact, which makes it even more difficult to draw definite conclusions. Some factors are easier than others to include in models. Change in planting date, for example, can be incorporated relatively more easily in impacts assessments;

but effects of irrigation and the role of new crop land can be more difficult (Challinor et al.,).

Many models on crop response to climate change have been made on major food crops in the advanced countries. This means that there are crops and combinations of crops commonly used in Africa that are not modelled in a satisfying way, like sorghum, millet, banana and yams. Models on intercropping, which is very common in Africa are not sufficient either. Another problem is that climate change models are often made on a very large scale while crop modelling is made on a small scale. Climate models then have to be downscaled in order to fit the crop models. It is also important to incorporate natural climate variations as well as extreme events, especially in Africa, since they are predicted to have a large impact on food production (Challinor et al., 2007).

Synthesis and Conclusions

This empirical literature review has discussed climatic trends in Ghana and how the climate (temperature and precipitation) is projected to change in the various eco-climatic zones in the near future. The projected rate of warming is more rapid in the northern inland regions of Ghana than the coastal regions. At the eco-climatic level, rainfall is projected to decrease at 2020, 2050, and 2080 in all regions. The effects of climate change and variability on agricultural production were also discussed. The literature shows that, while it is anticipated that the temperate and polar regions stand to gain in terms of productivity increase in agriculture because of additional warming, several developing countries, especially those in the tropics, are expected to be the worst affected, suffering significant agricultural production losses and increased ecological and economic stress. Changes in temperature and precipitation are again expected to alter the distribution of agro-ecological zones, leading to changes in soil moisture and the timing and length of growing seasons. West Africa has a high vulnerability profile in terms of its natural, economic and social systems; and due to this, climate change is expected to affect all the means of livelihood of the populations. Research into adaptation and mitigation techniques by farmers to withstand the changing climate is also discussed. However, these studies show that without government policy and interventions, these adaptation techniques fail because most farmers simply cannot afford the measures involved. The effect of climate change on cocoa production shows that climate affects the three phases of cocoa production – the seedling, establishment and processing phases.

The final section of the literature review outlines some climate and crop models used in assessing crop vulnerability to climate change. The strengths and weaknesses of these models are discussed as a justification of the conceptual framework used in this thesis.

CHAPTER FOUR

RESEARCH METHODS

Introduction

This chapter describes the methodology used in the study. The research design and the methods used to collect data to achieve the objectives and address key gaps in the literature are also discussed. It explains how the farming communities in the study area were selected and provides a description of these communities. The chapter highlights the sampling approach and describes how the qualitative and quantitative data were collected and analysed.

Research Philosophy

The study employs the realism philosophy. Born from a frustration that positivism was over-deterministic (in that, there is little room for choice due to the causal nature of universal laws) and that constructionism was so totally relativist (and hence highly contextual), realism takes aspects from both positivist and interpretivist positions. It holds that real structures exist independent of human consciousness, but that knowledge is socially created, with Saunders, Lewis, and Thornhill (2007) contention that our knowledge of reality is a result of social conditioning. According to Blaikie (1993), whilst realism is concerned with what kinds of things there are, and how these things behave, it accepts that reality may exist in spite of science or observation; and so there is validity in recognizing realities that are simply claimed to exist or act, whether proven or not. In common with intepretivist positions, realism recognizes that natural and social sciences are different, and that social reality is pre-interpreted. However realists, in line with the positivist position, also hold that science must be empirically-based, rational and objective; and so it argues that social objects may be studied ‘scientifically’ as social objects, not simply through language and discourse. Whereas positivists hold that direct causal relationships exist, that these relationships apply universally (leading to prediction), and that the underlying mechanisms can be understood through observation, realists take the view that the underlying mechanisms are simply the powers or tendencies that things have to act in a certain way, and that other factors may moderate these tendencies, depending upon circumstances, and hence the focus is more on understanding and explanation than prediction.

Although Blaikie describes realism as “ultimately a search for generative mechanisms”, he points out that realists recognize that the underlying mechanisms can act apparently independently or ‘out of phase’ with the observable events, and that events can occur independently of their being experienced, a view that Hatch and Cunliffe describe as a ‘stratified’ form of reality, whereby surface events are shaped by underlying structures and mechanisms, and what we see is only part of the picture. From an organizational perspective, Hatch and Cunliffe (2006) describe the realist researcher as enquiring into the mechanisms and structures that underlie institutional forms and practices, how these emerge over time, how they might empower and constrain social actors, and how such forms may be critiqued and changed. Realists take the view that researching from different angles and at multiple levels will all contribute to understanding, since reality can exist on multiple levels (Chia, 2002). Hence realism may be seen as inductive or theory building.

Research Design

According to Creswell (2007), a research design is a systematic plan to study a scientific problem. Bryman (2004) opines that it provides a framework for the collection and analysis of data. This study employed the case study design. The study used descriptive, correlational and exploratory research techniques. Descriptive research, according to Creswell (2005), attempts to describe a problem or service, and attem pts to answer questions of what, where, when and how. In this study, climate change occurrence was described from cocoa farmers' perspective. Correlational research, on the other hand, establishes or discovers the relationship or interdependence between two or more variables. The study attempted to establish the relationship between climatic variables (rainfall, temperature) and cocoa yield. It also used exploratory techniques because very little is known empirically about the nature and extent of vulnerability of cocoa production in a changing climate.

Research Approaches/Procedure

This study employed a mixed-method approach; it combined several methods such as the use of focused group study and structured interview guides to investigate different aspects of the vulnerability of cocoa production in a changing climate (Crawford & Christensen, 1995). Though the approaches, that is qualitative and quantitative methods have different epistemological and ontological backgrounds, they can be combined, and this allows deepening of understanding through cross-validation of data (Bryman & Bell, 2007). Qualitative methods are flexible and allow a deeper and better understanding of the extent of vulnerability of households and communities to climate change and variability (Winchester, 2005); but it may be difficult to generalise from the findings gained through such methods. Though not as flexible as qualitative approaches, quantitative methods tend to allow generalisation of results and predictions (Winchester). Bryman and Bell (2007) argue that a mixed-method enquiry is like combining two different and separate paradigms of research methods. They argue that quantitative and qualitative procedures have their epistemological implications and should not be seen as complementary. Nevertheless, climate change is a complex problem, and the use of different approaches helped to bring about a better understanding of the different dimensions of the problem.

Quantitative methods such as running means, time series and regression analysis were used to analyse the climate and the cocoa yield data. On the other hand, qualitative methods such as participatory diagnostic tools – informal semi-structured and formal structured surveys based on individual interviews, and key informant interviews of some selected farmers and other stakeholders – were used to comprehend and describe cocoa farmers' perception and adaptation to climate change, and the realities of cocoa farming systems in the study areas. This was done to ascertain the vulnerability of cocoa farmers to the prevailing climatic conditions and the strategies they have adopted to ensure sustainable livelihoods. Two sets of data, namely biophysical and socio-economic, were collected (see Appendix 1).

Target Population

The target population is the population about which a researcher ideally would like to generalise the results (Welman, Kruger, & Mitchell, 2005). The target population for the study was generally cocoa farmers in Ghana. The survey population for the study was made up mainly of cocoa farmers in the Central and Western Regions of Ghana. However, purchasing clerks, extension officers and grading clerks were also used for the study to solicit their views on climate change and its effects on cocoa production.

Sampling Procedure and Sample Size

Sampling deals with the selection of a subset of individuals from within a statistical population to estimate the characteristics of the whole population (Creswell, 2007). A well-chosen sample can usually provide reliable information about the whole population to any desired degree of accuracy and may be preferred as an alternative to a complete census, because it is cheaper and convenient (Sarantakos, 2005). The sample for the study was selected from all the cocoa districts in the Central and Western Regions of Ghana. A multi-stage sampling technique was employed for the study. This implies that different sampling methods were employed at different stages. First, the population (cocoa growing areas) was divided into two strata; new cocoa growing areas (Western Region) and old cocoa growing areas (Ashanti, Brong-Ahafo, Central, Eastern and Volta Regions). The Central and Western Regions were selected from the Old and New cocoa growing areas respectively. Purposively, a district each was selected from a region. However, two districts were selected from the Western Region, since for easy administration of the cocoa sector the region has been divided into two – south-west and North-west. The Assin Foso cocoa district was selected from the Central Region, and the Boako and Sekondi cocoa districts were selected from the North West and South West of the Western Region respectively. At the district level, communities which contributed much in terms of the district's production were selected with the help of the agricultural extension officers. However, this was done in a way to ensure that the selected communities were well distributed within the entire district.

Specifically, the purposive sampling technique was employed in the study. The researcher purposively chose respondents who, in his opinion, were relevant to the research topic. Cases that were judged to typify the views of the group were selected. The process of sampling, in this case, involved identification of the respondents and arranging times for meeting them. Farmers were chosen on the basis of the number of years they have farmed and the size of their farms. However, the researcher endeavoured to obtain an even distribution of the respondents across the cocoa growing areas to ensure fair representation.

Purchasing clerks, extension officers from the Cocoa Services Division of the Ministry of Food and Agriculture and chief farmers from the selected districts assisted in identifying the farmers. Some extension officers, grading clerks and purchasing clerks at post during the time of the survey were also interviewed, thus making use of accidental sampling.

In total, 444 cocoa farmers were selected for the study. This was made up of an average of 14 cocoa farmers from each of the 29 communities selected from the cocoa growing districts in the Central and Western Regions. Nine communities were purposely selected from the Assin Foso Cocoa District (which is made up of the Assin Foso, Twifo Praso and Breku political districts); and the remaining 20 communities were selected from the two districts in the Western Region (fifteen from Boako and five from Sekondi). The farmers selected for the study were chosen on the basis of their number of years in cocoa farming.

According to Hair, Anderson, Tatham, and Black (1998), reliable estimates can be obtained from samples that are between 100 and 150 respondents. Pallant (2005) also stressed that for quantitative studies, 100-150 sample size is adequate. In view of these assertions, 100, 135 and 209cocoa farmers were selected from Sekondi Assin Foso and Boako respectively.

Data Types

An examination of the effects of climate on agricultural production is usually complex, in view of the interplay of several elements, some endogenous and mechanical, while others could be exogenous, reflecting the responsiveness of the commodity market to demand trends. The variation of the data needed demanded the application of several methods of data collection, both formal and informal. Interactive dialogue with key informants, questionnaire survey, rapid appraisal techniques, and review and verification of secondary data such as institutional reports and documents from the Ghana Meteorological Agency were all used. In accordance with the specific study objectives, the types of data that were collected and used in the work have been summarised below;

1. Synthesis of secondary information and validation of meteorological data, especially on rainfall, temperature, humidity and sunshine for the study area.
2. Field study throughout the 2013 / 2014 cocoa season at Tafo and the other selected study sites by employing both formal and informal survey methods, including structured interviews of some cocoa farmers and purchasing clerks, as well as semi-structured interviews of opinion

leaders and agricultural extension officers within the selected cocoa farming communities.

3. Review of documents for climatic trends and climate change projections for Ghana.

Sources of Data

The quantitative data used in this project are the monthly averages for rainfall and the minimum and maximum atmospheric temperatures. The monthly averages were calculated from the daily readings that are recorded every 24 hours. This data was provided by the Ghana Meteorological Agency. The rainfall and temperature data were from 13 synoptic stations in the Central, Western, Ashanti and Eastern regions of Ghana and three other meteorological stations (Twifo Praso, Assin Foso and Sefwi Wiawso) located within the cocoa growing belt of Ghana (Figure 1).

Information about climate parameters which influence cocoa was obtained from the Tafo Cocoa Research Institute and an extensive review of related literature, especially on soils. Again, relevant secondary data about production in the past years from the study areas was obtained from the Monitoring, Research and Evaluation Department of the Ghana COCOBOD, the Produce Buying Company Headquarters, Accra, and from the Institute of Statistical, Social and Economic Research (ISSER), University of Ghana. Information was also collected from farmers on their knowledge of climate variability, its effect on cocoa production and their adaptive strategies. Secondary information for the literature review were sourced from published and unpublished works, books, journals, magazines, newspapers, institutional documents and the internet.

Research Instruments

The instruments designed for data collection in this study were principally guided interview schedules and questionnaires. A questionnaire survey was conducted in three purposively selected districts from two cocoa growing zones of Ghana, namely, the Central Region and Western Region. For easy administration and monitoring, COCOBOD has divided the Western Region into two sections, the North and the South. Both sections were considered in the study, for representativeness of the work.

Questionnaire Survey

A guided interview schedule (Appendix A) was administered to farmers, from all the three selected cocoa growing districts used in the study. These districts were selected on the basis of the availability of a meteorological station where climatic variables needed for the study are regularly measured.

The questionnaire for farmers was divided into seven sections, viz., bio data about the farmers, cocoa types grown, husbandry practices on farm, knowledge about climate change and its observation, perception of farmers on the effects of climate change on cocoa production, adaptive strategies and livelihood diversification options.

Some of the questions were open-ended to enable respondents to come out freely with divergent views on certain issues regarding the effects of climate change on cocoa production; but there were some close-ended questions also to enhance quick response and quantification of the data.

Pre-Testing and Training of Assistants

Due to the nature of the research, it was important to conduct a pre-test of the guided interview schedule, to find out its validity before using it for the actual exercise. A pre-test is a small test of single-elements of a research instrument that is predominantly used to check the mechanical structure of an instrument (Sarantakos, 2005). Pre-testing is undertaken to address issues such as respondent's comprehension, burden and interest, interviewer tasks, questionnaire issues, sampling as well as coding and analysis (Czaja, 1998). The researcher took advantage of the pre-testing to train five helpers who assisted in the final administration of the guided interview schedule. The population for this pre-test was selected among cocoa farmers in the Ajumako-Enyan-Essiam District in the Central Region. This cocoa district was selected because it has similar characteristics as the districts selected for the main study. Ten cocoa farmers purposively selected participated in the pilot testing in order to gauge the kind of responses that could be anticipated in the field. Apart from validity, the test also aimed at checking the sensibility, clarity, understanding and smooth running of the interview guides. During this test, the researcher was informed of certain explanations and translations that were needed when the guided interview schedules were finally administered. The test was conducted about a month prior to the start of the main study. Three days were used for the pre-test.

Field Survey

The survey was carried out between July 2013 and January 2014 using quantitative and qualitative methods. The researcher together with his team of assistants made personal visits to the selected communities. Entry into the community was made through the extension officers at the MoFA in each district. Permission was sought from the chiefs and elders of the communities prior to the date for the collection of the data. Other stake holders such as the chief cocoa farmer and some purchasing officers were also contacted. A meeting was arranged with extension officers in the district to inform them about the survey and solicit their assistance in organizing the farmers in order to administer the questionnaire. With the help of the extension officers, cocoa farmers who were considered relevant for the study were selected. The purpose of the study was explained to the selected farmers, and their consent was obtained in verbal form before administering the questionnaire. All the questionnaires were self-administered because, according to Armstrong and Overton (1977), cited in Mensah (2012), self-administered questionnaires yield relatively high response rates and avoid the non-response bias associated with mailing questionnaires to respondents. During the fieldwork, the research team met at the close of work every day to discuss the day's work and deliberate on any issues arising.

Challenges Encountered in the Field

A number of challenges were encountered during the data collection. There was difficulty in meeting the farmers to administer the interview schedule after their consent to participate in the survey had been sought. Initially farmers complained about the time involved in completing an interview, especially since it meant they could not visit their farms on such days. To overcome this problem, resting days selected by the various communities were targeted and used for administering the instrument. It was agreed with the farmers that those who had their farms very far from the settlements would be interviewed on such days.

With the help of extension officers, the selected cocoa farmers were organised, and a meeting was held to explain the purpose of the research. This helped to save time since the farmers had time to ask all questions related to the work; and the researcher, with the help of the extension officers, tried to address their concerns. This time of interaction created the right atmosphere and familiarization needed. The period of data collection coincided with preliminary harvesting and spraying of their farms. Most of the farmers therefore left their homes very early in the morning for their farms. The researcher had to go along with them to their farms and administer the instrument on the way to the farm, whilst they worked or during their break period. Administering was done is such a way that it would not affect their daily routines. The nature of the survey demanded a lot of time since the farms were far apart and they were mostly inaccessible by motor vehicles. On rainy days, moving from one community to another became almost impossible; and the research team on several occasions had to sleep overnight since they could not return to their stations. This increased the period for the survey and meant extra cost for paying field assistants and for accommodation.

Another major challenge faced was that farmers after sitting through the interview usually demanded some sort of payment for their time. To tackle this problem, the importance of the research was explained to them and they were glad to be a part of the research. Instead of giving money to individual farmers, they were grouped and refreshed. Those belonging to farmer-groups were given some token money for the group’s coffers. In most of the communities visited, the extension officers assigned to the community were trained and included in the research team. Their presence encouraged the farmers to willing participate and cooperate with the research team.

Obtaining secondary data was fraught with challenges since institutional record keeping had not been the best. Data obtained was either not properly entered, missing or not continuous. Nevertheless, these challenges did not significantly influence the findings of the study, since steps were taken to overcome them.

Response Rate

A total of 500 cocoa farmers (120, 150 and 230 from Sekondi, Assin Foso and Boako respectively) were interviewed. However, 100 135 and 209 responses were considered useful and appropriate for the study. This represented a response rate of 83%, 90% and 91% respectively. This response rate is high and ensures that the views of majority of the participants are captured. Mensah (2012) observes that the response rate of a survey is critical to the quality of the data.

Data Analysis

This research work analysed the atmospheric temperature, rainfall and cocoa production data of Ghana. Running means and trend analysis, daily, monthly and annual means were calculated. The data collected included the annual output of cocoa, mean monthly temperature and mean monthly rainfall.

The statistical tools employed to achieve the stated objectives were descriptive statistics, multi-logit regression analysis and correlation analysis. To establish the extent of climate variability in the study communities, a time series analysis was conducted for rainfall and temperature data obtained from the Ghana Meteorological Agency covering the period 1974–2013, for which data were available. Time series analysis was used because it allows a compact description and interpretation of data. In addition, hypothesis testing, forecasting and simulations were made. A combined effect of rainfall and temperature (using the De Martonne Aridity Index) was also used.

Descriptive statistics was used to describe farmers' perceptions to climate change in the selected cocoa districts and their coping strategies. Regression analysis was used to determine what socio-demographic factors influenced cocoa farmers' perception and adaptation to climate change. Regression analysis with the logit model was employed due to the nature of the decision variable, that is, whether climate change is perceived or not and whether adaptation is practiced or otherwise. For such a dichotomous outcome, the logit model is the most appropriate. The logit model considers the relationship between a binary dependent variable and a set of independent variables, whether binary or continuous.

Correlation analysis was used to examine the relationship, if any, between each of the climatic elements and cocoa production. Again, correlation analysis was used to examine whether there were any relationships between the socio-demographic characteristics of the cocoa farmers and their perception and adaptation choices.

Since trend variations occur over a substantially extended period of time, cocoa producing areas with over twenty years of climatic data were considered suitable for the trend analysis. Trend is determined by the relationship between the two variables (temperature and time or rainfall and time or cocoa production and time). Again, data on seasonal cocoa production from 2001/2002 to 2013/2014 crop seasons were collected and examined together with the meteorological data.

Expected future changes in temperature and rainfall figures were then compared with the needed favourable climatic conditions for cocoa production to establish vulnerability or otherwise of the cocoa crop in the cocoa growing areas.

Projected rainfall and temperature from 2020 to 2090 over the study area as forecast in the literature was summarised and discussed. A progressive rise in temperature and a reduction in rainfall will exacerbate soil moisture conditions during the dry season (November to March). Since cocoa is highly sensitive to drought in terms of growth and yield (Ali, 1969; Brew, 1991), it would be reasonable to anticipate consistent decrease in output from 2020 to 2090. Data collected from farmers was analysed using the Statistical Package for Service Solution, version 16 and Stata.

Ethical Considerations

Social science research often involves the study of real people in real situations, and this raises ethical questions regarding the relationship between the researcher and the respondents. Where care is not taken in conducting social science research, the validity of the research may be questioned.

The researcher, therefore, must take responsibility for all procedures and ethical issues related to the project. The research must be conducted in such a way that its integrity would be maintained, and any negative after-effects which might diminish the potential for future research would be avoided. Again the research must be conducted as an objective scientific project and without bias. The research took into account the issues of informed consent, anonymity and confidentiality.

To this end, all the research personnel used in the study were selected from agricultural extension officers who were already experienced in dealing with farmers. They were trained in all the procedures used in the study, and they took part in pre-testing the instruments used.

The research was carried out in full compliance with local customs, standards, laws and regulations. Proper community entry procedures were followed. In particular, permission was obtained at the regional, district and community level. The Chief Cocoa Farmer in each community selected was visited, and all issues related to the research were discussed. Local customs – the days on which farming activities were prohibited, for example, were observed.

Undue intrusion into the lives of respondents was avoided. Hence, questions relating to personal issues of farmers were not asked and farmers had the freedom not to answer any question they deemed to be personal. The welfare of the informants was considered important and their dignity, privacy and interests were protected. Questionnaires were only administered during periods which were favourable to the respondents, and effort was made not to significantly affect their daily routines. Therefore, farmers were often accompanied to their farms, and questionnaires were administered when they were on break.

Freely given informed consent was obtained from all respondents. Potential participants were informed (in a manner and in a language they could understand) of the context, purpose, nature, methods, procedures, and sponsors of the research. Verbal consent was obtained from participants who could not sign their names or read the information sheets (in which cases, the sheets were read out to them). Participants were made aware that their involvement in the research was voluntary. Participants were given the opportunity to ask questions that might be bothering them before signing the consent form.

Neuman (2007), states that researchers must not coerce anyone into participating in research and participation must be voluntary at all times. Hence, coercion was not used, and participants were fully informed of their right to refuse and to withdraw at any time during the research. They were informed of any potential consequences of their participation.

To avoid misinterpretation of responses, questions were asked in the local dialect of the respondents, and the responses given were repeated to them after writing. Full confidentiality of all information and the anonymity of participants were maintained. Anonymity protects privacy by not disclosing a participant’s identity after the information is gathered. Hence, names of respondents were not noted in the study. Farmers were assured of confidentiality; the information they provided was not to be divulged to any third party other than its intended purpose, which was an academic exercise.

Participants were offered access to the research results, presented in a manner and language they can understand. Limits of reliability and applicability of the results were made clear to all stakeholders. Lastly, unpublished as well as published works of other scholars used in the study have been properly acknowledged.

Chapter Summary

The methodology used for the study and the procedures that were followed to collect data from the field are discussed in this chapter. In brief, the chapter described the research design, study philosophy, sampling procedures and sample size. The research instrument used for the field survey are also discussed. Pre-test and actual data collection procedures are also presented. The last section of the chapter highlighted the methods of data processing and analysis of the study. The next chapter presents the results and discussions of how climate is changing in the cocoa growing areas and generates some scenarios for developing suitability maps for the cocoa sector.

CHAPTER FIVE

VULNERABILITY OF COCOA PRODUCTION TO CLIMATE CHANGE IN GHANA

Introduction

Agricultural development as well as its sustainability in Ghana, as in other countries of the world, is indeed, a function of climate, among other important factors. Invariably, climate has effects on what, when, where and how to produce, together with the level of output achieved. The effect of climate change is, therefore, demonstrated not only in the economic growth by way of self- sufficiency in food supply, but also on the welfare of farmers who are the units by which decisions about food production activities are actually taken.

The weather is the key source of uncertainty affecting crop yield, especially in the context of climate change (Alexandrov & Hoogenboom 2000; Chloupek, Hrstkova, & Schweigert, 2004). Among the variables relevant to the weather (especially in the context of climate change), rainfall and temperature are two important factors which have a large effect on crop yield (Abbate et al., 2004; Medori, Michelini, Nogues, Loreto, & Calfapietra, 2012; Runge, 1968). Accurate analysis and simulation of the joint distribution of rainfall and temperature are, however, difficult due to possible interdependence between them (Cong & Brady, 2012). Temperature and rainfall, among others, constitute major determinants of the physical nature and element of climate whose variation could have significant effects and impacts on agricultural productivity over time (Salman, 2011). Rainfall and temperature are considered to be the most critical climatic factors for growth of cocoa (Alvim, 1977).

Variations in rainfall and temperature may be tragic for cocoa farmers due to the sensitivity of the cacao crop to weather vagaries. Specifically, every stage of cacao development requires a favourable climate for optimum performance. In fact, too high rainfall promotes incidence of the black pod disease (Asare-Nyarko, 1974; Dakwa, 1973; Opeyemi & Abayomi, 2013; Wiah, Katara, & Danso-Addo, 2013), which normally accounts for the bulk of annual production losses. Such high incidence of disease also raises the cost of production through increased chemical usage and labour cost.

Reduction in sunlight hours is also inimical to cocoa production because the black pod disease and other pests are largely promoted under too high humidity. Some pathogens and pests can as well adjust to host resistance through genetic mutation. This often results in complete resistance to chemical control, thereby causing more havoc to cocoa pods and trees. Specifically, Davis (2010) submitted that drastic reduction in sunlight hours is able to adversely affect the growth of cacao trees and yields. In addition, effective drying of cocoa beans becomes very difficult if sunshine hours reduce. This ultimately affects the quality of processed cocoa beans and generated revenues.

The potential threat of climate change has led to several studies in recent years aimed at quantifying the magnitudes by which the various climatic elements, such as temperature and precipitation might change and possible time-frames within which such changes are expected. Such estimates usually referred to as climate change scenarios, are helpful in assessing the socio-economic effects of climate change.

In this chapter, trends in the observed time series of temperature and precipitation from some weather stations in cocoa growing areas, during the period 1971 – 2010, have been analysed and presented as graphs. The purpose is to show that the magnitude of climate change may differ from one location to another. Hence coping and adaptation strategies need to be locally designed to meet the needs of a particular farming system. Recorded cocoa yield data (dried cocoa beans) from some cocoa growing areas are compared with rainfall and temperature for the period 1999 – 2013 to investigate possible relationships that may exist.

Methodology

A large data set involving 30 - 40 years of rainfall and temperature data was examined using time series analysis-ARIMA methodology to analyse climatic trends and interactions. Correlation, and linear regression models were used to analyse the large data sets using ArcGIS, Stata, SPSS and Excel programs.

Data for the 30-year period 1961 – 1990, the current World Meteorological Organisation (WMO) baseline climatic period, was used to define the baseline values for both temperature and rainfall for each of the four eco-climatic zones where cocoa is generally grown. The choice of baseline period has often been governed by availability of the required climatic data. Examples of baseline periods that have been used in the past include 1951 – 1980 (Smith & Pitts, 1997) and 1961 – 1990 (Hulme et al., 1999). Sometimes, climatological reasons are given in favour of earlier baseline periods instead of later ones (IPCC, 1994). It is debated that later periods such as 1961 – 1990 are likely to have larger anthropogenic trends embedded in the climatic data, especially the effect of sulphate aerosols (Karl, Letelier, Tupas, Dore, Christian & Hebal, 1997). In this regard, the “best” time will be in the 19th Century when anthropogenic effects on global climate were negligible (EPA, 2008). However, for most impact assessments, the 1961 – 1990 baseline period is often preferred for the reason that observational climatic data coverage and availability are generally better, compared to earlier baseline periods.

Time series was used to determine the trend in the climatic parameters and yield of crops. Yield data available was only for the period 2001/2002 cocoa season to 2012/2013 cocoa season. Hence this was used and compared with rainfall and temperature data for the same period of time. Multiple and partial correlation analyses were employed to establish the relationship between the climatic parameters and crop yield; and also to show the joint and single contribution of the climatic parameters in the yield of cocoa.

The temperature and precipitation classifications were carried out using the Inverse Distance Weighted (IDW) interpolation method. Surface interpolation is any formal technique that uses values at sampled locations to predict values at un-sampled locations. Inverse Distance Weighted (IDW) interpolation implements a basic law of geography—things that are close to one another are more alike than things that are far apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. Those measured values closest to the prediction location have more influence on the predicted value than those that are farther away, hence the name “inverse distance weighted”. IDW assumes that each measured point has some local influence that diminishes with distance. This method was used for interpolation in the analysis.

The choice of the climatic parameters was based on their importance in determining the time of farm preparations and planting, growth, development and yield of crops in West Africa (Hayward & Oguntoyinbo, 1987). The choice of a weather station was on account of its capacity to serve the entire area and beyond.

Regression analysis assumes that only changes in climate can influence changes in yield. Because the absolute temperature or precipitation can be important for crop growth (i.e. their effects might be non-linear) an alternative regression including the original time series of yield and climate was considered.

The De Martonne Aridity Index formulae was used to examine the combined effect of rainfall and temperature on cocoa yield. Cocoa yield from some communities in the Ashanti, Western, Eastern and Central Regions of Ghana were compared with climatic elements from synoptic weather stations close to them. Figure 6 shows the study areas with their study weather stations.

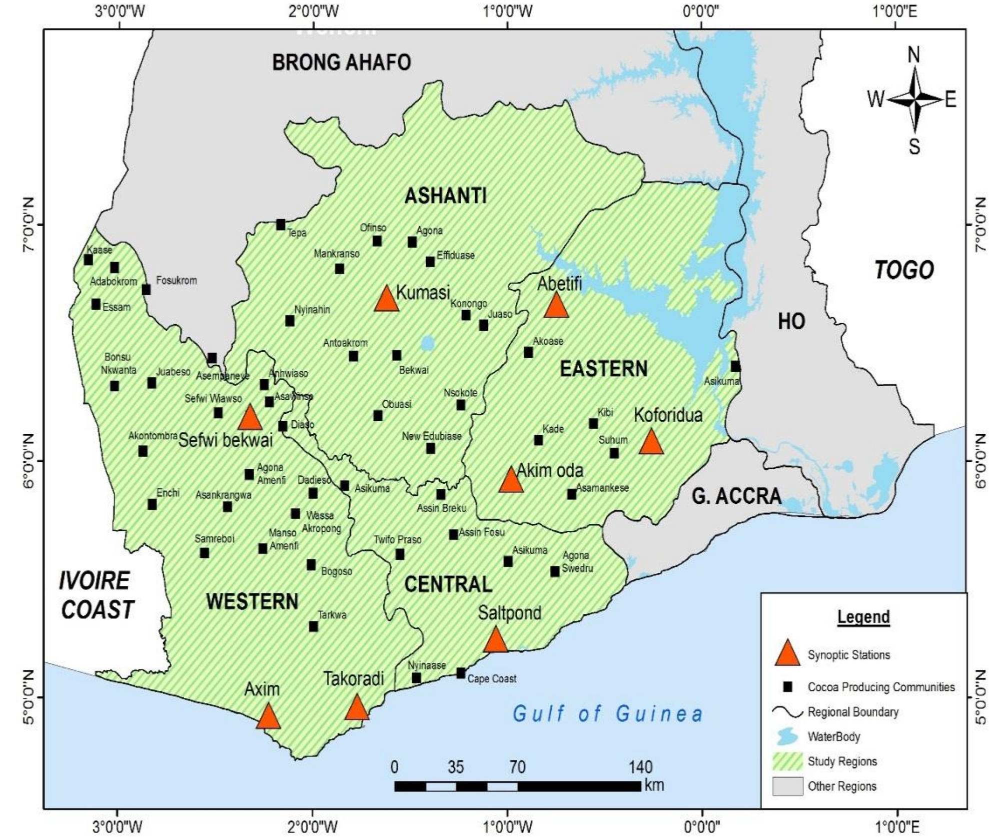


Figure 6: Map Showing Study Area with Study Weather stations

Source: GIS, Department of Geography and Regional Planning, UCC (Data from COCOBOD and Ghana Meteorological Agency)

Description of Weather Elements in the study areas

The main threat to cocoa production posed by climate change lies in the increased susceptibility of trees to drought. This is a particular concern in West Africa where the high variability in seasonal rainfall patterns is already a constraint to cocoa yields (Nelson, Morton, Chancellor, Burt, & Pound, 2010). The possible relationship between rainfall, minimum temperature, maximum temperature and yield is investigated in the following section.

Rainfall

Since the beginning of the 1970s, all climatic zones in tropical West Africa, from the arid Sahelian to the humid Guinea Coast climate, have experienced a decade-long period of below-normal annual rainfall amounts (Nicholson, Scom, & Kone, 2000).

The annual total rainfall in the cacao growing areas of Ghana is less than 2000 mm in most areas. Wood (1975) states that where the annual rainfall is below 1250 mm, the moisture losses of evapotranspiration will be greater than the precipitation supplies. The pattern of rainfall is even more important than its annual total. The general rainfall pattern in West Africa is characterised by two rainfall peaks around June and October. The peaks are separated by a brief, dry period in August. The long dry period lasts usually from November till March. In Ghana, cocoa growing is limited to those areas that receive at least 250 mm of rain during these five months (Mommer, 1999).

The rainfall distribution pattern is bi-modal from April to July and September to November in the study areas. There is a short dry period in August during which the relative humidity is still high, with over-cast weather conditions; and there is a main dry season from November to February-March in the study areas (Figure 7).

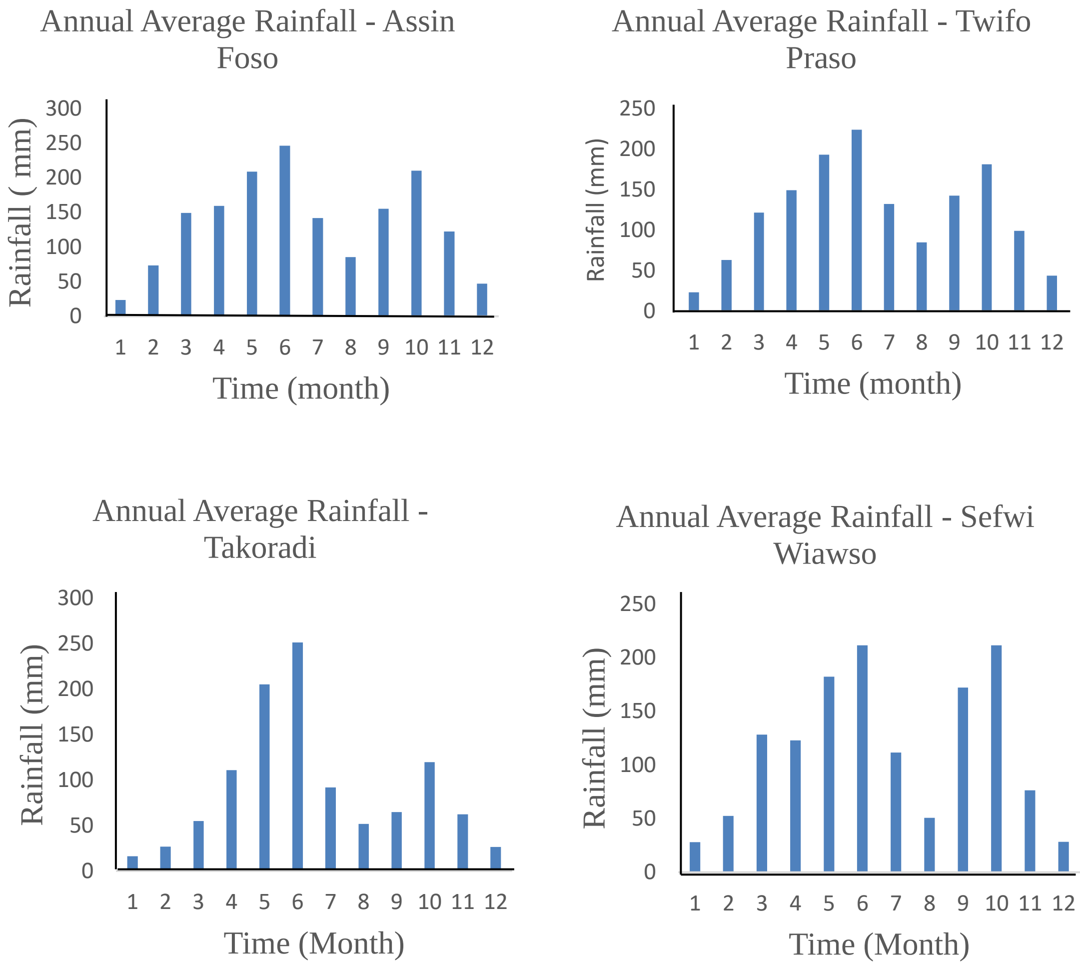


Figure 7: Annual Average Rainfall Distribution over the Study Areas

Source: Author with Climatic Data from Ghana Meteorological Agency, Accra.

The four to six months of dry weather results in soil water deficit; and since irrigation is not part of the farming system, cacao seedling mortality is high during the establishment phase. In bearing plants, the existence of the short dry season during main crop pod filling can affect bean size, if it is sufficiently severe. In adult plants, water deficits result in lower yields and an increase in the level of mirid damage.

To appreciate the trends in total annual rainfall amounts over the past years, the observed records for the period 1982 – 2012 were analysed and presented as graphs of the time-series of rainfall (Figures 8 to 11). Using a five-year moving average, the general trend in rainfall for the rain-forest belt depicts a gradual increase from the 1980s to about 1997 beyond which rainfall appears to be decreasing (Figure 8).

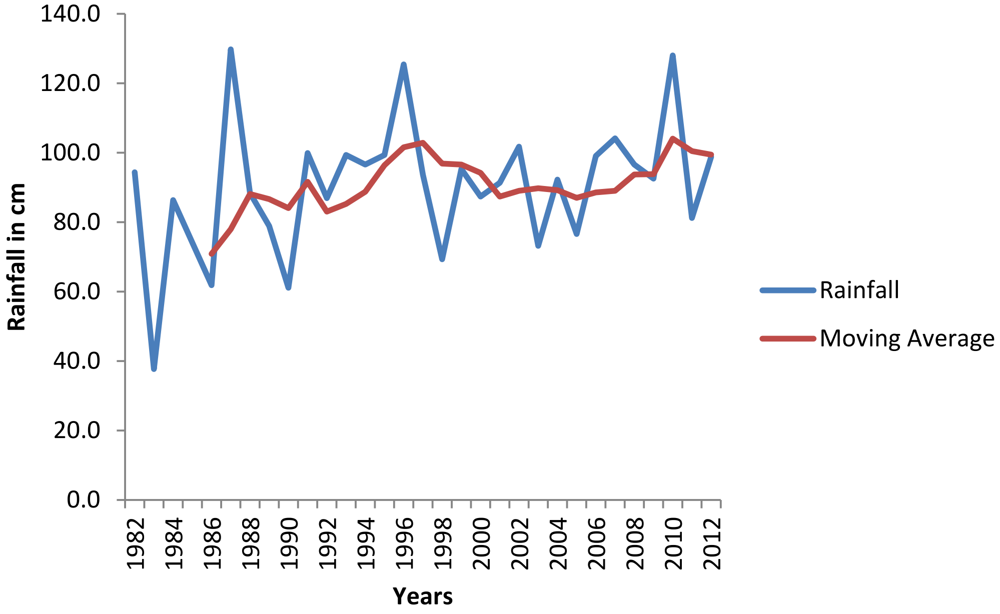


Figure 8: Rainfall Trend (1982 – 2012) over the Rain-forest Belt of Ghana

Source: Author with Climatic Data from the Ghana Meteorological Agency.

The deciduous forest belt (Figure 9) also shows a gradually increasing trend in rainfall from the 1980s to date (after the dip in 1983). Although the available historic data may show an increase in rainfall over the area, the distribution and the number of rainfall events have all changed. Rainfall alone is not a good predictor of climate change; and its effect on agriculture is best seen when its relationship with temperature is considered. The same amount of rainfall in different periods might have different significance to crop production, depending upon the prevailing temperatures, all other factors being constant.

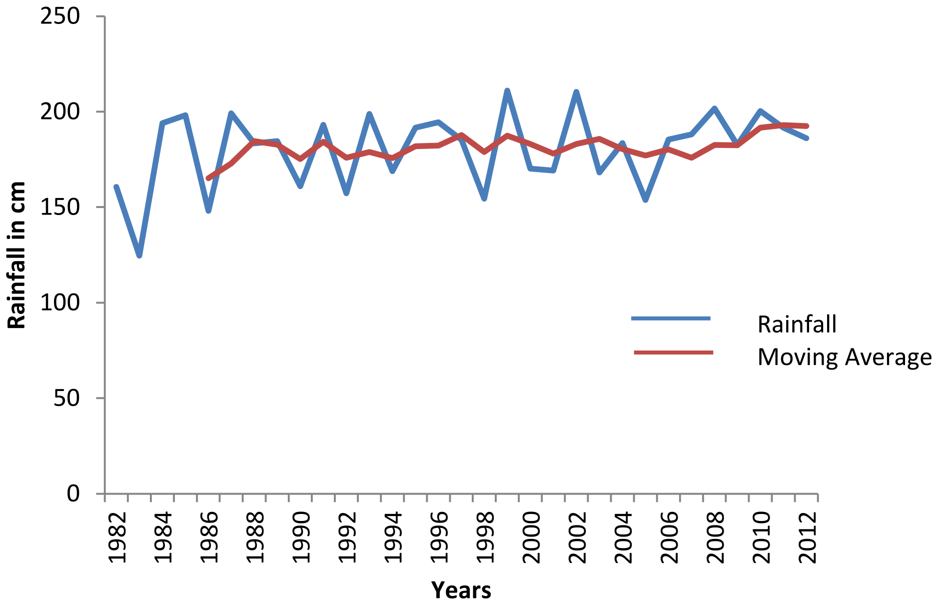


Figure 9: Rainfall Trend (1982 – 2012) over the Deciduous Belt of Ghana

Source: Author with Climatic Data from the Ghana Meteorological Agency.

The Coastal Savanna belt (Figure 10) and the Transitional belt (Figure 11) also show a gradual increase in rainfall from 1982 to date.

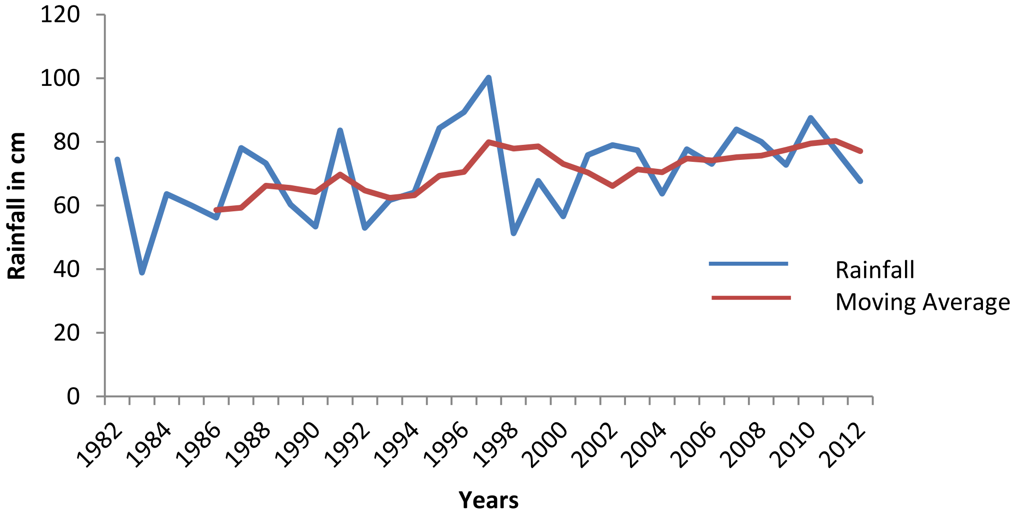


Figure 10: Rainfall Trend (1982 – 2012) over the Coastal Savanna belt of Ghana

Source: Author with Climatic Data from the Ghana Meteorological Agency.

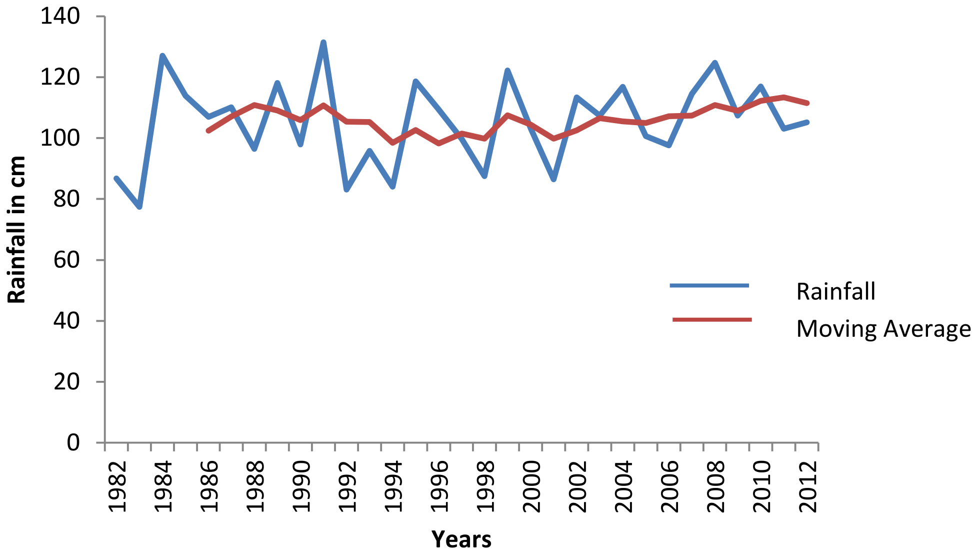
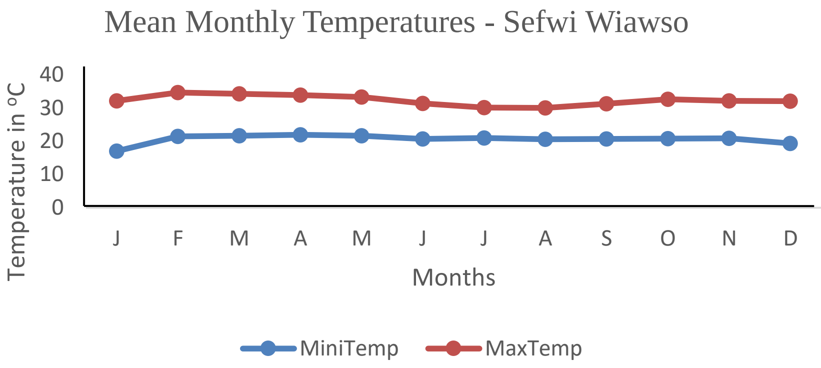


Figure 11: Rainfall Trend (1982 – 2012) over the Transitional Belt of Ghana

Source: Author with Climatic Data from the Ghana Meteorological Agency.

Temperature

Both minimum and maximum temperatures for the study areas were analysed to understand the general temperature regimes of the cocoa growing areas used for the study. Figure 12 shows the mean monthly minimum and maximum temperatures for the study areas.



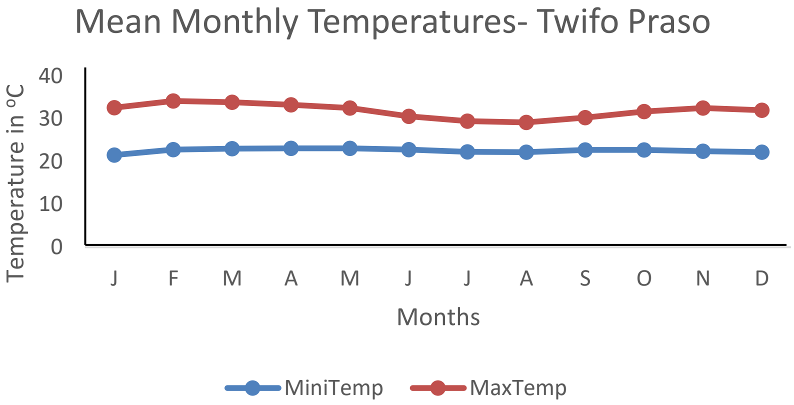


Figure 12: Mean Monthly Minimum and Maximum Temperatures for Some Study Areas

Source: Author with Climatic Data from the Ghana Meteorological Agency.

Both the highest monthly mean minimum temperature and the highest monthly mean maximum temperature occur in February in the study areas except in Takoradi where the highest monthly mean maximum temperature occurs in October. The lowest minimum and maximum monthly mean temperatures occur in August in all the study areas except for Twifo Praso where the lowest mean monthly minimum temperature occurs in January. The highest monthly mean maximum temperature lies between 31.9^{o}C and 34.7^{o}C, while the highest mean monthly minimum temperature lies between 21.9^{o}C and 23.5^{o}C in the study areas.

The effect of temperature on the growth of cacao seedlings and flowering of mature cacao trees has been studied in many different situations (in the field and laboratory) and in many different places. There are many hypotheses, but they are all applicable only in specific situations. Field data collected in Ghana led to the theory that flushing is suppressed when the daily maximum temperature falls below 28°C (Greenwood & Possenette, 1950).

Analysis of Trends in Cocoa Output and Selected Climatic Variables

Several factors including government policies, husbandry practices, soil fertility, genetic and environmental factors influence the yield of cocoa. However, variations in the yield of cacao trees from year to year are affected more by rainfall than by any other climatic factor. Rainfall is undoubtedly a determining agro-meteorological factor in the cultivation and production of cocoa (Ajayi, Afalobi, Ogunbodede & Sunday, 2010). Cocoa is highly susceptible to drought and the pattern of cropping cocoa is related to rainfall distribution. Significant correlations between cocoa yield and rainfall over varying intervals prior to harvest of cocoa pods have been reported (Oyekale, Bolaji, & Olowa, 2009). Again, Faisal (2008) showed that there was a positive association between yield and rainfall at certain times of year, but a negative association at other times. Variation due to the regression of yield on monthly rainfall varied up to 23 per cent, while a maximum variation of 31 per cent accounted for the regression of yield on the total rainfall of February to April in the Eastern region. Based on these findings, the variables under consideration were temperature and rainfall.

Temperature, rainfall and cocoa yield data for the period 2001 – 2013 were used. Using Assin Foso as an example, an attempt is made to show the possible relationship that might exist between rainfall, temperature and cocoa yield. Figure 13 shows the relationship between firstly, rainfall and yield and secondly, temperature and yield.

A study of the relationship between rainfall and cocoa yield (Figure 13a) shows that generally, cocoa yield increases with increases in rainfall, for most cases. For example, an increase in rainfall from 2001-2002, 2006-2007, 2009-2010 and 2011-2012 showed an increase in cocoa yield for the same period. In cases where rainfall decreased, yield also showed some decreases (2007-2009 and 2010-2011). However, it is worth noting that in some cases, yield continues to increase in certain years, though the rainfall values for those years are relatively lower than in the previous years. This suggests that, the rainfall of the previous year may have an impact on the current year's yield.

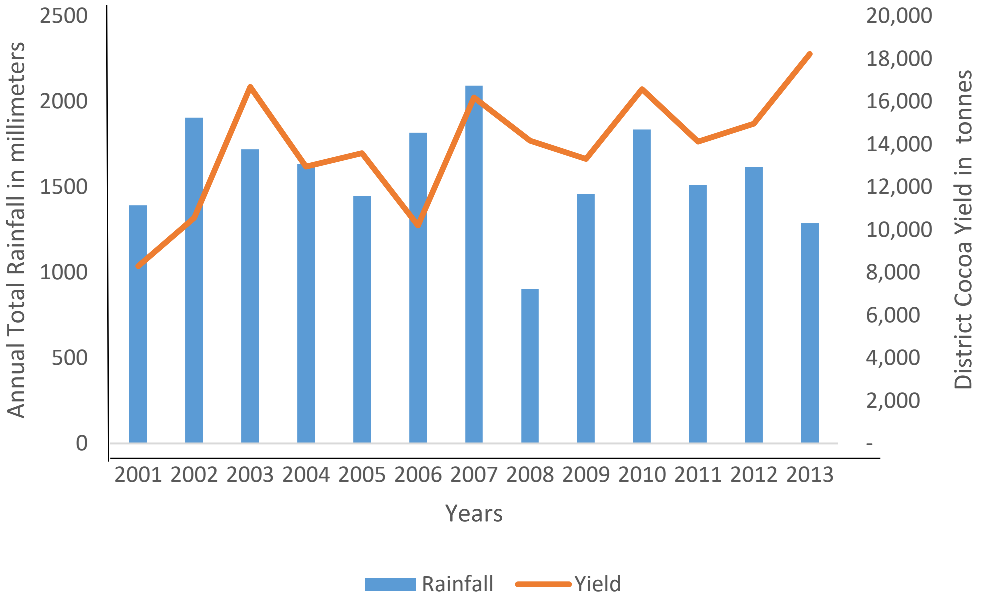


Figure 13a: Relationship between Rainfall and Cocoa Yield – Assin Foso for 2001 – 2013.

Source: Author with Climatic Data- Ghana Meteorological Agency and Cocoa Yield Data- COCOBOD.

The relationship between temperature and cocoa yield (Figure 13b) is similar to that between rainfall and cocoa yield. In some cases, an increase or decrease in one variable leads to a respective increase or decrease in the other variable. For example, a decreasing trend in temperature from 2007-2009 shows a similar decreasing trend in cocoa yield. Again, cocoa yield seems to rise as temperatures rise during the years 2009-2012. This pattern is, however, not consistent as seen in the year 2002 where very high temperatures recorded a comparatively low cocoa yield. This suggest that there may be temperature limits beyond which cocoa will not be economically viable.

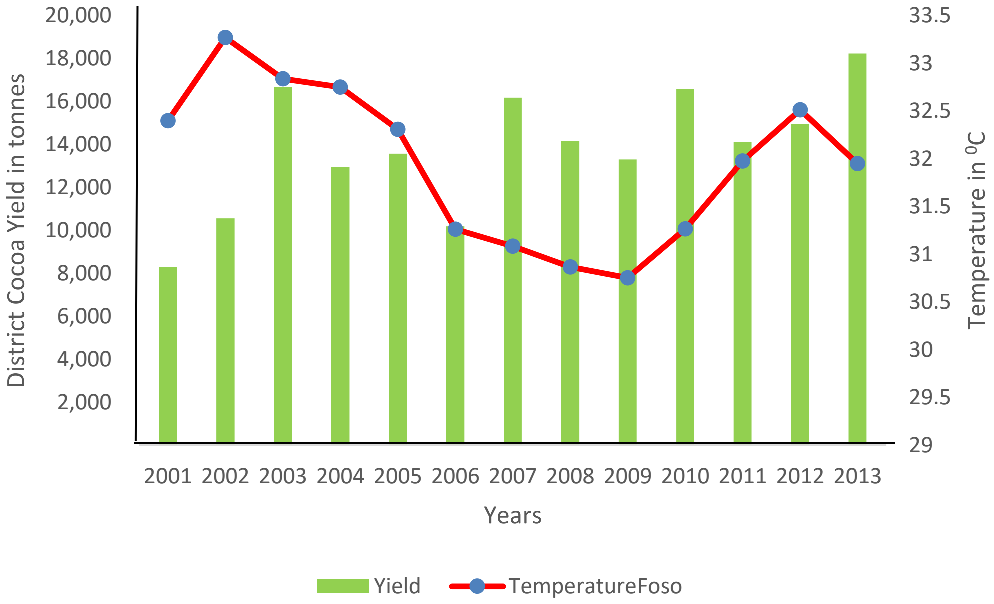


Figure 13b: Relationship between Cocoa Yield and Temperature– Assin Foso for 2001 – 2013.

Source: Author with Climatic Data- Ghana Meteorological Agency and Cocoa Yield Data- COCOBOD.

Analysis of the Correlation between Cocoa output and the Climatic Variables

Table 3 reports the correlation analysis between yield and some climatic parameters of some cocoa districts in the Ashanti, Eastern, Central and Western (North and South) regions of Ghana. The climatic data are minimum and maximum temperature and precipitation for a period of forty years. It is worth noting that there are two sets of data – country wide specific climatic data set and cocoa production data set from the specific cocoa districts under study. In this analysis the data interpolated for the producing areas were used instead of the country data set.

Table 3-*Correlation Analysis of Cocoa and Climatic Variables in the Selected Districts*

Variables	Minimum Temperature	Maximum Temperature	Current Year's Precipitation	Aridity Index	Previous Year's Precipitation
Cocoa Yield/Output	0.1791	0.3683	0.2880	0.1612	0.1054
(r^2)	3.207	13.564	8.294	2.598	1.112

Source: Author's Estimates, Buxton (2017)

There was a positive association between yield and minimum temperature, maximum temperature, current year's precipitation, aridity index and previous year's precipitation. This means that an increase in any of these climatic parameters will result in an increase in yield. Though the associations were relatively weak, they were all significant at the 0.5 significance level. Minimum temperature, maximum temperature, current year's precipitation, aridity index and previous year's precipitation explained 3.2%, 13.6%, 8.3%, 2.6% and 1.1% of the variations in the yield of cocoa respectively. Maximum temperature had the most significant relationship with yield.

Regression Analysis of Cocoa Yield and Climatic Variables

The regression equation was: Predicted yield for 2001_2011 = -90639 + 2593.67T + 11.76 R. The regression model is statistically significant, *F* (2, 536) = 69.31, *p* = .0000. This indicates that, overall, the model applied can statistically significantly predict the dependent variable, yield for 2001_2011. $R^2 = 0.172$, meaning that 17.2% variability in the yield 2001_2011 can be explained by the regression model. This means that about 17.2% of the variations in the yield of cocoa can be explained by changes in climate (rainfall and temperature). The partial regression coefficient for maximum temperature is 2593.67, meaning that for a one unit increase in maximum temperature, there would be a 2593.67 unit increase in yield; and it is a significant predictor (b=2593.67, p=.000)

The coefficient for rainfall 2001_2011 is 11.76, meaning that for a one unit increase in rainfall, there would be a 11.76 unit increase in yield and it is a significant predictor (b=11.76, p=.000)

To conclude, there is a direct relationship between the predictors (rainfall and temperature) and the dependent variable (yield). The equation predicts that, as maximum temperature and rainfall increase, the yield will also increase. Absolute temperature and rainfall can be important to the growth and yield of cacao. An increase in temperature (depending on the current prevailing temperature and the limit beyond which cacao cannot economically thrive) will result in an increase in yield. This is because, the extra temperature in available for photosynthesis and increase in the biomass (growth) of the plant. Low temperatures inhibit the photosynthesis rate. Low temperatures ht intensities, suppress flower production, with a considerable depressive effect on production. In Ghana, periods of high temperatures coincide with periods of flushing (Hurd & Cunningham, 1961). Thus, an increase in temperature will result in an increase in flowering and a potential increase in yield, all other things being equal.

Since cacao is a tree crop with roots reaching 3 meters deep, regular rainfall is very important for maximum yield. Cacao is thus liable to drought. In Ghana, most cocoa growing areas have annual rainfall less than the upper limit of 2500 mm necessary for optimum yield. An increase in rainfall in most areas will therefore lead to an increase in the yield of cacao since that will provide the extra moisture needed for potential yield.

De Martonne Aridity Index

The De Martonne Aridity Index was included in the model because, according to Oury (1965), despite the individual effects of rainfall and temperature on yield, there is a possible combined effect. When combined into one variable, due to concomitant interactions, weather variables may have a significant effect on crop yield. This is because the same amount of precipitation does not have the same meaning in all the seasons. It depends on the evaporation, which varies from season to season; it is substantial in summer and less in winter. Thus, the aridity index will have a negative or positive effect on crops depending upon their biology and phonological growth period (Oury,).

The inclusion of aridity index in the model also strengthens the argument that the yield response of precipitation ‘P’ is not constant rather it is a function of temperature ‘T’ and vice versa (Oury, 1965). This is because the same amount of precipitation will have different effects if accompanied by varying levels of temperature (Stallings, 1961). To test this, the De Martonne Aridity Index was used.

De Martonne's aridity index (I_{ar-DM}) is calculated using the formula:

$$I_{ar-DM} = P/(Tm + 10)$$

Where: P = total annual precipitation and Tm = mean annual temperature. The 10°C is used to produce positive results in regions with negative average annual temperatures, such as mountainous regions or deserts in median latitudes. In general, low values of I_{ar-DM} show dry conditions, while higher values show wet conditions. Table 4 presents De Martonne's climatic classification (1926) according to the I_{ar-DM} indicator.

Table 4- *Climatic classification according to De Martonne (1926)*

Classification	**Index**
Very Dry = desert (arid)	0 – 5
Dry = steppe, semi-arid (semi desert)	5 -15 (5 – 12)
Semi-dry (dry sub-humid)	15 – 20
Mildly wet (moist sub-humid)	20 – 30
Wet (wet)	30 – 60
Very Wet (humid)	Over 60

Source: Lungu, Panaitescu and Niţă (2011)

Aridity indexes calculated for some cocoa growing areas in the Ashanti, Eastern, and Central Regions, as well as the South and North of the Western region (see Appendix B) show that in most of these areas, the climate is gradually moving from the mildly wet to the wet in the De Martonne's climatic classification. Indices at 2001 compared to that of 2011 gives the impression that it is getting wetter. However, aridity indices from

2007 to date show a gradual decrease in the index. Though in some cases precipitation in some years appear to have increased, due to extreme temperatures, the overall available water for plants has reduced. This can be an indication that the climate is gradually changing, though the change may be slower than previously thought.

Synthesis and Conclusion

The yield of cacao, like many other agricultural crops is threatened in this era of climate change. Using climatic elements as a means to forecast the yield of cacao, which is an important export commodity, is necessary for future planning for economic development. However, results of research into the effect of climate change on the yield of cocoa have differed. All the same, the fact remains that there are significant correlations between climate and yield; and human has little control over the climate. More importantly, other factors that probably are significant in influencing the yield of cocoa can be improved upon through good husbandry practices. For a crop like cocoa which is cultivated mainly under rain-fed conditions with no irrigation in most cases, changes in climate cannot be ignored. The dynamics of cocoa production and factors affecting its yield are numerous and interrelated. More systematic research is needed to isolate the specific effects of climate. Coupled with this complication is the biennial bearing nature of the cacao tree which needs further research.

It is therefore recommended that site-specific strategies would be developed to reduce the vulnerability of cocoa farmers and the cocoa sector to future climate change. Any impact of climate change on the suitability to grow cocoa in Ghana will not only affect farmers’ livelihoods and incomes, but the entire national economy as well.

CHAPTER SIX

SOCIO-DEMOGRAPHIC CHARACTERISTICS OF COCOA FARMERS AND THEIR PERCEPTIONS OF CLIMATE CHANGE AND ITS EFFECTS

Introduction

Cocoa farmers in Ghana are generally smallholders who mainly operate family farms and cultivate acreages of about three acres or less in the Eastern and Ashanti regions, and about ten to twenty acres in the North Western and South Western regions (Asuming-Brempong, Sarpong, Asenso-Okyere & Amoo, 2007). A few outliers operate farms that are less than an acre, or up to about a hundred acres or more in some cases. This chapter presents the demographic and socio-economic characteristics of the cocoa farmers and their communities, as obtained from the field survey. This chapter also discusses climate change perceptions of cocoa farmers and how these socio-demographic characteristics of the farmers influence their perceptions.

Socio-Demographic Characteristics of the Farmers

In total, 444 farmers chosen from 29 different cocoa growing communities were used for the study. Of this number, 135(30.4%) were selected from the Assin Foso District in the Central Region. The Western Region is divided into two - North Western and South Western. The Boako District was selected from the North; the Sekondi District, from the South of the Region. Two hundred and nine farmers (47.1%) and 100 farmers (22.5%) were selected from the two districts respectively. Of the total 444 respondents, 313(70.5%) were males, and the remaining 131(29.5%) were females. Table 5 shows the distribution by gender in the various districts. The gender distribution depicts a typical farming community in southern Ghana where men dominate the headship of households and land ownership.

Table 5- *Gender Distribution in Selected Cocoa Districts*

Name of District	Gender of Farmer		Total
	Male	Female	
Assin Foso District	91(67.4%)	44(32.6%)	135
Sefwi Boako District	155(74.2%)	54(25.8%)	209
Sekondi District	67(67%)	33(33%)	100
Total	313	131	444

Source: Field survey, Buxton (2013)

Age and Gender

The ages of the respondents in the study were juxtaposed with their genders; and the ages were classified into three, namely, less than 36 years (*the youthful*), 36 years to 55 years (*the middle aged*) and 56 years and over (*those in their old age*). Tables 6 and 7 show the results.

Table 6 shows that out of the 444 cocoa farmers sampled for the study, 98% were above the age 36 years. Only 2% of the respondents were below the age 36 years. This suggest that, there are only few young people who practice cocoa farming as an occupation despite its prospects.

Table 6- *Age Groups of Cocoa Farmers*

Age Group	Frequency	Percentage (%)
Youthful (less than 36 years)	9	2.0
Middle age (36 – 55 years)	229	51.6
Old Age (56 years and over)	206	45.4
Total	444	100

Source: Field survey, Buxton (2013)

Table 7 shows that, of the 313 male respondents, 8(2.6%), 171(54.6%) and 134(42.8%) belong to the youthful, middle age and old age categories respectively. Among the female respondents, 1(0.8%) was in the youthful class, 58(44.3%) were in the middle age category and the remaining 72(55%) were in the old age group. Altogether, 9(2%) of the total of 444 respondents were in their youthful age, 229(52%) were in their middle age and 206(46%) were in their old age, as shown in Table 7. This generally gives the impression that a significant proportion of cocoa farmers is ageing and the youth in the farming communities are not attracted to cocoa farming. However, care must be taken in using this information since the nature of the research demanded that older farmers were canvassed as they had more experience observing climate change.

Table 7- *Age Distribution Among the Genders*

Gender	Youthful	Middle Age	Old Age	Total
Males	8 (2.6%)	171 (54.6%)	134 (42.8%)	313
Females	1 (0.8%)	58 (44.3%)	72 (55%)	131
Total	9 (2.0%)	229 (52%)	206 (46%)	444

Source: Field survey, Buxton (2013)

Gender and Migration Patterns of Cocoa Farmers

People move from one place to another for varied reasons which may be social, economic, political and situational. Migration is a common phenomenon in the cocoa sector owing to the fact that cocoa farming is very labour intensive.

The migration pattern of the respondents was compared among the gender groups, and the result is shown in Table 8. Out of the total number of 444 respondents in the study, 209(47%) were natives of the various communities visited; and the majority 235(53%) had migrated to the cocoa farming communities. Of the total number of 235 migrants, 163(69%) and 72(31%) were males and females respectively.

There is a noteworthy pattern in the migration trends in the Western Region. Most migrants in the South Western cocoa district of Sekondi had migrated from the Central Region. This is reflected in the predominance of the Fante language in the district. However, the Twi language is dominant in the North Western district of Boako, since most of the migrants there are from the Ashanti and Brong Ahafo regions.

Table 8- *Migration among the Genders*

Gender	Natives	Migrants
Males	150 (47.9%)	163 (52.1%)
	71.8%	69%
Females	59 (45%)	72 (55%)
	28.2%	31%
Total	209	235
	47%	53%

Source: Field survey, Buxton (2013)

Farm Ownership, Gender and Migrants

Land is an essential input in the cocoa sector and ownership of land and access to land greatly affect production levels, especially since in most cases, increases in output are the result of increases in farm sizes. Traditionally, sharecropping tenancy has been one of the longest practised agri-business models used by families and community members. Sharecropping tenancy is widespread in the southern part of the country (Kasanga & Kotey, 2001). In Ghana, the traditional sharecropping tenancy model has two variants – the "abunu" and "abusa" systems. These systems are commonly used in the tree crop industries (rubber, cocoa, oil palm, and mango) and usually involve informal, mostly verbal contract agreements.

Altogether, there were 309(70%) respondents who owned their farms. The remaining 135 were tenants. Of the 309 owners, Table 9 shows that 177 (57%) were natives and 132(43%) were migrants who had, over the years, gained ownership of the land on which they farmed. About 85% (177) of the native-cocoa-farmers owned their farms compared with about 56% (132) of the migrant-cocoa-farmers who owned their farms. The remaining 15% (32) of the native-cocoa-farmers were sharecroppers compared with a higher proportion of about 44 % (103) of their counterpart migrant-cocoa-farmers who were sharecroppers. This indicates that migrant farmers mostly take up the job of "caretakers" because migrants usually face difficulties accessing and owning land. Table 10 also shows that 220(71.2%) of the farmers interviewed who owned land were males and the remaining 89 (28.8%) were females. This is consistent with Ghana's demographic profile which shows that most household heads are males.

Table 9- *Land Tenure among Native and Migrant Farmers*

Residential Status	Type of Tenure			Total
	Owners	Abusa	Abunu	
Native	177 (84.7%) (57.3%)	4 (1.9%) (15.7%)	28 (13.4%) (25.2%)	209 (47.1%)
Migrant	132 (55.2%) (42.7%)	20 (8.5%) (83.3%)	83 (35.3%) (74.8%)	235 (52.9%)
Total	309	24	111	444

Source: Field survey, Buxton (2013)

Table 10- *Land Tenure among the Genders*

Gender	Type of Tenure			Total
	Owners	Abusa	Abunu	
Males	220 (70.3%)	18 (5.8%)	75 (24%)	313
	(71.2%)	(75%)	(67.6%)	(70.5%)
Females	89 (67.9%)	6 (4.6%)	36 (27.5%)	131
	(28.8%)	(25%)	(32.4%)	(29.5%)
Total	309	24	111	444

Source: Field survey, Buxton (2013)

Educational Background of Farmers

Table 11 presents the educational background of the cocoa farmers. About 70% of them (312 out of 444) had had some form of formal education. The remaining 132 (about 30%) had no form of formal education. Of this number, 62 (47%) and 70(53%) were males and females respectively. Among the 313 male farmers in the study, a little over 80% were educated compared with about 47% of the female farmers (Table 12). Very few of the respondents had had tertiary education; and they make up less than 1 % of the total number of respondents. Not surprisingly, these respondents were all male farmers. This confirms the fact that there is a significant gap between male and female education in Ghana; and that the highly educated do not find cocoa farming attractive.

Table 11- *Educational Background of Cocoa Farmers*

Educational Level	Frequency	Percentage (%)
Basic education	265	59.7
Secondary education	43	9.7
Tertiary education	4	0.9
No education	132	29.7
Total	444	100

Source: Field survey, Buxton (2013)

Table 12- *Educational Level among the Genders*

Educational Level	Gender of Farmer		Total
	Male	Female	
Basic education	215(81.1%) (68.7%)	50(18.9%) (38.2%)	265
Secondary education	32(74.4%) (10.2%)	11 (25.6%) (8.4%)	43
Tertiary education	4(100%) (1.3%)	0 (0%) (0%)	4
No Education	62 (47%) (19.8)	70 (53%) (53.4%)	132
Total	313	131	444

Source: Field survey, Buxton (2013)

Marital Status of Farmers

As depicted in Table 13, most of the respondents (about 75 %) were married while about 3 per cent were never married, with about 15 per cent widowed. About 5 per cent of the respondents are divorced and about 2 per cent are separated. The relatively large proportion of respondents who are widowed is a result of the sampling procedure which sought to select farmers who had farmed over a long period of time, and thus were old.

Table 13- *Marital Status of Cocoa Farmers*

Marital Status	Frequency	Percentage
Single	12	2.7
Married	335	75.5
Separated	10	2.3
Divorced	22	5.0
Widowed	65	14.6
Total	444	100

Source: Field survey, Buxton (2013)

Family Sizes

In traditional agricultural production, family labour plays a significant role in farm labour supply. The average farmer first exhausts all sources of labour in his family before hiring labour in order to reduce the cost of production (Muhammad-Lawal, Omotesho & Falola, 2009). The average household size of the respondents was about 7 persons. The smallest family size was 2 and the largest was 17. Most (84.7%) of the cocoa farmers in the study had family sizes between 5 to 12 persons. This suggests the possibility of family labour being available to the farmers for their cocoa farming activities. It is assumed that the more adult household members a farmer possesses, the more household labour would be available to him for farm activities in the adoption of cocoa technologies due to climate change.

Labour Supply in Cocoa Production

Cocoa farming is very labour intensive – from the clearing of land, felling of big unwanted trees, removing of stumps, cutting and lining of pegs, holing for plantain suckers and cocoa seedlings and sowing at stake. Labour is also needed for daily farm maintenance practices such as spraying insecticide, applying fertilizer, weeding, general sanitation and pruning and mistletoe control. During the harvest period, labour is again needed for plucking and breaking the pods, fermenting and drying the beans and finally, bagging and carting of the dry beans to the cocoa sheds. In farms where the care is good, the yield is usually much larger than in farms where maintenance is poor. Table 14 shows the type of labour used by farmers on their cocoa farms. When farmers were asked the type of labour they used on their farms, 263(59%) used a combination of family labour and seasonal labour. Members of the family did a greater part of the day-to-day work such as removing diseased or dead pods and pruning of trees on the farm; and extra labour was hired during weeding, fertilizer application, spraying and harvesting periods. About 10% used only family labour, and another 10% used only seasonal labour. Only 1% used permanent labour exclusively – that is, had permanent caretakers only on their farms. The size of a farmer’s family and the price of labour and its availability usually determine the choice of labour type used. In most of the cases, especially for those farmers who belonged to groups, communal labour (‘nnoboa’) was used during weeding, fertilizer application, removal of mistletoes and spraying. Some of the groups owned some farming equipment together.

Table 14- *Labour Types and Combinations Used by Cocoa Farmers*

Labour Type	Frequency	Percentage (%)
Family labour only	43	9.7
Permanent labour only	5	1.1
Seasonal labour only	46	10.4
Family and permanent labour	15	3.4
Family and seasonal labour	263	59.2
Permanent and seasonal labour	9	2.0
Family, permanent and seasonal labour	63	14.2
Total	444	100

Source: Field survey, Buxton (2013)

According to Mensah-Bonsu et al. (2011), the number of farm hands on a farm largely depended on the farm size. It was observed from the present survey that the large farms had more farm hands than the small farms. Table 15 shows the number of farm hands used on the farms. Due to the small size of most of the farms, 175(39%) of the farmers had only two farm hands who worked on the farm on daily basis. About 89% of them had between 1 and 4 farm hands. The largest number of farm hands on a farm recorded in the survey was 15; and this was found in Bechiwa in the Boako District where 66 acres of land was farmed by a farmer. Generally, the peak period of demand for labour is January to March when there is usually clearing of land, felling of trees and burning. During July and August, labour is needed for weeding. November is the peak month for harvesting the ripe pods, fermenting and drying the beans and carting the dry beans to the cocoa sheds for sale. Observations made confirm those of Asuming-Brempong et al. (2007) that the bulk of activities on mature cacao trees occurs from July to December in any typical cocoa year.

Table 15- *Number of Farm Hands on Cocoa Farms*

Number of Farm Hands	Frequency	Percentage (%)	Cumulative (%)
1	71	16	16
2	175	39.4	55.4
3	91	20.5	75.9
4	60	13.5	89.4
5	12	2.7	92.1
6	20	4.5	95.6
7	2	0.5	97.1
8	5	1.1	98.2
9	1	0.2	98.4
10	5	1.1	99.5
11	1	0.2	99.8
15	1	0.2	100
Total	444	100	

Source: Field survey, Buxton (2013)

Characteristics of Cocoa Farms

The discussion of the characteristics of cocoa farms is based primarily on the field study in the cocoa districts of Assin Foso, Sefwi Boako and Sekondi. The farmers selected for the study had farms ranging from a single farm to six farms. Most of the farmers (about 74%) had a single farm or two farms. However, some of them had three to six farms they took care of. Most of these farms are small in size. The number of cocoa farms owned by the farmer is assumed to have a positive impact on the adoption of cocoa technologies. A farmer having many cocoa farms could harvest more cocoa which may translate into higher income for the purchase of the relevant inputs to implement the adaptation strategy (Aneani, Anchirinah, Owusu-Ansah & Asamoah, 2012). Farm sizes range from as low as half an acre at Ghana Camp in the Assin Foso District (Central Region) to about 66 acres at Bechiwa in the Sefwi Boako District (Western Region). The size of cocoa farms among the adult male farmers ranged between 3.8 and 18.7 acres. The size among women farmers ranged from 0.5 to 15 acres. Both the smallest (0.5acres) and the largest (15 acres) were in the Central Region in Sienchem and Gold Coast Camp respectively. From this survey, the very large-sized individual cocoa farms are located in the Western Region. The desire to expand a farm depends mainly on the availability and affordability of land. In the Western Region land was usually available; but lack of financial resources limits expansion by the small scale farmers. In the other regions, land was not easily available; and the price was either too high or the contractual agreement was unfavourable.

Other Occupations apart from Cocoa Farming

The evidence in Table 16 buttresses the already known fact that the major occupation in rural communities in Ghana is farming. For example, out of the 444 farmers in the study, 440(99%) said cocoa farming was their major occupation. The remaining 4(1%) had teaching as their major occupation. However, some of the selected cocoa farmers had other occupations such as driving, trading (purchasing clerks), logging (timber merchants), tailoring, vegetable farming and teaching as minor sources of income (Table 17).

The farmers in all the districts cultivated food crops such as cocoyam, maize, plantain, cassava, vegetables such as tomatoes, garden eggs and pepper as well as cash crops like citrus and palm fruits. These products are used in the home or sold to supplement the income from cocoa. Cocoa is harvested annually or twice a year; but some of these other crops are available all year round. However, there is no organized and ready market for them while such a market exists for cocoa.

Table 16- *Major Occupation of Respondents*

Major Occupation	Frequency	Percentage (%)
Farming	440	99.1
Teaching	4	0.9
Total	444	100

Source: Field survey, Buxton (2013)

Table 17- *Other Occupations of Cocoa Farmers*

Minor Occupations	Frequency	Percentage (%)
None (Cocoa farming only)	383	85.3
Trading and Purchasing Clerks	41	9.2
Driving	8	1.8
Teaching	4	0.9
Tailoring	3	0.7
Vegetable farming	2	0.5
Animal rearing	2	0.5
Logging	1	0.2
Total	444	100

Source: Field survey, Buxton (2013)

Summary and Conclusion

The study confirmed that cocoa production in Ghana is predominantly a smallholder activity, and commercial cocoa plantations are non-existent in Ghana. Farm sizes typically average less than 5 acres in the Central Region, and 8 acres to 10 acres on the average in the “Western North” and “Western South” regions. Migrant cocoa farmers still dominate the sector. A significant portion of the farmers had no education or at best, basic education. Most farmers had two or more farms on which they worked. Land tenure systems mostly practised in the sector are the “abunu” and “abusa” systems. A significant portion of the farmers surveyed had family sizes ranging from 5 to 12 members. Farmers use a combination of family, hired and communal (nnoboa) labour in cocoa production. In general, the farmer’s household is the main source of labour for the cocoa farm. The peak demand for labour on mature cocoa farms occurs between July and December in any typical cocoa season. Cocoa farmers also cultivated food crops (plantain, cassava, maize, cocoyam, yam, rice, banana, pineapple, okro, tomatoes, pepper, garden eggs and ginger) and other tree crops (oil palm, citrus and coconut), with average farm sizes of about 2.5 acres and 5 acres respectively.

A study of cocoa farmers’ socio-economic characteristics is expedient considering the fact that it is the farmers’ socio-economic characteristics that govern their outlook on the environment.

Cocoa farmers’ Perceptions of Climate Change

Introduction

Adaptation to climate change requires that farmers first notice that the climate has changed, identify useful adaptations and implement them (Maddison 2006).

According to the 2001 report of the Intergovernmental Panel on Climate Change (IPCC), adaptation has the potential to reduce adverse effects of climate change. Hence there is the need for a good understanding of adaptation potentials and the limitations as pointed out by the IPCC. Current studies have tended to focus on financial, technical and institutional considerations to evaluate the adaptive capacity of a population. One factor that has been conspicuously left out is the issue of perception. The question is: How can one adapt to climate change in an adequate way if one does not perceive climate change as a reality now and in the future? It is arguable, therefore, that the first step towards adaptation is to perceive the problem.

One global issue concerning climate change and its effect on agriculture is whether farmers have the ability to perceive any change in climate that has occurred. Farmers need to understand how the global climate is changing to take appropriate initiatives to combat its effect on their production. This section describes cocoa farmers’ perception of climate change and some factors that influence this perception.

Assessing Farmer Perceptions of Climate Change

Although most of the farmers interviewed do not understand the concept and science of climate change, their observations on the effects of decreasing rainfall, increasing air temperature, increasing sunshine intensity and seasonal changes in the onset, duration, intensity and frequency of rainfall are very incisive.

The selected 444 respondents were interviewed personally with the help of a well- structured and pre-tested interview schedule. Data collection focused on farm history, memory of extreme climatic events, the impact of frequent anomalies and the management responses to those anomalies. The data thus collected have been tabulated and statistically analyzed to interpret the results. Descriptive statistics have been used to characterize farmers’ perceptions of climate changes.

First of all, farmers were asked which of the climatic elements they considered most important to cocoa production. They were asked to rank the elements in order of importance, giving the most important element the number 5. The responses of the farmers are shown in Table 18 below.

Table 18- *Most Important Climatic Element for Cocoa Production*

Rank	Most Important Element	Frequency	Percentage
5	Rainfall	404	91%
4	Sunshine	334	75%
3	Temperature	174	39%
2	Humidity	185	42%
1	Wind	203	46%

Source: Field survey, Buxton (2013)

Significantly, 404 (91%) of the respondents stated that rainfall was the most important desirable element for cocoa production. The next important desirable element, identified by 334 (75%) of the farmers interviewed was sunshine. Wind was the least desired element, according to 203 (46%) of the farmers used for the study. According to them, it led to losses, especially during the flowering and early fruiting stages of production.

Farmers were then asked if they had noticed any changes in the climate in recent years. Out of the 444 farmers interviewed, all but one answered in the affirmative. Respondents were then asked what form the changes in climate they had noticed took; and their responses are shown in Table 19 below.

Table 19- *Perceived Changes in Climate*

Perceived Changes in Climate	Frequency	Percentage (%)
No observation made	1	0.2
Long dry periods	146	32.9
Unpredictable rainfall patterns	123	27.7
High sunshine/ Temperatures	100	22.5
Short rainfall period	74	6.7
Total	444	100

Source: Field survey, Buxton (2013)

The results indicated that 33% of the farmers perceived that there was a longer dry period than before. An unpredictable rainfall pattern was another way in which the change had been noticed by another 28% of the farmers interviewed. To them, the total amount of rainfall might not have changed; but the timing of the rains was either earlier or later than expected. A hundred (22%) of the farmers had observed both increases in temperatures and sunshine, while the remaining nearly 17% said the rainfall season had become shorter than usual. They further added that the number of rainfall events during the rainy season had decreased consistently; and the number of heavy rain events during the rainy season as well as the total amount of rainfall had decreased.

Farmers single out rainfall as the single most important climatic variable which has notably changed over the past few decades and has had impact on their cropping system. This supports Adjei-Nsiah and Kermah's (2012) findings that a significant number of farmers considered a shortened rainy season and frequent droughts as the most significant indicators of climate change.

The farmers were also asked to indicate how they perceived some of the climate indicators – whether there had been an increase, a decrease or there had been no change in their observations. The results are presented in Table 20.

Table 20- *Farmers Observation of Climatic Occurrences*

Climatic Occurrences	Increase (%)	Decrease (%)	No change (%)	Total
Temperature	316 (71.2%)	21 (4.7%)	107 (24.1%)	444(100%)
Precipitation	33 (7.4%)	409 (92.1%)	2(0.5%)	444(100%)
Occurrence of Drought	434 (97.7%)	9 (2.0%)	1 (0.2%)	444 (100%)
Late onset of Monsoon	363 (81.7%)	70 (15.8%)	11 (2.5%)	444(100%)
Long dry spell	409 (92.1%)	29 (5.5%)	6 (1.4%)	444(100%)
Uneven distribution of rainfall	414 (93.2%)	17 (3.8%)	13 (2.9%)	444(100%)
Unpredictable rainfall	419 (94.4%)	9 (2.0%)	16 (3.6%)	444 (100%)

Source: Field survey, Buxton (2013)

With respect to temperature, while a majority 316 (71.2%) said it had increased in recent times, compared with the past, 107 (24.1%) felt there had been no change in this element. The remaining 21 (4.7%) felt that there had rather been a decrease in temperature. The observation of changes in temperature, unlike rainfall is usually difficult for most people without appropriate measurements. Thus the varied views of cocoa farmers on changes in temperature are not surprising. The results in respect of precipitation, however, show a remarkable uniformity of opinion across the sample. The vast majority 409(92.1%) of the farmers believed that the rainfall levels had decreased, thus an increase in the periods of dry spells. Furthermore, regarding the perception of changes in precipitation, nearly 98% of the farmers thought that the districts were getting drier and that there were pronounced changes in the timing of the rains and the frequency of droughts. A huge majority of the respondents also believed they had witnessed an uneven distribution and an unpredictable behaviour of the rains in recent years.

Farmers were also asked how long ago it was since they had noticed these changes. Table 21 shows that, the farmers had observed these changes in the past 1-2 years, 3-4 years, 5-6 years and some more than 6 years.

Table 21- *Number of Years since Farmers Observed Climate Change*

Number of years	Frequency	Percentage (%)
1 – 2 years	105	23.6%
3 – 4 years	206	45.4%
5 – 6 years	41	9.2%
More than 6 years ago	91	20.5%
Total	444	100

Source: Field survey, Buxton (2013)

Factors Affecting Farmer Perceptions of Climate Change

Some factors such as the age of the farmer, gender, farming experience, environmental consciousness, interaction with extension officers, innovativeness and exposure to the mass media were examined using correlation to see whether they in any way influenced the farmers' perception of climate change.

The results (Table 22) of the analysis of the factors influencing a farmer's perception of climate change revealed that farming experience, farmer's age and gender, environmental consciousness and exposure to the mass media had a positive and significant relationship with a farmer's perception of climate change. This means that the farmers best qualified to pronounce on whether climate change has occurred or not are those who have had the most experience in farming, are environmentally conscious and have exposure to the mass media.

On the issue of gender, further investigation revealed that male farmers are more likely to perceive changes in climate than their female counterparts. This is probably because usually males are more involved in cocoa farming activities than females who have other household duties to attend to.

Age was another factor which was positively correlated (r = 0.41) with the level of perception of the cocoa farmers. The implication is that the older the respondent, the higher the probability of him or her perceiving changes in climatic conditions. This finding on the effect of age on perception is in line with results reported by Deressa et al., (2008, 2009). The general impression is that older farmers have greater experience in observing climatic changes over time. However, this may not be entirely correct since age does not necessarily connote experience in farming.

The exposure of cocoa farmers' to the mass media was also positively correlated (r = 0.424) to the perceptions of cocoa farmers of climate change.

Cocoa farmers who have access to the radio, television, or the print media got some information regarding cocoa farming. In some of the communities visited, there were programmes targeting cocoa farmers that were periodically transmitted on some local radio stations. This made farmers who have access to the mass media aware of climate change and this influenced their perception of the phenomenon.

Table 22- *Factors that Influence Farmers' Perception of Climate Change*

Independent variables	'r' value
Farming experience	0.810*
Age	0.41*
Education	0.03
Environmental consciousness	0.45*
Contact with extension personnel	0.022
Innovativeness	0.215
Exposure to mass media	0.424*
Gender	0.441*

*=significant at 0.05

Source: Field survey, Buxton (2013)

Summary and Synthesis

The results indicated that the vast majority (99.8%) of the respondents in the study areas were aware of climate change issues. They perceived climate change in terms of changes in the rainfall pattern and in prolonged dry seasons. The respondents attributed the decline in cocoa production in the study area to climate change which brings about drought and an unpredictable rainfall pattern as experienced in the growing districts in recent years. Most of the farmers complained that they were unable to replant their dead cocoa farms due to high cocoa seedling mortality, the result of erratic rainfall and prolonged dry seasons. They indicated that the rainfall pattern over the past 3-5 years had been unstable.

The high incidence of the black pod disease was also attributed to the excessive rainfall in the hitherto short dry period between July and August. The agricultural extension officers and the cocoa purchasing clerks in the districts corroborated the observation of the farmers. The purchasing clerks and the grading clerks all agreed that the bean size and quality of cocoa beans had reduced on account of change in the climate.

On the basis of the findings of this study, policy makers should critically examine such factors as gender, educational level, age as well as farming experience in designing a holistic policy for sustaining adaptation measures by the farmers, since these factors affect their perception of climate change and hence their adaptation to it.

CHAPTER SEVEN

COPING STRATEGIES AND ADAPTATIONS OF COCOA FARMERS TO CLIMATE CHANGE AND VARIABILITY

Introduction

Climate change is arguably the greatest contemporary threat to agriculture and the livelihood of most people who live and work on land. It is one of the worst environmental, social and economic threats the world has ever faced (UNCTAD, 2005; IPCC, 2007). The effects are rather more rapid than previously expected, with serious devastating impacts, especially, on developing countries who are particularly vulnerable because of their relatively high dependence on natural resources, and their limited capacity to adapt to a changing climate (IPCC, 2001; Mendelssohn & Tiwari, 2000). Undoubtedly, vulnerability and adaptation to the adverse impacts of climate change are among the most crucial concerns of many developing countries. Reducing the vulnerability of these countries and the impacts of climate change on them requires strengthening mitigation and adaptation mechanisms.

Adaptation is identified as one of the policy options for reducing the negative impact of climate change (Adger, Huq, Brown, Conway & Hulme, 2003; Kurukulasuriya & Mendelssohn, 2006). Adaptation involves initiatives and measures to reduce the vulnerability of natural and human systems to actual or expected climate change effects (Ahenkan & Boon, 2010). Adaptation activities include behavioural, institutional and technological adjustments. Managing the risk to agriculture of climate change is especially important, not only for the direct impact that climate has on production, but also because most farmers tend to be risk averse. Risk aversion implies that farmers do not optimize their farm-plan for an upcoming season, with average market and climate conditions. Instead, they manage for adverse conditions (Rosenzweig & Binswanger, 1993). Reducing uncertainties of seasonal climate forecast may help farmers select more appropriate management strategies.

Adaptation to climate change is nothing new, neither as an empirical reality nor as a theoretical construct. Although much of the earlier international climate change policy debate in the 1990s and early 2000s was pre-occupied with mitigation, the past decade has seen a growing attention given to adaptation – both its practice and its politics (Hulme et al., 2007). Studies have shown that, without adaptation, climate change is generally detrimental to the agricultural sector. However, with adaptation, vulnerability can largely be reduced (Easterling et al. 1993; Mendelssohn, 1998; Smith, 1996). Vulnerability studies have therefore shifted their focus from the estimation of impacts to the understanding of farm-level adaptation and decision making. The understanding which is gaining ground is that while climate change is a global phenomenon, adaptation is largely site-specific (Mary & Majule, 2009). A common disadvantage for local coping strategies is that they are often not documented, but rather handed down through oral history and local expertise. As site-specific issues require site-specific knowledge, experience has shown that identified adaptation measures do not necessarily translate into changes, because there are context-specific social, financial, cultural, psychological and physiological barriers to adaptation (IPCC, 2007). It is very important to understand what is happening at the community level, because farmers are the most climate-vulnerable group. The evidence is that, cocoa farmers are not only keen observers of climate change, but they are also actively trying to adapt to the changing climatic conditions.

This study explored indigenous knowledge on perceptions of climate change, vulnerability, adaptations and coping strategies. This section discusses the coping strategies and adaptations practised by cocoa farmers in the study area, and the factors that determine farmers' adaptive capacity and some constraints faced.

Coping Strategies to Climate Change

The study distinguishes between farmers' short-term and long-term responses to climate variability and food insecurity. It defines short-term responses to a decline in food availability and income in abnormal years as "coping" or "coping strategies", and defines longer-term or permanent changes in the ways in which food and income are acquired as "adapting" or "adaptation strategies", after the work of Davies (1993).

Not surprisingly, only 5 out of the 443 cocoa farmers who had perceived a change in the climate, did not use any coping strategies. This number, added to the one person who had perceived no change in climate, makes a total of 6 farmers who did not use coping strategies. However, the majority (99%) of those who perceived some change in the climate practised several coping strategies. Farmers' coping strategies included those on crop, soil fertility and soil water management practices.

The various coping strategies used by farmers in response to the perceived changing climate are presented in Table 23. Analyzing the strategies used by all the respondents revealed that intercropping was one of the most important short-term measures taken by farmers in response to climatic vagaries. In addition to cocoa, most of the farmers engaged in the production of foodstuffs – plantain (*Musa* spp.), cassava (*manihot esculenta*), cocoyam (*Colocasia esculenta*), yam (*Dioscorea* spp.) tomatoes (*Lycopersicon esculentum*), pepper (*Capsicum* spp.) and garden eggs (*Solanum melongena*), among others. An integrated farming system was the next most popular strategy used by the farmers to combat climate change. A large majority (58%) of them practised this. In addition to cocoa farming, a significant majority of the farmers had some animals (poultry, sheep and goats) they kept to augment household demands for protein and also for sale to earn ready cash.

The importance of agro-forestry practices as a climate coping strategy has been widely emphasized in many parts of the world (Altieri & Nicholls, 2005; Kebebew & Urgessa, 2011; Mcneely & Schroth, 2006). For instance, the integration of agricultural systems with trees on the same piece of land can ensure the complementary use of environmental resources that can enhance productivity (Altieri & Nicholls,). Agro-forestry was the next most favoured strategy adopted by farmers to reduce the effects of climate change. A large proportion 262 (60%) of them had grown economic trees such as pears (*Pyrus communis*), oranges (*Citrus sinensis*), and mangoes (*Mangifera indica*) around their farms. In addition to providing shade for the farm, their fruits are sold for additional income. Through education by extension officers, most of the farmers have recognised the importance of planting economic trees (including commercial timber) on their farms to shade their crops as well as to eke out their livelihood. Growing of trees had little appeal to farmers in the past because of the trampling on farmer’s crops by timber companies and illegal chainsaw loggers. Farm crops were sometimes destroyed by timber merchants who claimed that they had permits to harvest trees in concessions that included farmlands outside the forest reserves.

In the past, to protect their crops, some farmers deliberately killed the trees on their farms. However, the current Timber Resource Management Amendment Act of 2002 provides that the right to extract timber from a specified area of land shall not be granted if there are farms on the land, unless the consent of the owners of the farms has been obtained, or if timber is already being grown on the land. Until 2002, all timber trees in Ghana were held by the government in trust for the people; and the government could give any area of land in concession to a timber company (Gyampoh, Amisha, Idinoba, & Nkem, 2009). However, the 2002 legislation does not significantly change the situation of the farmers vis-à-vis the timber merchants, because most of the farmers are unable to show clear proof of ownership of the trees on their farms. Sustained awareness programmes are needed to inform rural farmers of their rights and to empower them to protect their farms and, most importantly, to plant more trees. Agro-forestry systems provide both mitigation and adaptation measures to the menace of climate change (Nyong, Adesina & Elasha, 2007).

Stubble mulching was also practised by an estimable proportion (55%) of the farmers. They left residue of cocoa husks on the farms after the pods have been broken and the beans removed. Apart from a few of the farms where women later burnt the cocoa husks for soap making, the rest spread the husks under the trees. This, according to them, serves as fertilizer for the farm, in addition to mulching the land to prevent erosion and early loss of water.

Adjusting the farming sequence, including changing the time of raising nurseries and transplanting seedlings to take advantage of the changing climate, with its associated change in heat and moisture levels, adopted by 22% of the farmers, was another option. To cope with climate change, farmers have developed a wide range of management practices such as increasing shade, dry season vegetable farming and rice farming. The abrupt climate fluctuations, such as increasing drought, had made some farmers adopt the nursery method where they can augment water demands by watering from nearby streams and wells, and from rainwater harvest, in cases of critical water deficits.

At early developmental stages of some crops, the use of weather-based index insurance schemes has also been explored in many countries in Africa, including Malawi (Hess & Syroka, 2005) and Ethiopia (Hess & Im, 2007). The key principle underlying weather-based index insurance is that the government, through its principal agencies, provides insurance against specific climate events like droughts that could destroy crops (Hazell & Hess, 2010; Linnerooth-Bayer & Mechler, 2006). Hence, farmers who subscribe to this weather-based insurance are given specific payments to offset losses incurred from such droughts. Farmers within the same locality pay the same premium and are tied to the same local weather station (Antwi-Adjei, 2012). Although weather-based insurance schemes hold great prospects for climate adaptation in many parts of Africa, it was the least attractive means of coping with climate change. Only 3% of the farmers used it, although agricultural insurance is important, considering the fact that cocoa farming, like any agricultural production, is surrounded by high risks and uncertainties.

Undoubtedly, through agricultural insurance, cocoa farmers can be saved from losses associated with climate change. According to Ray (2001), crop insurance can cushion the shock of disastrous crop losses in a bad year, and help to ensure a considerable measure of security in farm incomes over a long period.

Table 23- *Farmers' Coping Strategies*

Coping Strategy	Frequency	Percentages (%)
Intercropping	375	86%
Agro forestry	262	60%
Integrated farming system	256	58%
Stubble mulching	243	55%
Change in time of farm operation	97	22%
Use of water conservation techniques	87	20%
Rainwater harvesting	82	19%
Pre-monsoon dry seedling	52	12%
Use of insurance	11	3%

Source: Field survey, Buxton (2013)

Adaptation strategies

In the cocoa sector, adaptation activities in the face of climate change include behavioural, institutional and technological adjustments.

Behavioural adjustments by cocoa farmers

Cocoa farmers in the study area have improved on their farm maintenance practices; since without proper care, the annual yield of their cocoa farms have fallen, more especially, with the effects of climate change.

Spraying

Two intervention programmes geared towards reviving and booming the cocoa industry have recently been initiated by the Government of Ghana through COCOBOD. A nationwide cocoa diseases and pests control programme, commonly known as “Cocoa Mass Spraying”, was started in the 2001/2002 cocoa season. This programme aimed at assisting cocoa farmers to fight the Black Pod and Mirid/Capsid diseases. Omane-Adjepong (2012) noted that 72 cocoa growing districts benefited from the Mass Spraying Programme – 35 districts were sprayed against the Mirid/Capsid disease only; 21 districts, against the Black Pod disease only; and 16 districts benefited from both programmes. A survey of the study area revealed that most of the communities had benefited from this programme one time or the other. The farmers, however, complained that the frequency and timing of the programme was disappointing since the inputs for spraying often came in after the pests and diseases had already taken their toll on the farms. Farmers were therefore obliged to supplement the efforts of the programme with their own spraying routines. However, some farmers depended solely on the mass spraying programme, with the result that no spraying was done in seasons when the scheme failed. Tables 24 shows the frequency of spraying by farmers in the study area. Out of the 444 farmers in the study, a very large majority (99%)

usually sprayed their farms. Only five farmers (1%) did not engage in any form of pest or disease control.

Approximately 44% of the respondents sprayed their farms 2-4 times in a cocoa season. Other farmers (39%) sprayed their farms 5-7 times. Only nine farmers (2%) sprayed their farms only once; and about 14% sprayed 8 times or more. It is important to note that a very large majority of the farmers sprayed their farms frequently as a result of the training they had received from extension officers assigned to the communities. Apart from the packages of fungicides and pesticides the farmers received from the Cocoa Hi-tech Programme, they also bought the needed chemicals from agricultural inputs stores on the open market.

Table 24- *Spraying Frequency of Cocoa Farmers*

Spraying Frequency	Frequency	Percentage
Never	5	1.1
Once	9	2
2 -4 Times	195	43.9
5 – 7 Times	171	38.5
8+	64	14.4
Total	444	100

Source: Field survey, Buxton (2013)

Fertilizer application

The effect of soil nutrient deficiency has been reduced in recent years by the timely introduction of the Cocoa Hi-technology Programme in the 2002/2003 cocoa season. Under this programme, farmers were supplied with packages of fungicides, pesticides and fertilizers to help increase the yields per hectare of farm land. The fertilizers were supplied on credit by COCOBOD to the beneficiary cocoa farmers. They paid later by instalments during the ensuing harvesting season (COCOBOD, 2007). Three hundred and fifty-seven (80%) of the farmers interviewed said they applied fertilizer to their farms. Apart from one farmer who applied organic fertilizer in the form of chicken droppings, the remaining 356 farmers used inorganic fertilizer as shown in Table 25. The most common fertilizer used by the farmers was 'Asaase wura'(59%). As shown in Table 26, other types of inorganic fertilizers used were cocofeed (36%), sidako (4%) and ammonia (1%). Of the number that used fertilizer, 344 (96%) applied it during March to May, with the remaining 13 (4%) applying it between October and November.

Table 25- *Kind of Fertilizer Used*

Type of Fertilizer	Frequency	Percentage (%)
None	87	19.6
Organic	1	0.2
Inorganic	356	80.2
Total	444	100

Source: Field survey, Buxton (2013)

Table 26- *Kind of Inorganic Fertilizer Used*

Name of Fertilizer	Frequency	Percentage (%)
Asaase Wura	210	59
Sidako	13	4
Cocofeed	128	36
Ammonia	5	1
Total	356	100

Source: Field survey, Buxton (2013)

Weed control

Controlling weeds on both young and mature cocoa farms is very important. Cocoa farmers were asked how often they cleared weeds on their farms and by what means this was done. Tables 27 and 28, present their responses. Manual weeding of farms was the most preferred means of controlling weeds for most (69%) of the farmers. A considerable number – 135 (30.4%) of them used a combination of manual weeding and weedicides. Use of machinery only and of weedicides only were least preferred, with only 2 (0.5%) of the farmers practising each of them.

Table 27- *Method of Controlling Weeds on Cocoa Farms*

Weed Control method	Frequency	Percentage (%)
Manual Weeding	305	68.7
Use of Machinery	2	0.5
Use of Weedicides	2	0.5
Use of Both Manual Weeding and Weedicides	135	30.4
Total	444	100

Source: Field survey, Buxton (2013)

Table 28- *Frequency of Weed Control on Cocoa Farms*

Number of Times	Frequency	Percentage (%)
Once	9	2.0
Twice	248	55.9
3 Times	160	36
More than 3 times	27	6.1
Total	444	100

Source: Field survey, Buxton (2013)

Responses on the frequency of weeding, reported in Table 29, revealed that about 2%, 56%, 36% and 6% of the respondents weeded their farms once, twice, thrice and more than 3-times respectively in a growing season. This shows that with the exception of 2% of the farmers who weeded only once, the remaining 98% kept to the recommended practice of at least two weedings in a year for mature cocoa farms.

Other farm maintenance practices

Both young and mature cocoa farms need regular maintenance. Maintenance is important because every activity carried out on a cocoa farm helps in creating the needed environment for optimal yield. Apart from spraying, weeding and fertilizer application, other farm maintenance practices examined were pruning, removal of damaged, diseased and dead pods, removal of piles of cocoa husks and removal of mistletoe.

From Table 29, it can be observed that the vast majority – 439(98.9%) – of the farmers engaged in pruning their cacao trees. This is probably due to the awareness of the importance of pruning in cocoa production given to the farmers by the extension officers. Farmers who pruned their farms could testify that yields had increased. This confirms the findings of Bonaparte (1981) that high light intensity stimulates flowering, while shade decreases or suppresses it. As farmers prune their trees, they reduce shade and hence increase the intensity of light on their farms.

Table 29- *Other Cocoa Farm Maintenance Practices*

Farm Activity	Yes (%)	No (%)
Pruning	439 (98.9%)	5 (1.1%)
Removal of damaged, diseased and dead pods	430 (96.8%)	14 (3.2%)
Removal of mistletoe on trees	437 (98.4%)	7 (1.6%)
Removal of piles of cocoa husks	49 (11%)	395 (89%)
Drainage of stagnant water on farms	134 (30.2%)	310 (69.8%)

Source: Field survey, Buxton (2013)

Farmers were asked why they pruned their farms; and their responses as shown in Table 30 included pruning was used to control the spread of pests and diseases by 183 (42%) of the farmers who practised pruning. For 147 (33%) farmers, pruning helped to increase air circulation on their farms which made their cacao trees grow well. The remaining farmers gave increase in yield (16%) and reducing shade (9%) as their reasons for pruning their farms. Further in-depth interviews with the five farmers who did not prune their trees revealed that, to them, pruning was wasteful of cocoa pods, since pruned branches often had some young pods on them.

Table 30- *Cocoa Farmers' Reasons for Pruning*

Reason for Pruning	Frequency (%)	Percentage (%)
Control of pests and diseases	183	42 %
Increase air circulation on farm	147	33%
Increase yield	68	16%
Reduce shade	41	9%

Source: Field survey, Buxton (2013)

Removing damaged, diseased or dead pods from cacao trees is an important act practised by cocoa farmers on a day to day basis. This helps to control the spread of pests and diseases that may have just emerged on the farms. Early detection helps to avoid spreading and extra cost in treating affected farms. Four hundred and thirty (96.8%) of the farmers interviewed removed dry, dead and diseased pods from their farms periodically. The removed pods were collected in baskets and sent away from the farm.

Mistletoe removal is another important farm maintenance practice in cocoa farming. This improves tree health, as these parasitic plants reduce the amount of food and water getting to branches and pods. Mistletoe left on cacao trees tends to affect their production; and it even kills the trees. When asked whether farmers removed mistletoe regularly, 437 (98.4%) of them answered in the affirmative. Those who did not remove mistletoe from their cacao trees gave lack of capital to employ labour for that purpose as their reason.

The husks of cocoa after harvesting and breaking of pods were left on the farm by 395 (89%) of the farmers interviewed. Some of the farmers said the women in the communities later burnt them for soap making. Where the husks were not burnt, they were spread under the cacao trees to serve as manure. However, this practice may serve as a means of spreading diseases and pests, since for most of the farmers, harvested cocoa was carried from other farms to a central point where breaking is done.

Farmers in all 134 farms where water remained stagnant during the rainy season drained their farms. Cacao trees standing in pools of water often become unhealthy. Stagnant water may also encourage the spread of the black pod disease. Stagnant water on farms is drained by digging small drainage canals.

Changing the frequency and timing of farm practices was a major behavioural adjustment made by cocoa farmers to adapt to climate change and to reduce the effects on their farms.

Institutional and technological adjustments

Change of variety

An important agricultural adaptation strategy is the promotion and cultivation of crops that have shorter gestation periods and are drought resistant. The Cocoa Services Department has developed and promoted this technology among cocoa farmers in the study area. Interviews with farmers and agricultural extension officers, backed by field observations, indicated that farmers were cultivating a variety of improved hybrids of cocoa, maize, cassava and cereals that have shorter gestation periods and thrive well under the current climatic conditions. The new cocoa hybrid, ‘akokra bedibi’, is gradually being accepted and grown by the farmers, although some are still sticking to the old varieties. This is because farmers, like any other group of people, have differences in the rate at which they accept change. Most farmers are risk averse and will rather maintain their old methods than try a new method with an uncertain outcome. Even where farmers have changed the variety of cocoa they grow, the new variety (akokra bedibi) has been planted on a small scale in addition to the old variety. About 40% of the farmers have changed the variety of cocoa they grow.

Farmers were further asked whether their decision to change the variety of cocoa grown was a result of climate change. Out of the 179 farmers who had changed the variety of cocoa they grew, 162 (91%) attributed the change of variety to a change in climate.

Extension Services

Another significant institutional adjustment made is the re-zoning of cocoa growing areas into cocoa districts for easy administration and monitoring. More extension officers have been trained and assigned to specific farming communities which they visit on a regular basis. Training and personal farm visits are made so that problems on site are identified early, and the appropriate remedies are taken to forestall spreading and total destruction of cocoa farms. Majority (88%) of the cocoa farmers had some interaction with the extension officers assigned to their communities.

How often extension officers visit a site is very important to help control the spread of pests and diseases, in addition to education on current and improved farming methods. Cocoa farmers in the study area confirmed an increase in the number of visits to their communities and farms by the extension officers. About 72% of the farmers had monthly visits to their farms as shown in Table 31.

Table 31- *Frequency of Visits by Extension Officers*

Visit Frequency by Extension Officers	Frequency	Percentage (%)
No Visit	52	11.7
Once a month	321	72.3
2- 4 times in a year	71	16.0
Total	444	100

Source: Field survey, Buxton (2013)

These behavioural, institutional and technological adjustments, to some extent, reduce present vulnerabilities without necessarily accounting for future climate change. It must be emphasized that, for adaptation strategies to be effective and successful, they should reduce present and future vulnerabilities to climate change as well as increase resilience (Huq, Rahman, Konate, Sokona, & Reid, 2003; Van Aalst, Cannon, & Burton, 2008). In other words, climate adaptations should seek to maximize the potential benefits that can be derived from a more resilient society (Mitchell & Maxwell, 2010).

Factors Influencing Adaptation

Several factors influence the willingness of a cocoa farmer to adapt to climate change. Interaction with the 444 cocoa farmers showed that, firstly, cocoa farmers who observed changes in the temperature and rainfall patterns are prospective adapters to climate change. Secondly, more experienced farmers are more likely to take some adaptation measures because such farmers are in a better position to compare the climate over time. Besides, experienced farmers have great farming skills and management abilities which enable them to make informed decisions when confronted with climate change. These results confirm the findings of Nhemachena and Hassan (2007) and Gbetibouo (2009) in studies of adaptation carried out in the Southern Africa region and in the Limpopo Basin in South Africa respectively.

The results also show that, farmers who engage in non-farming activities or have other sources of income are reluctant to adapt to climate change. Access to advice from extension officers regarding best farm practices and adaptation also strongly increases the probability of a farmer adapting to climate change. A farmer’s level of education also greatly increases the probability of adaptation. Educational status is assumed to positively influence the choice of adaptation strategy employed by farmers because, with a higher level of education, the farmer would be in a position to technically and economically assess the new crop or technology, to clear doubts and uncertainties associated with it and enhance its adoption. It is also observed that large farms are more likely to adapt to climate change. This is consistent with the notion that adaptation has a large fixed cost element in information gathering, implying that adaptation is less worthwhile for small farmers. However, other studies on adoption of agricultural technologies indicate that farm size has both negative and positive effects on adoption, signifying that the effect of farm size on technology adoption is inconclusive (Bradshaw, Dolan, & Smith, 2004).

Environmentally conscious farmers who visit their farms regularly and have good mass media exposure because they usually listen to radio programmes specifically broadcast to educate farmers on climate change and adaptation issues, also appeared willing to adapt.

Access to credit is a notable factor which determines willingness to adapt as well as the adaptation measure possible. Farmers who have access to credit are more likely to adapt to climate change, especially because of the large fixed cost element in adaptation.

The results also indicate that male-headed households adapt more readily to climate change than their female counterparts. This finding supports the argument that male-headed households are more likely to get information about new technologies and take risks than female-headed households (Asfaw & Admassie, 2004; Deressa, 2008). It also supports an argument that male-headed households are more likely to take up adaptation methods because they have greater access to resources and information (Deressa, Ringler & Hassan, 2010).

Family size was another factor that informs a farmer's ability to adapt to climate change since it offers a farmer a source of labour. This result is in line with the argument that large family size is usually associated with a large labour endowment, which will enable a farmer to accomplish various agricultural tasks, especially during peak seasons (Croppenstedt, Demeke, & Meschi, 2003).

Household factors

Age of household head

In the existing literature, researchers do not seem to agree on the nature of the effect of age on the decision to choose an adaptation strategy. For example, whereas Deressa et al., (2010) report that age has a positive influence on the choice of livestock sale as an adaptation strategy by farmers during extreme climatic events, Hassan and Nhemachena (2008) have found age to have no significant effect on the choice of an adaptation strategy to climate change and variability. It was observed from the study that, older farmers who had benefited from cocoa farming were interested in adaptation to ensure that the farms continue to be a source of livelihood for the family.

Gender of household head

The influence of gender on the choice of an adaptation strategy to climate change and variability is not straightforward in the literature. Whiles the studies of Hassan and Nhemachena (2008), Deressa et al., (2010) and

Mandleni and Anim (2011) have concluded that a male-headed household is more likely to adopt an adaptation strategy because males have more access to and control of resources, Nhemachena and Hassan (2007) report that female-headed households are more likely to adapt to climate change and variability, since much of the agricultural work is done by women.

Education of farmer

The influence of education on the choice of the adaptation strategy used by farmers in adjusting to climate change and variability is also ambiguous. Deressa et al., (2010) noted that an increase in the educational level of farmers increases the probability of selling livestock as a coping strategy. However, Mandleni and Anim (2011) reported that education appears not to have an influence on adaptation.

Observed Reduction in Yield

Out of the 444 cocoa farmers interviewed in the study, 298 (66.1%) said that their yields had reduced over the years. The factors to which the cocoa farmers attributed the reduction in yield are shown in Table 32. Over half (51%) of those who said their yield had decreased attributed it to unfavourable weather conditions experienced in recent years. Diseases and pests (23%), poor farm maintenance (12%), old age of cacao trees (11%) and loss of soil fertility (3%) were other reasons given. The remaining 146 (32.9%) of the 444 farmers canvassed had experienced increased yields. They attributed the increases to good maintenance practices (51%), application of fertilizers (37%), increase in farm size (9%) and use of the hybrid variety

(3%). It was observed that all those farmers who attributed a reduction in yield to climate change engaged in one or more coping strategies.

Table 32- *Reasons for Observed Changes in Cocoa Yield*

Yield	Reasons	Frequency (%)	
Increase	Good maintenance	75(51%)	146 (100%)
	Fertilizer application	54(37%)	
	Increase in farm size	13 (9%)	
	Hybrid variety	4 (3%)	
Decrease	Unfavourable weather	152 (51%)	298 (100%)
	Diseases and pests	67 (23%)	
	Poor maintenance	35 (12%)	
	Soil fertility	10 (3%)	
	Old trees	34 (11%)	

Source: Field survey, Buxton (2013)

Access to Information on Cocoa Production

The farmers used for the study were asked to indicate the various sources from which they obtained information on cocoa farming. Their responses are shown in Table 33.

Table 33- *Sources of Information to Farmers on Cocoa Production*

Sources of Information	Yes	No
Television	37 (8%)	407 (92%)
Radio	335 (75.5%)	109 (24.5%)
Newspapers	14 (3%)	430 (97%)
Agric extension officers	403 (91%)	41 (9%)
Friends	80 (18%)	364 (82%)
NGOs (Cocolink, Echoes)	60 (14%)	384 (86%)

Source: Field survey, Buxton (2013)

Cocoa farmers in the selected districts received information on cocoa production from various sources. A very large majority (91%) of the farmers received help from the agricultural extension officers assigned to their communities. The radio also served as an important medium through which a large proportion (75.5%) of the farmers got some education on cocoa farming practices. Very few cocoa farmers obtained information on cocoa farming from television programmes (8%) and newspapers (3%) since the majority of them did not have television sets; and they did not read the newspapers. This means that, radio education and good extension services are the best mediums for education on best farming practices and improved technology to the farmers. Access to information by farmers will enable them make informed decisions on adaptation to climate change.

Access to Credit

Access to credit is a major factor in the development of the agricultural sector, particularly, in the cocoa sector. Currently, access to credit by cocoa farmers, especially medium-term and long-term finance, is limited. Only about 16% of the farmers in the study area had access to credit during the 2013 cropping season (Figure 16). This low percentage can be attributed to high interest rates (ranging between 20% and 28%) and cumbersome application procedures. Hence, smallholder farmers rely on informal credit sources, such as family members, friends and informal loan providers (‘susu’). Farmers have extreme difficulty in accessing credit from the formal sector, not only because they are perceived by financial institutions as high risk (no-collateral) borrowers, but also because they are mostly illiterate; and they find the loan application process cumbersome. In cocoa areas where credit is available, it is disbursed to individual farmers who are part of a farmers' group. The Opportunity International Savings and Loans Limited, through its Cocoa Livelihood Program, is the major source of credit to the farmers. Agricultural inputs, such as knapsack sprayers, mist blowers, protective clothing, Wellington boots, fertilizers and insecticides are sold to farmers on credit.

The fact is that, access to credit has a significant impact on the likelihood of using adaptation strategies. Easy access to agricultural credit increases the probability of using adaptations as climate change occurs. For example, access to credit enables farmers to adapt by purchasing chemicals such as fertilizers, pesticides and herbicides. It also gives farmers the financial capability to acquire more land in their area or move to a different site, in order to reduce the negative impact of climate change.

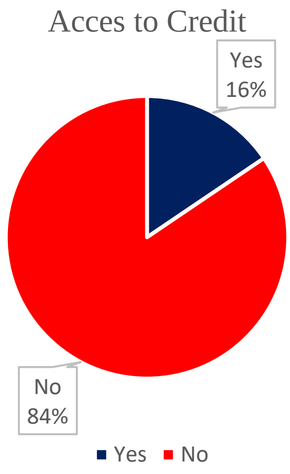


Figure 14: Farmers Who Have Access to Credit

Source: Field survey (2013)

Non-Farming Activities or Other Sources of Income

McNamara, Wetzstein and Douce (1991) reported that off-farm employment may present a constraint to adaptation because it competes with on-farm managerial time. Cocoa farming is very labour intensive and requires day to day farm visits in order to promptly identify possible threats to the crop. Only 14% of the farmers used in the study had non-farm activities as their major source of income. The remaining 86% had cocoa farming as their major source of income. Hence, their day-to-day activities revolved around farming. Farmers who have cocoa farming as their major source of income are more likely to adapt to changes in climate since such changes threaten their main livelihood.

However, Gbetibouo (2009) suggests that expanding smallholder farmers' access to non-farming sources of income increases the probability that they will invest more in farming activities.

Land Tenure and Ownership

The results also showed a significant positive relationship between land tenure and adaptation to changes in climate in the study area. It was found out that landowners tended to adopt new technologies more readily than tenants. This finding justifies efforts in many countries to reduce tenure insecurity (Lutz, Pagiola, & Reiche, 1994). The argument is that, with proper property rights, farmers may be able to use adaptations such as changing the amount of land under cultivation to adjust to changing climates.

Farm Size

The farm size of the cocoa farmers surveyed also had a significant positive correlation with their willingness and ability to adapt to climate change. This is because a large farm size is always associated with greater wealth and more capital resources (Aneani et al., 2012). Therefore, the larger a farmer's farm size, the greater the probability of the farmer adapting to climate change in the study area. Larger farm sizes are often associated with specialization in agriculture. Eneyew (2012) shares this opinion when he reports strong evidence of negative effect of farm size on livelihood diversification.

The effect of farm size has been a controversial issue in the literature. Several studies on adoption of agricultural technologies indicate that farm size has both negative and positive effects on adoption, suggesting that the effect of farm size on technology adoption is inconclusive (Bradshaw, Dolan & Smith, 2004). The finding of this study therefore agrees with the views of Daberkow and McBride (2003), that given the uncertainty and the fixed transaction and information costs associated with innovation, there may be a critical farm size below which a farm cannot adapt to technological change. The conclusion is, smaller farms are less likely to adopt innovations, given the large fixed transaction and information costs.

Access to Agricultural Extension Services

The study revealed that access to extension services had a significant positive correlation with the adaptation strategies used by cocoa farmers. Access to extension services increased the likelihood of using the adaptation measures. This finding is in line with the results of various studies in developing countries which indicate that a positive relationship exists between access to information and the adaptation behaviour of farmers (Yirga, 2007); and that access to information through extension services increases the likelihood of adapting to climate change (Deressa, Hassan, Alemu, Yesuf & Ringler, 2008; Maddison, 2006; Nhemachena & Hassan, 2007).

Temperature

There is increased likelihood of adapting to climate change when there is a rise in mean annual temperature. The choice of adaptation strategies employed by farmers greatly depends on the nature of climate change observed. Where farmers perceive an increase in mean annual temperatures, they are likely to choose such adaptation options as change in time of farm operations, pre-monsoon dry seedling, mulching seedlings and agro-forestry. Crop diversification and soil conservation methods also show a positive relationship with rise in temperature. The finding that adaptation to climate change increases with rising temperature agrees with the observation by other researchers that increasing temperature is damaging to African agriculture and farmers respond to it through the adoption of different adaptation methods (Deressa, 2008; Kurukulasuriya & Mendelssohn, 2006).

Rainfall

It may be expected that as rainfall quantities decrease, the probability of adapting to climate change, would increase. This study shows a significant relationship between rainfall and such adaptation options as the use of water conservation techniques (especially at the seedling stage) and change in planting dates. A delay in the onset of rainfall is likely to push farmers to delay their planting dates and methods. Most cocoa farmers are now using seedlings instead of the old method of planting at stake. This result confirms the finding in a previous study that decreasing rainfall significantly increases the likelihood of using different planting dates as an option (Deressa et al., 2008).

Barriers to Climate Change Adaptation

The implementation of the various adaptation strategies may be impeded by several barriers. Barriers may be defined as factors or obstacles that reduce the effectiveness of adaptation strategies. The research shows that some farmers are willing to adapt to climate change but face several challenges. Several studies have documented that agricultural adaptation to climate change and variability could be impeded by economic, cultural and social barriers including land tenure insecurity (Esham & Garforth, 2012; Jones & Boyd, 2011; Nielsen & Reenberg, 2010).

When farmers were asked whether there were any factors hindering their readiness to adapt to a changing climate, 207(47%) said there were some constraints. Some of the constraints identified by the farmers are lack of financial capital, lack of education and technical know-how, land acquisition issues and deforestation. Table 34 shows the different types of constraints affecting farmers' ability to adapt to a changing climate.

Table 34- *Constraints to Climate Change Adaptation*

Constraint	Frequency	Percentage (%)
Financial	98	47
Deforestation	66	32
Scarcity of the hybrid variety	22	11
Land acquisition	14	7
Education	7	3
Total	207	100

Source: Field survey, Buxton (2013)

Financial constraints

Cocoa farming requires some level of capital investment in terms of money to acquire land for growing new varieties, hiring labour for land preparation and seedling establishment, acquiring inputs for farm maintenance practices like spraying insecticides, fertilizer application, among others. Some adaptation measures are costly; and most farmers, though willing to adapt, are limited by the lack of financial capital which influences the choice of adaptation measures practised. Because of financial constraints, farmers will opt for a less costly measure rather than the most efficient method of minimizing the effects of climate change on their farms. Forty-seven per cent of the farmers identified lack of money as a major constraint to adaptation. The lack of credit schemes compounds the problem further. Readily available credit will make adaptation measures more attractive to farmers. The farmers used in the study all agreed that though the producer price for cocoa had increased over the years, the value of the money had decreased. They explained this by giving a list of goods they could previously buy with the money from cocoa sales, but which they could not buy now. This leaves no room for personal savings which farmers could otherwise re-invest into their farms.

Deforestation

Exploitation of the forests for timber is a critical factor in the degradation of the forest ecosystem needed for the establishment of cocoa farms. In addition to timber companies, charcoal burners and illegal loggers operate seriously in the forests, sometimes with the connivance of some community members. Illegal loggers often end up destroying nearby cocoa farms in their wake. Therefore, there is no incentive to expand farms by growing new varieties since such investments are likely to be destroyed by illegal loggers. According to 66 (32%) of the farmers who admitted that there were constraints to adaptation, the activities of illegal timber operators posed a serious problem for adaptation.

Scarcity of the hybrid variety

The availability of the new cocoa variety to farmers who wanted to change from the old variety was another constraint some of the farmers identified. According to 22 (11%) of the farmers who talked about constraints to adaptation, it was often impossible to get the seedlings of the new variety for re-planting or expansion. Farmer groups have tried to make nurseries on their own; but these nurseries have often not been able to serve all the members.

Land acquisition

An unfavourable land tenure system in the farming communities was observed as another constraint to adaptation. Farmers who had access to land could easily practise some of the adaptation strategies. Seven per cent (7%) of the farmers identified the difficulty in accessing land for farming as a constraint on adaptation to climate change.

Education

Although a majority of the farmers used for the study had had some education, three per cent (3%) of them still identified lack of education regarding some of the adaptation strategies as constraints. These farmers were mostly those who had no interaction with the agricultural extension officers. Adaptation methods need education and training, including demonstration, for the farmers to understand and agree to try them.

Livelihood Alternatives

The most affected livelihood source of the population is cocoa production. As indicated earlier, over 80 per cent of the population in the survey area depend on agriculture for their livelihood. Agriculture is mostly subsistence in nature, with a high dependence on rainfall. Interviews and consultations with the District Agricultural Officers and farmers indicated that the area has generally experienced a reduction in precipitation over the past 5-10 years; and this is attributed to climate variability. The reduction in precipitation has had both direct and indirect impacts on agricultural productivity in all the districts.

The greatest impact of climate change is on the production of cocoa and food crops. Over time, farmers have experienced severe crop failures which have threatened households' livelihood and subsequent investment in farming. For instance, affected households have reduced their scale of operation in the subsequent planting season, switched to another farming enterprise or embarked on non- farm activities (Gordon & Graig, 2001).

In addition to the planting of economic trees, Table 35 shows in an order of importance, alternative livelihoods that have been identified as effective climate change adaptation strategies practised by farmers in the cocoa growing communities used in the study. A notable proportion (44%) of the farmers have tried animal rearing, 29%, 14% and 7% have taken to vegetable farming, fish farming and bee and snail keeping respectively, while a small 3% have resorted to soap making or mushroom farming. The products contribute substantially to improve nutrition in the households, either as part of the family diet or as a means to achieving household food security.

Table 35- *Alternative Livelihoods Practised as Adaptation Strategies*

Livelihood Options	Frequency	Percentage (%)
Animal rearing	195	44
Vegetable farming	129	29
Fish farming	63	14
Bee and snail keeping	28	7
Soap making	15	3
Mushroom farming	14	3
Total	444	100

Source: Field survey, Buxton (2013)

Summary and Conclusion

The study showed that farmers who perceived that the climate had changed and had had some effect on their production usually employed adaptation measures. Significant among the strategies used are intercropping and agro-forestry; and the least used strategy is crop insurance. The study also showed that the factors influencing adaptation to climate change by cocoa farmers include the education level of the farmers, household size, gender of the farmer, livelihood options of the farmers and availability of credit. The main barriers to adaptation identified by the farmers include lack of information on the adaptation methods and financial constraints to using the methods. Most of the farmers preferred animal rearing and vegetable farming as alternatives to cocoa farming in the event that climate change drastically reduced their yields.

It is observed that farmers’ responses vary when confronted with the same stimuli. Such varied responses, even within the same geographic area, are partly related to the variety of agricultural systems involved and the different market systems in which farmers operate (Bryant et al., 2000). However, a more important factor of such varied farmers’ responses is the differences between farmers in terms of personal managerial and entrepreneurial capacities and family circumstances. Also, farmers can be influenced by their peers’ perceptions and by values prevalent in their communities, as well as their professional associations. Hence, there is the need to carefully explore how farmers’ choice of adaptation measures is influenced by socioeconomic as well as political characteristics so as to enable region-specific adaptation policies to be designed and implemented.

The assessment of the adaptation options used by cocoa farmers to combat the adverse effect of a changing climate on cocoa production is important to help formulate policies that enhance adaptation as a tool for managing the different risks associated with climate change. However, understanding the likely adaptation responses of farmers to anticipated climate change presents serious challenges to researchers. One major challenge is to isolate the adaptations in response to climate stimuli from adaptations in response to other stimuli, such as market price or government policy changes that farmers face in the real world. Assessing adaptation strategies also provides the information needed by cocoa farmers to increase their capacity to moderate potential damages and to take advantage of opportunities, if any, to survive in a changing climate. It is also worth mentioning that a better understanding of farmers' perceptions of climate change, on-going adaptation measures, and the decision-making process in agriculture is important in formulating policies aimed at promoting successful adaptation of the agricultural sector. Successful adaptation will require the involvement of multiple stakeholders, including policy makers, extension agents, NGOs, researchers, communities and farmers. However, the question of whether there are limits (thresholds) to adaptation – whether adaptation by society is limited, in some way, once climate change crosses some danger threshold – is yet to be answered. Again, uncertainties associated with forecasting future climate change limit success in adaptation. These gaps in the status of knowledge about future climate change can have an important bearing on the way adaptation decisions are made, and thus, can limit adaptation. There is also the need to fully incorporate adaptations to climate change projections, thus moving away from vulnerability estimates based on simulated effects when actual adaptation by farmers is occurring. Failure to reflect the full range of adaptation possibilities in estimates of climate change impacts is likely to result in over-estimation of vulnerability.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The study is summarized in this chapter. Some significant findings and the implications of these findings are noted. Conclusions relating to the research objectives are also presented in this chapter. The chapter ends with recommendations on the basis of the findings and conclusions of the study and suggestions for future research.

Summary

The study sought to examine the potential effect of climate change on cocoa production in Ghana. The study also sought to determine the ability of smallholder cocoa farmers to detect climate change and to ascertain how they have adapted to whatever climate change they believe has occurred. The study also aimed at forecasting cocoa production in a changing climate, focusing only on changes in rainfall and temperature in the cocoa growing areas. This work, unlike others based on structural modelling of agronomic responses, relies on the observed responses of the cacao plant and of the farmers to varying climates. It examined the effect of climate change on the production of cocoa in reality and considers the behaviour of farmers as an important factor in response of cocoa production to climate change.

Four specific objectives of the study were: (1) to examine the impact of climatic variables (i.e. rainfall and temperature) on cocoa yields; (2) to develop a model that can be used to predict future cocoa production in Ghana;

(3) to assess the perception of cocoa farmers to changes in climate; and (4) to explore the adaptations of cocoa farmers to changes in the climate.

The study used a combination of both qualitative and quantitative methods to analyse both primary and secondary data gathered through key informant interviews, household interviews of smallholder cocoa farmers and institutional reports and data-bases.

Examination of the climatic data and other works forecasting climate change in Ghana proves that the climate is indeed changing, though the rate may be slower than otherwise predicted. The data shows that, the magnitude of change in climate will differ among the different ecological zones and, hence, affect the cocoa growing areas differently. On the whole, some areas will no longer be economically suitable for cocoa production in the future. Some areas, on the other hand, may become more suitable.

In Ghana, generally, increase in cocoa production results usually from an increase in the area under cocoa cultivation. With climate change and competition by other land uses, cocoa production cannot be expanded indefinitely. Currently, the new cocoa growing areas are in the Western Region where there is great competition for land as a result of the discovery of crude oil in the Region. The implication of this is that, without any effort to ensure sustainability in the cocoa sector, its contribution to the Ghanaian economy will be reduced. Some findings based on the objectives of the study are discussed below.

The Impact of climatic elements on cocoa production

Of all the climatic elements that affect cocoa production, the work found out that rainfall and temperature remains the most important for cocoa production, according to the farmers. Cocoa is highly vulnerable to drought conditions, and the rainfall distribution in a season informs the farmer as to which farming activity to engage in. Farmers expect a high yield during a year with high rainfall, though this is not always the case. This work suggests that the rainfall of the previous year plays an important role in determining the yield in the current growing season, among other factors.

Modelling future cocoa production in Ghana

Knowledge of the climate in cocoa growing areas can be a useful tool in forecasting the potential yield of cacao in a growing season, all other things being equal. This work makes an assumption that, the climate is the only factor affecting cacao yield that man has no control over. It considers that, where the best cacao variety, husbandry practices and soil conditions are met, rainfall and temperature measurements can be important in forecasting future cocoa production. The forecast model is $Predicted\,Yield = -90639 + 2593.67\,T + 11.76R$ where T and R are maximum temperature and annual rainfall respectively. The regression model used predicts an increase in yield of 11.76 units per unit increase in rainfall and an increase of 2593.67 units in yield as temperature increases by a unit. As rainfall increases, the available moisture needed for growth and production is obtained. Where soils are suitable, the release of the available water from the soil to the tree ensures high yield. Since cacao is highly vulnerable to drought, the amount and distribution of rainfall is very important. An increase in temperature (within the limits of 30 – 32^{o}C) is conducive to cocoa production. Flushing also occurs during periods of high temperatures and thus increases the number of pods formed. High temperatures are also necessary for proper drying of cocoa beans and reduce humidity and the incidence of fungal diseases which usually increases yield losses. This explains why increases in rainfall and temperature can lead to an increase in yield. With climate models adequately predicting seasonal changes in the weather, cocoa yield can be forecast for planning purposes.

Perception of cocoa farmers to climate change

This work also found out that cocoa farmers perceive that the climate is changing. Although most cocoa farmers do not understand the concept and science of climate change, experience in cocoa farming over the years has enabled them to notice that there are longer dry periods than before. With a shorter rainfall season, the rainfall pattern has changed and is unpredictable. Changing patterns in rainfall are easily detected by most of the farmers. It is rather difficult for them to detect changes in temperature; but they agree that the ambient air temperature appears to have increased. Some effects of climate change noticed by farmers on their farms include loss of *Cherelles*, ripening of young pods, incidence of some diseases and pests in areas where they were not previously observed and increased loss of seedlings at the establishment phase.

Cocoa farmers' adaptations to climate change

Vulnerability and adaption to the adverse impacts of climate change are among the most important concerns of countries seeking to achieve food security and a sustainable agricultural sector. Farmers have attempted coping with climate change, using intercropping, agro-forestry and integrated farming systems, among others. Major adaptation strategies have been behavioural adjustment by farmers, institutional adjustment by the Cocoa Services Department and technological adjustments introduced by extension officers as a result of research. Lack of credit, inadequate hybrid seedlings and difficulty in acquiring land for expansion are some of the constraints to adaptation. Suggested alternative livelihoods include animal rearing, vegetable farming and establishing fish ponds.

Theoretical Implications

Many models on the response of crops to climate change have been made for major food crops. This work is one of the few on a tree crop. One major theoretical implication of the study is that it provides a cocoa yield model and adds to the literature on adaptations of farmers in general and on cocoa farmers in particular. By demonstrating that there are significant relationships between the climatic variables and cocoa yield, this study gives important insights into how climate change affects cocoa production. Besides, studies on climate change and crop production have tended to focus on financial, technical and institutional considerations in evaluating the adaptive capacity of farmers. One factor that has been usually overlooked is the issue of perception. Yet there cannot be any adaptation without first perceiving a threat. This work contributes to the literature on farmers' perception of climate change.

Practical Implications

The results of the current study have practical implications also for the cocoa sector in general and the livelihoods of thousands of small-scale cocoa farmers in particular. For example, the results suggests that it is needful that cocoa farmers improve upon their adaptation and coping strategies for combating the adverse effects of climate change, if they are to be able to safeguard their income levels. This is because, it is becoming almost impossible to increase the land area under cocoa cultivation due to increased competition for land, especially in the Western Region (where the cocoa belt is moving because of the relatively favourable climate there) on account of the discovery of crude oil in the area. Since in the past, most increases in production have been the result of increases in the acreage under cultivation, this threatens the potential for increasing output in the future, unless farmers' adaptation and coping strategies would be enhanced.

The results also suggest that because most of the cocoa farmers are old and not well educated in the technical knowhow needed for adapting to climate change, the extension officers, need to step up their efforts at communicating the necessary adaption measures to the farmers. Farmers tend to stick with the old and tried farm practices. Although a newer variety of cocoa ("akokora be di bi") is being nursed and distributed to cocoa farmers as a measure of coping with the change in climate, most of the farmers still cultivate the older cocoa varieties of Amazonia and Tetteh Quarshie. This means that success in introducing the newer variety will be achieved only when there is a conscious effort to educate the farmers. Frequency of visits by extension officers should be increased to give the necessary training and education. Farmers can plan better investments in their farms during the cocoa season, if they have knowledge of what to expect in respect of the climate.

Conclusion

It is generally accepted that the climate is changing with striking effects, especially on the agricultural sector, although the direction of the effect is still not clear. Some generally agree that while tropical countries seem to be disadvantaged because of the additional warming, temperate countries are likely to benefit from it.

Climate change due to anthropogenic factors has led to new patterns of temperature and precipitation. These new patterns are projected to reduce agricultural yields, including cocoa, globally. The possibility that climate change would change the quantity of cocoa produced in the country is, therefore, worth investigating; and this formed the centre-piece of this study. Several factors affect the production of cocoa. Most of these factors can be improved upon by humans where they are not favourable. However, unlike the other factors, the climate must be necessarily favourable since man has no considerable control over it. Rainfall and temperature are the most important climatic elements for cocoa production. Climatic limits set by the cacao tree imply that changes in climate will affect both the quantity (as a result of reduction in the suitable areas for cocoa production) and the quality (due to poor weather for drying cocoa beans) of cocoa production. On the basis of the results, it can be concluded that the cocoa sector is vulnerable to changes in climate. Considering the number of smallholder cocoa farmers in the country, the effect will be devastating, threatening the livelihoods of many households. A reduction in household income in most cocoa growing areas due to climate change will widen the vicious circle of poverty and decrease the general well-being of cocoa farmers and their usually large number of dependants.

Cocoa farmers are adapting to climate change on the basis of the training given to them by extension officers. The study shows that the adjustments must be behavioural, institutional and technological for the effects of climate change to be wholly mitigated. Also, localized strategies integrated with indigenous knowledge must be identified, developed and introduced to the farmers to equip them to ensure a sustainable livelihood for their households.

The importance of cocoa, as the major cash crop of Ghana is not only in the contribution of about 25% of the total foreign exchange earnings annually, but also in being the source of livelihood for many rural farmers; hence the need for a sustainable production. Sustainable cocoa production means producing cocoa in a way that does not destroy the ability of future generations to also cultivate it. This ability is influenced by actions taken and policies pursued today. Climate change does not only bring bad news; it also offers a lot of potential opportunities. The winners will be those who are prepared for change, and know how to adapt.

Recommendations

The development and implementation of adaptation strategies to face progressive climate change depend on the participation of all actors in the cocoa sector. The recommendations below, based on the findings of the study, are specific to each of them.

To the farmers, it is recommended that they practise farm diversification with alternative crops such as the orange, oil palm and cashew for areas that will become unsuitable for cocoa in future. Farmers who receive credit facilities under the Cocoa Hi-technology Programme would do well to pay on time. This will enable them or new farmers to benefit from such credit facilities during subsequent crop seasons. Deforestation by cocoa farmers could also be controlled if abandoned farms which otherwise have suitable soils for cocoa cultivation could be rehabilitated. This will make production more cost effective, since monies otherwise spent to improve the fertility of unsuitable land will be saved. Vast areas of the country's forests could be saved and protected, if the cocoa farmer would be advised to use suitable soils and adopt appropriate agronomic practices for cocoa production. Cocoa farmers should therefore be encouraged through the provision of seedlings and inputs to move to old traditional growing areas to reestablish farms. Again, cocoa farmers should be encouraged by extension officers to form groups that will meet regularly to discuss problems and share ideas. Effective utilization of farmers’ knowledge and skills through their group meetings will help younger farmers to learn from the more experienced ones.

The following recommendations are made to the government: Due to the fact that some farmers still depend solely on the intervention programmes on production, it is recommended that government should intensify support for the Cocoa Mass Spraying and Hi-technology Programmes by providing the needed resources to sustain the programmes. This will go a long way to help farmers cope with the changing climate. To improve the rate of fertilizer application, the government should subsidize the cost of fertilizer to make it affordable to farmers. Government policies should ensure that terms for bank credit are flexible to enhance farmers’ access to affordable credit. This will increase their ability to boost crop production and productivity and enhance their flexibility to change crop and soil management strategies in response to climate change.

Government should develop an attractive scheme to attract private investors to the sector to provide credit to cocoa farmers. The establishment of a viable credit system for farmers will enable them cope better with climate change. There should also be pragmatic policies by government to increase the returns to cocoa farmers. This will provide them with the needed capital for adapting to climate change. Government, through the COCOBOD, should give appropriate and timely compensation for losses due to climate change. Government should support research and development on appropriate technologies to help farmers adapt to climate change.

Recommendations to Institutional Heads are as follows: There should be strict supervision by officials of the Ghana COCOBOD in respect of allocating and disbursing materials meant for the two intervention programmes. Stringent measures should be taken by the government and the COCOBOD to ensure that monies and materials provided for the programmes are not misappropriated. There should be established efficient and effective input delivery system for cocoa farmers. The Ministry of Agriculture, the COCOBOD and produce buying companies must collaborate to support research into adaptation strategies that fit local climatic conditions. Limits to adaptation should be considered. Dialogue with farmers is crucial to the adaptation process. Given the inadequacy of extension services in the regions, many more people should be trained as extension officers. In this regard, improving the knowledge and skills of extension service personnel about climate change and adopted management strategies should be of high priority.

This will provide an effective information support system to farmers. Increasing the extension officer-farmer ratio, and making the extension services more accessible to farmers appear to be key components of a successful adaptation programme. The Ministry of Food and Agriculture, through the Cocoa Services Department, should plan sensitization and training programmes for farmers regarding the impact of climate change and measures that can be adopted to combat changes in the climate. The Cocoa Services Department, through the extension officers, must increase technical support for farmers who are interested in adopting adaptation strategies. District authorities and traditional heads should lease out lands on favourable terms to farmers to help them expand their farms or establish new farms with the new variety.

The following recommendations are pertinent to researchers: There should be research on drought-tolerant cocoa germplasm and the potential of irrigation systems for cocoa production, especially in areas where there is access to water bodies. Further research into the development of site specific nutrient stock fertilisers should be considered. There should be research to identify alternative crops for areas where cocoa will become unsuitable. There should be further research on the effects of climate change on cocoa, including the implementation of technological alternatives to explore better environmental and economical options. There should be research to evaluate the implications of changes in cocoa quality and quantity on the livelihood of the growing communities, as well as the poverty and equity among them. There has been much research into the possible effect of climate change on crop production and probable adaptations. However, the findings of these research works have been shelved and not shared with the appropriate potential beneficiaries. It is recommended that research findings of the impact of climate change on crop production should be properly disseminated in a form and language that can be easily understood by farmers so that they will be well placed to adapt to the changing climate.

Future Research

There is the need for more scientific research into the factors that affect the yield of cacao. Proper identification and quantification of these variables will be helpful in predicting the yield of cocoa for future planning purposes. In this regard, the hypothesis that cocoa, like some other fruit trees may exhibit biennial yielding must be investigated. The nature of this possible yielding pattern must be properly established if cocoa yield can be most accurately predicted for planning growth and development in Ghana. Further research into site specific fertilizers for cocoa is also needed, since yield results among farmers tend to suggest that fertilizers perform differently on different farms, depending on the underlying soil type. Cocoa production suitability maps should also be developed and communicated to willing migrant cocoa farmers.

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APPENDIX A

A SURVEY OF FARMERS ON THEIR KNOWLEDGE OF CLIMATE VARIABILITY AND ITS EFFECT ON COCOA PRODUCTION

Introduction

I am a Ph. D. Student from the University of Cape Coast. I am here to ask you some questions pertaining to your knowledge on climate variability/ change and its effect on cocoa production. The information is needed for studies into the vulnerability of the cocoa crop given the event of climate change in Ghana. Information obtained will be solely for academic purposes and will be treated with the confidentiality it deserves. Thank you.

Instructions: Please fill in and tick as applicable.

A. Background Information

1. Name of District
   ____
2. Name of Community______________________________
3. What are the main socio-economic activities in this district/community? ______________________________
4. What are the key crops grown in this district/community?
   ____
   ____
   ____
5. Nationality of Farmer______________________________
6. Gender: Male [ ] Female [ ]
7. Marital Status
   a) Single [ ]
   b) Married [ ]
   c) Separated [ ]
   d) Divorced [ ]
   e) Widowed [ ]
8. Age:
   a) 20 – 30 [ ]
   b) 31 – 40 [ ]
   c) 41 – 50 [ ]
   d) 51 – 60 [ ]
   e) 60+ [ ]

9. Household size ______________________________________

Category	Number
Adult Male	
Adult Female	
Boys	
Girls	

10. Form of religion
    a) Christian [ ] b) Islam [ ] c) Traditional [ ]
    d) Other (specify)________________________________
11. Educational Status
    a) Basic Education [ ]
    b) Secondary cycle [ ]
    c) Tertiary [ ]
    d) No Formal Education [ ]
12. Do you come from this community or you migrated here because of farming?
    a) Citizen [ ] b) Migrant [ ]

Cocoa production

13. Occupation a) Major ________________________
    b) Minor ________________________
14. Number of years in cocoa farming:
    a) < 5 [ ]
    b) 6 – 10 [ ]
    c) 11 – 15 [ ]
    d) 16 – 20 [ ]
    e) 21 – 25 [ ]
    f) 26 – 30 [ ]
    g) 31 – 35 [ ]
    h) 35+ [ ]
15. Who owns the farm(s)?
    a) Self [ ]
    b) Lease-managed [ ]
    c) Care taker [ ]
    d) Sharecroppers [ ]
16. What labour type do you use on the farm?
    a) Family labour [ ]
    b) Permanent labour [ ]
    c) Seasonal labour [ ]
    d) Family and Permanent labour [ ]
    e) Family and Seasonal labour [ ]

f) Permanent and Seasonal [ ]
g) Family, permanent, seasonal [ ]

17. How many farm hands do you have on the farm? ______________

18. What is the major source of water for the farm?
   a. Rain [ ]
   b. Irrigation [ ]
   c. River/Stream [ ]

19. Which principal tools and equipment do you normally use on your farm?

____
____
____
____

20. a) Would you say cocoa farming has been beneficial to you and your family over these years of farming?
   a) Yes [ ] b) No [ ]

b) If Yes, why?

____
____
____
____

c) If No, why?

____
____
____
____

21. a) Is cocoa production your major source of income?
   a) Yes [ ] b) No [ ]

b) If No, mention the other sources

____

c) How much do you get from these sources in a year

____

22. What quantity of cocoa did you harvest at the end of the last growing season (in bags)

____

23. a) Has there been an increase or decrease in your cocoa yield(s) over the years?
   a) Increase [ ] b) Decrease [ ]

b) If there has been an increase, what could be the cause?

____
____
____
____
____

c) If there has been a decrease, what could be the cause?

____
____
____
____
____

24. From which of these sources do you obtain information about farming?
a) TV [ ]
b) Radio [ ]
c) Newspapers [ ]
d) Extension Officer [ ]
e) Other(s) please specify
____

25. A) Do you have regular interactions with extension officers?
a) Yes [ ] b) No [ ]

B) If yes, how often?
____

26. Is there any credit available to you?
a) Yes [ ] b) No [ ]

27. If yes, what is the source?
____

28. How many farms do you have? _________________________

29. Have you ever changed the variety of cocoa you grow?
Yes [ ] b) No [ ]

30. If yes, when and why did you change it?
____
____
____
____
____

31. Was the climate a contributing factor for the change in variety?
Yes [ ] b) No [ ]

Complete the following table

	Farm 1	Farm 2	Farm 3	Farm 4
Age of Farm				
Cocoa Type				
Source seeds/ seedlings				
Farm size (acres)				
Production / farm yield (bags)				

Husbandry Practices on Farm

- **Weeding**

32. How do you check weeds on your farm?
    a. By manual weeding [ ]
    b. Use of machinery [ ]
    c. Use of weedicides [ ]
33. How many times do you weed your farm in the cocoa season?
    a. Once [ ]
    b. Twice [ ]
    c. More than twice [ ]

- **Fertilizer Usage**

34. Do you use fertilizer on your farms?
    a) Yes [ ] b) No [ ]
35. If No, why?
    ____
    ____
    ____
    ____
36. If Yes, what kind of fertilizer do you use on your farm?
    a) Organic [ ]
    b) Inorganic [ ] Type(s) ______________________
37. How often do you apply fertilizer on your farm?
    a) Once [ ]
    b) Twice [ ]
    c) More than twice [ ]
38. How do you apply fertilizer?
    a) To the leaves [ ]
    b) To the ground [ ]
39. What period do you apply fertilizer?
    ____
    ____
    ____
40. How much on the average do you spend on fertilizers per acre of land? ____
41. Does fertilizer usage help increase your yield?
    a) Yes [ ] b) No [ ]

- **Spraying**

42. Do you spray your farm?
    a) Yes [ ] b) No [ ]
43. If Yes, how often do you spray your farm?

44. When during the day do you spray your farm?

45. How many hours do you spend spraying one acre on the average?

46. Where do you obtain chemicals for controlling pests and diseases?

47. Have you had to re-spray your farm because of unexpected rainfall?
    a) Yes [ ] b) No [ ]

- **Pruning**

48. Do you engage in pruning of your cacao trees?
    a) Yes [ ] b) No [ ]
49. If yes, why do you prune your cacao trees?

- **Sanitation**

50. Which of the following forms of sanitation practices do you carry out on your farm?

Removal of dead, diseased or damaged pods	
Removal of Mistletoe on trees	
Removal of piles of cocoa husks	
Drainage of Stagnant water	

Knowledge about climate variability and its observation

51. Have you noticed any changes in climate over the years?
    a) Yes [ ] b) No [ ]
52. If yes, in what way?

53. When did you begin to notice the change?

____

____

54. Tick the following in terms of mostly noticed change in climate.

Noticed Change	**Increased**	**Decreased**	**No Change**
Temperature			
Precipitation			
Occurrence of drought			
Late onset of monsoon			
Long dry spell			
Uneven distribution of rainfall			
Unpredictable rainfall			

55. Which of the following climatic elements is the most important in your opinion when it comes to cocoa farming? Give the highest 5 and the lowest 1.

Element	**Rank**
Rainfall	
Temperature	
Humidity	
Sunshine	
Wind speed	

56. Which of the climatic elements is most irregular?
   a) Rainfall [ ]
   b) Temperature [ ]
   c) Sunshine [ ]

Perception on the Effects of Climate Variability on Production

57. Does climate variability affect your production?
   a) Yes [ ] b) No [ ]
58. If yes, in what ways does this manifest?

____

____

____

____

Adaptive Strategies and Livelihood Diversification Options.

59. What adaptive strategies have you put in place to forestall the effects of climate variability on your production? Please tick as many as applicable to your farm.

Adaptive Strategy	
Integrated farming system	
Use of short duration crop varieties	
Use of water conservation techniques	
Change in time of farm operation	
Soil conservation techniques	
Pre-monsoon dry seedling	
Stubble mulching	
Intercropping	
Rainwater harvesting	
Agro forestry	
Use of Insurance	

60. Are there other adaptive measures you would like to take to offset the effects on climate change on your farm?
a) Yes [ ] b) No [ ]
B) If yes what are they?
____
____
____
____
____

61. Are there any constraints to adaptation due to climate change?
a) Yes [ ] b) No [ ]
B) If yes what are they?
____
____
____
____
____

62. In your opinion, is cocoa production still a viable venture in this community?
a) Yes [ ] b) No [ ]

63. If No, in your opinion, what should be done to revamp the industry?
____
____
____
____

64. What other livelihoods do you think should be introduced to offset the effect of cocoa production failure due to climate variability?
____
____
____
____

Personal

1. Estimated age of trees (indicate range)___________________________
2. Topography (flat, gentle, steep)________________________________
3. Drainage (good, medium, poor)________________________________
4. Shade coverage (heavy, medium, light, unshaded)__________________
5. Soil fertility (high, medium, low)_______________________________
6. Average number of stems per stand_____________________________
7. Average number of main branches______________________________
8. Average spacing of cacao trees to other trees_____________________
9. Presence and size of open spaces (large, small, none)______________
10. Average number of shade trees per hectare/acre___________________

APPENDIX B
ARIDITY INDEX FOR SOME COCOA GROWING AREAS IN GHANA

TOWN_NAME	Aridity Index 2001	Aridity Index 2002	Aridity index 2003	Aridity Index 2004	Aridity Index 2005	Aridity Index 2006	Aridity Index 2007	Aridity Index 2008	Aridity Index 2009	Aridity Index 2010	Aridity Index 2011
ADABOKROM	30.41726007	34.88542623	32.4664	30.9972	29.95050558	30.53297919	35.2585	35.4824	32.4185	34.7225	32.99583056
AGONA	28.91782193	37.37368488	31.387	33.4449	29.77361465	30.65788822	36.0566	35.2257	32.8562	34.664	35.18578774
AGONA AMENFI	28.99170607	31.85281973	33.3504	30.0934	29.4759643	32.19369146	32.6567	37.282	32.113	35.2954	33.76805873
AGONA SWEDRU	24.17218178	30.72436985	24.5386	25.806	25.03741223	24.87128445	26.3237	28.8041	24.3458	29.2527	27.79720213
AKIM ODA	24.30181957	34.03907972	25.2975	31.5136	24.37993115	29.98513037	31.9885	33.5751	28.5689	35.4194	31.39776943
AKOASE	25.63385131	36.02991295	26.7061	33.4836	25.77997683	31.66212837	33.7878	35.4183	30.2679	37.4142	33.14922983
AKONTOMBRA	29.80304266	33.99464078	33.1519	30.6912	29.96016969	31.37462969	34.2897	36.357	32.4198	35.9222	33.83402414
ANHWIASO	29.07290334	31.09160561	33.8984	30.0338	29.49971078	32.88662914	32.2571	38.3121	32.5352	34.4933	33.78371835
ANTOAKROM	26.91162976	36.36928132	27.7215	31.8946	27.08218	28.86933587	30.6653	33.0064	29.1139	34.2328	33.29121995
ASAMANKESE	26.8655835	39.19512065	26.6576	32.973	25.77571257	29.7171944	27.0958	34.1631	27.8479	36.0406	33.6441032
ASANKRANGWA	30.20155126	35.77599976	32.4801	31.508	30.6985881	30.29279686	35.5993	34.1614	31.8557	38.0604	34.35878445
ASAWINSO	30.49502297	35.8827813	32.9553	31.8218	31.10918466	30.28736985	35.9523	34.2041	32.0798	38.0339	34.64078231
ASEMPANEYE	24.49902758	32.00389259	33.1004	30.4089	29.19009815	31.69953528	32.9567	36.9999	32.363	34.0584	33.0012702
ASIKUMA	25.16811039	32.74060511	25.4163	28.8251	27.47520457	26.99692879	27.276	30.0997	26.3481	31.5533	30.51021064
ASSIN BREKU	26.73840399	33.18161247	26.9602	29.5332	27.90066361	28.22060772	31.1275	30.9354	28.2036	33.6285	31.45686598
ASSIN FOSU	28.49633	34.66978251	30.3169	31.0346	29.05325975	30.27817224	33.7832	34.1772	30.8962	35.1342	33.8322725
BEKWAI	28.00836481	36.68994323	31.2742	32.6447	28.98509407	28.94612729	37.7661	34.2511	33.5281	31.3025	34.61769979
BOGOSO	29.22649214	34.26371084	31.6643	30.9534	29.71547152	30.6401719	34.1156	34.5894	31.3152	36.3056	33.69572319

BONSU NKWANTA	30.03087879	35.96504878	30.7719	30.8799	29.80567743	29.32283782	35.3201	33.0564	31.3113	36.3751	32.71268035
CAPE COAST	30.39984536	36.88797384	32.2087	32.8915	30.54980179	31.62140556	35.4415	35.9254	32.853	37.1976	35.6404563
DADIESO	31.03312852	37.01521204	30.8266	31.8529	30.97234969	29.21990958	37.0527	31.2848	31.1018	40.096	33.57311147
DIASO	26.4589932	31.18365531	33.5924	29.9886	29.3956522	32.63305366	32.2139	37.8912	32.2592	34.6928	33.76989305
EFFIDUASE	29.1237929	39.59172064	32.4021	34.8037	30.26320627	29.8300797	40.6568	35.5592	35.5485	32.1696	36.53760513
ENCHI	28.32776129	33.21675378	32.0285	31.2024	28.59527722	29.40843916	33.9184	33.9051	31.5916	34.6941	31.41842272
ESSAM	29.2959306	33.67117536	32.0229	30.7872	29.01226378	30.18045607	34.1113	35.3064	32.1353	33.578	31.85229778
FOSUKROM	28.68152329	33.28906394	31.5541	31.0216	28.6116747	29.43275144	33.9198	34.1413	31.6698	33.2877	31.05017026
JUABESO	28.23236341	32.6594225	31.639	30.7508	28.24561186	29.29508754	33.5968	34.0492	31.4921	33.5911	31.07748848
JUASO	30.07183376	36.2645623	33.8184	33.5943	30.81606947	32.18039655	37.7288	37.203	34.4304	35.2489	35.49057392
KAASE	27.45934387	33.07689425	31.2098	30.8442	28.16875724	28.88932589	33.8802	33.7027	31.5151	32.4942	30.14862865
KADE	26.41355001	32.82504055	25.7303	28.0834	23.22745747	29.9776773	28.1792	31.3848	27.3333	30.7381	30.14686995
KIBI	27.48077628	32.20616447	25.9249	26.8735	22.3029132	30.90175491	26.8011	30.8556	27.5091	29.1261	29.52989473
KONONGO	27.23153473	37.4047035	29.6315	33.8474	28.1487981	30.39302361	36.6762	35.3161	32.6313	34.2512	34.42603692
MANKRANSO	25.59891364	35.05727471	27.2734	32.2416	25.91487876	29.35642916	33.4803	33.4568	29.9922	33.6928	32.26113432
MANSO AMENFI	27.89922583	32.83634128	31.5871	31.2198	28.5730803	29.23316338	33.51	33.2415	31.0035	34.9768	31.37113191
NEW EDUBIASE	26.69158497	36.81060032	27.397	32.1719	26.69044881	29.40021373	31.445	33.5899	29.3031	34.7031	33.93699792
NSOKOTE	28.44443455	32.87566958	31.9712	32.5468	28.56995011	29.29131117	35.6832	33.4312	32.1919	33.9738	31.46334833
NYINAASE	28.44460788	38.68165523	28.4688	33.4681	28.46389682	30.29426522	30.9688	34.5125	29.9232	36.8618	35.27853387
NYINAHIN	27.92301161	36.92977278	31.504	32.9569	28.87531059	28.11364832	38.5748	34.0683	34.2599	30.1942	34.00170747
OBUASI	27.1195801	36.62043317	30.77	32.6289	28.41833747	27.71545383	38.5538	33.5333	33.787	29.6701	34.01790966

OFINSO	27.81201705	37.95290763	31.562	33.861	29.30666991	28.6734939	39.2488	34.5197	34.6874	30.7048	34.93753145
SAMREBOI	29.55003983	34.09797298	33.0644	31.0573	29.91153062	31.23277011	34.4395	35.8763	32.2019	36.3598	33.91181668
SEFWI BEKWAI	29.01565401	30.94235909	33.9006	29.8604	29.44468261	32.86770329	32.107	38.3038	32.4203	34.7276	33.74060251
SEFWI WIAWSO	28.99831781	31.06901908	33.8446	29.8269	29.33522212	32.76318479	32.2292	38.3595	32.5265	34.4555	33.64758116
SUHUM	22.37494607	26.71323351	25.224	26.409	22.50243141	24.7220949	27.0909	28.2809	24.5758	27.2803	25.66927361
	27.42357913	30.34151971	21.6691	27.6033	22.82243677	29.38965869	30.9553	28.4477	27.4883	34.8118	24.06409517
TARKWA	32.10843133	38.25937144	30.0544	31.7969	34.95290683	30.74699297	30.4504	34.3011	33.0831	39.5879	31.57916
TEPA	28.6726501	33.02503457	27.4981	37.5366	30.71360914	33.15730439	28.5492	28.287	38.6573	34.308	32.990845
TWIFO PRASO	26.84237388	33.24794001	26.0534	34.7083	26.22307136	30.41476495	27.3113	28.1252	28.6562	31.5024	32.180635
WASSA AKROPONG	28.91677612	33.93883905	29.2485	30.4938	34.53672987	29.85052151	29.7845	33.8375	31.8988	39.2728	32.506256