KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

SMALLHOLDER FARMERS' MITIGATION OF AND ADAPTATION TO CLIMATE CHANGE AND CLIMATE VARIABILITY IN THE BOSOMTWE DISTRICT OF ASHANTI REGION, GHANA

By

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DECLARATION

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ABSTRACT

Agriculture has provided humanity with food and other resources necessary for human development since time immemorial and is the backbone of many developing economies. Recent patterns of anthropogenic induced greenhouse effect is however posing a threat to this role. In the Bosomtwe District, known micro-climatic trends for agricultural activities have become inconsistent and unpredictable, with consequential effects on productive agricultural engagement. This study therefore examined smallholder farmers' adaptation to climate change and the potential for agricultural based climate change mitigation through Reduced Emission from Deforestation and Forest Degradation with forest conservation and sustainable management (REDD+) and Land Use Change (LUC) in the Bosomtwe District of Ashanti Region. Primary data was acquired through interviews and questionnaire administration to key informants and 152 smallholder farmers respectively who were selected from twelve communities in the study area. The Statistical Package for the Social Sciences and Excel software were used to analyze the quantitative data while content analysis was used to analyze the qualitative data. The study rejected the null hypotheses that there is no significant relationship between annual average temperature and quantity of maize produced. Results revealed that 93% of smallholder farmers in the Bosomtwe District have adapted to climate change. Also 93% of respondents are still considering other sources of livelihood activities other than agriculture which is the primary occupation. Majority (64%) of them are willing to undertake REDD+ mechanisms as avenues for benefits and conservation of carbon stocks in trees. Although the pattern of land use change is constraining farmers' ability to adapt to climate variability and climate change, land use change is not climate induced. It is recommended that the Ministry of Agriculture policies be directed towards streamlining autonomous adaptation, securing farmers livelihood and harnessing local potential through a participatory approach for the effective mitigation and adaptation to climate change at the community level.

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LIST OF ABBREVIATIONS

AFOLU	Agriculture, Forestry and Other Land Uses
AGDP	Agricultural Gross Domestic Product
AGRA	Alliance for a Green Revolution in Africa
AMCEN	African Ministerial Conference on Environment
APF	African Partnership Forum
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CCAFS	Climate Change, Agriculture and Food Security
CDM	Clean Development Mechanism
COMESA	Common Market for Eastern and Southern Africa
CO_2	Carbon Dioxide
CSIR	Centre for Scientific and Industrial Research
CVCC	Climate Variability and Climate Change
DFID	Department for International Development
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Agency
EU	European Union,
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Greenhouse gases
IET	International Emissions Trading
IPCC	Intergovernmental Panel on Climate Change

ITCZ	Inter Tropical Convection Zone
JI	Joint Implementation
MICCA	Mitigation of Climate Change in Agriculture
MoFA	Ministry of Food and Agriculture
NAMAs	National Appropriate Mitigation Actions
NAPAs	National Adaptation Programs of Action
NCAR	National Center for Atmospheric Research
NCCC	National Climate Change Committee
NDPC	National Development Planning Commission
NGO	Non-Governmental Organizations
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reducing Emissions from Deforestation and Forest Degradation with conservation and sustainable management
R-PIN	REDD Readiness Plan Idea Note
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
UNFCCC	United Nations Framework Convention on Climate Change
WAC	World Agroforestry Centre
WiAD	Women in Agricultural Development
WMO	World Meteorological Organization

DEDICATION

To my parents Mr. and Mrs David and Elizabeth Yamba for the investment made in me. May God richly bless and sustain them.

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CHAPTER ONE

FARMERS' MITIGATION OF AND ADAPTATION TO CLIMATE CHANGE

1.1 INTRODUCTION

Man has over the years burnt large amount of fossil fuel resulting in an increased atmospheric concentrations of carbon dioxide, methane, and other greenhouse gases. This has amplified the global warming, inducing changes in the earth's climate system (JICA and ITTO, 2012). Although not new, climate change has in recent times taken the center stage in global development deliberations (Kankam-Yeboah *et al.,* 2010). The earth's capacity to absorb greenhouse gases (particularly carbon dioxide) is strained and this is the crust of the current climate change bother. With a gradual acceleration, the impact of global warming for most countries could be managed (Schwartz and Randall, 2003).

However, recent studies confirm that abrupt changes are to be expected once temperature exceeds a particular threshold resulting in adverse weather with some regions experiencing 2-5 degrees Celsius drop in temperature in a single decade (Schwartz and Randall, 2003). The current trend is largely due to human activities across the globe. The emission of heat trapping gases as carbon dioxide, methane, and nitrous oxide into the atmosphere has had considerable warming effect on the global climate. According to Olivier *et al.,* (2013) global emissions of CO_2 reached 34.5 billion tonnes in 2012 which represented an increase of 1.4% from 2011.

The earth generally has experienced temperature increase with decreased rainfall globally (Fancherean *et al.,* 2003 cited in Mabe *et al.,* 2012). Such increase in global temperatures, exceeding 2–3°C will result in ecological, social and economic sways and increase the risk of catastrophic impacts, due to significant changes to the carbon cycle. This is already being experienced across the globe (Human Development Report, 2007). Although the impacts will vary from region to region, scientific evidence indicates that some benefits may accrue to countries in the temperate and polar regions of the earth supporting agriculture in those regions (Mendelsohn, 2000). Pressure on global agriculture is expected to persist as the need to meet the needs of an ever increasing population using finite resources coupled with climate related constrains surges (Rosegrant *et al.,* 2008). Agricultural output is expected to decline in the tropics and sub-tropics resulting from an increased evaporation, increased frequency of droughts, increased run-off and changes in rainfall patterns (Krishna *et al.*, 2004).

Off-farm practices and strategies according to De Pinto *et al.,* (2012) are obvious ways to reduce vulnerability to climate change. The magnitude of the challenge to stabilize greenhouse gas (GHG) concentrations in the atmosphere and limit average temperature increases makes it imperative that the contributions of all sectors with significant mitigation potential be tapped to the fullest extent (FAO, 2008). Mitigation embraces diverse components and as such cannot be restricted to a particular approach (Bausch and Mehling, 2011). Commitments made by the Western industrialized nations on specific mitigation as per the Kyoto Protocol constitutes three 'flexible mechanisms': an International Emissions Trading (IET) regime; Joint Implementation (JI); and the Clean Development Mechanism (CDM) (Winkler, 2005). All three have to be enforced to achieve the desired level of GHG mitigation (Cheng *et al.*, 2008). The Commission of the European Communities (2009) among a number of related issues emphasized that climate change mitigation in agriculture should be pursued as part of an integrated approach to sustainable agriculture to limit conflicts with other economic, environmental and social objectives, whilst ensuring a positive contribution to climate mitigation at the global level. The Clean Development Mechanism (CDM) is part of the global carbon market developing rapidly as part of the Kyoto response towards mitigation of global warming (Olesen and Porter, 2009). The dual aim of the CDM is to achieve sustainable development in developing countries and cost-effective reduction of greenhouse gases emission in developed countries.

For adaptation to be effective, it is required that livelihoods become very flexible (Lisa and Schipper, 2007). A more vulnerable livelihood could compel farmers to increasingly resort to other off farm livelihood activities. In recent times, off-farm livelihoods account for over 85 percent of household income in the United States of America (Antle, 2009). Anim-Kwapong and Frimpong (2006), in their study on the impacts of climate change on cocoa production in Ghana found that off-farm activities of farmers contribute significantly to household income. The World Bank Group recommended the provision of micro-credit and skills for diversified livelihoods to minimize impacts of climate change on the poor and vulnerable in developing countries (World Bank Group, 2011). It is necessary to explore alternative livelihood sources that smallholder farmers are partially or totally resorting to, in the face of climate variability and climate change- CVCC.

Efforts to mitigate climate change by reducing greenhouse gas emissions in developing countries is pressing because their emissions is likely to exceed those of the developed nations (Chandler *et al.,* 2002). Africa is one of the continent's most vulnerable to climate change and yet is the least contributor to the global phenomenon. According to Reid and Huq (2007), Africa (excluding South Africa), together with Small Island Developing States, Mega Deltas particularly in Asia and Polar Regions have together contributed 3.2% of total global carbon dioxide compared to 23.3% for United States, 24.7% for EU, 15.3% for China and 4.5% for India. They continue to espouse that Africa is particularly most vulnerable because of multiple stressors and low adaptive capacity. Agriculture constitutes the backbone of most African economies and is the largest contributor to GDP, the biggest source of foreign exchange, accounting for about 40% of the continent's foreign currency earnings and the main generator of savings and tax revenues.

The African Partnership Forum (2007) affirms that agricultural production is likely to be severely affected by climate variability and change. This could lead to a reduction in crop yield by up to 50% by 2020. Much study has been done in the region on the effects of climate change on food system, impacts on crop yield and farmers' adaptation among many others. Adejuwon (2006) for example assessed the sensitivity of crop yield to inter-annual changes in climate and the variable significance of the impact of the weather of each year on crop with the motive of deriving models with which crop yield could be predicted using seasonal weather forecasts. Whatever the case, it is quite obvious that the African agricultural sector must adapt to uncertainty and thereby confront a threefold challenge: it must produce more food for a growing population, it must adapt better to climate change and in doing so it should not in itself cause increased greenhouse gas emissions.

Reducing Emissions from Deforestation and Forest Degradation- REDD, has been suggested as a climate change mitigation strategy that is based on the philosophy to reward developing countries especially those in the tropics for reducing their deforestation and forest degradation. The expected financial benefits via the generation of carbon credits hold great potential for mitigation strategies (Plugge *et al.*, 2013). The role of farmers in the realization of this initiative cannot be over-emphasized as they may stand to benefit financially from the REDD+ initiative. According to the World Agroforestry Centre - WAC, (2012), the Africa Bio-carbon Initiative is promoting a whole-landscape approach to carbon management that takes into account the full opportunities for reducing emissions and increasing carbon stocks in Agriculture, Forestry and Other Land Uses (AFOLU).

The Africa Bio-carbon Initiative called on the international community to incorporate REDD+ in the post 2012 climate change agreement as a first step to a broader

AFOLU climate change deal. Also, the WAC (2012), noted that there was consensus for a REDD agreement in Copenhagen that will include reducing emissions from deforestation, forest degradation, forest conservation and afforestation (known as REDD+). Because tropical forests have a high sequestration potential, supporting tropical forest development, sustainability and management is key in global climate change mitigation action (Arcidiacono *et al.,* 2010).

The Tanzania Natural Resource Forum (2011), recognized that REDD awareness creation is leading to greater understanding of forest conservation benefits, and in turn changing peoples' attitudes about charcoal making and wildfires in village forests. Such interventions can both reduce vulnerability to climate change and enhance peoples' capacity to adapt to it (Brooks *et al.,* 2013). However little is known of farmers' knowledge of REDD+ and their willingness to adopt it. A number of options for adaptation that have been found to prevail on the continent include intensification of agricultural production and expansion of farms. Gregory *et al.,* (2005) estimated that cereal production alone will lead to a 47% increase in extensification practices in Sub-Saharan Africa - SSA by 2020. The adoption of either of these approaches as an adaptive strategy needs to be critically assessed in the light of unique regional characteristics that would not result in mal-adaptions. Majority (90%) of terrestrial carbon opportunities is found in developing countries and they represent 30% of total GHG reduction opportunities (Keane *et al.,* 2009).

Climate variability and climate change has become evident even to the ordinary Ghanaian. Since 1960, Ghana's mean annual temperature has increased at an average rate of 0.21°C per decade (McSweeney *et al.,* 2008). The country had high rainfall amount recorded in the 1960s which steadily declined in the latter parts of 1970s and early 1980s. According to the National Development Planning Commission (2009) agriculture is the highest contributor to GDP and provides employment for over 60 percent of the population. The World Bank Group (2011) indicated that Ghana is highly vulnerable to climate change because its economy is agro-based and over-dependent on food and cash crops. The National Development Planning Commission (2010) noted that, anticipating a drop in agricultural output by 30% in Africa, it is imperative that Ghana makes contribution to international efforts to mitigate the negative effects of climate change. Climate change impacts on various sectors could be massive. In the light of this, policymakers and stakeholders are increasingly advocating that climate change mitigation and adaptation be prioritized in development agenda (Bausch and Mehling, 2011).

In Ghana, the National Climate Change Committee (NCCC) under the auspices of the Ministry of Environment, Science and Technology is developing national strategies on Climate change mitigation and adaptation for forestry, agriculture and energy as part of the national climate change policy development (Bampo *et al.,* 2010). Ghana‘s REDD Readiness Plan Idea Note (R-PIN) gives an estimation of the relative importance of the various drivers of deforestation as: agricultural expansion [50%]; harvesting of wood [35%]; population and development pressures [10%]; and mineral exploitation and mining [5%] (Bampo *et al.,* 2010). The country’s agriculture sector has grown at an average of 5% in the last 25 years with Agricultural Gross Domestic Product (AGDP) increasing from GH¢ 5.3 billion in 2007 to GH¢ 6.6 billion in 2012 (Sarpong and Anyidoho, 2012: GSS, 2010). Hence, as the backbone of the nation, global issues as Climate Variability and Climate Change (CVCC) that have a direct impact on the agricultural sector is not to be taken lightly.

1.2 PROBLEM STATEMENT

Quite an appreciable number of studies have been done in Ghana on impacts of CVCC on food production (Codjoe *et al.,* 2013). The connexion between climate change and food security has largely been explored in relation to impacts on crop productivity and hence, food production (Gregory *et al.,* 2005). Little attention has however been given to adaptation strategies of farmers and farmers awareness of mitigation measures such as REDD+ in the Bosomtwe District.

The Bosomtwe District of the Ashanti Region is one of the agrarian districts which is experiencing considerable climate variability. Like other districts in the country, this has affected the rainfall pattern and hence water availability for crop cultivation. Changing climatic variables such as temperature, rainfall, humidity and solar radiation have determined to a large extent the micro climate favorable for food crop cultivation. Such changes are however rendering traditional agricultural production practices ineffective. This coupled with low adaptive assets among smallholder farmers has made their livelihoods more vulnerable.

In the face of low crop yield, other off-farm alternative livelihoods such as charcoal production engaged by some farmers has had considerable effects on forest cover and hence carbon sequestration. In addressing the issues of climate change adaptation and mitigation measures, there is paucity of data on the actual adaptation and mitigation strategies among smallholder farmers to ensure sustainability of livelihood and continuity of household food supply. The various alternative livelihoods available to farmers and how the interaction of these factors are resulting in agricultural land use changes in the Bosomtwe District necessitated this study. The presence of the Lake Bosomtwe in proximity to some farming communities offers prospects for fishing as an alternative livelihood and continuous food crop production through irrigation by lessening the challenge of water unavailability posed by climate variability. However, there is no known mechanized water utilization facilities for irrigated agriculture in the district as compared to areas further away from the Lake. This made it more necessary to conduct a comparative study among communities in the district to examine the differences in the adaptation techniques of farmers with easy access to water for irrigation and those that do not. Further, considering the presence of forest and agricultural land use mixes in the district, it was also imperative to examine the Agriculture and Forest Land Use (AFOLU) potential for Reducing Emissions from Deforestation and Forest Degradation with conservation and sustainable management (REDD+) in the Bosomtwe District.

1.3 RESEARCH QUESTIONS

The following were the research questions that served as the basis for the objectives:

a. What is the trend of climate variability in the Bosomtwe District from 1981 to 2011?
b. How are smallholder farmers adapting to CVCC in the district?
c. Which alternative livelihoods are smallholder farmers increasingly resorting to in the face of climate variability?
d. What agro-forestry land use potentials are present among smallholder farmers in the district?
e. How is CVCC affecting agricultural land use?

1.4 OBJECTIVES OF THE STUDY

The main and specific objectives that served as a guide for the study were as follows:

1.4.1 Main Objective

The main objective was to assess the mitigation and adaptation strategies of smallholder farmers in the face of climate variability and climate change in the Bosomtwe District.

1.4.2 Specific Objectives

The specific objectives of the study were;

a. To analyse the trends of CVCC in the Bosomtwe District from 1981 to 2011.
b. To examine smallholder farmers’ adaptation strategies to CVCC.
c. To assess the alternative livelihood of smallholder farmers to agriculture in the Bosomtwe District.

d. To evaluate the Agricultural and Forest land use potential for Reduced Emission from Deforestation and Forest Degradation with conservation and sustainable management (REDD+) among smallholder farmers in the District.

e. To assess the patterns of agricultural land use change by smallholder farmers in the face of climate variability

1.5 HYPOTHESIS AND PROPOSITIONS

A hypothesis and two propositions formed the basis for this study.

1.5.1 Hypothesis

H_0: = There is no statistically significant relationship between annual average temperature and annual quantity of maize produced.

H_1= There is a statistically significant relationship between annual average temperature and annual quantity of maize produced.

1.5.2 Propositions

The propositions for the study are:

1 Smallholder farmers are not willing to take part in REDD+ initiatives as avenues for benefits and conservation of carbon stocks in trees.

2. The pattern of agricultural land use change is not constraining farmers' ability to adapt to CVCC.

1.6 METHODOLOGY

1.6.1 Introduction

This section outlines how the study was carried out in accordance with the set objectives of the study. Information on sources and types of data, sampling techniques and the process by which information was collected and analyzed is therefore presented. It details out the individual pragmatic steps that were followed to achieve the objectives of the study; the course pursued in the data collection, analysis and the presentation of findings and hence substantiates the validity of the work done based on the procedures used.

1.6.2 Research Design

Research design is a process which enables a researcher to develop and undertake a research work taking into cognizance the topic and answering critical questions of why and how the particular problem to be researched should be scientifically investigated to arrive at logical conclusion (Creswell, 2014). Social research approached according to Regionel (2010) include experimental research- (where the researcher has some degree of control over his research variable) , case study research (where he researcher focuses on a single case rather than a sample or population), longitudinal research (involving the collection of data over a long period of time) and a cross-sectional research (collecting data from a population or a sample within a short and specified period of time). The research design chosen thus guides the path of the research based on principles that are in tandem with the design chosen (Creswell, 2014). A study such as this, focusing on smallholder farmers' mitigation and adaptation strategies to climate change in the Bosomtwe District required that only a representative sample of the population be selected and the study carried out within a maximum of two year. Hence this is a cross-sectional study.

1.6.2 Research Approach

The study employed the mixed method strategy of both quantitative and qualitative data with their respective analytical methods. This method was deemed suitable as it serves not only to provide data that is amenable to wide and varied range of statistical analysis but also provides in-depth and insightful understanding from the analysis of the qualitative data. It was also preferred due to the multi-faceted nature of climate change and its interconnectivity with agriculture, the socio-economic characteristics of farmers and the physical environment. The study was conducted in twelve (12) communities in the Bosomtwe District where questionnaires and interviews were used to elicit both qualitative and quantitative data from respondents. Hence, the study followed the apposite use of instruments for qualitative and quantitative data collection and analysis.

1.6.3 Types and Sources of Data

Primary and secondary of data- both quantitative and qualitative- was used for the study. The secondary data were obtained through review of literature related to the study. This included research articles in journals, periodicals and other related publications. Secondary data on rainfall and temperature were acquired from the regional meteorological office of the Ghana Meteorological Agency (GMA) while secondary data on maize yield was acquired from the regional office of the Ministry of Food and Agriculture (MoFA). Primary qualitative and quantitative data was gathered from smallholder farmers and key informants using partially pre-coded questionnaires and interview schedules respectively.

1.6.4. Sampling Procedure

This section focuses on the description of the target population, the sample size determination and the sampling method used for the research.

1.6.4.1 Target Population

The study population for the study consisted of farmers in the Bosomtwe District while the target population consisted of smallholder farmers plus relevant key informants in appropriate institutions namely the District Extension officer, District Crop Research Officer and the Director for Women in Agricultural Development.

1.6.4.2 Sampling Technique

A multistage sampling techniques was used to select the respondents through three stages. There are sixty six (66) communities in the district out of which twelve were selected. In the first stage, the communities in the district were clustered into two, namely: those located around the Lake as the first cluster (14 communities) and those located further away from the Lake as the second cluster (52 communities). In the second stage, six communities were selected from each cluster, giving a total of twelve (12) communities for the study. This is because the primary interest was in the communities around the Lake for two reasons. Firstly, the Lake is an opportunity for continuous crop cultivation amidst current trends of climate variability and climate change and secondly, the terrain around the Lake is undulating and different from the rest of the district. Hence adaptation strategies in the district could vary based on these. To ensure fairness in the comparative discussion, six communities were also selected from the second cluster. The twelve communities were selected by the simple random, using the fishbowl method without replacement. Of the twelve communities those located further away from Lake Bosomtwe are Amankwadei, Dedesua, Kokodei, Ayuom, Aduampong and Brodekwano while those located around the Lake are Abaase, Aborodwom, Pipie Old Town, Anyinatiase, Nkowi and Obo. In the third stage of the sampling process, the respondents who consist of smallholder farmers were identified using the simple random sampling technique. This sampling technique was preferred to enable generalization to be made about the population.

1.6.4.3 Determining the Sample Size

The unit of analysis was smallholder farmers from the twelve selected communities. The sample size was determined using the formula $n= N/ 1+N (e)^{2}$ where "n" is the sample size. "N" is the total number of people in the twelve selected communities and "e" is the margin of error (Jensen and Shumway, 2010). With 8% margin of error (92% confidence level), from a total population of 6,986, the sample size is 152. The respective samples "S" allocation by quota to the selected communities were then determined by the proportionate sampling method [given by S = (b/100)152].

Table 1.1 Sample Size Determination for Each Study Community.

COMMUNITY	POPULATION (a)	PERCENTAGE (b)	SAMPLE SIZE (S)
Dedesua	1225	20	30
Kokodei	950	15	23
Nkowi	672	11	16
Ayuom	338	5	8
Obo	571	9	14
Aduampong	138	2	3
Abaase	313	5	8
Aborodwom	145	3	5
Amankwadei	359	6	9
Anyinatiase	579	9	14
Brodekwano	204	3	5
Pipie (Old Town)	688	12	17
TOTALS	**6,182**	**100**	**152**

Source: Bosomtwe District Assembly, (2010).

1.6.5 Analyses and Presentation of Findings

Tools within the Statistical Package for the Social Sciences (SPSS), prominently, correlation, regression analysis, chi-square, frequencies and cross tabulation were used. The excel software was also used in the inter-annual rainfall trend analysis of rainfall. The quantitative data gathered were subjected to multiple regression analysis, Pearson's product-moment correlation was used to determine the strength, direction and association, between variables respectively. Also contingency tables and frequencies were extensively used for multivariate distribution of variables and counts respectively, all embedded in the Statistical Package for Social Sciences (SPSS) version 17 and results displayed in tables, charts and graphs. The diagrams generated in the SPSS, were exported to excel for editing for better visual presentation. Monthly data for surface air temperature and rainfall in the Bosomtwe District from 1981 to 2011 was analyzed using the statistical anomalies method.

Open-ended qualitative responses were integrated in the discussions under the various thematic treatments of the sections of the study.

1.6.6 Justification of Study

Climate change and its impact on various sectors has been widely studied. In Ghana much has been done with regard to climate change and food crop production. This study however delves into the climate variability mitigation and adaptation, and forest and agricultural land use nexus in the Bosomtwe District which has not been done. This study provides in-depth knowledge on the trends of climate change in the Bosomtwe District, the varied ways by which farmers are adapting to the situation and the potential of mitigation embedded in on-farm and land use practices. It also seeks to identify particular practices that could form the basis for government interventions and maladaptive practices that need to be curtailed.

Fashioning appropriate policies to make the agricultural sector robust and resilient to the vagaries of the climate and other environmental hazards is key for the sustainability of the agricultural sector. This would enhance understanding of the complex relationship between climate and agriculture. The findings seek to inform policy makers, enabling them to better comprehend the interconnections between CVCC, food crop production, the biophysical and socio-economic characteristics of farmers and the environment within which agriculture is undertaken. Information obtained from this study could help to outline clear cut areas to concentrate resources in stakeholder involvements, capacity building and development.

1.6.7 Scope of the Study

The study is confined to smallholder farmers' on-farm adaptation practices and off-farm alternative livelihood activities. It also considered only the potential opportunities that could be capitalized upon in the implementation of REDD+ in the district and the pattern of land use change referenced to climate change. Although varied study paths could be pursued in line with the thematic areas of the objectives of this study, these were its peculiar jurisdictions in order to maximize the resources of time and finance available for the study. The study was cross-sectional, focusing on twelve communities within the Bosomtwe District. These were Amankwadei, Dedesua, Kokodei, Ayuom, Aduampong, Obo, Abaase, Aborodwom, Brodekwano, Pipie, Anyinatiase and Nkowi. Of the entire population, only a representative proportion was examined. Although the reverberations of climate change is felt across various sectors, this study focused on its impact on smallholder farmers in the agricultural sector.

1.6.8 Limitations of the Study

Due to the high incidence of illiteracy in the study areas, the studier had to translate the questions into the local language for them to understand. Respondents were also hesitant in providing information especially on variables such as age, household size, income level, farm size due to respondent fatigue, on the basis that information is gathered every year but does not yield any benefit. A brief explanation of the purpose of the study as being beyond an academic exercise and having the potential of informing policy that could help them adapt to and mitigate climate change together with other benefits facilitated the survey.

1.6.9 Organization of the Study

The study was systematized into six chapters. The first chapter constitutes an introduction to the study, statement of the problem and the resultant study questions from which study objectives were derived. It also contains the study hypothesis and propositions that formed the backbone of the study and the peculiar study approach adopted in working towards the achievement of the stipulated objectives. Chapter two focused on the review of relevant literature to put this academic work into proper theoretical, research and academic perspective. Chapter three profiles the Bosomtwe District, focusing on its biophysical and socio-demographic characteristics of the district in context of key aspects of the study focus. Findings and discussions on trends of climate change, farmers' adaptation to CVCC and their alternative livelihoods amidst current trends of climate (thus objectives 1, 2 and 3) in the Bosomtwe District were put together in chapter four. Chapter five focused on agricultural based climate change mitigation with findings and discussion on the potential for the implementation of REDD+ in the Bosomtwe District and the pattern of agricultural land use change which are objectives four and five respectively. Chapter six presents a summary of findings of the study, conclusions and appropriate policy recommendations.

1.6.10 Ethical Considerations

The study had smallholder farmers at the focal point of the study, it was necessary to effectively undertake this study without infringing upon their rights. It was therefore necessary to consider the ethical implications of this work in tandem with the rights of the respondents in order not to overlook or take their rights for granted. Hence, the researcher showed his student identification card to respondents to prove his identity as a student undertaken this study for an academic purpose. Also, an introductory letter from the researcher's department (Department of Geography and Rural Development) was taken to introduce him and state his purpose to key institutions that were involved in the study and to request for their cooperation in the study. The researcher also assured the respondents of the anonymity and confidentiality of their personalities and the data collected from them. Respondents' consent were sought before recording responses during interviews and the recordings were played to the interviewees at the end of the interview. Appointments for interviews were booked with interviewees based on their convenience.

CHAPTER TWO

CLIMATE CHANGE MITIGATION AND ADAPTATION WITH AGRICULTURAL AND FOREST LAND USE NEXUS

2.1 INTRODUCTION

This chapter sought to review related literature that contextualizes the study and emphasizes its worth as being key to current paradigms of climate related discussions and research. The chapter explores farmers' mitigation of and adaptation to global climate variability and climate change. It critically looks at farmers' livelihoods and the potential for implementation of REDD+ at the community level amidst agricultural and forest land use modification trends. It therefore sets forth to assess related works by researchers, scholars, and authors on climate change and variability and the adaptation of farmers to divulge the various explanations of the concepts. The chapter is organized into five sub-sections. The first section looks at the global trends of climate change and climate variability and its causes. The second section assesses smallholder farmers' experiences of climate change mitigation and adaptation strategies from a global to local perspective. The third section reviews farmers' livelihood security amidst climate change while the fourth section discusses the agricultural and forest land use potential for the implementation of REDD+ at the grassroots. The final section assesses climate induced agricultural land use change and modification trajectories.

2.2. GLOBAL TO NATIONAL TRENDS OF CLIMATE VARIABILITY AND CLIMATE CHANGE

2.2.1 Past and Current Causes Of Climate Variability and Climate Change

It has been scientifically proven that climate change is triggered by natural and human activities (Geological Society of America, 2013). The natural greenhouse effect is caused by water vapor, carbon dioxide, methane, nitrous oxide, changes in solar radiation and ozone keeping the earth warm and without which the average temperature of the earth would be -8° C making life impossible (Harris *et al.*, 2015).

Geological studies have revealed that the earth in times past has experienced major changes in its climate (Geological Society of America, 2013). Most of these changes have however been due to natural causes and either gradually occurred over long periods or are short lived. During the glacial periods for instance, change in the volume of ice over a period of three million years was correlated to orbital changes. Periodic volcanic eruptions and El Nino events have briefly affected global climates in the past. These were however ephemeral and did not result in long-term patterns of change (Geological Society of America, 2013).

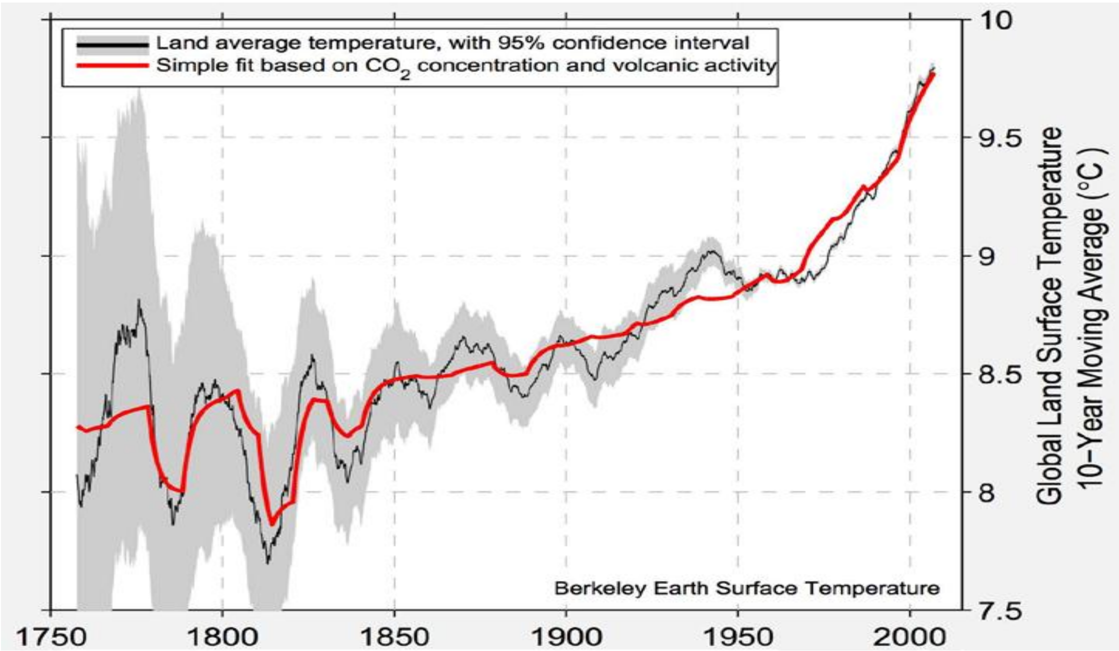
The World Meteorological Organization -WMO (2013), adds that a uniform increase in temperatures in all strata of the atmosphere is expected if the sun is causing the current warming. It is quite obvious that the current global warming being experienced does not fit the characteristics of global climate change caused naturally. It is concluded that some natural causes of climate change occurred within a prolonged time-scale that do not fit the current trend. The other natural processes that induce climate change such as volcanic eruption and El Nino also do not have such widespread global impacts as is being currently experienced. Increased greenhouse gases through anthropogenic activities hereby remain one of the major explanation for the global warming. Svante Arrhenius conjectured over a hundred years ago that the greenhouse gas effect would be amplified by increased concentration of carbon dioxide (CO_2) in the atmosphere (Harris *et al.,* 2015). Man in pursuit of development, has exponentially increased the concentration of heat trapping gases, particularly carbon dioxide in the atmosphere, resulting in a sustained increase in global mean temperatures (Symon, 2013). Human-driven emissions of carbon dioxide and other greenhouse gases, as well as land-use change, are the processes primarily responsible for the increase (Climate Change Information Resource, 2005:1).

Human activities contribute an annual amount of 20 billion tonnes of carbon dioxide to the global atmospheric CO_2 while the earth's natural system balances out on the amount of carbon dioxide it emits and that which it absorbs. The excessive release of CO_2 from anthropogenic sources disrupts this balance, resulting in the current global warming (Cook, 2010). Burning of fossil fuel has been the main anthropogenic source of carbon emission although appreciable amounts of nitrous oxide and methane release, deforestation and land use change have also contributed significantly (WMO, 2013: Ramanathan *et al.*, 2005).

2.2.2 Global Trends of Climate Variability and Climate Change

Mean annual temperature, precipitation and carbon dioxide levels are the usual basis for climate change projections (Kingwell, 2006). Figure 2.1 shows how an increased global trend in the temperature variation is consistent with increases in atmospheric carbon dioxide from 1750 to 2000 (a period of 150 years).

Figure 2.1. Global land surface temperature and carbon dioxide from 1750 to 2000.



Source: Adopted from Cook *et al.*, (2013).

The black line is the moving average for global temperature while the red line is the moving average for carbon dioxide and volcanic eruptions from 1750 to 2000 (Cook *et al.*, 2013). Volcanic eruptions from 1750 to 1850 resulted in brief periods of cooling giving rise to a more variable trend from 1750 to 1850. The steady increase in CO_2 concentration in the atmosphere ultimately resulted in a corresponding increase in global temperature (California Department of Food and Agriculture, 2013). This clearly shows a relationship between CO_2 and global warming, demonstrating the strong relationship between CO_2 concentrations and global warming (Olivier *et al.*, 2013).

Scientific research has proven that the earth is now experiencing warmer temperatures compared with any period within the last 1300 years (Blanco *et al.*, 2014). The increase in global mean temperatures is felt across the planet through rising sea level, melting of ice and permafrost at the north and south poles, changes in weather patterns, increased frequency of thunderstorms and cyclones, and increased atmospheric and oceanic temperatures. Most of these changes have not occurred on the planet for decades and millennia (Symon, 2013). King (2007), for examples shows that in Greenland's ice sheet is now melting though formerly said to be stable. Particularly, mean global temperature for 2009 together with some years is categorized as the second warmest years recorded since 1880 (Fletcher, 2010). The IPCC, (2013) indicated that from 1901 to 2012, global surface temperature has increased quickly. Since 1850, only the 19th, 20th and 21st centuries have record rapid successive increase in global surface temperatures (IPCC, 2014). Consequently, weather events have also varied significantly since 1950 and continue to increase in recent times (Symon, 2013).

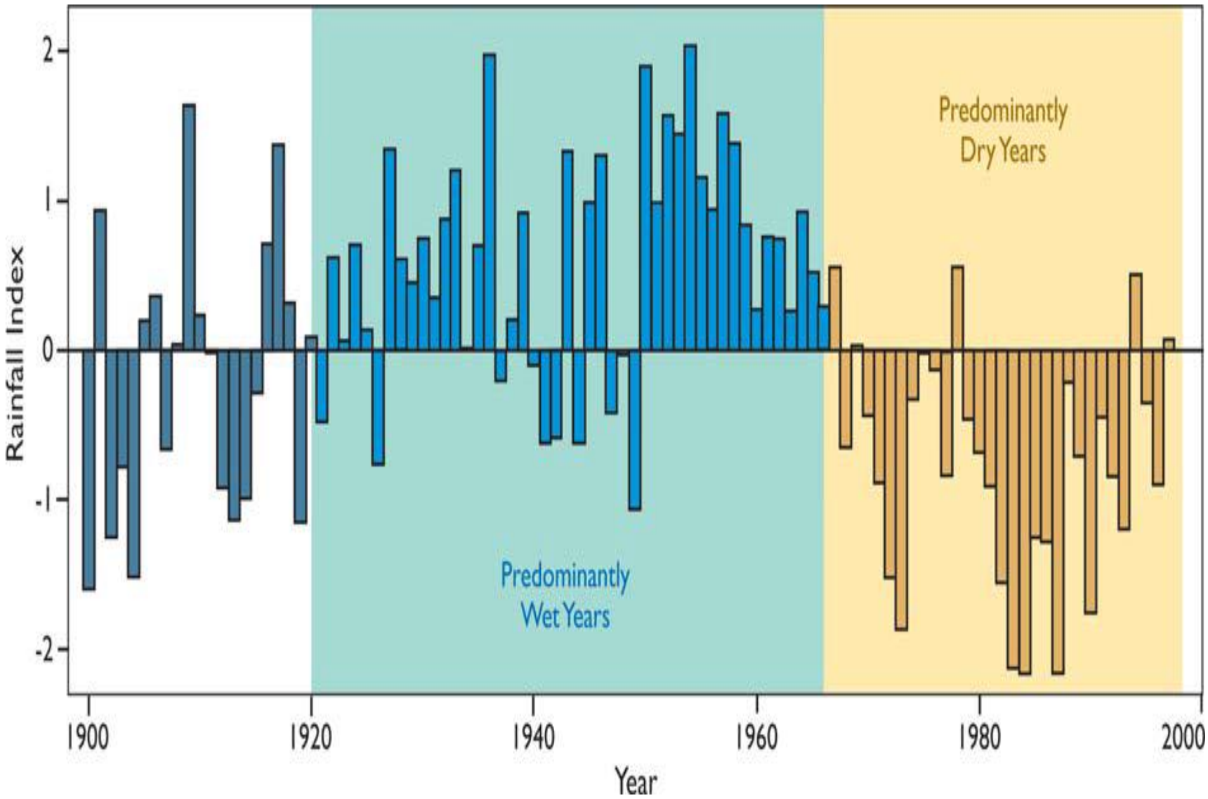
2.2.3 Climate Variability and Climate Change Trends in Africa

Warming is occurring rapidly on the African sub-region than at the global scale (African Ministerial Conference on Environment, 2010). The alternation of the monsoons, the Inter Tropical Convergence Zone (ITCZ) now called Inter Tropical Discontinuity (ITD) and the El Niño-Southern Oscillation (ENSO) are the major determinants of the African climate (Conway, 2009). Patterns of high temperatures and droughts in Africa have resulted from ENSO with widespread impact on the continent with net temperature increases of 0.6 °C in recent decades (Malhi and Wright, 2004). Kandji *et al.,* (2006) pointed out that El Niño results in major disasters such as floods and droughts. Palaeolithic records and observations from other centuries point to the fact that ITCZ changes with climate and also results in changes in the atmospheric energy balance (Schneider *et al.*, 2013). According to Conway (2009), whenever the ITCZ advances beyond its usual northern limit, the Sahel receives heavy rains and flood as was the case in 2007 and when it travels further south than usual, over the Indian Ocean, Southern Africa becomes very dry (Conway, 2009). In West Africa the ITCZ primarily determines rainfall pattern (ECOWAS-SWAC/OECD, 2008)**.**

Kirkman *et al.,* (2012) points out that severe drought have persist in sub-Saharan Africa. Droughts in SSA is gradually extending into the rainforest zone. This is because the dry season within this region is becoming extreme (Malhi and Wright, 2004). Variations in the monsoon systems have had significant impact on the continent from national to local scales (World Climate Research Programme, 2011). Key waters resources as the Niger, Volta, Senegal, Congo, and the Gambia have dwindled due to reduced stream flows (ECOWAS-SWAC/OECD, 2008).

Although Africa has contributed only 3.8 per cent of greenhouse gas emissions globally, the impacts of the resultant CVCC is widely felt across the continent (African Ministerial Conference on Environment, 2010). Tropical rainforest temperature for instance is increasing by an average of 0.29°C per decade since 1900 (Conway, 2009). Hence there is more of an increase in temperature on the African continent in recent times. This trend is revealed clearly in Figure 2.2. The rainfall pattern on the continent is increasingly exhibiting seasonal and annual variability. From a general perspective however, there is a decreasing trend of rainfall on the continent (Malhi and Wright, 2004).

Figure 2.2: Rainfall regimes in Africa (1900-2000)



Source*: African Ministerial Conference on Environment (2010)*

2.2.4 Ghana's Climate Change: Trends and Experiences

From 1961 to 2000 Ghana has experienced increase in temperature and decrease in rainfall across the various agro-ecological zones (Agyemang-Bonsu *et al.*, 2008). Temperatures for Ghana usually ranges between 24 °C to 30 °C though the south occasionally records low temperatures as low as 18 °C while the north also sometimes records very high temperatures such as 40 °C (Asante and Amuakwa-Mensah, 2015).

Sudan and Coastal Savannah experienced increases in mean annual temperatures for a 40-year period with respective increments of 28.1°C in 1960 to 29.0°C in 2000 for the Sudan Savannah and 27.0°C in 1960 to 27.7°C in 2000 for the Coastal Savannah (Adaptation Fund, 2012). Nelson and Agbey (2005) confirm that surface air temperatures have been increasing since 1960 to 2000 for all the ecological zones. The Sudan Savanna, Guinea Savanna and transitional zones have high temperature and low rainfall (Asante and Amuakwa-Mensah., 2015).

Ghana has two main rainfall regimes for the forest belt and one rainfall regime for the savannah belt. The major rainfall regime for the forest belt starts from April peaking in June and ends in July. As the monsoons travel up north, the single savannah belt rainfall regime begins from July peaks in August and ends in September. As the monsoons travel towards the south, the minor season of the forest belt starts in September, peaks in October and ends in November, allowing the dry season to set in (Environmental Protection Agency, 2011). The wettest part of Ghana is the extreme South-western portion with mean annual rainfall ranging from 1500 mm to 2500 mm. The northern part of the country, which falls within the interior savannah belt has an average rainfall amount of about 1000 mm while the forest belt receives mean annual rainfall between 1500 mm to 2000 mm. The coastal belt receives a mean annual rainfall of 900 mm making it the driest part of the country. The rainfall is controlled by the movement of the tropical rain belt, also known as the Inter-Tropical Discontinuity (Dyoulgerov *et al.,* 2011).

Ghana's climate has shown unequivocal signs of change evidenced through inconsistent and unpredictable rainfall pattern, changes in the onset of rains, temperature variations and recurrent droughts (Smith, 2013). These trends have consequently led to drying of rivers and streams, shift in cropping season, reduced yield, frequent flooding and extreme warm conditions among others (Obeng *et al.,* 2011). Codjoe and Owusu, (2011:7) noted that "the bimodal rainfall regime in Southern Ghana is being replaced with a unimodal rainfall regime". This is because the rainy season which usually starts from April to July for the major agricultural season, breaks in August and begins again in September to October for the minor agricultural season is gradually changing into a longer rainfall regime without the canonical break in August. They specifically indicated that evidence of Ghana's variable climate includes

a) Very hot weather conditions in January–July 1976:

(b) Drought with year-long bush fire from1983–1984;

(c) Very hot weather conditions from October–December 1989;

(d) Lots of rains throughout the year in1991;

(e) About 40 days of intensive rains in 1995;

(f) Cold periods resulting in animal deaths in 2005;

(h) A week of intensive rains in August 2006;

(i) Lots of rains in August and September in 2007.

Nelson and Agbey (2005) also point out that climate change is also felt along the coast of Ghana as sea level rise has led to increased frequency of floods, coastal erosion, and intrusion of sea water into ground aquifers.

The earth's climate in past centuries has undergone periods of warming and cooling. The nature of the current global warming being experienced is distinctively characterized by rapid increase in temperature within a comparatively shorter period of time. It has been proven to be due to excessive release of greenhouse gases, primarily carbon dioxide into the atmosphere from anthropogenic sources. It is imperative not only to adapt to CVCC but also to mitigate it by increasing carbon sinks and reducing carbon dioxide and other greenhouse gas emissions (Geological Society of America, 2013). Ghana's climate is fast changing and this change is manifest through droughts, floods, declining rainfall and increasing temperatures. This has been felt across the agricultural, health and environmental sectors of the country (Climate Change Development-Adapting to by Reducing Vulnerability- CC DARE, 2011). Climate change and variability coupled with the reliance of the Ghanaian economy on agricultural, energy and forestry sectors make the country more vulnerable (Asante and Amuakwa-Mensah, 2015). There is there a pressing need to adopt the appropriate adaptation and mitigation policies, which seek to help people cope with climate change while working at reducing the countries greenhouse gas emissions.

2.3 SUSTAINABLE FARMERS' ADAPTATION AND MITIGATION STRATEGIES TO CLIMATE VARIABILITY AND CLIMATE CHANGE

2.3.1 Introduction

Crop production in Sub-Saharan Africa is affected by many aspects of climate change stemming primarily from average temperature increase, change in rainfall amounts and patterns, rising atmospheric concentration of CO_2 , changes in climatic variability and extreme weather events and sea water rise (Chijioke *et al.*, 2011: World Initiative for Sustainable Pastoralism, 2010: Ringler., 2007). With regard to food security, agriculture provides livelihood for 80% of the African labour force and food for its populace (Tadesse, 2010). It is therefore not surprising that the need for an effective adaptive responses to CVCC has caught the attention of policy-makers and development practitioners since the publication of the 4th Assessment Report (Harmeling and Kaloga, 2009).

"Adaptation is described as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001a: 72). Such adjustments have become very critical for the sustenance of agriculture on the African continent. This is dependent on such assets as knowledge base, capital, technology, farm tools, opportunity for off-farm engagements, social support systems and provision of farmers' support services that make such adjustments possible (Dickie *et al.*, 2014).

The ability of a system to adjust to climate change, minimize potential harms and take advantage of the circumstance, or cope with the consequences reflects its adaptive capacity. Resources, including: social, financial, natural, physical and human capital, are required for planning, preparing for, facilitating and implementing adaptation measures

(Adejuwon, 2006). The adequacy and ease of access to these resources in the available systems determines the extent of practical mitigation and adaptation that occurs in agriculture and other sectors. In their work, Reid and Huq (2007) clearly distinguish that since the developing countries have a relatively small greenhouse gas emission, their concern is skewed towards adaptation. This is because they are relatively more vulnerable to climate change impacts (Reid and Huq, 2007).

However, there is cause for the consideration of climate change mitigation on the African continent as they stand to benefit from major global mitigation interventions as Clean Development Mechanisms and REDD+. Ndaruzaniye *et al.,* (2010) espouse that the public sector has a key role to play in the short-term, by incorporating mitigation financing into various agricultural financing channels to reduce pressure on mitigation efforts of smallholders. Generally "the process of adaptation includes structural or technological choices; legislative, regulatory and financial interventions; institutional or administrative changes; market based; and increasing technology, information and knowledge tools to enhance adaptive capacity, and on-site operations" (Masiga, 2013: iv).

2.3.2 Agriculture Related Climate Change Mitigation and Adaptation Efforts in Africa

Alliance for a Green Revolution in Africa- AGRA (2014), advocates that integrating adaptation and mitigation programmes into national budgets is necessary to influence political will towards tangible actions favourable to smallholder farmers' adaptation and mitigation. Although Reid and Huq, (2007), in their work did not clearly emphasize collective regional approaches to adaptations to climate change, Nzuma *et al.*, (2010) brings to bear that at the regional level, a number of collective adaptation approaches have being deployed that are more suited to respective geographical and climatic regions.

The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) for example has adopted, a range of climate change adaptation strategies in agriculture constituting binding policies and intervention at the national level. According to Chemnitz and Hoeffler (2011), Africa needs to take advantage of its national and regional experience to adapt effectively with respect to its farming systems. This is key in ensuring the long term sustainability of various climate change adaptation and mitigation interventions. The place of local level actors as farmers must be emphasized and properly instituted into national adaptation policies.

This approach will serve to segment and clearly outline the various regional manifestation, impact and experience of climate change, forming a solid basis for effective adaptation and mitigation policy planning and implementation. According to Smit and Skinner, (2002: 87) “a critical question to be considered at the local level is what is it that agriculture is adapting to- increased flooding, changing rains, rising temperature, prolonged dry season, etc.?” To this Uddin *et al.,* (2014), purports that adaptation is in itself a process occurring within a particular context. A structured approach will not apply, as an in-depth understanding of the processes involved is essential. Hence, there is the need to appreciate the various differences in the various climatic stimuli of change experienced and to properly fashion interventions to that effect.

In Africa adaptation activities comprise infrastructural development, capacity building at various levels, and the amendments in decision-making situations (Tubiello, 2012). The Sahara and Sahel Observatory- OSS (2010) indicates that farm-level adaptation occur in three ways: building adaptive capacity, increasing the ability to implement adaptation and increasing their ability to response to stimuli. Of these Ngigi (2009) outlines that capacity building is particularly more critical. An individual’s ability to learn, read, gather information, and research essentially amounts to adaptation (OSS, 2010).

Adaptation at the farm level could be anticipatory or reactive, autonomous or planned, strategic (long-term) or tactical (short-term) and influenced by private or public actions (Nhemachena and Hassan, 2008: Smit *et al.*, 2002: Shelton, 2014). Autonomous adaptation is more prevalent on the African continent. This is widely interpreted to be initiatives by private actors (farmers and agro-industries) rather than by governments, prompted by actual or anticipated climate change (Otitoju, 2013). This is essentially so because of their direct investment in agriculture and hence the need to make the most of the situation to recoup their investments. In the short-term, autonomous farm-level adaptation may be sufficient, but in the longer run, adaptation in the form of technological and structural changes will become necessary. Difficulty in predicting future climate change trends may have also led to low private sector interest in anticipatory action (Tompkins *et al.*, 2005).

2.3.3 Sustainable Agricultural Greenhouse Mitigation and Adaptation to Climate Change

A synthesis of adaptation and mitigation approaches to dealing with climate change will present a forceful and efficient solution to the global warming and the challenges posed to agriculture and other sectors (Mimura, 2006). Since they can interactively play complementing roles, there should be corporation between National Appropriate Mitigation Actions (NAMAs) and National Adaptation Programs of Action (NAPAs) (Wollenberg and Seeberg-Elverfeldt, 2012). Locatelli *et al.*, (2011) espoused that mitigation deals with the roots of climate change while adaptation deals with the effects of climate change. In the spatial scale, mitigation is basically an international concern as mitigation provides global benefits while adaptation is chiefly a local problem, mostly providing benefits at the local scale.

Agriculture's contribution to climate change is a major justification for its consideration in the mitigation of climate change (Wollenberg and Seeberg-Elverfeldt, 2012). Due to over-reliance on agriculture in most developing countries, the agricultural sectors is a significant contributor to national greenhouse gas emissions. Land clearing for agriculture alone in Africa accounts for 43% of total CO_2 emissions on the continent (Gledhill *et al.,* 2011). Mitigation based activities in the agricultural sector could yield either positive adaptation or negative adaptation outcomes (Smith, 2010). Hence in considering mitigation in agriculture emphasis should be laid on approaches that would not yield maladaptive outcomes at the local level. Lipper *et al.,* (2011) acknowledged that soil carbon sequestration alone can account for about 89% of agriculture based climate change mitigation.

Research has proven that use of sustainable land and water management practices dampens the effects of climate change at the plot, farm, and landscape level (Nkonya *et al.*, 2011). Some climate smart agricultural practices can reduce or remove greenhouse gases (mitigation) and these embrace sustainable land and water management practices (adaptation). In support of this Recha *et al.,* (2014) mentioned specifically that strategies for reducing greenhouse gas emissions in agriculture include sustainable land management practices such as soil nutrient management, tillage and residue management, agronomic practices, agro-forestry, soil and water conservation, and improved livestock management. These constitute on-farm practices that will go a long way to mitigate climate change, make agriculture sustainable and improve environmental services provided by ecosystems. These can contribute to sustainable climate change mitigation through adaptation as they increase carbon sequestration and secure carbon stocks in soils and trees.

Bryan *et al.,* (2011) and Gledhill *et al.,* (2011) emphasized that there is a triple win strategy for achieving increased productivity, adaptation and mitigation through agricultural mitigation of climate change. However, with varied local geophysical as well as socio-economic circumstances, it is impossible to outline particular practices acclaimed to be better than others. The triple win benefits can only be actualized if stakeholders comprehend and integrate the various dimensions relevant in peculiar situation and their interconnectivities (Kelvin *et al.*, 2015).

2.3.4 Experience of Climate Change Mitigation and Adaptation in Ghana

From 1961 to 2000 Ghana has experienced increase in temperature and decrease in rainfall across the various agro-ecological zones (Agyemang-Bonsu *et al.,* 2008). This has implication for agriculture and related livelihood dependent households. Ghana has six ecological zones namely coastal savannah, guinea savannah, rainforest, semi-deciduous forest, Sudan savannah, and the transitional zone (Nelson and Agbey, 2005). However, these delineations can be re-categorized into two constituting the savannah zone and the forest zone based on similarity of characteristics.

The Sudan Savanna, Guinea Savanna and transitional zone have high temperature and low rainfall with arid and harsh climatic conditions (Asante and Amuakwa-Mensah, 2015). Adaptation practices are therefore considered within the context of these two broad categorization *viz* savannah zones (Coastal Savannah, Sudan Savannah, Guinea Savannah and the transitional zone) and the forest zones (semi-deciduous forest and the rainforest).

2.3.4.1 Adaptation in the Savannah Zones

The coastal and interior savannahs distinctively have variable rainfall with hotter temperatures in comparison with the forest ecological zones (Yaro, 2013). The vegetation in the coastal savannah zone is mainly grass and scrub with rather poor soils due to salinization caused by the seas water. This supports the cultivation of staples such as maize, cassava and vegetables and livestock rearing (Barry *et al.*, 2005). The effect of sea erosion and tidal flooding is shoreline recession, increased flooding and salinization of surface and ground water as experienced in the coastal savannah ecological zones (Linham and Nicholls, 2010: AMCEN, 2011). This has informed particular adaptation practices that serve to ameliorate the challenge posed to crop production in this regard. Proper management systems such as weeding, mulching, irrigation with fresh water, and thinning applied by the farmers are key adaptation strategies that help overcome salinity and drought (Uddin *et al.,* 2014).

The interior savannah zone experienced a single maxima rainfall regime, starting from late April, peaks in August and ends in October. This is followed by the dry season during which crops can only be grown under irrigation (Barry *et al.,* 2005). Food crops such as cereals, root and tubers, legumes and some tree crops -mango, tick tree, shea tree, and cashew are cultivated (Mabe *et al.*, 2014). To adapt to varying climatic conditions, key on-farm adaptation practices that have prevailed include creating or improving drainage system, early planting, stopped farming in low-lying areas and water way, irrigation or dry season farming, planting more trees and cover crops, planting drought resistant and early yielding crops, early planting, improved farm management practice, diversification into livestock rearing and increasing fertilizer (Antwi-Agyei *et al.,* 2013; Asante and Amuakwa-Mensah, 2015; Mohammed *et al.,* 2014; Nti, 2012: Stanturf *et al.,* 2011).

Planting of drought resistant crops has been one key traditional adaptive strategy in the zone. Sorghum for example, has for generations proven to be drought resistant and tolerant of harsh conditions. Being more tolerant than other cereals sorghum is usually preferred to maize and millet (Buah *et al.,* 2010). Sorghum thrives under many harsh climatic conditions, can withstand water-logging from heavy rain, and can grow in both temperate and tropical zones, producing up to three harvests a year (Stone *et al.*, 2011). Use of medium heat-tolerant maize variety are very useful approaches in dealing with climate change in these dry and drought prone areas (Tachie-Obeng *et al.,* 2013: Gyampoh *et al.,* 2011). This ensures that even if the time of planting is earlier than the rains for a particular season, the seeds still geminates at the on-set of the rains. Nyantakyi-Frimpong (2013) however asserts that farmers in some parts of Northern Ghana still prefer to plant traditional crop varieties — as opposed to hybrid or synthetic ones — because they are better suited to local conditions. Proposed technologies for adaptation among smallholder farmers across Sub-Saharan Africa include in-field rain water harvesting, small reservoirs and zai pits (FANRPAN, 2013).

One key factor that influences farmers' adaptation to flood and drought is the activities of Non-Governmental Organizations (NGOs). Nti (2012) found that in anticipation of interventions from NGOs some farmers in Northern Ghana did nothing in response to flooding and drought. Technological advancement, building capacity and the corresponding political will to invest in these areas are key for effective adaptation in the savannah zones (Tachie-Obeng, *et al.,* 2013). There is the need to make agricultural extension services widely available to smallholder farmers in northern Ghana in order to boost the adoption of improved breeds and varieties as noted by Al-Hassan *et al.,* (2013). Etwire *et al.,* (2013) add that increased awareness of CVCC among smallholder farmers could facilitate the adoption of modern technologies in the savannah ecological zone.

2.3.4.2 Adaptation in the Forest Ecological Zones

Traditional ecological farming practices have helped to sustain fragile environments and preserve local crop varieties in the forest zones. Farmers have since time immemorial found ways of coping with the vagaries of the climate and other catastrophic events that affect their lives and livelihoods. With respect to the current CVCC, some coping strategies in the forest zone of Ghana have been categorized by Codjoe *et al.,* (2013) as soil fertility strategy, shade management strategy, land preparation strategy, farm size strategy and lining and pegging strategy.

On-farm adaptation practices identified include change in crop types, reduced farm size, planting short season varieties, changing planting dates, and crop diversification (Fosu-Mensah *et al.,* 2010). They established that crop diversification and changing planting dates are the major adaptation strategies. Acquah (2011) agrees to this and adds tree planting, irrigation practices, soil conservation, water harvesting and prayers as other adaptation measures used by the farmers.

Changing planting date is an obvious autonomous adaptation as farmers have to respond simultaneously to the changing pattern of the onset of rains. The Crop Research Institute of the Centre for Scientific and Industrial Research (CSIR) has over the years developed varieties of crops in efforts to improve agricultural productivity in Ghana. These have come in handy to aid farmers' adaptation to the vagaries of the climate. However, other adaptation strategies as irrigation have become imperative in the forest ecological zone in recent times to buffer for the water deficiency associated with climate change for crop production (Nyuor *et al*., 2016).

Cocoa, a major cash crop in the forest zone for example is particularly sensitive to slight variation in the supply of moisture. Cocoa is highly sensitive to changes in climate from hours of sun, to rainfall and application of water, soil conditions and particularly to temperature, due to effects on evapo-transpiration (Codjoe *et al.,* 2013). Irrigation has traditionally not been part of cocoa farming activities in the forest zone as emphasized by Anim-Kwapong and Frimpong, (2006) and Agyemang-Bonsu *et al.,* (2008). There have been two major shifts in cocoa production as adaptations to the uncertainties of the climate. First is an emerging trend of a shift from cocoa to other plantation crops as oil palm and orange. Secondly, there is a shift towards the production of food crops such as maize and cassava in place of cocoa (Anim-Kwapong and Frimpong, 2006). The latter is particularly conducive as farmers stand to benefit from the advantages of a mixed cropping system in contrast to mono-cropping. This is a form of insurance as losses in particular crops that are vulnerable may be buffered by gains in other that are less vulnerable to particular climatic stimuli experienced. Mixed cropping also dominates among smallholder farmers in the forest zones (Midttun *et al.*, 2009).

Farmers are also diversifying their work activities and engaging in off-farm income generating activities such as trading particularly among women and artisanship among men (Midttun *et al.,* 2009: Anim-Kwapong and Frimpong, 2006). Diversification of income sources vary based on interests, skills and opportunities (Rodriguez-Solorzano, 2014). In Ghana staples and vegetables are generally grown in the savannah zone while export crops are grown in the forest zones (Arndt *et al.,* 2015). This has resulted in variation in adaptation practices in these zones. Off farm adaptations measures have served to insulate farming household from the adverse impacts of climate change. An approach incorporating landscape planning, tenure systems, livelihood activities and capacity building at the community level is required when considering climate change mitigation and adaptation (Foli and Makungwa, 2011). Generally, farmers in Ghana are coping through several strategies that are respectively suited to their ecological zones. Hence a holistic approach that considers all these amidst prevailing local to national socio-economic conditions and institutional framework is necessary.

2.4 FARMERS' LIVELIHOOD SECURITY AMIDST CHANGING CLIMATE

2.4.1 Introduction

Climate change has threatened the livelihood of millions in developing countries, especially the very poor through direct impacts on livelihood sources (Chambwera and Stage, 2010: Chirstian Aid, 2009). Diverse cultural systems, socio-economic conditions and environmental exposures makes household's sources of income vulnerable over time (Selvaraju *et al.,* 2006). Some livelihood assets such as agricultural production knowledge and tools become redundant, influencing sustainable livelihood strategies- ways of combining and using assets are jeopardized as climate becomes increasingly variable (DFID, 2001).

Amidst such eventualities, opportunities for livelihood diversification become critical in determining community and household ability to cope with climate related stresses and shocks (Practical Action, 2009). Climate variability and change through diverse stimuli and intervening factors affect economic, social, cultural and natural conditions of individuals and communities, altering the value and usefulness of various livelihood assets (Selvaraju *et al.,* 2006). The current trend of CVCC and the resultant effect on agriculture has necessitated the adoption of alternative livelihoods among farmers in order to secure their livelihoods. Conceptually, "livelihoods" connote the means, activities, entitlements and assets by which people make a living (Elasha *et al.,* 2005:4). These are spread across social, natural, financial, human and physical assets as outlined by the Department for International Development (2001).

The need to strengthen livelihoods has been recognized as being very necessary in CVCC mitigation and adaptation efforts (Practical Action, 2009). Developing adaptive capacity to minimize the damage to livelihoods from climate change is to this end a necessary strategy to complement climate change mitigation efforts. An understanding of the nature of local livelihoods – what types of livelihood strategies are employed by local people and what factors constrain them from achieving their objectives are very important. According to the DFID (2001), such an understanding cannot be gained without social analysis so that particular social groups and their relationship with factors within the vulnerability context can be identified.

2.4.2 African Farmers Livelihood Security

Climate change has been found to impact agricultural output, vary ecological boundaries and the location of flora and fauna species. This adversely affects the livelihood of poor communities dependent on primary occupations such as agriculture that is directly dependent on nature (Reid, 2004). Nasreen *et al.,* (n.d.) showed that climate related impacts on health, crops, fisheries, and water resources of coastal communities have adversely affected their livelihoods. For agriculture dependent households, changes in rainfall and temperature particularly makes their livelihoods vulnerability (UNDP, 2007). Climate shocks such as droughts, floods and thunderstorms tend to destroy crops and property and cause increased food prices (UNDP, 2007). The opportunity to engage in alternative livelihood activity is hence critical in ensuring that households are cushioned to withstand these shocks and stresses arising from climate change.

In parts of Eastern and Southern Africa, climate change has negatively affected agriculture, water sources and quality, biodiversity, health and ecosystems which are key components of local livelihood assets (Colls and Ikkala, 2009). The rate of change has marginalized already vulnerable livelihoods, made those that could have adapted more slowly less adaptive and handicapped new livelihood opportunities in the near term (Basar, 2009). Some livelihood alternatives that farmers resort to include seasonal migration of livestock keepers and distribution of livestock herds in different places; rainwater harvesting; and doing casual labour to be able to get food and other household needs, selling of livestock, engagement in small businesses, including shops, local restaurants and kiosks (Kangalawe and Lyimo, 2013).

Vulnerability of an individual depends on his/her assets base, the choice pattern and use of these assets. With limited livelihood assets, the response of vulnerable individuals and communities could be unsustainable or even maladaptive. Inefficient institutional policies and processes could also act to amplify shocks and stresses at the local level (Kangalawe and Lyimo, 2013). This restricts livelihood strategies and corresponding livelihood outcomes. The ability to adapt to future trends of climate change and variability can be determined by using current coping and adaptive capacity as a proxy (Elasha *et al.*, 2005). Hence the less appropriate their coping and adaptive capacity, the more vulnerable their livelihoods will be to future stresses.

2.4.3 Security of Farmers' Livelihoods in Ghana

Reduction in rainfall, variation in rainfall regimes, droughts, and high temperatures are some evidence of climate change in Ghana. These have affected the livelihoods assets of communities exposing them to hunger and poverty (Amisah *et al.,* 2009). Floods and bushfires caused by high temperatures have destroyed farmlands, biodiversity and wild-life which are the basic natural capital that rural people depend on for their livelihoods (Akudugu and Alhassan, 2012). Diversification, encompassing migration, non-farm work and social support networks, in addition to livestock production, according to Roncoli *et al.,* (2001) has moderated the adverse effects of climate variability on farming households. Hunting and gathering of wild fruits, charcoal production and chain saw operations are important coping strategies and a means of building assets that have become common in Ghana (Yaro, 2013: Stanturf *et al.,* 2011). Armah *et al.,* (2013) includes petty trading, security work, craftsmanship, salaried work as well as production of charcoal and selling of firewood emphasizing that in Ghana, the people's livelihood depends on farming and other off-farm income generation activities.

However, McCarthy and Sun (2009) submits that trading is the predominant alternative livelihood activity among smallholder farms. Most farmers also migrate to more vibrant and economically productive areas to sell their labour. Demeke and Zeller, (2012) explain that when the rains are poor, farmers commit more labour resources to less risky alternative livelihood activities. Hence, sale of labour to off-farm livelihood activities lessens the impact of their vulnerability to rainfall on household income and food supply. However Yaro (2013), pointed out that storing wealth in the form of healthy livestock has been challenged by the suspension of free government programs in eliminating livestock diseases. This was a source of investment aiding adaptation of livelihoods in times of shocks and stress, hence building resilience. The resilience of livelihoods must be prioritized in climate change and adaptation deliberations (Tanner *et al.,* 2015). The collection and sale of shea nuts, dawadawa, fuel wood and wild fruits has become major livelihood options, especially during the lean season in Africa (Perez *et al.,* 2014).

In 2007, the three Northern regions of Ghana experienced flooding that destroyed houses, displaced families, and destroyed farmlands eroding natural, social, and physical assets. Households lost their livelihoods and the resources to engage in alternative livelihood activities were scarce (Akudugu and Alhassan, 2012). Amidst such dire situations, the collection of shea nuts and dawadawa provided a source of income in the short term as these are readily available across the Northern regions of Ghana. While most farmers have sought alternative livelihood options, there have been some exceptions to this trend. According to Eshetu *et al.,* (2010) involvement in alternative income generating activities besides agriculture has not been prioritized in some parts of Ethiopia. This although not clearly outlined could be due to some form of security that complement such needs. The United States Department of Agriculture, (2015) purports that the relevance of alternative livelihoods differ from farm to farm, reducing as farm output increases. Off-farm livelihood engagements are in recent times significantly contributing to the income sources of agriculture based households (United States Department of Agriculture, 2015). These alternative livelihood activities provide a window of hope to which agriculture based households whose income and food supply is threatened by CVCC can channel limited capital and labour resources to yield outcomes that ensure continuous household food and income supply (Armah *et al.,* 2013).

In Ghana, off-farm income appears to be an important component of incomes, particularly for relatively labour-abundant households within scarce land environments (McCarthy and Sun, 2009). Effective development policies must improve livelihoods by enhancing peoples' capabilities, improving equity, and increasing the sustainability of resource use. A livelihoods perspective in the climate change discourse must place people at the centre of the analysis, located within, rather than dominated by, ecosystems, technologies, governments, markets, experts, or resources (Tanner *et al.*, 2015). These must be geared towards expanding farmers' asset base to enable them engage in varied livelihood strategies that yield sustainable livelihood outcomes.

2.5 AGRICULTURAL AND FOREST LAND USE POTENTIAL FOR THE IMPLEMENTATION OF REDD+ AT THE GRASSROOTS

2.5.1 Introduction

Reducing emissions from deforestation and forest degradation (REDD) is a one component of mitigation action that international climate change discussions have revolved around (O'Sullivan *et al.,* 2010). It has been argued that REDD+ could be a cost effective means of handling global warming (Angelsen *et al.,* 2012). The philosophy behind REDD is to conserve forest by giving it a fiscal value that is higher than what would have been gained from its exploitation primarily through deforestation. REDD+ has a broader scope as it incorporates conservation and sustainable forest management (Vahanen *et al.,* 2009). In this regard, some countries have integrated REDD+ with prevailing land uses including reforestation, afforestation, agro-forestry and assisted natural regeneration using these as key drivers of REDD+ interventions (Kissinger *et al.,* 2012). This requires that agriculture be addressed as a key driver of deforestation and a significant source of land-based greenhouse gas emissions (Bishaw *et al.,* 2013).

2.5.2 The REDD+ and Deforestation Nexus

According to Jurgens *et al.,* (2013) forest resource exploitation and farm-frontier expansion into forests have contributed extensively to deforestation trends in the tropics. REDD+ provides an opportunity to enable forest communities and small holder farmers to curtail deforestation, make agriculture more sustainable and build climate resilient livelihoods and communities (Kalaba *et al.,* 2010). Forest in Latin America are mostly converted to ranching or pasture, whereas forest conversion in South East Asia and Africa is skewed towards intensive agriculture and smallholder agriculture respectively (Harris and Feriz, 2011). In Africa, 43% of total CO_2 emissions originate from land clearing for agricultural use and a further 316 billion tons of CO_2 are stored in top soils which are at risk of being released into the atmosphere through degradation (Gledhill *et al.*, 2011). Forest related mitigation schemes should seek through afforestation, reforestation, and restoration to maintain carbon in their various natural stocks and increase potential sequestration of atmospheric carbon dioxide (Bishaw *et al.*, 2013).

Minang *et al.*, (2014) purport that REDD+ can be linked to agroforestry by considering agro "forest" management to increase carbon sequestration and curb degradation. If agroforestry does not meet the requirement for forest, then it could be viewed as a solution to the drivers of deforestation. Whatever the case, agroforestry should constitute an integral part of efforts to reduce GHG emissions from land use (Bishaw *et al.*, 2013).As interests in the mitigation potential of forests heightens, studies in the area has gained much attention in recent years seeking to validate the feasibility and cost effectiveness of the approach (Hatcher, 2009). It is increasingly being validated that secure tenure rights in local communities can contribute to an effective REDD+ through local management (Hatcher, 2009). It is within such an inclusive context that agroforestry, especially within forest frontiers becomes critical for consideration in the development of mitigation policies.

2.5.3 The Potential for Agroforestry

Agroforestry is already present and prominent in Africa. In Tanzania, adopted agroforestry practices include home gardens, alley intercropping, improved fallows, and boundary and scattered (Mbwambo *et al.*, 2013). Through traditional agroforestry practices, communities have sustainably managed forests in the past with benefits of increased productivity, sustained soil fertility, erosion control, biodiversity conservation and income diversification through the harvest and sale of non-timber forest products accruing to them (Bishaw *et al.,* 2013). Agroforestry practices in rural communities in Southern Africa include improved fallows, rotational woodlots and indigenous fruit trees in the parklands system (Kabala *et al.,* 2010).

The Cancun agreement states clearly that respect for the rights of local people and the conservation of biodiversity and natural forests must be upheld in the implementation of REDD+ initiatives (Scriven and Malhi, 2012). REDD+ through avoided deforestation, has the potential to reduce GHG emissions. It could conversely result in leakages and increased degradation in adjoining marginal lands (Gorte and Ramseur, 2008). Herein lies the need for agro-forestry to absorb such leakages by augmenting the benefits of forests to forest communities and agriculture. Carbon sequestration in trees initially increase as trees grow but eventually declines as the trees age (FAO, 2010). Agricultural and forested lands present major carbon sequestration opportunities if the appropriate land use and management practices are adopted (Bishaw *et al.,* 2013). Since agricultural extensification could threaten REDD+ interventions it should focus not only on forests but also on forest-farm frontiers (Scriven and Malhi, 2012).

REDD+ can contribute significantly to land-based mitigation of climate change in two ways. Firstly reducing land based greenhouse gas emissions and secondly sequestering carbon dioxide through reforestation and agro-forestry (Tanzania National REDD Task Force, 2009). Decision on land use at the grassroots involving stakeholders as smallholder must be a key target of REDD+ interventions (Scriven and Malhi, 2012). The Energy and Resources Institute (2013), therefore recommended that in order for REDD+ to be effective, there is the need for stratification considering prevailing land use options and patterns.

Kissinger *et al.,* (2012) espouses that the forest degradation and lose in Africa is attributed to fuel wood collection, charcoal production, and livestock grazing. Although many developing countries have the potential to benefit from REDD+, they are however not adequately prepared to utilize their forest and forest-frontier potentials to benefit from the REDD market (Streed *et al.*,2012). To deal with leakages, REDD+ must go beyond forest and their frontiers to low pressure forest areas (Pacheco *et al.*, 2011). Ghana, has implemented five emission reductions and removal enhancement activities for REDD+ intervention in off-reserve areas (Agyei *et al.*, 2014). These are avoided deforestation, avoided degradation, sustainably managing production forests, forest carbon stock enhancement and conservation of forest carbon stocks.

Forests provides communities with ecological services and products such as hunting and fishing grounds, wild fruits and seeds, fire, wood and agricultural land for cultivation (Llanos and Feather, 2011). These together with various benefits associated with agroforestry will encourage local people to manage natural resources sustainably. Managing the standing forest is essential but creating more sinks is more critical. Unsustainable agriculture, REDD+ leakages and the demand for forest products will be a daunting issue for REDD+ if not properly dealt with. It remains therefore that REDD+ projects be made all inclusive and highly participatory.

2.5.4 Challenges of Agriculture and Forest Land Use (AFOLU)

Challenges and experiences of community forest management must be brought to bear on forest related climate mitigation initiatives such as REDD+ (FAO, 2010). An understanding of the factors influencing farmers' land use decision can aid the fashioning of appropriate farmer friendly policies which they can easily identify with and accept (Mercer, 2004). Improving already existing policies and forest management practices while seeking to address key challenges through extensive research is imperative (Bishaw *et al.*, 2013).Also Thanh *et al.*, (2005) purports that the application of agroforestry model and their evaluation is constricted by natural, economic and social condition. With regard to

REDD+, one needs to consider whether these are related to or influenced by CVCC. Low level of knowledge on the benefits of agroforestry and conservation agriculture and low capacity to engage in these have been major hindrances in some developing countries such as Rwanda (World Agroforestry Centre, 2012). Factors constraining the development of agroforestry on the African continent are variegated. An individual's decision to engage in agroforestry is influenced by a variety of factors including socio-economic condition and the institutional environment (Oino and Mugure, 2013). Mbwambo *et al.,* (2013), explained that land size and tenure, access to extension services and capital, crop yield and household income are key in determining farmers' adoption of agroforestry. To this the World Agroforestry Centre, (2012) found the adoption of agroforestry in Rwanda to be influenced by age of the household head, farmer group membership and ability to purchase seedlings.

Nouman *et al.,* (2008) also found that farmers in Pakistan foresaw agroforestry as incompatible with productive agricultural activities as trees would compete with their crops for water and soil nutrients. Conversely, Abagale *et al.,* (2003) realized that in forest fringe communities of the Asunafu District in Ghana, perceptions about agroforestry in villages were key drivers of the adoption of agroforestry. This is because they perceived agroforestry to have a potential of solving fuel wood needs, improving the soil fertility, and micro-climate for crops. This served as a motivation for the adoption of agroforestry. Community participation is very essential in ensuring that what Llanos and Feather (2013) calls "Carbon Pirating" is avoided. In Peru, 'Carbon pirates' are capitalizing on the ignorance of local communities on REDD+ and agroforestry to sell their rights to land and carbon. Climate change mitigation efforts in forest and natural resource dependent communities need *insitu* approaches that take cognizance of the dynamics and relationships in such circumstances (Bishaw *et al.,* 2013).

Perhaps the most daunting challenge that REDD could face is that related to tenure rights (Jurgens *et al.,* 2013). To this Kotru, (2009) asserts that clarity of tenure and hence right to benefits present challenges at the community level. Personal land ownership in contrast to rented or borrowed lands facilitated the adoption of agroforestry systems in the Masaka district in Uganda since majority of farmers held personal land. In contrast, other types of land ownership have hindered the adoption of agroforestry systems (Sebukyu and Mosango, 2012). Djagbletey and Adu-Bredu (2007), found in Nkroranza in Ghana that ownership of teak farms was dominated by natives because tree planting on a parcel of land by an individual customarily implied his or hers ownership of it. Settlers and migrants were therefore less actively involved in tree planting initiatives (Djagbletey and Adu-Bredu, 2007). According to Adaba (2005), in Northern Ghana, families establish woodlots on family lands as alternative sources of income and fuel wood. Communal woodlots were however not popular because individual and family access and utilization of these communal woodlots were usually restricted.

Amidst these challenges, agroforestry as noted has proven to be very useful if properly designed to suit the ecological and socio-economic needs of the environment and farmers respectively. Carbon sequestration in forest is determined by tree species, management practices and land use pattern such as agroforestry that reduces demand for forest resources (FAO, 2010). REDD+ policies and interventions hence need to be cognizant of prevailing socio-economic and ecological characteristics. Reducing emissions from deforestation and forest degradation with sustainable management and conservation together with agroforestry provides the opportunity to make the most of our worst ecological, environmental and socio-economic situation for climate mitigation and adaptation and sustainable development.

2.6 AGRICULTURAL LAND USE CHANGE AND MODIFICATION INDUCED CLIMATE CHANGE

2.6.1 Introduction

Man has over decades cleared forests, changed land cover and burned fossil fuel, altering the carbon cycle (Folger, 2009). These activities have significantly affected global mean temperatures, altering the radiation balance of the earth through increased greenhouse gas concentration in the atmosphere resulting in climate change (van der Molen *et al.,* 2011). Land and land use is a critical factor in development. Understanding how land use decisions and patterns at the local, regional and national level influence climate change is essential for proper integration of land related policies in climate change adaptation and mitigation interventions (Lefroy *et al.,* 2010). The current rates of population growth in developing countries and their dependence on land-based natural resources has resulted in various land use changes (Schneider *et al.,* 2013).

The effect of variations in albedo due to land use change is similar to that of increased greenhouse gases concentration in the atmosphere (as the concept of radiative forcing) (Betts *et al.,* 2007). Land use and land cover changes affect micro and macro climates (Ellis, 2013). Global land conversion annually amounts approximately to the size of Peru and is the second largest contributor to global emission of carbon dioxide (Murphy *et al.,* 2009). Proper land use planning can buffer the high micro-climate temperatures associated with climate change, thereby building community resilience and contribute significantly to global climate change mitigation efforts.

2.6.2 Land Use and Climate Mitigation Potential in the Temperate and Tropics

Betts *et al.,* (2007) asserted that land use change in the temperate regions as afforestation or reforestation will decrease the surface albedo and induce a warming whereas in the tropics this will increase carbon sequestration. Deforestation in the tropics initially results in an increased albedo but in the long run this is reversed as evapotranspiration is reduced and sequestered carbon in trees is released into the atmosphere amplifying the warming (Desjardins, 2007). Hence land use patterns in the tropics cannot be left out in the consideration of climate change mitigation alternatives as it could either negate or support global mitigation efforts. Lobell *et al.,* (2006) used the National Center for Atmospheric Research (NCAR) general circulation model to demonstrate that a reduction in tillage can have a significant dampening effect on the warming trend by increasing the surface albedo. With irrigation, this is could yield as much as 8^{o}C reduction in temperature at the local scale and 1.3^{o}C at the global scale. Land cover change also affects global warming through cloud formation. Land use practices that encourage forest conservation and expansion equally increase evaporation, supporting cloud formation. This results in a cooling effect by shielding the earth from incoming solar radiation (van der Molen *et al.,* 2011).

The Voluntary Carbon Standard (2008) pointed out that tropical land use change led by deforestation accounts for 20% of global GHG emissions, without agriculture and over 30% with agriculture. From the agricultural land use modification and practices perspective, albedo is determined by crop type, crop phenology, management practice, land surface condition, time of day and time of year (Desjardins, 2007:29). However, Pielke, *et al.,* (2007) assert that albedo decrease due to loss of forest to agriculture is usually restored through secondary growths in short period. Hence some assertions on the contribution of deforestation to climate change is not entirely true. Quite conversely, such lands in the long term are mostly converted to land uses devoid of secondary growths such as in peri-urban settlements.

2.6.3 Land Use Change (LUC): Drivers, Trends and Interactions

The Organization of Economic Co-operation and Development [OECD] (2012), projected a global population of 9 billion or more by 2050, increasing global pressure on land for water, food and other natural resources. Besides agricultural expansion, other factors also directly and indirectly drive land use change (Lefroy *et al.*, 2010). Shifts in productive regions and poor soil quality due to climate change and increased demand for biofuels are key in this regard (Ward *et al.*, 2014). In recent times, high demand for land for other purposes has affected traditional slash and burn and fallow practices. With resettlement or land allocation, for example, more permanent forms of agriculture are practiced on land used formerly for shifting cultivation (Lefroy *et al.*, 2010). This will significantly alter long term albedo values experienced as agricultural permanence, gradual shifts from fallow practices and permanent conversion of agricultural land to other land use occur within a medium to long term periods. Hamwey (2007) purports that increased public education particularly on effect of land use and other activities that affect albedo could provide opportunity for communities and individuals to contribute to climate change mitigation through informed land use decision making. With a proper understanding of these, particular agriculture, forest and other land use modifications and practices can be encouraged or discouraged through the appropriate policies and institutions. In most cases forests are first converted to agricultural land. After going through a series of modification, they are converted to other land uses. Several land use patterns are possible with their respective implications (Ometto *et al.*, 2013). van Delden *et al.*, (2008) for instance put forth that from 1990 to 2000, agricultural land in Europe decreased while that of commercial, industrial and residential increased except for the Baltic state where agricultural land increased at the expense of forest cover.

Alig *et al.*, (2010) in modelling on land base interactions between forests, agriculture, and residential development inferred that incentives to landowners discouraged forest conversion to other land uses. In Brazil, Féres, Reis and Speranza, (n.d.) also established that a decrease in the rate of forest conversion contributes a dampening effect on CO_2 emissions and a decrease in CO_2 emissions moderates climate change. Socio-economic factors primarily determine agricultural land use and land use change such as extensification and intensification. Agricultural land is usually abandoned when it ceases to be economically profitable (Berry *et al.,* 2006). Transfer of land from one sector to another is usually underpinned by its potential economic value in one sector as against the other (Alig *et al.,* 2010). In agriculture, because land use change implies a reduction in productivity, only unprofitable, marginally productive or surplus lands are changed (Smith *et al.,* 2007).

Land use decision is influenced by varied factors. It is hence imperative to investigate and understand these factors and their role in land use decision. Taylor *et al.,* (n.d.) for instance explain that climate strongly impacts both recreation and tourism and is strongly linked with micro economies. This keenly influences the land use decision within this catchment area significantly as varied land uses have varied economic benefits within particular socio-economic and demographic environments. Between agricultural land use and other land uses as residential, industrial and commercial, van Delden *et al.,* (2008) observed a loss of agricultural land to tourism and recreation over the period 1990-2000 in the Mediterranean. Some of these land use change may be prevailing because farmers envisage a more sustainable livelihood sources directly or indirectly as recreation and residential expansions will create more jobs and attract people and provide the economic backbone for the development of livelihood options alternative to agriculture. This could be a pull factor towards such trends of land conversions.

2.6.4 Land Use Change in Ghana

In Ghana, trends of land use change and the driving forces thereof are not different from those persisting on the continent as a whole. Expansions in recreational, commercial, industrial and agricultural sector continue to yield varied land uses in Ghana resulting from a dynamic interplay of socio-economic and institutional factors (Ayivor and Gordon, 2012: Ministry of Lands and Natural Resources, 2012). Land use change and energy consumption are two prime sources of Ghana's carbon dioxide emission (Asante and Amuakwa-Mensah, 2015). Ghana's REDD+ Readiness Proposal, (2010:35) identifies the principal drivers of deforestation and degradation broadly as: agricultural expansion (50%), wood harvesting (35%), urban sprawl and infrastructure development (10%) and mining and mineral exploitation (5%). Urbanization and urban sprawl have increased demand for land, constraining sustained agricultural activities within and around urban and peri-urban areas (Danquah, 2013).

In Northern Ghana, arable land degradation is predominant due to intensive cropping and livestock grazing practices (Asante and Amuakwa-Mensah, 2015). This coupled with climate change vulnerability trend in the region requires that land use decisions be influenced to ensure sustainability of livelihoods, and conservation of soil carbon stocks through sustainable land use practices. Expansion of cocoa farms into forest frontiers has been the prime means of increasing cocoa production in the forest belt of Ghana (Anim-Kwapong and Frimpong, 2006). Shifts from shaded cocoa farming systems to open cultivations has increasingly led to rapid loss of forest cover especially in the Western Region (Bampo *et al.*, 2010). This results in both a reduction on atmospheric carbon sequestration and reduction in forest carbon stock of the country amplifying global warming. Anim-Kwapong and Frimpong, (2006) in response to the trend in cocoa production in Ghana add, low income, lack of facilities, high cost of inputs, low level of knowledge on best cocoa farming practices and behavioral change as contributors to a high deforestation rate in the cocoa production belt. Illegal mining, indiscriminate sand winning, charcoal extraction, reduced fallow periods in response to population pressures, are activities outlined by Pagett and Acquah, (2012) that lead to forest loss and land degradation.

However, these also drive land use change indirectly. An appreciable number of these practices underpinning land use change also constitute key adaptation practices as found by Ngigi (2009). Ayivor and Gordon (2012) found that land use in the Densu, Birim and Ayensu river basins have undergone major changes in the last 30 years. This has predominantly been from forest to agriculture, residential, urban, transport and grazing. Changes in land cover and land use affect climate variables as temperature, precipitation and humidity (Nduati and Mundia, 2013). The land users are in most instances ill-informed on the climatic and environmental implication of their land use decisions (Gyasi *et al.*, 2006). Brown *et al.*, (2014) purport that landowners may not be willing to modify land use to support climate change mitigation and adaptation because of three major reasons. First, land use decisions are influenced by socio-economic, cultural and policy among others and not only climate. Secondly, some land covers are just difficult to modify or change and lastly, uncertainties of who climate mitigation and adaptation benefits may accrue to discourage land owners from subscribing fully to such programmes. Hence, the economic value of land is an overriding factor in land use decisions in most cases (Lin *et al.,* 2012).

An enhanced understanding of the factors influencing land use decisions and the ability to project for future trends is essential if land use and land cover change is to be seen and utilized as one of the major channels of mitigating climate change (Solomon *et al.*, 2009). Inconsistency of the land policy with other policies due to lack of land use plans at the Regional and District levels is a major challenge. There is the need for a coordinated land policy and planning at all spatial levels - national, regional, district and plot.

2.7 ACTION THEORY ON ADAPTATION: A THEORETICAL FRAMEWORK

2.7.1 Introduction

The study primarily considers action undertaken by smallholder farmers in response to climate variability and climate change as stimulus and therefore adopts the action theory on adaptation (Eisenack and Stecker, 2010). The action theory on adaptation conceptualizes adaptation to climate change as actions, systematically analyzing the actor relations involved in adaptations and the barriers to their implementation. By framing adaptations as actions, the purpose of adaptations and how they tend to connect in means-ends chains becomes crucial. Actors can take different functional roles as exposure unit, operator and receptor of adaptation. A mismatch of these roles can lead to barriers to adaptation, of which four types can be deduced: complex actor relations, missing operators, missing means and unemployed means (Eisenack and Stecker, 2010).

The theory relies specifically on human systems, individuals and collective actors built around established concepts. It is premised on the fact that actions require actors and must be underpropped by intentions. These intentions are geared towards the impact of stimuli- climate change (Eisenack and Stecker, 2010) Furthermore, adaptations require the use of resources as means to achieve the intended ends. The action theory on adaptation is hereby deemed an appropriate body of knowledge to put the study into a broad theoretical perspective within research and academic discourse.

2.7.2 The Stimulus Concept

In the theory, a *stimulus* is defined as a change in biophysical (in particular meteorological) variables associated with climate change. Stimuli can thus refer to changed values of statistical parameters such as average intensity, frequency, or higher statistical momenta (e.g. variance). They can also refer to abrupt large-scale events in the earth system (Eisenack and Stecker, 2010). According to Eisenack and Stecker (2010), there is also a difference between strictly meteorological effects, such as temperature and precipitation patterns on the one hand, and more or less indirect effects such as rising sea level or greater frequency of river floods as was also noted by Trenberth *et al*., (2002). As this study focuses on CVCC in the Bosomtwe District, variations in such statistical parameters as temperature, rainfall amount, intensity and frequency and the indirect effect of flooding are eminent and therefore considered as the stimuli necessitating adaptation.

2.7.3 The Exposure Unit Concept

A stimulus is only relevant for adaptation when it influences an *exposure unit*. The *exposure unit* broadly refers to all those actors, social, technical or non-human systems that depend on climatic conditions, and are therefore exposed to stimuli (Eisenack and Stecker, 2010). The abstract term is necessary to encompass the broad diversity of affected entities or systems that may be considered in an adaptation assessment. Although we are concerned with an action theory here, we explicitly do not restrict exposure units to human systems. Climate change and climate variation in the Bosomtwe District directly influences, farmer knowledge of rainfall pattern that informs type of crop planted and the farming system/practice adopted. It therefore implies that smallholder farmers, crops and their farm practices constitute exposure units within the action theory of adaptation.

2.7.4 The Impact Concept

From the theory, an *impact* of climate change is understood by a combination of a stimulus and an exposure unit. More broadly, it can be a set of stimuli with an associated set of exposure units (Eisenack and Stecker, 2010). Mahrenholz, (2008) defines adaptation as actions taken in response to or in anticipation of actual or projected climate change (stimuli) to reduce or curtail impacts or maximize available opportunities in the change constitute adaptation. These actions as Mahrenholz (2008), puts it are undertaken by the exposure units in response to the various stimuli in question. In the case of this study, variation in farmers' knowledge of rainfall seasons, reduced crop yield and changes in farm practices are impacts of inconsistent and reduced rainfall, floods and drought (stimulus) on farmers' knowledge, crops, and farm practices (exposure unit) respectively. The impacts therefore reflects the interaction between the stimuli and the exposure unit necessitating the potential and possible response to the resultant interaction between the two. Adaptation is thus a kind of a synthesis between the stimulus (independent) and the exposure units (dependent). Hence the greater the interface (exposure) between the exposure unit and the stimuli, the greater the need to adaptation (Eisenack and Stecker, 2010).

2.7.5 The Operators and Actions Concepts

In this theory on adaptation, the individual or collective actors that exercises the response is called the *operator*. This distinct term is necessary, since actors also play other roles in this theory. An operator can be, for example, a private household, a firm or a governmental actor. But in all cases it is a social entity, so that machines, artifacts and natural systems are ruled out as operators. Not all activities of an operator are actions. Only those activities with a *purpose* qualify for this term (Eisenack and Stecker, 2010). The operator tries to achieve intended ends that are associated with (other) actors, social or non-human systems. The ends are ultimately targeted at impacts. This is hence the resulting effect of a planned adaptation that is focused (Moser and Ekstrom, 2010)

With respect to this study, the response actors are the farmers, district agricultural extension officers, meteorological service and NGOs. The district agricultural extension officers, meteorological service and NGOs are not the exposure unit as they are not affected by variations in temperature, rainfall amount, intensity and frequency and the indirect effect of flooding and drought. They rather exercise response through changes in on-farm and off farm agriculture and livelihood related activities (by farmers) and increased education of farmers on best farming practices amidst current trends of CVCC (by district agricultural extension officers and NGOs). These are activities purposefully undertaken with the intent of lessoning and or mitigating the impacts of CVCC in the Bosomtwe District.

2.7.6 The Receptor Concept

The actor or system that is the target of an adaptation (the purpose) is called the *receptor*. Receptors can be both biophysical entities (e.g. the crops of a famer) and social systems (e.g. the farmer household), depending on the objective of analysis (Eisenack and Stecker, 2010). In this case the receptors are farmers' knowledge, crop type and farming system/practice with the purpose of ensuring appropriate prediction of rains by farmers, adoption of appropriate crops and farming system/practices. It is however not required that the receptor of an adaptation is an exposure unit at the same time.

2.7.7 The Concept of Process and Actions

The theory distinguishes between purposeful action and non-purposeful actions categorizing the former as action and the latter as a process. There are many social phenomena that are not purposeful. In this case, we do not call them actions, but mere processes. *Processes* are sequences of events in time that may occur in a biophysical, technical or social entity or system. They can be framed as being linked through causality, that is, in a mechanistic way. Actions are a special class of social processes that additionally have a teleological component (Eisenack and Stecker, 2010). Tying this to discussions by Smit and Skinner (2002) who categorize adaptation as being anticipatory (proactive), concurrent (during) or responsive (reactive), it comes out clear that Smit and Skinner (2002) looked at adaptation from an inherently purposeful action perspective but only distinguished them based on the time taken for such an intended action to be planned and executed.

2.7.8 The Concept of Means and Conditions

Per the action theory on adaptation, to implement adaptation (*purposeful action*), the operator needs resources, here called *means*. These could be access to financial or other material resources, legal power, social networks, knowledge, or availability of information. In addition, the general body of knowledge that enables the farmer to effectively execute his/her farming endeavors, land and other natural resources as water for irrigation, farm implements and inputs and access to information are all "means" for adaptation. Action is further shaped by constraints and resources that cannot be controlled by the operator. These are called the *conditions* (Eisenack and Stecker, 2010). These constitute government policy that influences farmers' access to early warning system, agricultural inputs and facilities, environmental and ecological resource management policies among others. Public funding, education and equipping of district extension officers and the meteorological services to properly carry out their mandate also constitute *conditions* in this regard.

It is helpful to further differentiate three notions of means: available means, employed means and necessary means. Available means are those that are disposable by the operator (available), while the employed means is that part that is actually used for a specific adaptation. That does not imply that the adaptation is effective, since success requires the use of the necessary means – which might be available or not. It is important to note that these three types of means are not necessarily identical. The use of this action theory on adaptation yields a complex interaction between the stimuli, the actors, means and the concomitant adaptation processes and barriers resulting from it.

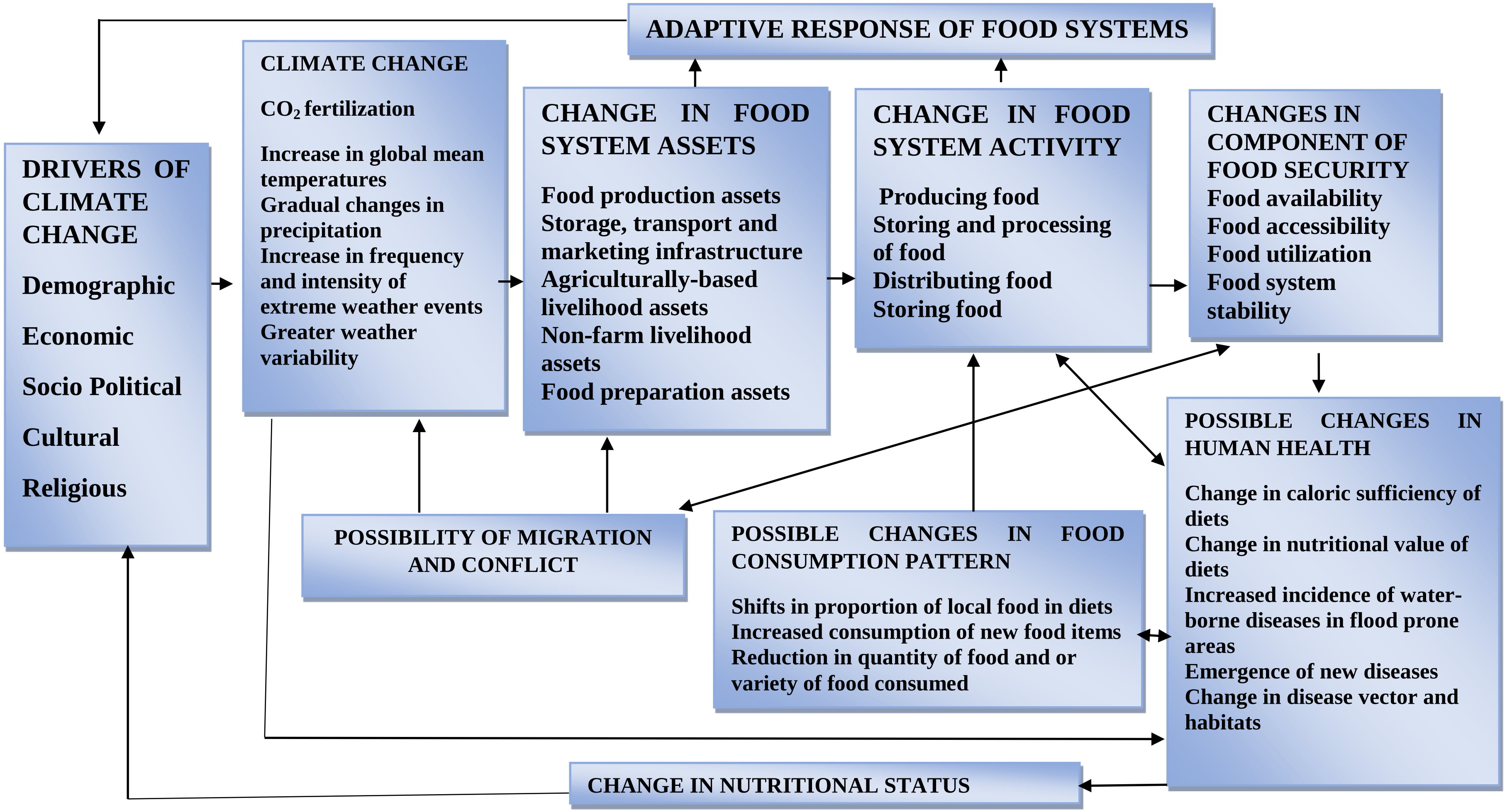
2.8 CONCEPTUAL FRAMEWORK

2.8.1 Climate Change and Food Security: A Conceptual Framework

The Food and Agricultural Organization of the United Nations (FAO) developed the Climate Change and Food Security framework -CCFS framework (FAO, 2008) that explains the inter-relationship between climate change and food security. The framework as illustrated in Figure 2.3 shows how climate change affects food security outcomes for the four components of food security *viz* food availability, food accessibility, food utilization and food system stability in various direct and indirect ways. Climate change variables influence biophysical factors such as plant and animal growth, water cycles, biodiversity and nutrient cycle, and the ways in which these are managed through agricultural practices and land use for food production. Climate change affects all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It also has an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. People who are already vulnerable and food insecure are likely to be the first affected (FAO, 2008).

The framework outlines the drivers of global warming as demographic, economic, socio-political, technological, cultural and religious and the resultant climate change is induced. This change affects food system assets and is together with the drivers influenced by the adaptive response that emerge in the process. Change in food system assets impinges on food system activities which in turn induces changes in the components of food security –food availability, food accessibility, food utilization and food system stability. Pattern of food consumption is equally affected in the process (FAO, 2008). Migration and conflict are possible outcomes of change in climate and also influences food system assets and the components of food security. The entire process culminates to changes in human health. This affects the drivers of global warming through change in nutritional status. The framework illustrates how adaptive adjustments to food system activities will be needed all along the food chain to cope with the impacts of climate change. Climate change will affect food security through its impacts on all components of global, national and local food systems. Agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material (FAO, 2008).

Figure 2.3 Climate Change and Food Security: A Conceptual Framework

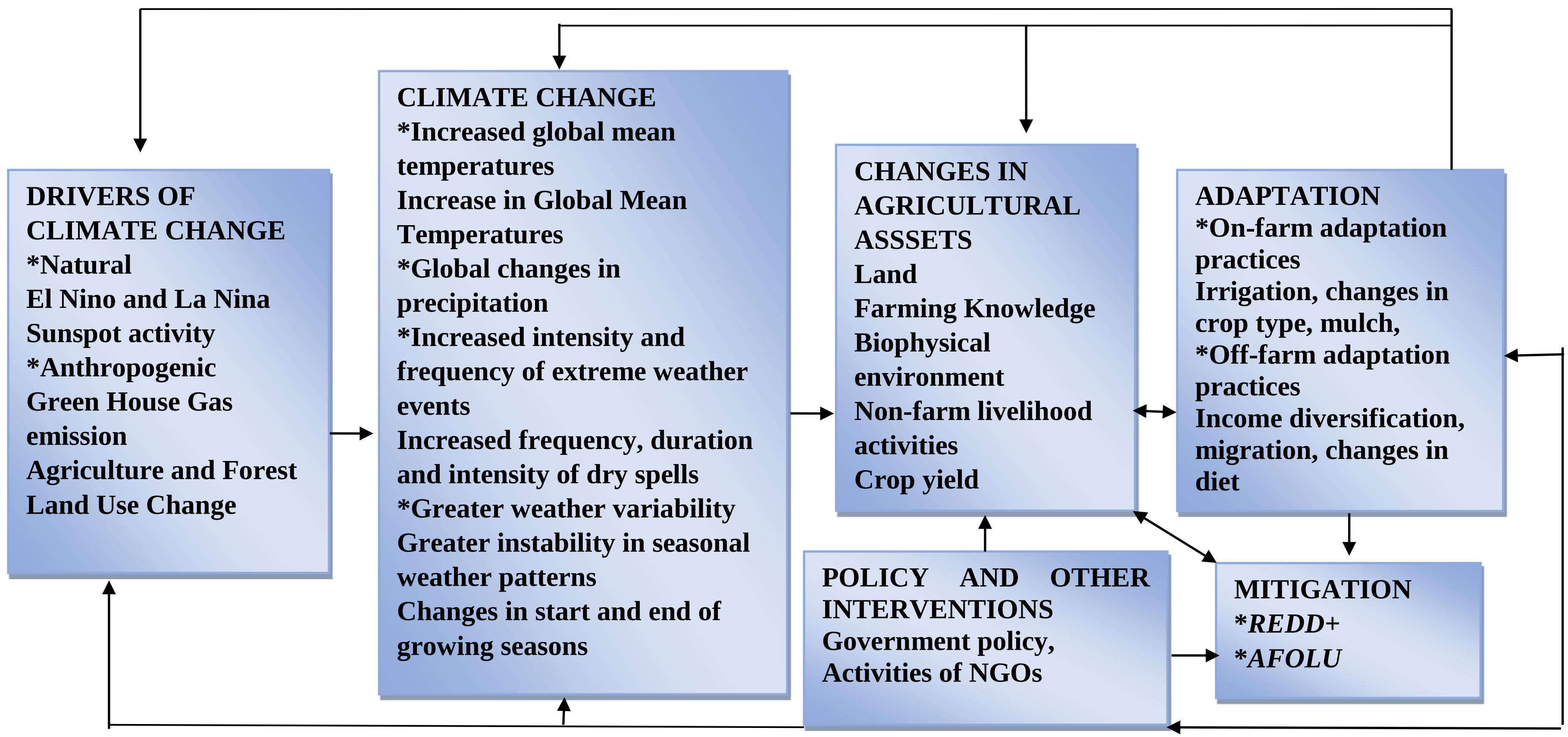


Source: Food and Agricultural Organization, (2008, p13)

This framework has been adopted and modified to bring out clearly the relationship between climate variability and climate change, and farmers' mitigation and adaptation strategies. The modified framework (Figure 2.4) outlines natural and anthropogenic element as drivers of global CVCC. The United States Environmental Protection Agency- EPA, (2010) attests that climate change is caused by both natural and anthropogenic factors. Human activities such as land development for roads, farms and cities, deforestation, and burning of fossil fuel release greenhouse gases into the atmosphere enhancing the natural global warming system and thereby inducing change in the global climate. Climate change has since time immemorial been part of the earth's natural system, resulting naturally from oceanic and atmospheric circulation, changes in the earth's orbit, changes in solar radiation and volcanic activities (U. S. A. EPA, 2010). Anthropogenic activities have since the industrial era however increased the concentration of greenhouse gases in the atmosphere amplifying the greenhouse effect. This has led to the current warming being experienced on the earth's surface (DeGaetano, n.d.)

This trend of variation affect key assets necessary for agriculture such as the knowledge base for productive agricultural engagement, biophysical environment that support agricultural activities and non-farm livelihood assets that supports agriculture such as access to capital positively and negative. To ensure continues crop production and sustained household food and income supply, adaptation at the on-farm and off-farm level is necessary. Climate change as an environment-related risk poses threat to natural assets (such as farmland, soil quality), physical assets (such as storage sheds, implements, animals, crops) financial assets (such as access to loans) human assets (such as farming knowledge) and social assets (like social networks, communal support systems) in agriculture directly and indirectly (Caldecott *et al.*, 2013).

Figure 2.4: Farmers Mitigation of and Adaptation to Climate Variability: A Conceptual Framework



Source: Adopted and Modified from FAO (2008).

Climate change affects crop yield and hence food security through direct impact on soil fertility and grown crops (Defang *et al.,* 2014). In the tropics, crops such as beans, maize, rice, wheat and potatoes will be adversely affected due to their sensitivity to temperature changes. These are key food sources for millions in Africa (IPCC, 2001b). Such changes in agricultural assets necessitates both on-farm and off-farm adaptation in order to ensure sustained household food and income supply. These according to Ngigi (2009) include adoption of improved crop varieties, proper soil nutrient and water management practices, irrigation and diversification of livelihoods to involve non-farm income sources. Babatunde and Qaim, (2012) explains that important synergies exist between agriculture and other non-agricultural development. Off-farm income sources are increasingly gaining prominence.

The change in these assets affect various mitigation activities as REDD+ and AFOLU that are adopted and the extent to which these mitigation activities can be sustained. To this Smith *et al.,* (2014:842) asserted that social actors in the AFOLU sector include individuals (farmers, forest users), social groups (communities, indigenous groups), private companies (e.g., concessionaires, food-producer, multinationals), subnational authorities, and national states. Also, level of education, cultural values and tradition, as well as access to markets and technology, and the decision power of individuals and social groups, all influence the perception of potential impacts and opportunities from AFOLU measures. Bwalya (2010) notes that climate change must be addressed effectively to ensure global food security.

A two-way relationship exists between policies and interventions on one part and the drivers of climate change, manifestation of climate change, agricultural assets, adaptation and mitigation on the other. The various adaptive responses will to some extent influence the various manifestation of climate change at the local, national and regional levels and also influence vulnerability. Magnan, (2014) purports that maladaptation can negatively affect adaptation initiatives and increase vulnerability to CVCC. It is therefore important that mitigation and adaptation efforts be flexible enough to incorporate dimensions that secure social, physical, natural, financial and human capitals of the vulnerable to safeguard their livelihoods from current and future risks.

The manifestations and experience of climate change in the temperate and tropics are disparate because of varied agricultural systems, socio economic patterns and policy response. Hence, there exist disparity and uncertainties of impacts of climate change on agriculture (Ludi *et al.,* 2007). The total cost accruing to humanity from CVCC is revealed in three ways: impact costs, mitigation cost and adaptation cost (Olesen and Porter, 2009). Government policies have been geared towards adaptation and mitigation by direct or indirect impacts on the drivers of greenhouse gas emission (Bockel *et al.,* 2011: Wilkes *et al.,* 2013). Due to the threat posed to access to assets amidst current trends of climate change and the concomitant interventions to ameliorate the situation, Slater *et al.,* (2007) called for a rights-based approach to enhance the bargaining power of the vulnerable and poor and the strengthening of their asset base. These efforts must be holistic, ensuring that all stakeholders at the farm, regional, national, and global scales are resourced and enabled to play their respective roles effectively. The framework illustrates that there exists an intrinsic interconnectivity between climate change, agriculture, adaptation, mitigation and policy.

The framework pivots around climate change and its repercussive influence beyond direct impacts on agriculture. Clearly, there is a multifaceted connectivity with farmers' response to CVCC either as autonomous or planned adaptation. Also, it cannot be affirmatively said that governments response will yield the planned or desired outcomes as many demographic and socio-economic factors influence adaptation and mitigation though policy will influence the drivers of climate change through both as well as agricultural assets.

The climate change and food security framework is deemed appropriate because of the similitude of its key components with this study being climate and agriculture. However a modification was necessary to help highlight the particular components in this study and clearly establish the interconnections therein. The framework helps to appreciate such connectivity and offers the opportunity to critically assess the linkages that exist among these component.

CHAPTER THREE

BIOPHYSICAL AND DEMOGRAPHIC CHARACTERISTICS OF SMALLHOLDER FARMERS IN THE BOSOMTWE DISTRICT

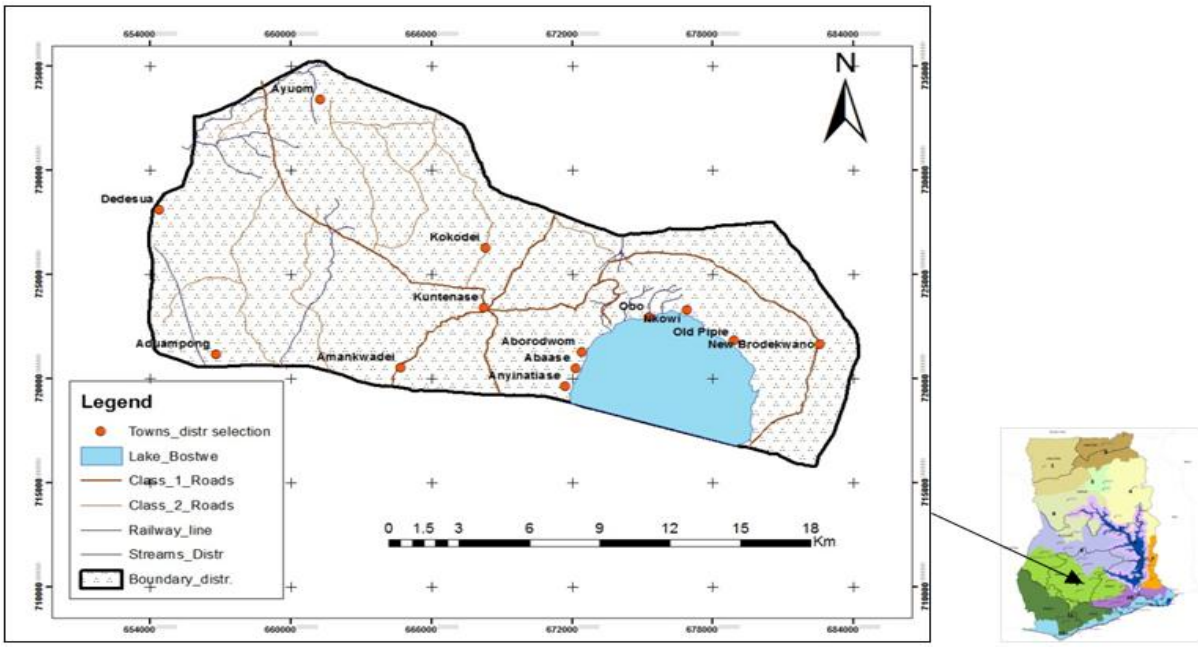
3.1 INTRODUCTION

This chapter gives the detailed background information on the study area. This analysis is categorized into geographical and socio-economic characteristics, as relevant to the objectives of the study. The chapter also contain maps showing the Bosomtwe District in national context and the geographical location of the twelve selected study communities. The data revealed that the district is predominantly agrarian with a high dependence on forest resources for livelihoods. Climate variability and climate change indices as temperature, rainfall, droughts and floods have been experienced in the district. This coupled with peculiar socio-economic characteristics of residents and the physical features of the district results in a distinctive situation with respect to adapting to the situation. Also, the forest has undergone various forms of anthropogenic disturbances due to various land use changes with ramifications for forest cover.

3.2 LOCATION AND SIZE

The Bosomtwe District is located at the central portion of the Ashanti Region. It lies within Latitudes 6° 24' South and 6° 43' North and Longitudes 1° 15' East and 1° 46' West (See Figure 3.1 showing Bosomtwe District in the National and Regional context with the selected communities in the Bosomtwe District). The District is bounded on the North by Kumasi Metropolitan Area, to the East by Ejisu-Juaben Municipal and Bosome Freho District and on the West by Atwima-Kwanwoma District. The Southern section is bounded by Bekwai Municipal Area. Kuntanase is the district capital (Bosomtwe District Assembly Profile, 2010).

Figure 3.1: Bosomtwe District in the National and Regional context with the study communities



Source: Author's construct (2015).

According to the 2010 Population and Housing Census, the District covers an area of approximately 500 square kilometers. This forms about 1.5% of the land area of Ashanti Region with part of the eastern end being covered by Lake Bosomtwe. The District is made up of three Area Councils namely: Kuntanase, Boneso and Jachie area councils. Its proximity to the Kumasi Metropolis poses a serious challenge in terms of efforts to develop market centers as most farmers prefer sending their produce to the metropolis to sell for higher prices. The rural dwellers are gradually losing their farm lands to residential developers and this has also made the cost of land very expensive. However, the District's nearness to Kumasi makes it easy to access some specialized high level commercial, health, administrative and other services (Bosomtwe District Assembly Profile, 2010).

3.3 PHYSICAL FEATURES

3.3.1 Relief and Drainage

With the exception of the Lake that has an outer ridge that maintains a constant distance of 10km from the center of the Lake and stands at an elevation of 50m to 80m, the rest of the district cannot boast of any unique topographical features. The drainage pattern of the Bosomtwe District is dendritic. The rivers flow in a north-south direction. Examples of such rivers are Afoa, Atasuo, Atetesua, Obo and Kwabena. These streams are perennial, forming a dense network due to the double maxima rainfall regime. Notable streams in the district are Oda, Butu, Siso and Supan.

3.3.2 Climate

The district falls within the equatorial zone with a rainfall regime typical of the moist semi-deciduous forest zone of the country. There are two well-defined rainfall seasons. The main season occurs from March to July with a peak in June with an annual average rainfall of 1400mm. The minor season starts from September to November with a peak in October. August is cool and dry. The main dry season occurs in December to March during which the harmattan winds blow over the area. The temperature of the area seems to be uniformly-high and throughout the year with a mean of around 32ºC. The highest mean occurs just before the major wet season in February. The mean minimum occurs during the minor wet season. Relative humidity (RH) is generally high throughout the year. The morning relative humidity (RH) is highest in August (71.6%) and the lowest in January where it is around 42.5%.

3.3.3 Vegetation

The natural vegetation of the area falls within the semi-deciduous forest zone of Ghana, which is characterized by plant species of the *Celtis-Triplochiton* Association.

However, due to extensive and repeated farming activities in the past, the original vegetation has been degraded to mosaic of secondary forest, thicket and re-growth.

3.4 DEMOGRAPHIC CHARACTERISTICS

3.4.1 Population Size and Growth Rates

The 2010 Population and Housing Census gave the population of the district as 93,910 comprising 44,793 males and 49,117 females. The percentage of males and females population is 47.7% and 52.3% respectively. The district shares of the region's population is 4%. It has an estimated growth rate of 3.0% which is less than the regional growth rate of 3.4%. The age dependency ratio for the district is 0.8:2 while the economic dependency ratio of 0.76:1 is almost equal to the age dependency (Ghana Statistical Service- GSS, 2014).

3.4.2 Population Density

The population density of the district has been increasing steadily. Currently the district has a population density of 222.3 persons per square kilometers which is higher than 196 persons per square kilometers for the region (GSS, 2014). Migration towards the urban centers is high causing lower densities in some rural areas.

3.4.3 Household Sizes

Households are of the family and compound types especially in the rural areas. Relatives and family members live together in houses with an average household size of four (4) people. However, rural communities in the district have an average household size of four point one (4.1) while urban communities have an average household size of three point nine(3.9) (GSS, 2014). This is made up of extended family system of grandfather, father, grandmother, children and mothers. Most houses are built of landcrete with few made of sandcrete. Buildings are roofed with thatch and bamboos especially in remote areas of the district. Nevertheless, in some of the major settlements there are houses built with cement blocks and roofed with aluminum sheets. Some of the peri-urban settlements have tile roofs.

3.4.4 Age and Sex Composition

The age and sex structure of the district depict a situation where males outnumber females in the age group from 0-14 years. However, a revers situation is seen other age cohorts with the exception of the 40-44 age cohort where males are more than females. This can be explained among other reasons by the fact that, it is mostly, the men who migrate in search of jobs leaving the women to take care of the children (GSS, 2014).

Table 3.1: Age Distribution of Population

Age cohort	Percentage
0-14years	44.0%
15-64yrs	49.0%
Above 64years	7.0%

Source: 2010 Population and Housing Census Report.

The dependent population conceptually, is made up of age group 0-14 years (Child dependency) and 65 years and older (older dependency). The dependent population of the district is 75,618 (51.7%) and the working population is 70,410 (48.3%). The ratio was estimated to be 0.8:1, which implies that, there are more people in the working age group. The critical issue here is their productivity levels and how many of these people are gainfully employed. The economic dependency ratio is estimated at 0.76:1 that is even lower than the age dependency. This means, there is a potential for savings that can lead to investments and job opportunities in the district (GSS, 2014).

3.4.5 Land Related Practices

The lands are relatively flat with the exception of areas around Lake Bosomtwe where hilly lands are found. There is a lot of indiscriminate bush burning in the district. This results in soil degradation, and directly affects flora and fauna. Most of the forest in the district has turned into secondary growths. Teak trees have been cultivated in most part of the District with Tetrefu recordings the highest number. There is also a Non-Governmental Organization with Agro-Forestry Programme along the Lake Basin. This can be located at Jachie and Behenase with 11.5 hectares and 10.4 hectares respectively. The district has extensive forests with the existence of species such as Mahogany and Wawa. Unauthorized lumbering activities are found in most communities under the Boneso Area Council. Notable amongst them are Mim, Asisiriwa and Brodekwano. Crop farming also occurs in the forest, providing employment for about 57.4% of the population. Some farmers practice slash and burn. Most of the inhabitants use fuel wood obtained from the forest as their main source of energy (Bosomtwe District Assembly Profile, 2010).

3.5 ECONOMIC AND LIVELIHOOD ACTIVITIES

The district economy is made up of agriculture, servicing and commerce. The major occupation in the district is agriculture that employs 62.6% of the labour force. Of this, crop farming employs 57.4% and fishing 5.2%. Crops produced in the district include maize, cassava, vegetables, yam and plantain. Maize, which is the predominant crop, has an advantage over the other crops because it has good market, matures early and can also do well on all the soils within the district. It can also be cultivated twice on the same field in one year. Cassava also thrives well in greater parts of the district. About 41% of those engaged in other occupation still take up agriculture as a minor occupation (Bosomtwe District Assembly Profile, 2010).

Table 3.2: Structure of District Economy

Occupation	Percentage
Service	19.0%
Industry	17.0%
Agriculture	62.0%
Other	2.0%

Source: 2000 Population and Housing Report, (2010)

The second highest occupation is service. It employs about 19.1% of the working population. This sector comprises government employees, private employees and other workers. The educated labour force dominates this sector. Industrial activities are undertaken in both small and medium scales. It also employs 16.7% of the working population. The problem with the industrial sector is its weak backward and forward linkages with the agricultural sector. Most of the industries are agro-based. Another category in the occupation structure is trading which employs about 11.31% of the working force. Women dominate this sector. About 56% of the goods are industrial hardware brought from Kumasi and sold within and outside the district. Even though it would be very difficult to really assess real unemployment, seasonal or disguised unemployment form about 20% of the working age group (Bosomtwe District Assembly Profile, 2010).

CHAPTER FOUR

SMALLHOLDER FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE: THE EVIDENCE

4.1 INTRODUCTION

This chapter constitutes the analysis and discussion of the demographic data of smallholder farmers in the Bosomtwe district. It also examines the trend of climate variability using secondary data from the meteorological services department. This was done by analysing climate data on rainfall and temperature of the Bosomtwe District for a 30 year period from 1981 to 2011, focusing on annual, inter annual and monthly variation in rainfall and temperature patterns using the statistical anomalies method. Temperature and rainfall average values for a 30 year period known as climatological normal is usually used to determine climate for a particular region (Dinse, 2011). Lastly, on-farm and off-farm adaptation practices, and alternative livelihood of smallholder farmers was assessed.

4.2 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Analysis of the socio-demographic characteristics of the smallholder farmers revealed a trend that brings to the fore the imperative need of farmers to adapt. Majority of the respondents (46%) were of the age group 46-55 years. The next two successive categories were the 36-45 years and 56-65 years. They had 33% and 21% respectively. A total of 79% of respondents were less than 56 years implying they were young and energetic. Most of the respondents (82%) were married, and therefore needed to cater for their households through diverse economic activities including agriculture. Also, 51% of respondents were household heads while and 46% were spouses of household heads and the remaining 3% were other relations. The communal nature of the societies is such that information is not restricted to household heads only. Frequent migration among males, especially in the lean and dry season, coupled with the fact that much of household spending is done usually by the women makes them adequately informed on household spending patterns. Okonya *et al*., (2013) found that female-headed households in Niger were less likely to respond to climate change than male-headed households. This was probably because in the traditional African setting, it is a man's duty to ensure that household food supply is secured and women in most cases are expected to play complementary roles. This was however not the case in the Bosomtwe District as both male and female heads made effort to adapt. The analysis also showed that 63% of the respondents had formal educational level below senior high school while only 11% were educated up to the senior high school and only one percent had tertiary education. Also 25% had no formal education as is evident in Table 4.1.

Table 4.1: Level of education of respondents

Level of education	Frequency	Percentage
No formal education	39	25%
Primary	29	19%
Junior High School	67	44%
Senior High School	17	11%
Tertiary	1	1%
Total	**152**	**100%**

Source: Author's field data (2015).

A low level of education was generally observed amongst farmers and this could affect their adaptation to climate change as was found by Wamsler *et al.*, (2012) in El Salvador and Brazil. Majority of the farmers (90%) had household size of 1-10 members implying there were many mouths to feed and a decrease in crop yields might lead to hunger and starvation. Apata, (2011) likewise found in Nigeria that a larger family size increased the need of adaptation. Majority of the farmers had farming experience of 16-20 years (38%) and 21 years and more (41%). This confirms that most of the respondents have been farming long enough to have noticed changes in seasonal weather patterns.

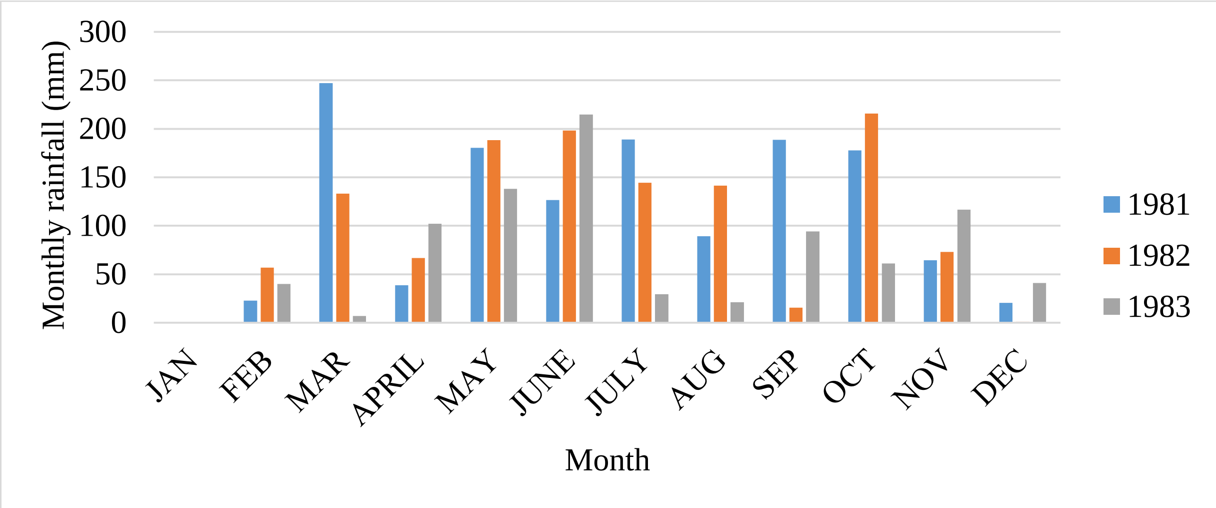
4.3 TRENDS OF CLIMATE VARIABILITY AND CLIMATE CHANGE IN THE BOSOMTWE DISTRICT

4.3.1 Analysis of Rainfall Trend

The district falls within the equatorial zone with a rainfall regime typical of the moist semi-deciduous forest zone of the country. Two well-defined rainfall seasons are experienced. The major season occurs from March to July reaching its peak in June and the minor season starts from September to November with a peak in October. August is usually cool and dry as the Inter Tropical Convergence zones shifts up north for the single maxima rain period of the Northern part of Ghana. The main dry season occurs in December to March during which the dry harmattan winds blow over the area but sometimes with few rains (Environmental Protection Agency, 2011). The bimodal and unimodal rainfall regimes in Ghana results in rainfall variation depending on the geographical location of a place and the particular season (rainy or harmattan). Crop yield is expected to be adversely affected by climate change through stress on water sources for agriculture. This includes rainfall and surface and ground water (Thompson *et al.,* 2010). Monitoring surface and groundwater will enable forecasting for floods and droughts for early public awareness creation (Akoh *et al.,* 2011). Such an understanding will not be complete without an awareness of rainfall trends that primarily makes water available for agricultural activities and recharges both surface and ground water.

The average rainfall amount for the period 1981 to 2011 was 117.4mm which served as a baseline for analysis of the rainfall pattern. The period 1981 to 1983 generally experienced a decrease in mean rainfall of 16.5mm below the average baseline of 117.4mm with 1981, 1982 and 1983 respectively recording average rainfalls of 112.1mm, 112.1mm and 78.6mm. The period experienced high amount of rainfall in the major season up to 247.2mm although 1984 recorded rainfall amount as low as 6.9 in March. The minor season for the period quite inversely recorded an appreciable amount of rainfall than expected with a maximum of 215.6mm and a minimum of 94.2mm. The month of January was dry. August, the respite period between the two regimes noticeably recorded 89.1mm, 141.4mm and 21 mm of rainfall from 1981 to 1983. Relatively low recording for January, February and December can be seen to have adversely affected the overall average for the period. This trend is shown in Figure 4.1.

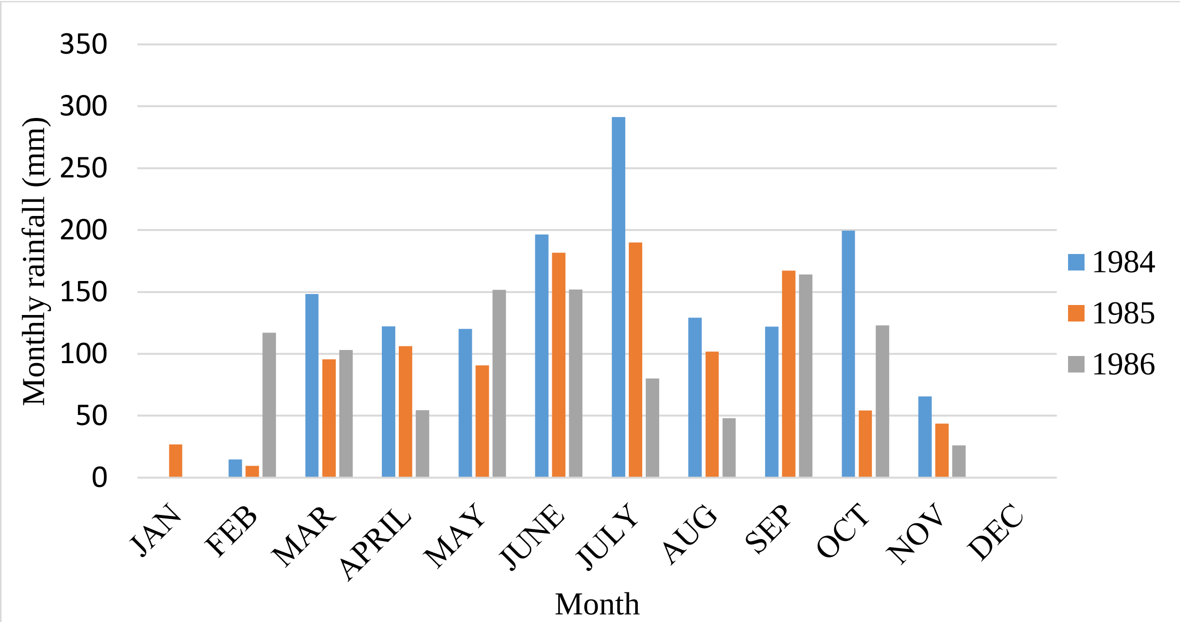
Figure 4.1: Intra annual rainfall distribution from 1981-1983.



Source: Author's construct using District data from Regional Meteorological Office.

The amount of rainfall received for the years 1984 to 1986 fell by 4.1mm below the baseline of 117.4mm of rainfall. Hence this period as compared to the earlier received a higher amount of rainfall although it experienced a very dry season in December and January with the exception of January in 1985 which received 26.9mm of rainfall. Hence the harmattan season from 1984 to 1986 was distinctively dry and the wet season equally very wet. The respective yearly average rainfall for 1984, 1985 and 1986 were 140.9mm, 97.0mm and 101.9mm. The highest amount of rainfall for the major season was 291.4mm and the lowest was 54.6mm while the minor season recorded 199.5mm as its highest and 26.1mm as its lowest which was generally higher than that recorded for the 1981 to 1983 period. The trend was monotonous as usual except for 1983 and 1984 when the major season rainfall peaked July in instead of June. For the minor season of 1985, it peaked in September instead of October. The month of August equally received appreciable amount of rainfall such that instead of a perceived break, there rather seemed to be a continuation resulting in a unimodal rainfall trend. This is shown in Figure 4.2.

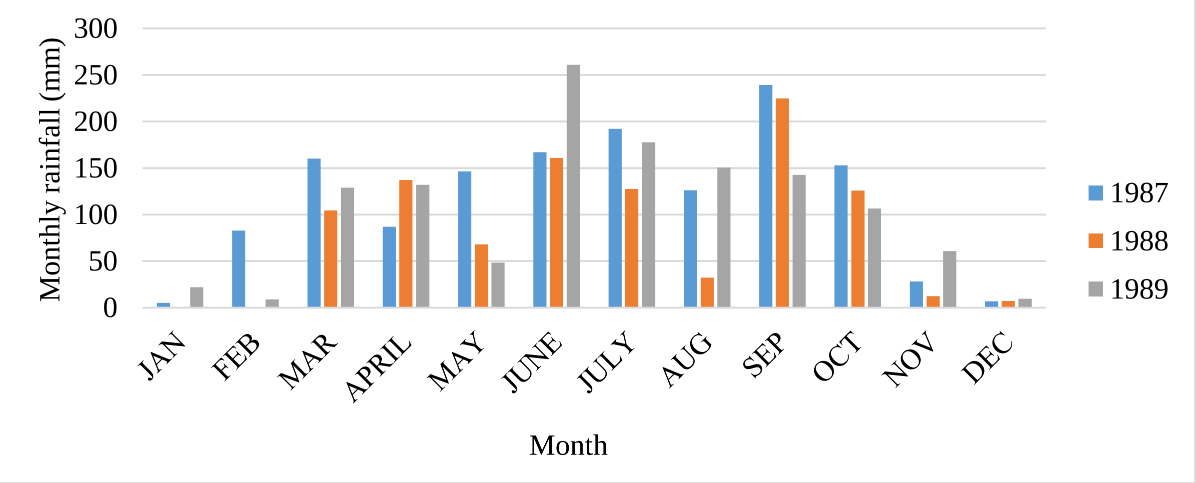
Figure 4.2: Intra annual rainfall distribution from 1984-1986



Source: Author's construct using District data from Regional Meteorological Office.

The soil is expected to remain moist during the major season from March to July when much rain is received to support vigorous agricultural activities. Soil moisture content is likely to reduce in the minor season as the rains reduce and the harmattan season begins. On-farm practices such as use of cover crops, mulch, less or no till practices and irrigation could be adopted to conserve soil moisture. The average rainfall received during the period 1987 to1989 was 10.7mm below the baseline average of 117.4mm which also represents a 6.6mm decrease from the previous period. The highest rainfall recorded for the major season of the said period was in June 1989 which had 260.9mm of rain while the lowest was 68.1mm. July 1987 also recorded the highest for that year instead of June as can be seen in Figure 4.3.

Figure 4.3: Intra annual rainfall distribution from 1987-1989.

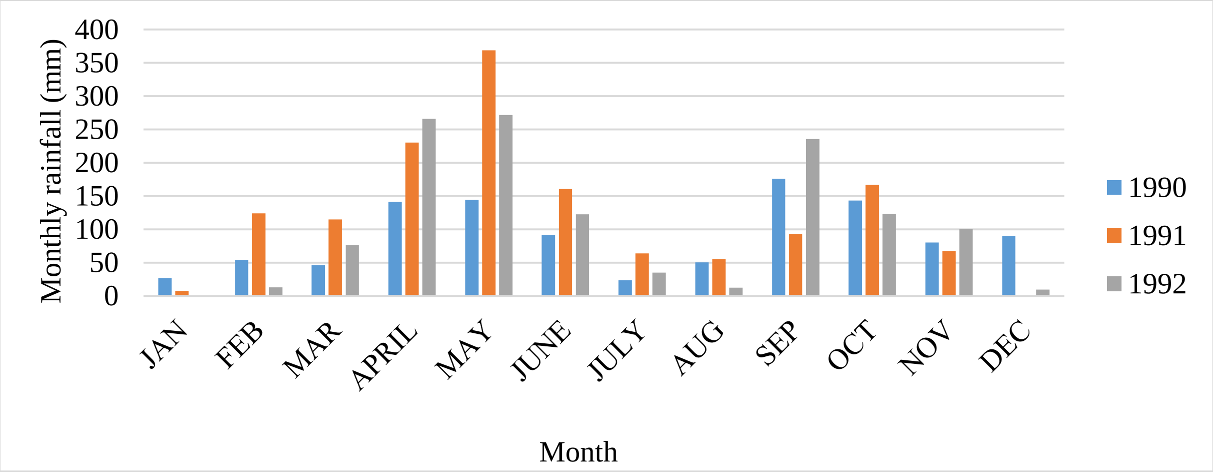


Source: Author's construct using District data from Regional Meteorological Office.

For the minor season, September recorded the highest amount of rainfall instead of October which is said to be the peak month for the minor season with 1987, 1988 and 1989 recording 239.1mm, 224.8mm and 142.6mm respectively. High amount of rainfall within this period was recorded in the major season as compared to the minor season. A unimodal trend is revealed in the 1987 and 1989 rainfall patterns. Particularly for 1989, the amount of rain after peaking in June decreased gradually from 269.0 mm in June, 117.9mm in July, 150.6 mm in August then to 142.6mm in September. Hence, the period experienced a unimodal rainfall regime instead of the usual bimodal trend. The dry season from December to February was not dry. This is clearly seen in Figure 4.3.

Rainfall amount for the years 1990 to 1992 appreciated by 5.2mm above the 1987 to1989 period bringing it to 5.5mm below the baseline of 117.4mm. Within these years, higher amounts of rainfall were recorded in the major season than in the minor season as expected. The period equally experienced significant variation from the usual trend as rainfall peaked in May instead of June for three consecutive years from 1990 to 1992. The month of July received the lowest amount of rainfall in the major season. September also received the highest amount of rainfall for the minor season in 1990 and 1992 while that of 1991 peaked in October. There was a clear break in August for the entire period as rainfall amount fell to 50.4mm, 55mm and 12mm and rose suddenly to 175.8mm, 92.7mm and 235.5mm in September for 1990, 1991 and 1992 respectively. The dry season which stretched from December to February received some amount of rain with February 1991 recording 123.9mm of rainfall though December 1991 and January 1992 received no rainfall, vividly shown in Figure 4.4.

Figure 4.4: Intra annual rainfall distribution from 1990-1992

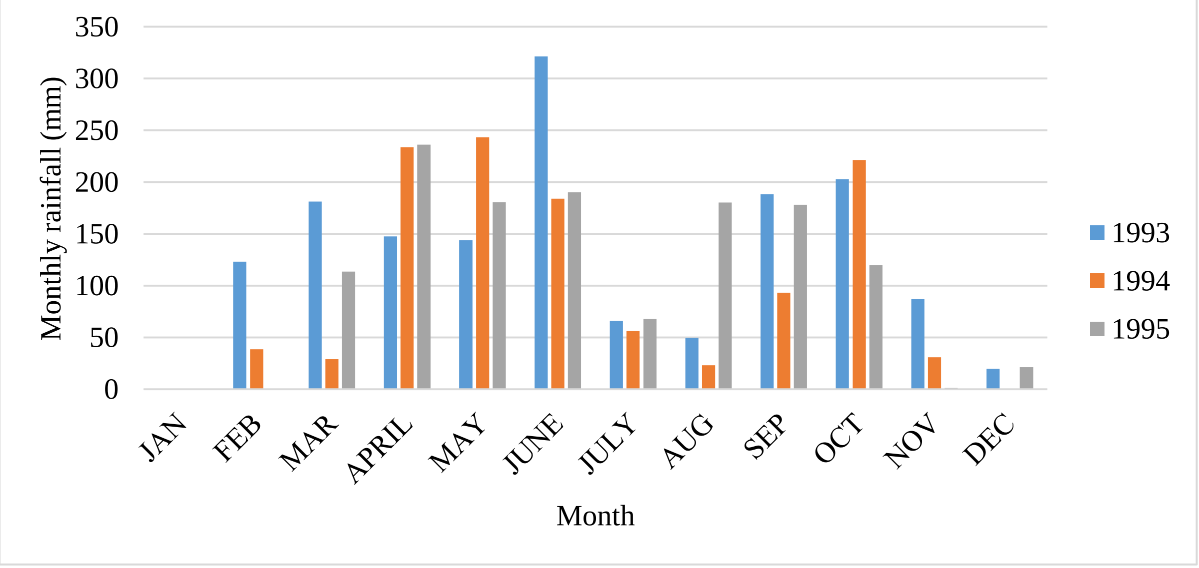


Source: Author's construct using District data from Regional Meteorological Office.

From the foregoing discussions, it is quite imminent that the onset of the rains, its anticipated peak period for both the major and minor season and the tipping off period of the minor season into the dry season has varied quite significantly. Such changes could have adverse effects on the time of planting crops. Also, farmers who are unable to plant early in the minor season may suffer crop loss due to the short period of the minor season and the onset of the dry season that follows. Again, the gradual emergence of the long unimodal regime from April to November has significant implications for the kind of crops that are grown. The brief respite in August allows for cereals proper formation and drying of cereals and other important staples. Such changes without correspondent changes in crops cultivated and agricultural practices may lead to post harvest loses. Use of early maturing crop varieties would be most appropriate. Also improved post-harvest methods would help reduce post-harvest loses. Use of early forecast and warning systems to inform farmers on yearly trend could enable them adapt to the situation effectively. Increased practice of mixed cropping could also lessen farmers' vulnerability to the vagaries of the rainfall trends as loss in a particular crop would be buffered by gains in another.

From the years 1993 to 1995, the mean annual rainfall increased drastically to 127.7mm which was 10.3mm above 117.4mm. The trend was somewhat anomalous as the major season rains peaked in June for 1993 and 1995 though that of 1994 occurred much earlier in May. The minor season rains peaked in October as expected for 1993 and 1994 while that of 1995 occurred in September. The dry season was quite pronounce with January receiving no rain for the entire period. Compared with earlier periods, the 1993 to 1995 period was expected to result in an agricultural boom. This is illustrated graphically in Figure 4.5

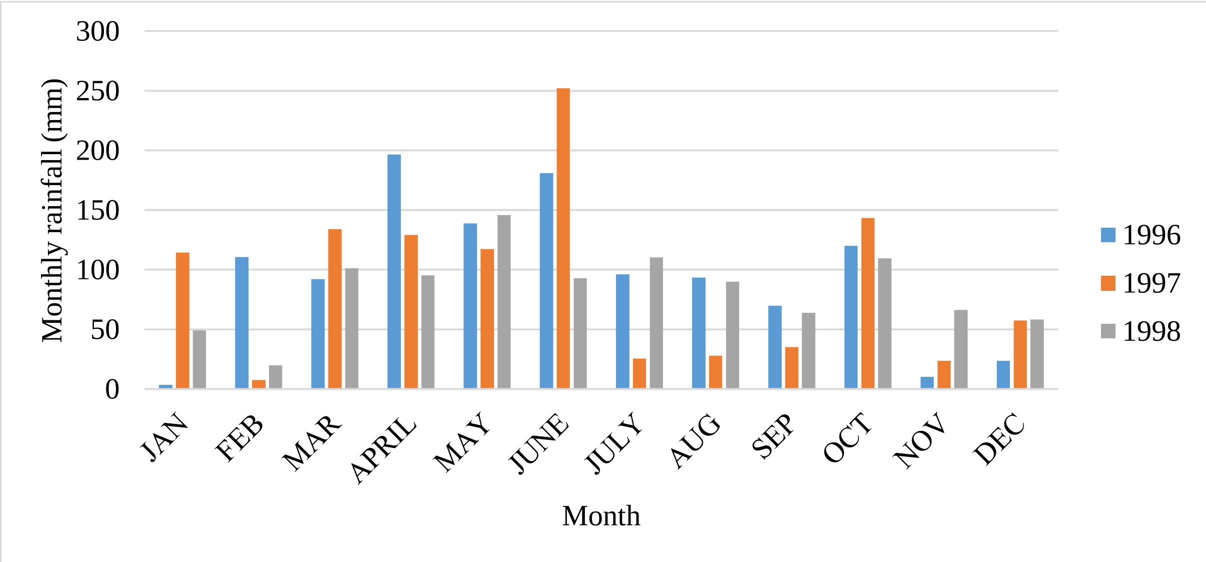
Figure 4.5: Intra annual rainfall distribution from 1993-1995



Source: Author's construct using District data from Regional Meteorological Office.

The 1996 to 1998 stretch quite conversely saw the most drastic reduction in rainfall for the entire thirty year period under consideration. It recorded an average rainfall of 89.0mm which is 28.4mm less the baseline of 117.4mm. Quite noticeably, the rainfall pattern seems to be more evenly distributed in the year as compared with all preceding periods considered as can be seen in Figure 4.6. The major rainfall season peaked much earlier, occurring in April in 1996 and May in 1997 and 1998. The minor season was rather more canonical as the rains climaxed in October for all three consecutive years. Another significant trend in the period is that it did not have any completely dry month with January 1997 recording as high as 114.4mm of rainfall. High amount of rainfall was received in the major season as compared to the minor season. The years 1996 and 1997 also saw a similar unimodal regime trend as did the 1984, 1985, 1987 and 1989 periods as illustrated in the Figure 4.6.

Figure 4.6: Intra annual rainfall distribution from 1996-1998

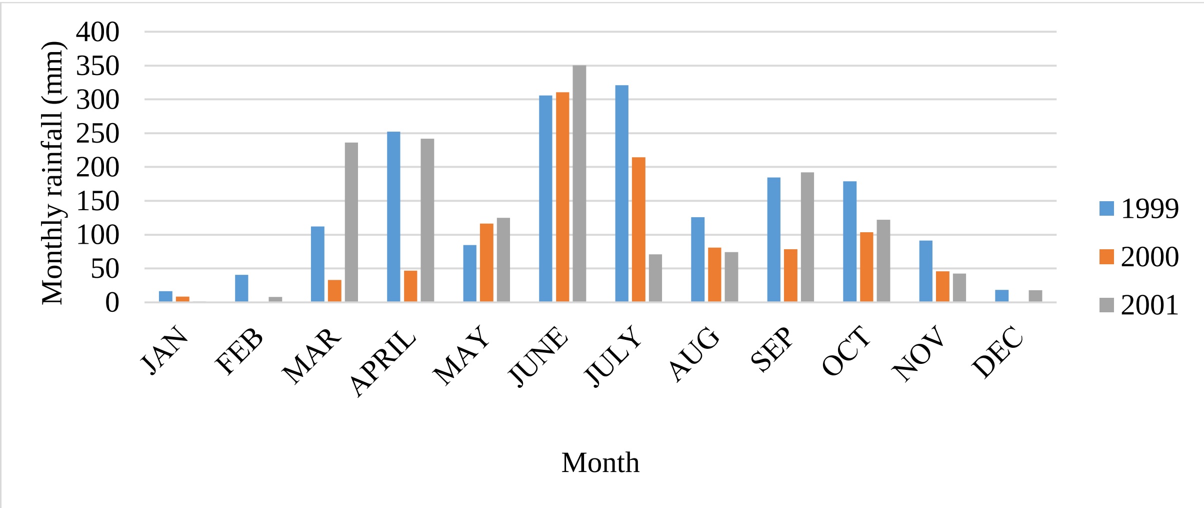


Source: Author's construct using District data from Regional Meteorological Office.

The even distribution of rains throughout the 1996 to 1998 stretch implied that surface and ground water could be constantly recharged throughout the year which could be harnessed for effective agricultural activities. Irrigation, together with soil moisture retention practices as mulching, less or no till, planting of cover crops and the adoption of zai pits could enhance agricultural activities making year round cultivation of crops possible.

The 1999 to 2001 interval recorded a momentous increase in rainfall gaining an average of 0.7mm above the baseline amount of 117.4mm. This is an addition of 29mm from the 1996 to 1998 period of 89.0mm bringing it to 118.1mm. The main rainy season had high rainfall amounts which climaxed in June as expected. The minor season however recorded appreciable rainfall amounts for 1999 and 2001 in September whereas that of the year 2000 occurred in October. The trend for the period denotes a bimodal trends as opposed to the 1996 to 1998 trend. This period did not experience any significant dry spell with the exception of February and December 2000 (Figure 4.7).

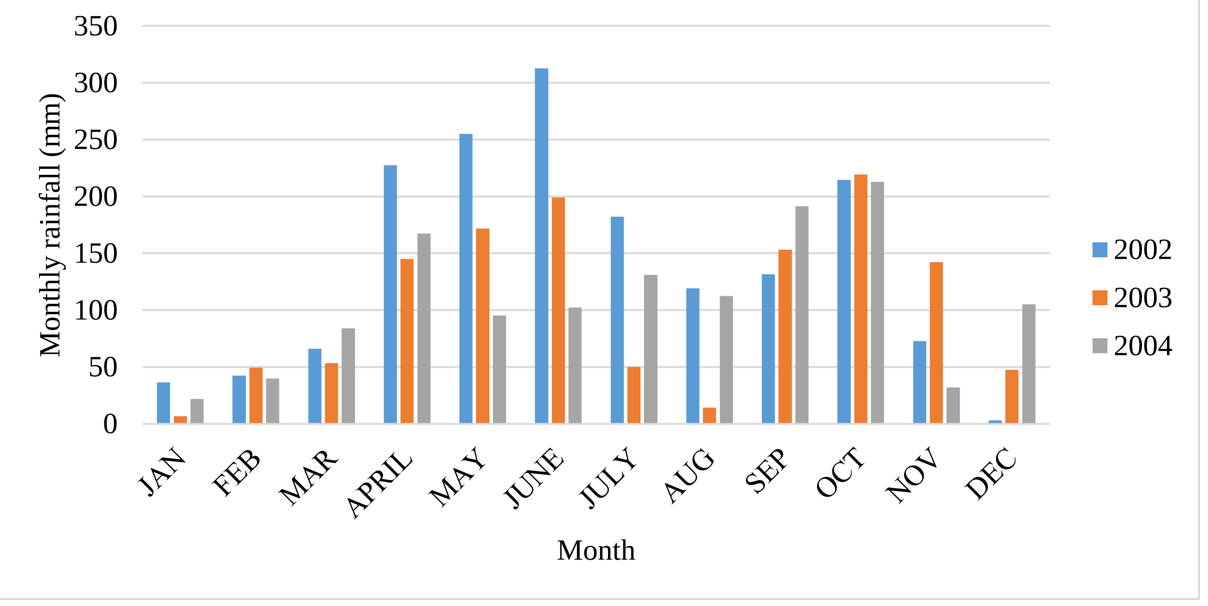
Figure 4.7: Intra annual rainfall distribution from 1999-2001.



Source: Author's construct using District data from Regional Meteorological Office.

The period 2002 to 2004 experienced mean annual rainfall of 116.9mm which is 0.5mm below the average baseline. This represents a decline from the 1999 to 2001 period by 1.2mm of rainfall. The maximum rainfall amounts for the main season for 2002 and 2003 were recorded in June but that of 2004 rather occurred in April. The year 2002 particularly recorded very high amounts of rainfall. The minor season saw high records of rainfall in the month of October as expected. High amount of rainfall was recorded in the major season as compared to the minor season. The brief respite expected in the month of August was not so as it also recorded 119.4mm, 14mm and 112.4mm for 2002, 2003 and 2004 respectively (Figure 4.8). Hence the graph shown in Figure 4.8 does not reveal a clear break but rather one of unimodal trend. This period did not experience any significant dry season except that the month of December to March experienced low amount of rainfall.

Figure 4.8: Intra annual rainfall distribution from 2002-2004



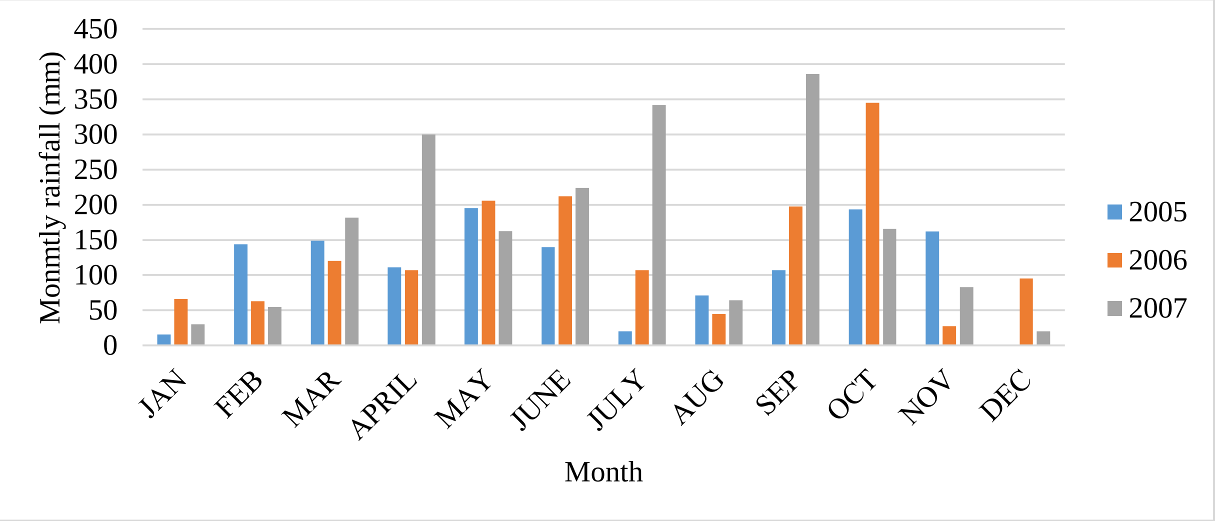
Source: Author's construct using District data from Regional Meteorological Office.

Although there was a decrease in the amount of rainfall for this period compared with the previous one, this trend is generally in conformity to past trends which farmers, farming systems and farm practices have over the years been adapted to. Only that the amount of rainfall decreased. The harmattan period for 2002 to 2004 was relatively wet but the period from 1999 to 2001 had February and December 2000 being completely dry and January 2001 receiving only 1.2mm of rainfall. Use of farming knowledge, improved farm practices and the adoption of improved technology, farmers could sustain productivity.

For the triennial period 2005 to 2007, mean average appreciated by 19mm above the average baseline of 117.4mm bringing it to 136.4mm which was 19.5mm above the 2002 to 2004 period. The decreasing trend of rainfall distribution changed in this period to an increasing trend. The maximum rainfall amounts received in the major farming season occurred in May for 2005 and 2006 and July for 2007 instead of June. For the minor season the rainy season peaked in October for 2005 and 2006 and September for 2007.

High amount of rainfall was recorded in the major season as compared to the minor season within these years. The major season is clearly distinguished from the minor as the amount of rainfall recorded dropped to 71.1mm, 44.4mm, and 64.4mm in August and then rose to 106.8mm, 197.8mm and 385.8 in September for 2005, 2006 and 2007 respectively (Figure 4.9). The harmattan season was not entirely dry as some amounts of rain was recorded from December to February except for December 2005 which was completely dry.

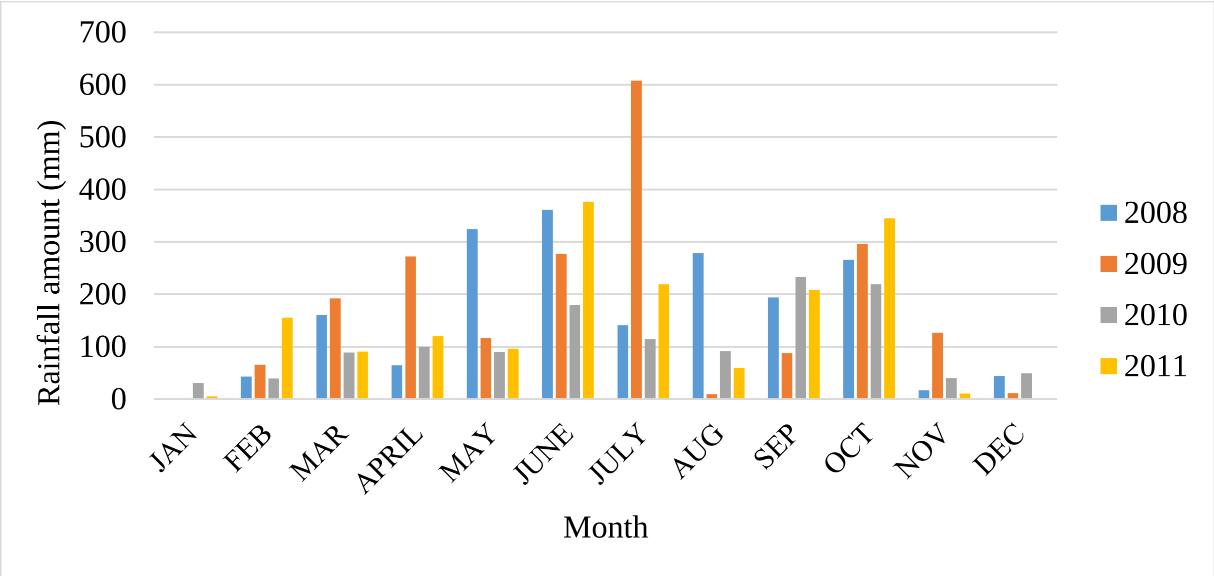
Figure 4.9: Intra annual rainfall distribution from 2005-2007



Source: Author's construct using District data from Regional Meteorological Office.

The period 2008 to 2011 received the highest amount of rainfall for the entire thirty year period under consideration. It had a mean average of 144mm which was 26.6mm increase above the baseline average of 177.4mm. The major seasons recorded the highest amounts of rainfall consistently in June and the minor rainfall season peaked in October as anticipated. The dry season was more pronounce in January with 2008 and 2009 not receiving any rains for this month. The period also demonstrated a bimodal rainfall regime (Figure 4.10).

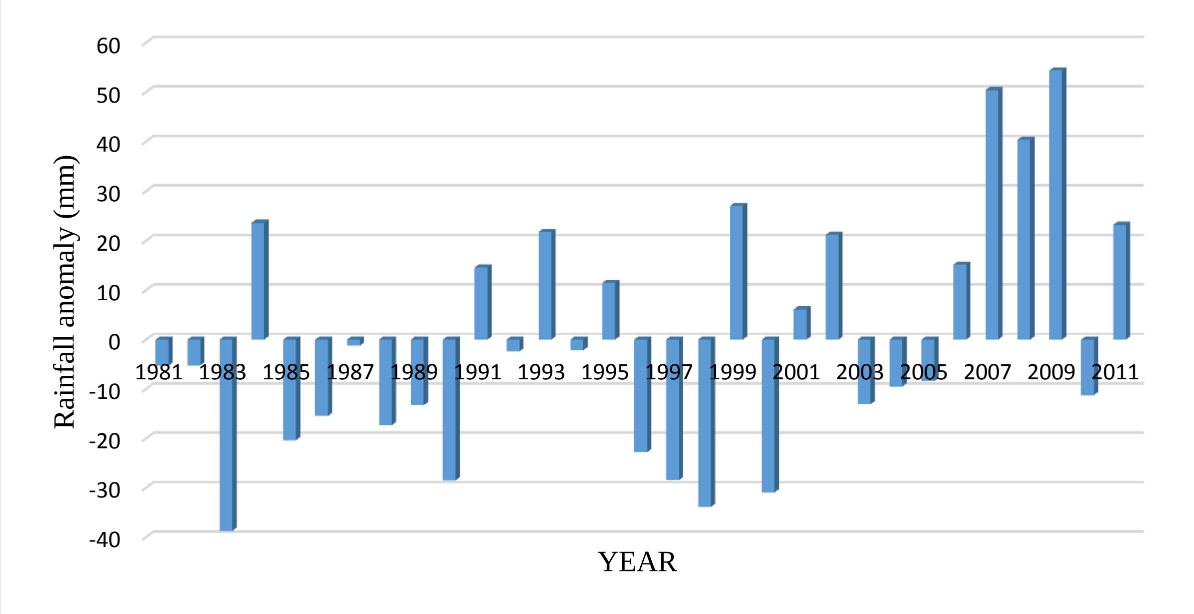
Figure 4.10: Intra annual rainfall distribution from 2008-2011



Source: Author's construct using District data from Regional Meteorological Office.

An increasing trend is observed from 1999 to 2011 with most months receiving some amount of rainfall. The major season has consistently received more rainfall as compared with the minor season. In the event of flooding of farms due to excessive rains, the construction of farm drains could help regulate the amount of water needed for effective farming activities. The peak rainy periods for both the major and minor season has however been inconsistent as with the dry season. Variation of farming systems, change of crop types and crop variety, use of improved technology and the adoption of soil moisture retention practices are key in insulating farmers from the vagaries of the climate, especially in the minor season.

Figure 4.11: Mean Annual rainfall anomalies from 1981-2011.



Source: Author's construct using District data from Regional Meteorological Office.

In three decades (1981 to 2011), the annual rainfall averages have to a greater extent been below the average baseline of 117.4mm. Only twelve (12) years had their average above the baseline for the three decades examined. These were 1984, 1991, 1993, 1995, 1999, 2001, 2002, 2006, 2007, 2008, 2009 and 2011. For the first decade of the period under study, a decreasing trend seemed to prevail as only 1984 had mean annual rainfall above 117.4mm. In the second decade period from 1991 to 2001 five years recorded averages above the baseline of 117.4mm. The last decade from 2002 to 2011 had six years with 2006 to 2009 in a row recording an increase in amount of rainfall received above the average baseline of 117.4mm. This suggests that rainfall trend has been oscillating. Figure 4.11 further reveals a varied inter annual variability in rainfall amounts from 1981 to 2011. The triennial decade experienced variation with a minimum deviation of -38.7mm in 1983 and a maximum deviation of 54.3 in 2009 from the average baseline for the period under study.

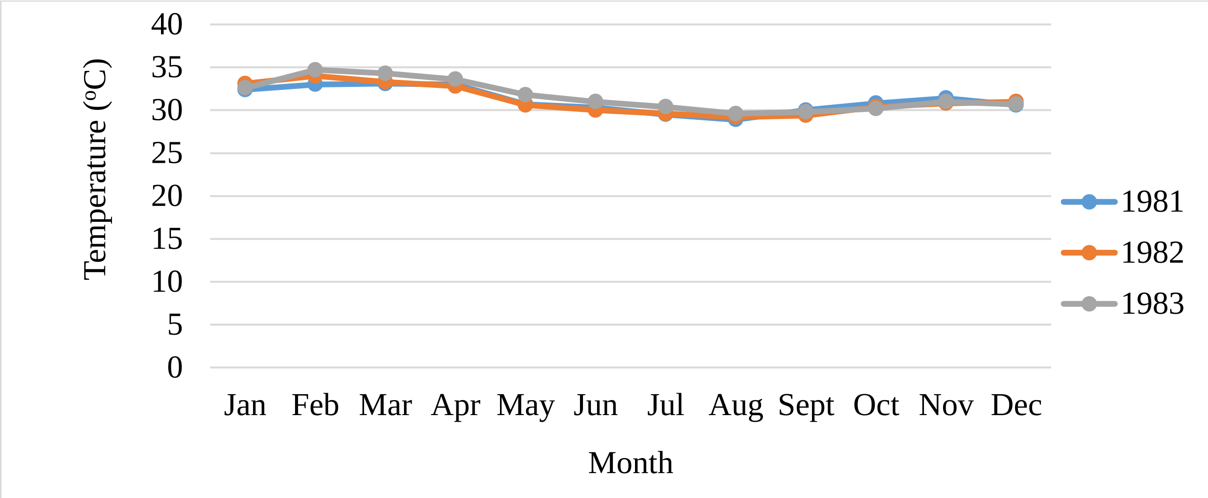
Such a trend of variability makes the future of agriculture oblique unless appropriate adaptation and mitigation measures are put in place to ensure sustainability. Hence, developing improved crop varieties for farmers and effectively disseminating relevant information on crop types, improved farming methods and weather to farmers by the appropriate agencies is crucial in any adaptation process. Farmers must also embrace these and vary their farm systems and practices to adapt to the current trend. Ching, (2010) for example, advocates for research on climate change mitigation in agriculture. Foli and Makungwa, (2011) emphasized the need to advance mitigation action on evidence-based research. This hinges on an informed understanding of local climate trends which this study provides.

4.3.2 Analysis of Temperature Trends

Food systems are affected by temperature through direct impact on standing crop, changes in rainfall causing drought and floods and changes in atmospheric temperature. The surface temperatures over a given region vary seasonally and annually depending upon latitude, altitude and location with respect to geographical features such as a water body (river, Lake or sea), mountains, etc (Gregory *et al.*, 2005). The temperature anomalies were analyzed using the mean monthly intra-annual distribution and deviations from the mean monthly temperatures.

The period 1981 to 2011 had an average temperature of 32.2^{o}C. The first triennial period from 1981 to 1983 recorded an average temperature of 31.3^{o}C with 1981, 1982 and 1983 respectively recording 31.1^{o}C, 31.1^{o}C and 31.6^{o}C. The month of February recorded the highest for all three years in the period being 33^{o}C, 34^{o}C and 34.7^{o}C for the consecutive years. July recorded the lowest of 28.9^{o}C in 1981 while August recorded 29.2^{o}C in 1982 and 29.6^{o}C in1983 as the lowest values. Temperature within the major agricultural season (March to July) varied extensively with a minimum of 29.5^{o}C in July 1981 and a maximum of 34.3°C in March 1983 as can be seen in Figure 4.12. The minor season (September to November) also had the peak month of the period for rainfall (October) recording 30.8°C, 30.4°C and 30.2°C sequentially from 1981 to 1983. This trend is likely to result in a high level of evapotranspiration. Increased evaporation from surface water due to high temperatures would blight farmers' ability to engage in irrigation. To this, Battisti and Naylor (2009) assert that higher growing season temperatures considerably impact crop yield and consequently farm incomes and food security.

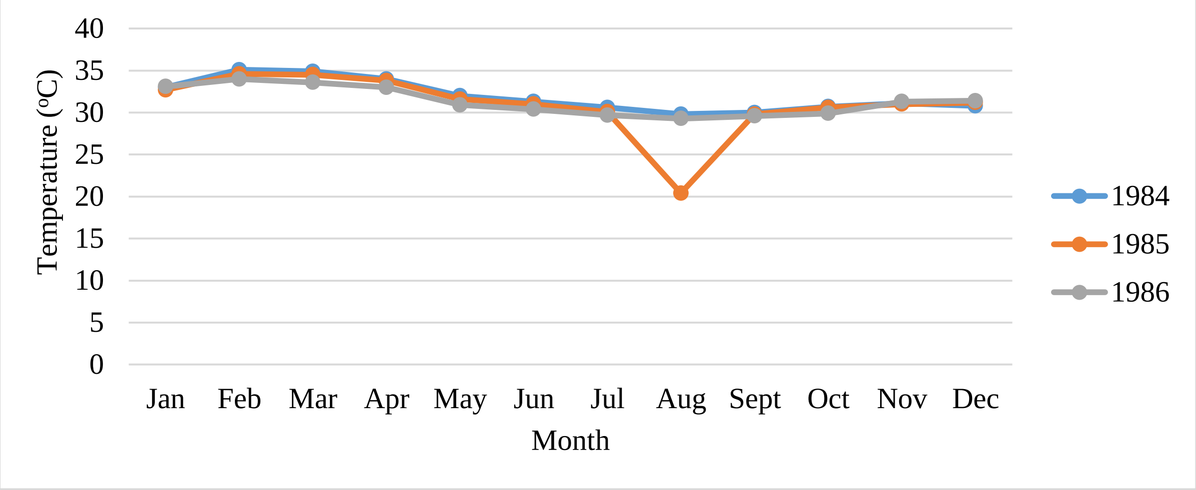
Figure 4.12: Intra annual temperature distribution from 1981–1983



Source: Author's construct using District data from Regional Meteorological Office.

The 1984 to 1985 period saw a slight increase in average temperature bringing it to 31.4°C resulting from a slight increase in average yearly figures for the three year period. The respective maximum temperatures for 1984, 1985 and 1986 were 35.1°C, 34.6°C and 34°C which were all recorded in February. The lowest amounts of temperature for the period were recorded in August which were 29.8°C, 20.4°C and 29.3°C. The highest temperatures for the major agricultural season were repeatedly recorded in March just at the onset of the farming season while that of the minor season occurred in November. This is shown in Figure 4.13.

Figure 4.13: Intra annual temperature distribution from 1984-1986

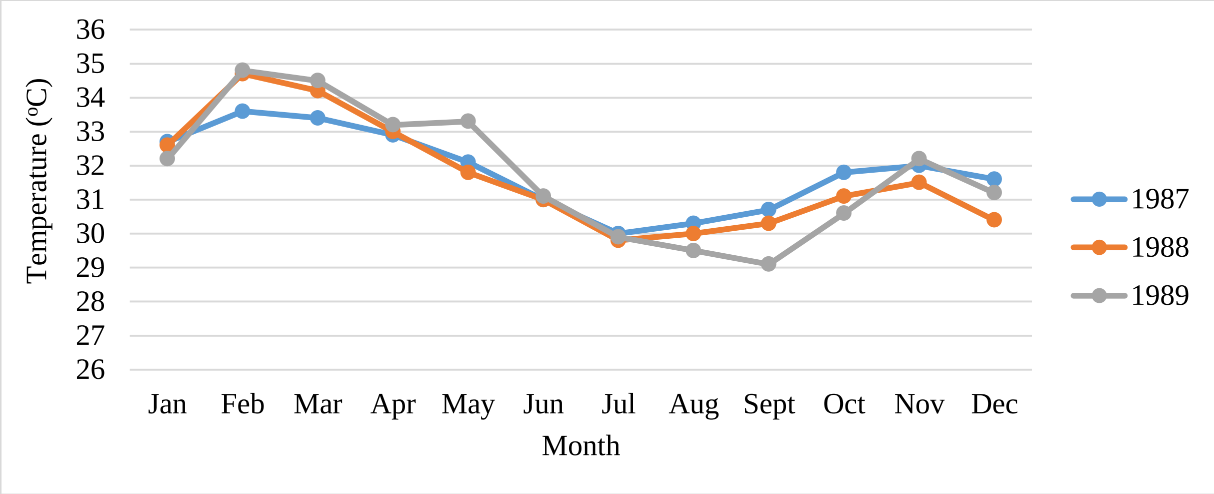


Source: Author's construct using District data from Regional Meteorological Office.

This trend favours such farm practices as slash and burn at the onset of the major farming season. The high temperatures in November were also favourable to the drying of harvested crops which helps to prevent post-harvest loses. For the major farming season temperatures decreased in the peak month of June as compared with earlier months for the period 1984 to 1986 while for the minor season it rather increased compared with preceding months. This may require that farmers irrigate because the minor season usually receives less rainfall. Moreover, crops left standing in the field after the main lean season harvest could dry instead of maturing properly.

The average temperature for 1987 to 1989 were 31.7°C with 1987, 1988 and 1989 recording averages of 31.8°C, 31.7°C and 31.8°C respectively. February recorded the highest temperatures for all three years which were 33.6°C, 34.7°C and 34.8°C. July 1987 and 1988 recorded 30°C and 29.8°C as the lowest temperatures for the period while 1989 has its lowest of 29.1°C in September (Figure 4.14). For 1991 and 1992 the month with the highest temperature was February whiles in 1990 it was in March with 34°C, 36°C and 34.3°C respectively.

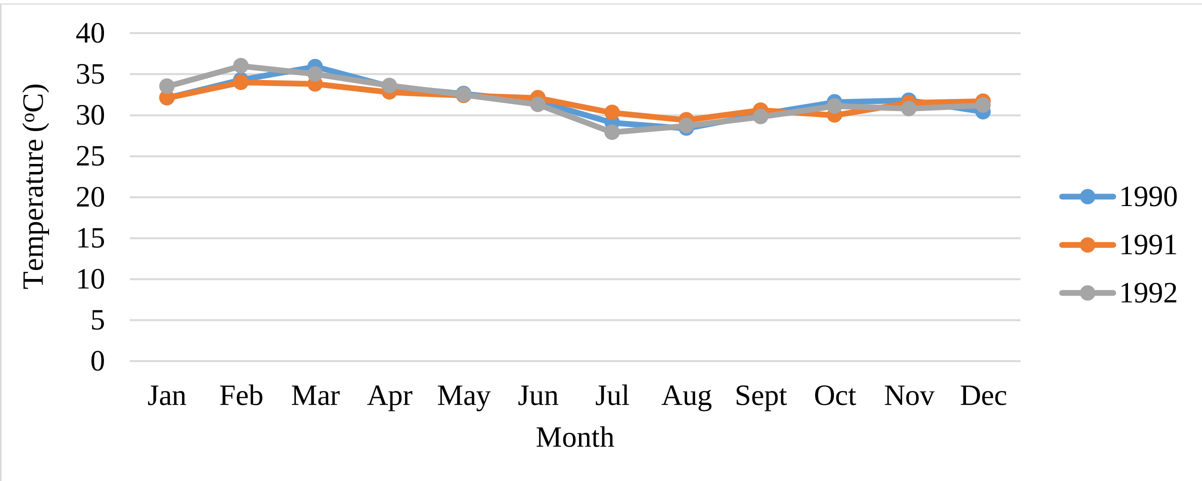
Figure 4.14: Intra annual temperature distribution from 1987– 989



Source: Author's construct using District data from Regional Meteorological Office.

In 1990 and 1991 the lowest temperature occurred in August whiles in 1992 it was in July with temperatures of 28.4°C, 29.4°C and 29.9°C respectively as illustrated in Figure 4.15. The 1987 to 1989 temperature trends in the major and minor seasons followed that of the previous year with the peak month of rains in the major farming season recording lower amounts of temperature compared to preceding months while the reverse was the case for the minor season.

Figure 4.15: Intra annual temperature distribution from 1990 – 1992

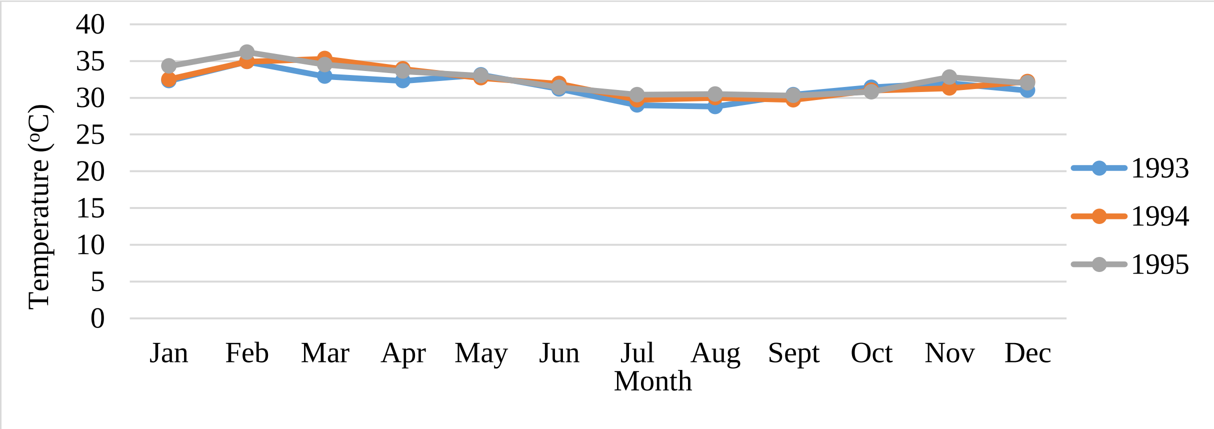


Source: Author's construct using District data from Regional Meteorological Office.

The adoption of moisture retention practices as use of cover crops and mulches would hence be very vital in the minor season especially because it received less rainfall compared with the major season. Adoption of agro-forestry and climate smart agriculture are more sustainable, environmentally friendly and long –term changes that could help ameliorate the situation.

The triennial period from 1993 to 1995 did not seem any different from previous periods. It recorded an average temperature of 32.0°C and 1996 to 1998 had an average temperature of 32°C indicating high temperatures throughout the period. Quite distinctively though, in February it recorded a very high maximum temperature of 34.9°C for 1993, 34.9°C for 1994 and 36.2°C for 1995 with that of 1995 being the second highest temperature recorded for the entire period under analysis as is vivid in Figure 4.16. The least figure was recorded in August for 1993, July and September for 1994 and that of 1995 was in September correspondingly being 28.8°C, 29.7°C and 30.3°C.

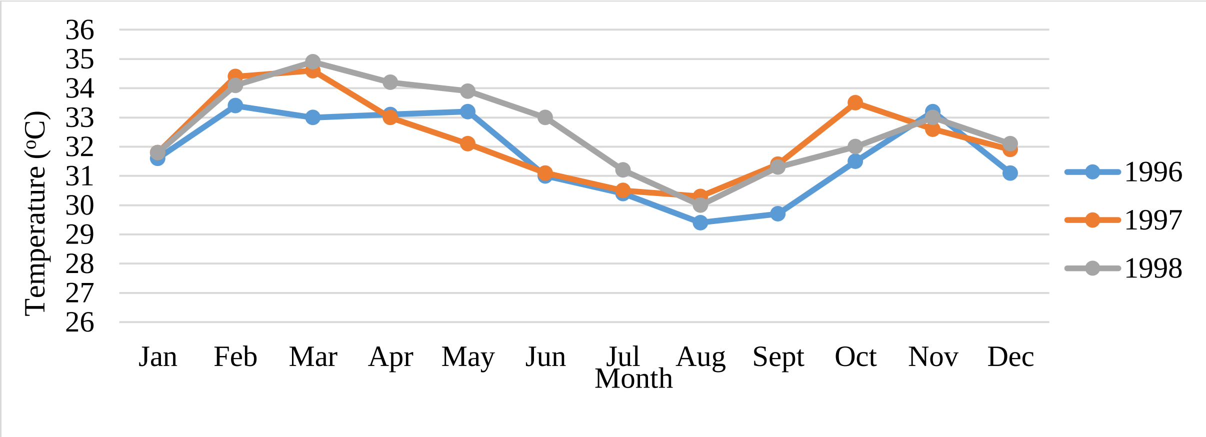
Figure 4.16: Intra annual temperature distribution from 1993–1995



Source: Author's construct using District data from Regional Meteorological Office.

The 1996 to 1998 period recorded yearly averages of 31.7°C, 32.2°C, and 32.6°C and had a period average of 32.2°C. Also from 1996 to 1998, the month which recorded the highest temperature was February in 1996 and March in both 1997 and 1998 with temperature figures of 33.4°C, 34.6°C and 34.9°C respectively. August recorded the lowest in all three successive years with temperatures of 29.4°C, 30.3°C and 30°C respectively (Figure 4.17).

Figure 4.17: Intra annual temperature distribution from 1996-1998

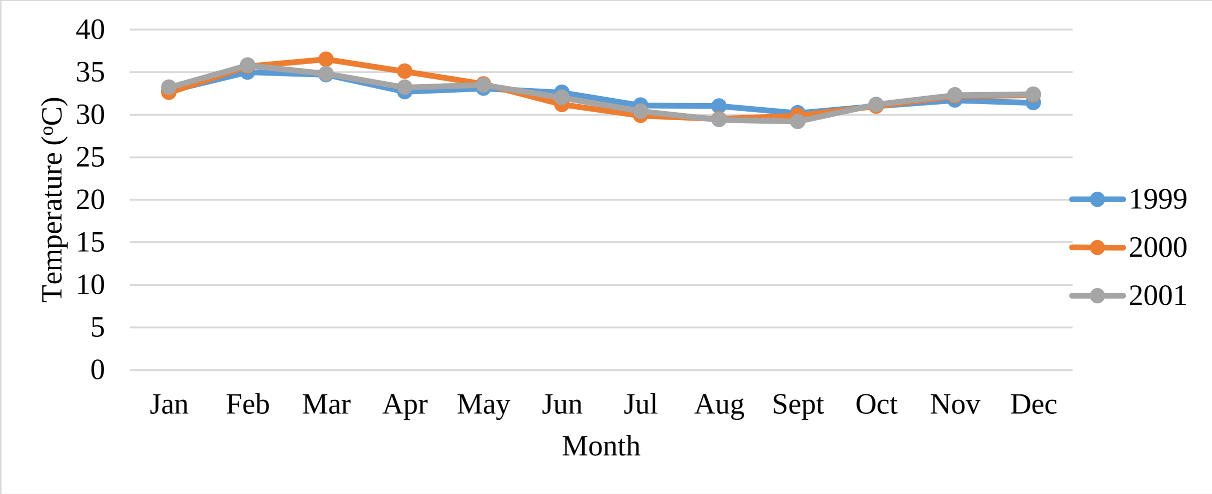


Source: Author's construct using District data from Regional Meteorological Office.

This statistics suggest that temperature was generally causing stress on rain fed plants leading to low crop yield as this temperature caused drought stress and led to high rate of evaporation. It is expected that farmers in proximate location to surface water sources as streams, rivers and Lake Bosomtwe would seek to utilize these for irrigation to sustain agricultural production. Varying of crops to include more drought tolerant and early maturing varieties would also ensure continuous crop production.

The mean temperature for the period 1999 to 2001 was 32.3°C. The month of February recorded high temperatures in 1999 and 2001 and March in 2000 with temperatures of 35°C, 35.8°C and 36.5°C respectively. Low temperatures were also recorded in September for 1999 and 2001 and in August for 2000 with temperatures of 30.2°C, 30.4°C and 29.5°C respectively, confirmed in Figure 4.18.

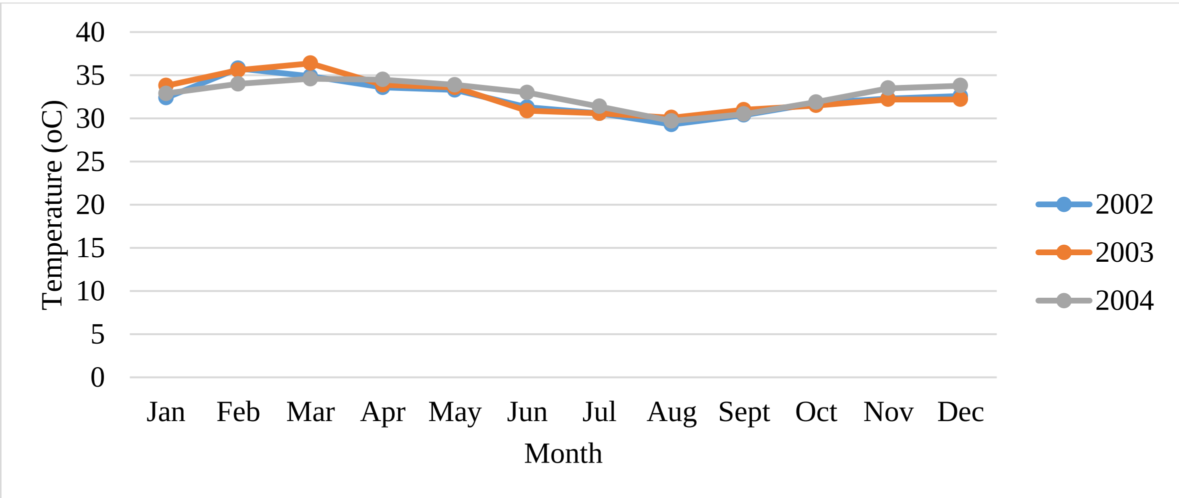
Figure 4.18: Intra annual temperature distribution from 1999–2001.



Source: Author's construct using District data from Regional Meteorological Office.

Also during the period from 2002 to 2004, high temperatures were recorded in the months of February in 2002 and in March in the years 2003 and 2004 with temperatures of 35.8°C, 36.4°C and 34.6 °C respectively. For low temperatures, it was all recorded in the month of August with temperatures of 29.3°C, 30.1°C and 29.7°C respectively. The period had an average temperature of 32.6°C which is 0.5°C above the average baseline of 32.1°C (Figure 4.19).

Figure 4.19: Intra annual temperature distribution from 2002-2004

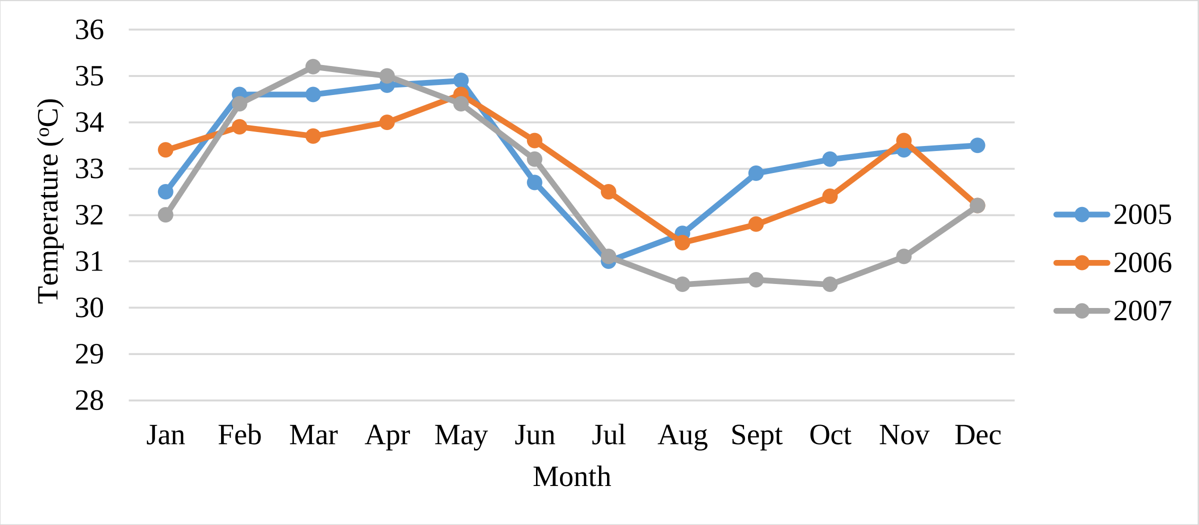


Source: Author's construct using District data from Regional Meteorological Office.

These high temperatures induce drought which consequently favours bush-fires. This affects plants and crops since they cannot thrive in hot temperatures as soil moisture is reduced. This would reduce crop yield within these periods. Also, high temperatures increase the rate of evaporation reducing surface water sources for irrigation such as streams and on-farm dug out wells which are usually used for irrigation.

The years from 2005 to 2007 and 2008 to 2011 experienced high average temperatures recording 0.8°C and 0.5°C respectively above the average baseline. This triennial period from 2005 to 2007, had an average temperature of 33°C. Within the peak agricultural month of June in the major season, temperature as high as 32.7 °C was recorded in 2005, 33.6°C was recorded for 2006 and 33.2°C for 2007. A similar trend is revealed in the peak month of October in the minor season with 33.2°C in 2005, 32.4°C in 2006 and 30.5°C in 2007. High temperatures were also recorded in May of 2005 and 2006 and in March of 2007 with temperatures of 34.9°C, 34.6°C and 35.2°C accordingly (Figure 4.20). Low temperatures were also recorded in July of 2005, August of 2006 and August and October in 2007 with temperatures of 31°C, 31.4°C and 30.5 °C respectively.

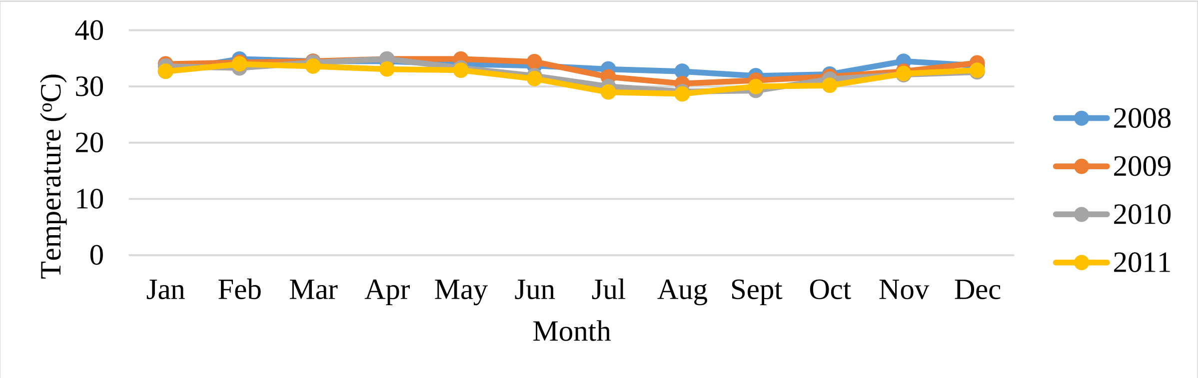
Figure 4.20: Intra annual temperature distribution from 2005–2007.



Source: Author's construct using District data from Regional Meteorological Office.

The period 2008 to 2011 recorded an average of 32.6°C. It also had high temperatures recorded in the months of February in 2008, April and May in 2009, April in 2010 and March in 2011 with temperatures of 34.9°C, 34.9°C, 34.9°C and 33.6 °C respectively. Low temperatures in the months of September in 2008, August in 2009 as well as 2010 and 2011 with temperatures of 31.9°C, 30.5°C, 29.1°C and 28.7°C respectively, were recorded presented in Figure 4.21.

Figure 4.21: Intra annual temperature distribution from 2008-2011

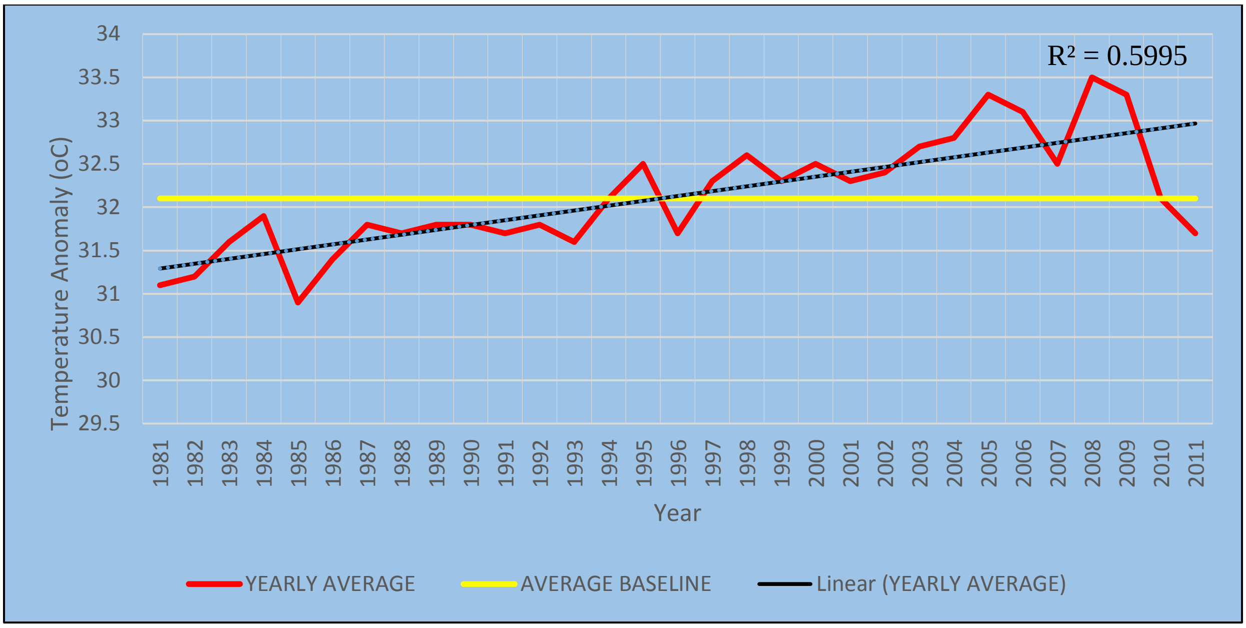


Source: Author's construct using District data from Regional Meteorological Office.

The dependence of farmers on rain for their activities makes them very vulnerable to the ever increasing trend of temperature. Farmers in proximate location to sources of water can sustain their agricultural activities through irrigation to buffer the water deficits caused by high temperatures. Others without such opportunities have resorted to increased cultivation of crops that are early maturing, drought resistant and other soil moisture conservation practices as mulching.

Figure 4.22 shows that temperature for the 30 year period from 1981 to 2011 as indicated by the red line has been very erratic, with 1985 recording the lowest average temperature of 30.9°C while the highest temperature was recorded in 2008 which was 33.5°C. The yearly average from 1981 recorded temperature values below the 30year period average of 32°C (yellow line) until 1995 which was 32.5°C and then continues to increase. The linear yearly average line (black line) for the said period clearly indicates that temperature in the Bosomtwe District has been increasing continuously suggesting that the climate of the district is experiencing change- at least within the context of the definition of climate change as provided by Dinse (2011, p1) as long-term continuous change (increase or decrease) to average weather conditions asserting that a thirty year period is long enough to generate average values that are not influenced by yearly variability.

Figure 4.22: Mean Annual temperature anomalies from 1981-2011.



Source: Author's construct using district data from regional meteorological office.

In analyzing the trend of climate variability and climate change in the Bosomtwe District from 1982 to 2011, it was realized that temperature and rainfall patterns have changed. Three major things were found in the analysis of rainfall pattern. Firstly, there has been shifts in the onset of rainfall in the major rainy season from April. It sometimes comes earlier or later than expected. Secondly, there has been shifts in the peak rainfall months in the major and minor season which is usually June in the major season and October in the minor season. Lastly, there has been deviations from the known bimodal rainfall regimes to uniimodal rainfall regimes.

Temperature in January was generally high. It decreased to its lowest in July and August and then it increased again towards January. The analysis revealed that most of the high temperatures were experienced in the early months of the year between January and March which recorded low rainfall. This period is usually associated with the dry harmattan winds. Temperature in the Bosomtwe District has been increasing steadily. Five of the triennial periods had average temperatures below that for the entire period. These were from 1981 to 1995 while 1996 to 2011 had averages above it. Also the triennial averages demonstrated an increasing trend rather than variation above and below the baseline average from 1981 to 2011. This is vivid in Figure 4.22 which shows the temperature anomaly for the various years in the Bosomtwe District.

It can be observed from the modified CCFS framework (Figure 2.4) that increase in mean temperatures and variation in precipitation pattern have been identified as critical changes. These have affected agricultural assets such as traditional farming knowledge of seasons, biophysical environment and the land necessitating adaptation. The United Kingdom Meteorological Department (2013) in analyzing global average temperature anomaly from 1850 to 2000 observed a similar trend and explains that slow-downs and speed-ups in global mean temperatures occur from time to time. Temperature variation affects moisture available in the soils for plant use and the viability of crops themselves as different crops respond differently to varying temperatures, affecting yield (Hansen *et al.,* 2013). Adoption of soil water conservation practices, use of irrigation and the harvesting of rain water are key strategies that help farmers to cope with the situation.

To ascertain the veracity of the hypothesis put forth for the study, average annual temperature as an independent variable for 15 years period (from 1997 to 2011) was regressed against annual quantity of maize as a dependent variable for the same period.

Table 4.2: Linear regression showing the relationship between average annual temperature and annual quantity of maize

Independent Variable	**Beta Coefficient**	**Sig. P-Value**
Constant	31824.327	.014
Average annual temperature	-781.641	.041*

***Significant at 0.05**
Source: Author's field data (2015).

The results showed that average annual temperature is negatively and significantly related to annual quantity of maize produced (at 5%) as can be seen from Table 4.2.

The linear regression equation is in the form $Y= b_1+b_2X$ with b_1 as the intercept, b_2 the regression coefficient, X as the independent variable (average annual temperature) and Y the dependent variable (annual quantity of maize yield). The intercept (b_1) indicates that if the average annual temperature was $0^{O}C$ then annual quantity of maize produced will be 31824.327metric tons per hectare. The gradient of -781.641 is indicative that an increase in annual temperature by 1 ^{O}C will result in a decrease of 781.641 metric tons per hectare in annual quantity of maize. The maize variety that is predominantly used is the early maturing type and averagely, it is estimated to produce 1.4 metric tonnes per hectare (Bosomtwe District Assembly Profile, 2010). This implies that the effect of increasing temperature in the Bosomtwe District is not to be taken lightly.

Maize cannot be grown in places with mean daily temperature less than $19^{o}C$ (Purseglove, 1992 cited in Obeng-Bio, 2010). Boateng (2011) concurs to this, by affirming that maize requires temperature between 18°C to 32 °C for growth and development with temperatures above this range inhibiting crop yield. Slight variations in temperature also has severe impacts on maize crop yield. Temperature in the Bosomtwe District from 1997 to 2011 ranged from 32.00 °C to 33.50 °C. This may explain why the relationship between average annual temperature and annual quantity of maize is negative.

Thus the rising trend of temperature as shown in Figure 4.22 was perhaps resulting in a decrease in annual maize yield. The model had an R^2 of 0.28, indicating average annual rainfall accounts for only 28% of the variation in annual quantity of maize produced. Hence, 72% of variation in annual maize yield may be attributed to other factors not considered in this model. These could be soil moisture and nutrient management practices, and crop variety used. In a related study, Lobell and Burke (2010), concluded that the average impact of temperature increase by $2^{O}C$ results in a 14.4% decrease in crop yield compared with a 20% decrease in precipitation resulting in a 5.8% decrease in crop yield. Hence increase in temperature adversely affects crop yield more than decrease in precipitation. The same trend was revealed as the respective influence of fertilizer application, irrigation, rainfall and temperature (as independent variables) was regressed against maize yield (as a dependent variable) in the Bosomtwe District (Table 4.3). These independent variables were preferred because the study focused on on-farm adaptation practices which include use of fertilizer and irrigation while temperature and rainfall are the basis for climate change studies. Table 4.3 shows the effect of the independent variables on the constant (maize output) in accordance with their respective degrees of freedom.

Table 4. 3: Multiple regression on factors determining annual maize yield.

Independent Variables	Beta Coefficient	Sig. P-Value
Use of irrigation	50.211	.898
Use of fertilizer	-167.754	.675
Rainfall	-.652	.288
Temperature	-721.789	.093**

****Significant at 0.1**
Source: Author's field data (2015).

From the results, fertilizer, rainfall and temperature had negative impacts on the output of maize. With the exception of temperature which was significant at 10% error margin, all the other explanatory variables exceeded the 1%, 5% and 10% acceptable error terms regarding their effect on maize output. The coefficient of determination (R^2) indicates that 39% of the entire model is explained by average annual rainfall. The data sourced and analyzed is indicative of the fact that there exists a relationship between temperature and maize yield. In this regard, one has to accept (failed to reject) the null hypothesis that there is no significant relationship between average annual temperature and the quantities of maize produced annually in the Bosomtwe District.

4.4 SMALLHOLDER ADAPTATIONS TO CLIMATE VARIABILITY AND CLIMATE CHANGE

4.4.1 Introduction

Adapting to climate change has become a need and not an option for millions of people in developing countries (Reid and Huq, 2007). According to Ngigi (2009), the major challenge is for policy practitioners and other development partners to understand farmers and other stakeholder responses to climate change. This will enable adaptation and mitigation interventions to be fashioned to augment and support plausible practices (Ngigi, 2009). Actions taken in response to or in anticipation of actual or projected climate change to reduce or curtail impacts or maximize available opportunities in the change constitute adaptation (Mahrenholz, 2008). Ngigi (2009) further mentions a number of adaptation options available and those that are applicable to farmers at the farm level include intensification of food production by smallholders through better access to improved seed, soil fertility management (eg, fertilizer application, mulch), improved agricultural water management, adoption of drought and heat tolerant crop varieties and livestock breeds. Access to extension services, markets, credit and other forms of security as machinery and livestock also influences farmers' adaptation strategies (Nhemachena and Hassan, 2008). Reid and Huq (2007), indicate that the need to adapt is more eminent for poorer nations due to their high level of exposure to the risks posed by climate change. Their vulnerability is further heightened by rapid environmental degradation, exposure to drought and floods, high rates of poverty and food insecurity coupled with low levels of technology, skills and financial resources to combat climate change.

One of the objectives was to assess the various adaptive strategies of smallholder farmers amidst the current trend of CVCC in Bosomtwe District. This is very critical as the district is predominantly agrarian in nature. Agricultural activities, dependent on such climate variables as rainfall and temperature and adversely affected by weather extremes viz floods and droughts is highly vulnerable amidst persistent CVCC (Adaptation Fund, 2012).

4.4.2 Factors Determining Adaptation in the Bosomtwe District

To determine factors influencing adaptation of smallholder farmers in the Bosomtwe District, age, educational level, type of crop, average household monthly income, observed changes in rainfall intensity, practice of agroforestry, land modification and access to extension services (as independent variables) were regressed against adaptation (as a dependent variable) as seen in Table 4.4..

Table 4.4. Regression on factors determining adaptation

Coefficients[a]

Independent Variables	Beta Coefficient	Sig. P-Value
Age	.047	.028*
Educational level	-.029	.116
Type of crops	.029	.009*
Monthly income	.038	.017*
Change in rainfall intensity	.100	.027*
Agroforestry	-.088	.024*
Land modification	.007	.357
Access to extension	-.060	.176

***Significant at 0.05**
Source: Author's field data (2015).

The findings of the regression results as presented in Table 4.4 indicated that (at 5%), age, crop type, income, observed changes in rainfall intensity and agroforestry are significant and positively related to adaption of farmer to climate change except for agroforestry which was negatively related. However farmers' educational level, agricultural land modification and access to extension service had no significant relationship with adaptation because their *'P'* values were greater than *0.05*. The probability of adapting hence significantly increased as the age, crop type, income and observed changes in rainfall intensity also increased. The probability of farmers adapting to climate change however because of the negative connotation decreases as agroforestry practices increases.

The significant relation between age and adaptation implies that smallholder farmers find it more necessary to adapt as age increases. This is because older farmers are less mobile and lack the strength to expand their farms and engage in other active economic activities, or migrate. Migration is high in the district and prevalent among the youth (Bosomtwe District Assembly Profile, 2010). With the current trend of climate variability in the Bosomtwe District, making the most of their farming endeavours by adapting is the most prudent economic decision to make. This is in contradiction with findings by Apata *et al.*, (2009) who found that adaptation among arable food crop farmers in South Western Nigeria was not significantly influenced by age of the farmers.

Also, with more income, smallholder farmers are likely to invest in farm assets as fertilizers, purchase of farm machinery and adopt use of improved technology and crop varieties that have financial implications for them. This is in harmony with findings by Aniah *et al.*, (2014) that coping/adaptation strategies of smallholder farmers in the Bongo district of Ghana was influenced by their income. The Sahara and Sahel Observatory (2010) also identified personal motivations, government policy, and financial pressures are major factors determining adaptation actions. In agreement with the crop type cultivated, Boateng (2008) found that most farmers in the Afigya Sekyere and Atwima Districts had the desire to grow food crops to ensure continuous household food supply. Nearly all of the respondents in the Bosomtwe District practiced mixed cropping dominated by the cultivation of staples such as maize, cassava, plantain and other vegetables.

Nhemachena and Hassan, (2008) also point out that African smallholder farmers cultivate at least one staple food crop. The need to ensure that household food supply is secured motivated smallholder farmers in the Bosomtwe District to adapt to climate change. Changes in rainfall was also significantly related to farmers' adaptation as it is the most tangible evidence of variability with respect to farming activities. In support of this 91% indicated that the rainfall in recent times has been inconsistent and unpredictable as opposed to nine percent who indicated otherwise. Agroforestry was inversely related to farmers' adaptation because views expressed by farmers indicated that trees and for that matter forest have a negative impact on agricultural activities and crop production although farmers expressed sound knowledge about the relevance of forest. As high as 99%, 80%, 92% and 38% indicated that forest/vegetation have benefits of preventing intense surface heating, creating favourable local climate, serving as water sheds and enhancing cloud formation respectively. Agyei *et al.*, (2014) posit that agroforestry has myriad of benefits, adding that cocoa farmers are likely to cultivate shade-tolerant varieties anticipating benefits inherent in agroforestry.

Crop type had the greatest influence on adaptation of smallholder farmers, followed by income, then agroforestry, changes in rainfall intensity and lastly age. Hence crop type determined adaptation to a greater extent among smallholder farmers in the Bosomtwe District. The coefficient of determination (R^2) indicates that only 20% of the entire model is explained by income, type of crop cultivated, practice of agroforestry, observed changes in rainfall intensity, and age. The remaining 80% is attributed to other factors as adaptation among smallholder farmers could be influenced by farming experience, facilities and inputs used, cropping system, and seasonal or year-round farming.

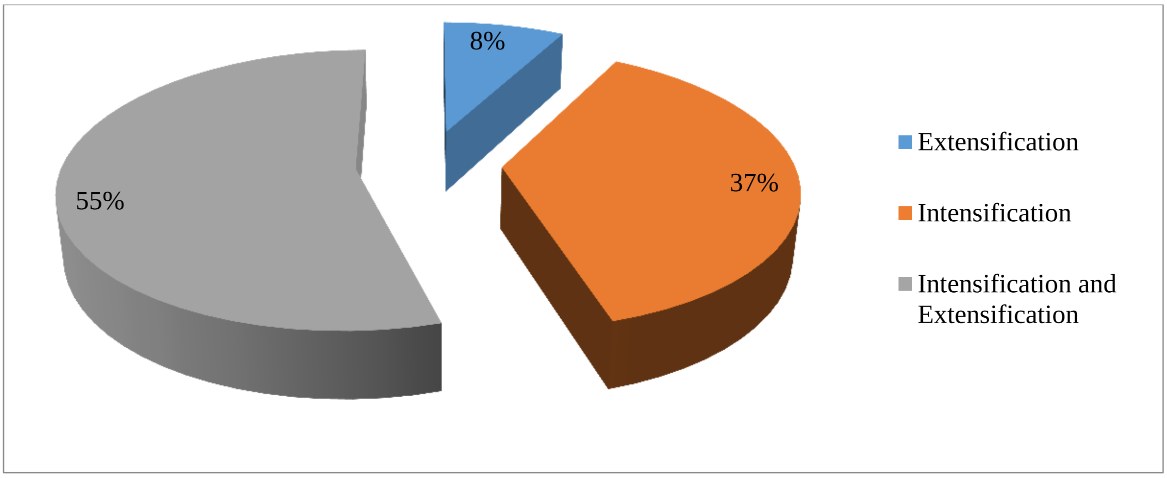
The model equation: $y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + e$ is explained as:

$Ad = 0.047A + 0.029Cr + 0.038In + 0.10RI - 0.088Ag + 0.05$ where Ad = Adaptation, A = Age, Cr = Crop type, In = Income, RI = Rainfall Intensity, Ag = Agroforestry, a = constant and e = standard error. The equation reveals the culminated impact of these factors on smallholder farmers' adaptation to CVCC in the Bosomtwe District. Thus per this equation, it is the net effect of these factors that has resulted in the various adaptation strategies adopted in the district.

The various on-farm adaptation practices are broadly grouped into two. They are extensification and intensification practices. Beranger (n.d) defined extensification as the process of developing and utilizing large areas of land for agricultural production purpose characterized by minimal inputs, including capital and labour while intensification seeks to increase the productivity on a given (fixed) area of land by progressively increasing the inputs including capital and labour (Beranger, n.d). Extensification is operationalized as any effort at increasing the area under cultivation either within an existing farm or acquiring a new farm in an uncultivated land while Intensification is operationalized as any on-farm effort aimed at increasing the unit output of an existing farm without increasing the area under cultivation.

Results from the respondents revealed that 93% of smallholder farmers in the Bosomtwe District have adapted to climate change while seven percent have not. On-farm adaptation practices of the farmers were broadly categorized into two: intensification and extensification. The results indicated that a majority (55%) practiced both intensification and extensification while 37% and eight percent practiced only intensification and extensification respectively. Extensification of agriculture as an adaptation strategy among smallholder farmers is particularly challenged by access to land and land use change patterns. This is presented in Figure 4.23.

Figure 4.23: Pie chart showing adaptation categorization in the Bosomtwe District.



Source: Author's field data (2015).

4.4.3 On-Farm Adaptation Practices

On-farm adaptation practices are varied (Ngigi, 2009). In the Bosomtwe District, these include irrigation, use of agro-chemicals and fertilizers, mulching, change of crop type and change of crop variety.

4.4.3.1 Irrigation

Nhemachena and Hassan, (2007) indicated that irrigation is an important adaptation measure because it helps buffer for moisture deficits induced by changes in climate. Variations in the onset of rains and seasonal rainfall and temperature variations can exacerbate water availability (Cook *et al.*, 2013). Water sources for irrigation in the district include Lake Bosomtwe, River Oda, streams and boreholes.

The results suggested that although 50% of farmers had farms located near these sources of water that could be harnessed for irrigation to make up for moisture deficits due to climate variability, only 28% of them actually practiced irrigation. This pattern is particularly so because irrigation in the district is done either with a water-pumping machine which only a few could afford or by using watering cans. Although irrigation is predominantly done in the off-season, it is increasingly being used in the event of delayed rains until the onset of the rainy season. This was confirmed by the district agricultural extension officer that "*some farmers have increasingly resorted to the use of irrigation to buffer for reduction and irregularity in the pattern of rainfall*". This finding agrees with that of Nhemachena and Hassan, (2007) who noted that irrigation and water conservation techniques are important as these help to lengthen the growing period of crops. Hence, it is a critical adaptation strategy employed to make up for shifts in the growing season.

4.4.3.2 Application of agro-chemicals and fertilizer

In a study by Owusu and Klutse (2013), maize yields in general were high in good years of rainfall attributed to the application of agro-chemicals and fertilizer and other factores. Use of agro-chemicals as an adaptation strategy is important as a method of dealing with loss of rich top soil through run-off and loss of soil nutrient through leaching. Among smallholder farmers in the Bosomtwe District, use of agro-chemicals and fertilizer to help increase crop yield and pesticides and weedicides to control pest was minimal. Only 11% of respondents indicated that they use agro-chemicals while 89 did not. Close to 60% (57%) of respondents asserted that the cost of agro-chemicals was high and as such they could not afford. The district extension officer asserted that *"some farmers have also resorted to the use of other un-recommended chemical in their farming practices because they are cheaper"*. Lumpkin and Sayre, (2009) made similar observations in Mexico and explained that astounding prices of chemical fertilizers together with government restrictions through rationing limited farmers' access to agro-chemicals such as herbicides, weedicides and fertilizers. The minimal usage is also attributed to the fact that 84% of the respondents had not experienced increase in the incidence of diseases and pest with the variable climate while only 16% had. Farmers indicated that agro chemicals would have come in handy to complement crop loss due to strong winds.

4.4.3.3. Mulching

Smallholder farmers in the Bosomtwe District also practice mulching as a key adaptation strategy. While 92% of respondents pointed out that they retain crop residue after harvest on the surface of the soil, only eight percent indicated using it to re-enforce farm boundaries. Approximately 92% (91.6%) of those who practiced mulching said it has been effective pointing out that it improved soil nutrient level and retained soil moisture and nine percent said otherwise. Destructive traditional farming practices such as slush and burn has been discouraged while mulching has been encouraged by agricultural extension officers among smallholder farmers in the Bosomtwe District. There are other benefits associated with this practice that lessens the impact of climate change at the on-farm level. Belliveau *et al.,* (2006) writing on the benefits of plant residue on the farmland by grape farmers in Canada acknowledged that it reduces soil and wind erosion, controls weeds and preserves soil nutrient and moisture. Nambiza (2013) also found in Tanzania that farmers used mulching as soil nutrient and moisture conservation method. Mulching prevents soil erosion and preserves soil carbon stock.

Although mulching has been a traditional agricultural practice among smallholder farmers in the district, farmers have found the practice to be very helpful amidst current trends of CVCC. This adaptation strategy is also prevalent because beyond the challenge of water deficit associated with climate change, farmers with farmlands closer to the communities cannot expand their farms and hence can only intensify. The dominance of this practice can by inference be attributed to the fact that mixed cropping is the predominant farming system among smallholder farmers in the Bosomtwe District. Hence after the harvest of one crop, the residue cannot be burned but at best only removed from the farm.

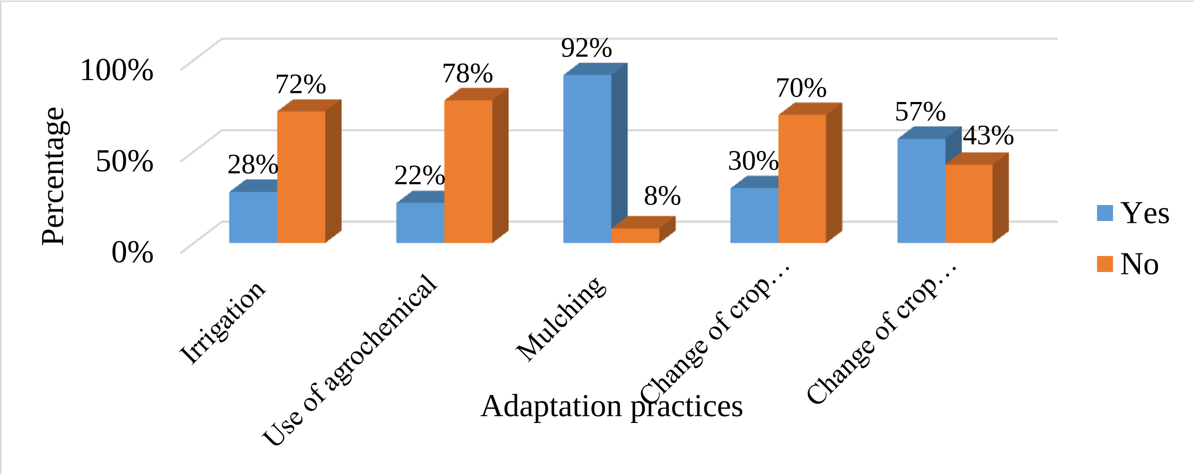
4.4.3.4 Change of Crop Variety

Improved crop varieties lessens farmers vulnerability in that they mature much faster and are hence less likely to be adversely affected by climate change compared with the traditional varieties (Alliance for Green Revolution in Africa , 2014). Changing the type of crops grown was another strategy that helped smallholder farmers to in the Bosomtwe District to adapt to CVCC. Climate change according to smallholder farmers in the Bosomtwe District is made manifest through droughts, flooding, shifts in crop growing season and variations in rainfall and temperature patterns. The impact of these has been loss of crops prematurely and crop failure. Hence, 43% of respondents indicated changing the variety of crops grown and 57% indicated otherwise. The crops were particularly maize and cassava. This represents the gradual emergence of a shift from the traditional crop variety to hybrids that mature much early. This was an effort at reducing their vulnerability to the precarious climatic trends.

4.4.3.5 Change of Crop Type

Although only 30% of smallholder farmers had changed crop type in order to adapt to CVCC, the majority (70%) of have not. This change was skewed towards crops that require less water, are more drought tolerant and adaptive to the precarious nature of the growing season such as cassava and plantain rather than maize. This trend was equally revealed in Nomedjoh and Nkolenyeng in southern Cameroon when Chia *et al.*, (2013) looked at the adaptation of forest communities to local climate variability and forest-carbon conservation conditions. Farmers were increasingly planting improved and new crop varieties as a form of security against the vagaries of the climate (Chia *et al.*, 2013). In the Limpopo Basin in South Africa, the key adaptation strategy to increasing temperature was changing crop cultivars (Di Falco and Veronesi, 2013). This trend was equally seen in Tanzania where farmers bought variety of sorghum that was known to be mature early (Nambiza, 2013). On-farm adaptation (intensification) practices among smallholder farmers in the Bosomtwe District is shown in Figure 4.24.

Figure 4.24: On-farm adaptation (intensification) practices among smallholder farmers in the Bosomtwe District.



Source: Author's field data (2015).

4.4.4 On-Farm Extensification Practices

The results of the study revealed that extensification is a major adaptation practice in the Bosomtwe District and exist in two forms *viz* clearing of forest for agricultural purpose and expansion of current farm. Cultivated land in Africa increased from 132 in 1970 to 184 million hectares in 2010 with permanently cultivated land increasing from 14 to 23 million hectares (Alliance for Green Revolution in Africa, 2014).

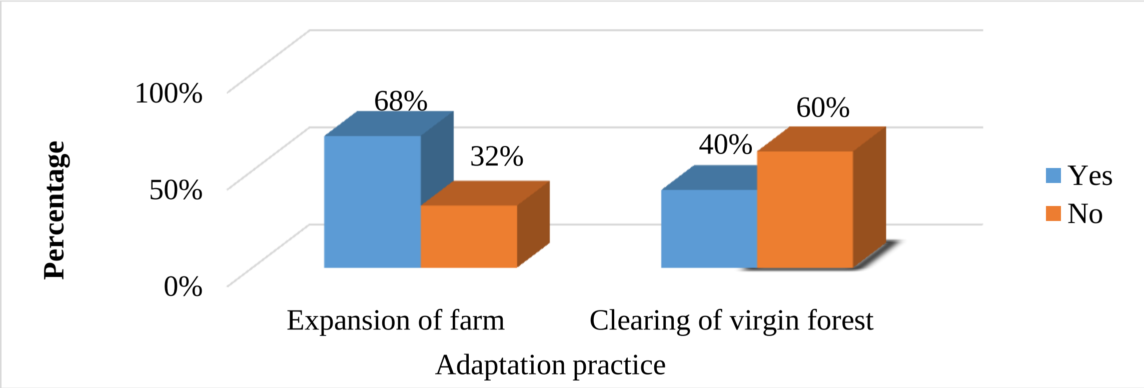
4.4.4.1 Expansion of Farms and Clearing of Forest for New Farmland

The ability of smallholder farmers to expand their farms is seen as a key adaptation strategy to climate variability. This is usually seen as a long-term or strategic adaptation strategy. The majority representing 68% have been able to expand their current farms by a few meters to help make up to loses of crops or reduction in crop yield due to declining soil fertility and negative impacts of climate variability. Over a third of farmers were not able to expand any of their farms due to lack of land for expansion. Hence they have had to resort to intensification practices as irrigation where possible, mulching, use of fertilizer and agro-chemicals and change of crop type or variety. The Alliance for Green Revolution in Africa, (2014) reports that increasing agricultural output through farm expansion is feasible for a few countries. This study results indicates that at least expansion of farms among smallholder farmers in the Bosomtwe District and for that matter Ghana is one of the prevailing adaptation strategies.

Extensification in agriculture to a greater extent has been seen to encompass the expansion of farmed lands. It is imperative also to acknowledge the clearing of forest to open up new farmlands as an adaptive strategy to CVCC. This study observed that 31% of farmers have cleared virgin forest for new smallholder farmlands as an adaptive strategy to climate change although they are the minority, compared to 69% of respondent who have. This was also meant to make up for reduction in crop yield due to the high productivity of soils from new farmlands. They mentioned that "*the output of new farmlands was much better compared with that of old ones*".

According to Chia *et al.,* (2013), in Cameroon farmers in Nomedjoh and Nkolenyeng attested to this finding, indicating that newly open fields in forest frontiers are more fertile, yielding higher output. Nambiza (2013) also found this trend emerging among small- scale farmers, who cleared forest to open up new agricultural fields in Kilosa and Chamwino in Tanzania. Smallholder farmers in the Bosomtwe District who have not been able to engage in this practice attributed it to scarcity of arable land (unfarmed lands belonging either to other adjourning communities or other people) and high cost of clearing forest. This practice is however a maladaptive strategy as the clearing of forest releases carbon in these sinks into the atmosphere, further contributing to the global climate menace. Extensification as practiced among smallholder farmers in the Bosomtwe District is presented in Figure 4.25.

Figure 4.25: Extensification (adaptation) practices among smallholder farmers in the Bosomtwe District.



Source: Author's field data (2015).

4.4.5 Likelihood of Farmers Persistently Practicing a Particular Adaptation Strategy

The possibility of some farmers persistently practicing a particular adaptation strategy in comparison with others was ascertained. The disposition of a farmer increasingly resorting to a particular adaptation practice resulting from current weather trends and the resultant effect on crop yield was analyzed using binary logistic regression modelling. This was to assess which of the prevailing adaptation practices farmers were likely to uphold should the prevailing conditions of inconsistent and unpredictable rainfall pattern and the resulting low crop yield and crop losses continue. This was done using the ODD ratios for the likelihood continuation of a practice.

To this end, respondents were asked to indicate 1 = Yes implying the practices they adopted have been effective and 0 = No, implying they have not been effective. The step-wise logistic regression was run in the SPSS software. The model without predictive variables was taken as the null hypothesis, which therefore states that there is no significant difference between the dummies (Yes and No) and the response variable. In other words, the model would better predict the outcome without the inclusion of the independent variables while the alternative hypothesis states that the model would not predict better without the independent variables. This means, there is significant difference in the dummies in the response variables. In the first step of the model (block 0), the model without the inclusion of the predictive variables measured at the y= the constant, indicated the overall percentage correct of prediction was 91.4% with a probability value of significance at $P < .000$, with n B (EXP) = 0.94. However, by adding the predictive variables to the alternative model (block 1) equation, the overall percentage correctness of the prediction was 96.1% which was better than the null model at a significant value of $P < .000$, with a Chi-square value $\chi^2 = 52.546$ at 5 degrees of freedom. The *Nigelkerke* R^2 which is a pseudo coefficient of determination, indicates that the model can offer only 66.1% explanation of the variation in the dependent variable due to the variation in the independent variables. There were eleven independent variables, entered into the alternative hypothesis equation as non-categorized. However four of them were significant in predicting a farmers' likelihood of persistently practicing a particular adaptation strategy. These independent variables were irrigation, mulching, use of agro-chemicals and changing the type of crop. Since the timing and amount of rains has varied significantly in recent times, utilizing irrigation from hand-dug wells, boreholes, streams, Lakes and rivers have become a necessity if production is to be continued.

Another predictive variable was the practice of using mulch. Most farmers used crop residue as mulch to help conserve soil moisture and improve soil nutrients. This practice according to farmers also controlled weeds and therefore lessened their work in preparing the land at the onset of rains. Use of agro-chemicals was also significant as a long term adaptation strategy. This is meant to make up for reduced crop yield due to destruction of crops by adverse climate events as strong winds and flooding. Additionally, changing the type of crop cultivated is likely to be a long term strategy as it enables the farmers to choose which crops have proven to be more adaptive and resilient, and economically prudent to cultivate amidst current climatic trends in the district.

Irrigation, mulch, use of agrochemicals and changing the type of crop cultivated were respectively significant at $P < .027$, $P <.000$, $P < .020$ and $P < .035$. At a 95% and 99.9% confidence interval (CI). These variables had lower to upper CIs for each of the EXP (B) respectively at CI = .009-.746, CI = 19.287-8.328, CI = 1.798-981.453 and 1.359-4.0380. Furthermore, five out of the eleven independent variables had (EXP)B > 1 of likelihood to predict the outcome of the dependent variable of changing farming as an occupation when those independent variables were used on the response variable at B(EXP) = 4.513—400.787 times. (Table 4.5). This means the Odds of predicting the effectiveness of the adaptation measures can be predicted by the independent variables at four hundred odd likelihoods of the farmers practicing these adaptation strategies.

Table 4.5: Logistic Regression table likelihood of farmers persistently practicing a particular adaptation strategy

Predictive variables	B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
							Lower	Upper
Age of respondent	-.427	.597	.511	1	.475	.653	.203	2.103
Size of household	1.507	.910	2.741	1	.098	4.513	.758	26.860
Irrigation (I_r)	-2.514	1.134	4.919	1	.027*	.081	.009	.746
Extensification	-1.088	1.426	.583	1	.445	.337	.021	5.505
Mulch (M_c)	5.993	1.548	14.990	1	.000*	400.787	19.287	8.328E3
Use of agro-chemicals (Ag_c)	3.738	1.608	5.405	1	.020*	42.006	1.798	981.453
Changing the type of crop cultivated (T_c)	4.346	2.061	4.447	1	.035*	77.148	1.359	4.380E3
Type of crop	-.728	.391	3.458	1	.063	.483	.224	1.040
Clearing new farmland	-.689	1.137	.368	1	.544	.502	.054	4.657
Changing the variety of crop cultivated	17.515	6.926E3	.000	1	.998	4.043E7	.000	.
Constant	-54.371	1.385E4	.000	1	.997	.000		

***Significant at 0.05, **Significant at 0.01**
Source: Author's field data (2015).

By substituting the variables in eqn. 3, the result would appear as follows;

$$p = \left[\frac{e\{5.993\mathrm{M_c} + 4.346\mathrm{T_c} + 3.738Ag_c - 2.514I_r - 54.37\}}{1 + e\{5.993\mathrm{M_c} + 4.346\mathrm{T_c} + 3.738Ag_c - 2.514I_r - 54.37\}} \right] \quad \text{Eqn. l}$$

The strong B (EXP) values obtained indicates that the Odd likelihood of prediction is more than four hundred times likely farmers will continue to engage in these adaptation strategies as avenues of lessening the adverse impact of CVCC.

4.4.6 A Comparative Analysis of Adaptation Practices Based on Proximity of Communities to Lake Bosomtwe

The study also sought to compare the adaptation practices of communities close to Lake Bosomtwe and those of communities farther away from the Lake. The communities located farther away from the Lake are Dedesua, Kokodie, Ayuom, Adwampon, Amankwadei and Brodekwano and those located near the Lake are Nkowi, Obo, Abaase, Aborodwom, Anyinatiase and Pipie old town.

Generally, communities farther away from the Lake tend to practice irrigation more than those located close to the Lake although all farmers showed interest in practicing irrigation. Pearce (2009) concurs to this finding by citing that increasing drought conditions had led to more interest in irrigation in Manitoba, Canada. The two highest percentage for practice of irrigation among those located further away from the Lake are 67% at Adwampon and 60% at Brodekwano. Those Figures were much higher than the two highest for those closer to the Lake being 38% at Abaase and 35% at Pipie old town. Also, for communities located farther away, nine percent was the lowest as compared to those closer to the Lake who no engagements in irrigation. On the contrary, Yaro (2013) in a study on building resilience and reducing vulnerability among farmers in selected communities in Ghana found irrigation to be prevalent among communities closer to rivers than otherwise.

Also, the topography around Lake Bosomtwe is generally rugged and as such is much difficult to cultivate and irrigate as compared to that of communities farther away with gentle sloping or relatively flat lands. This has been a challenge to the adoption of irrigation in communities close to the Lake. The National Report of Turkey Mountain

Watershed Management (2008), makes it clear that the geographically mountainous conditions of Turkey makes it difficult to distribute water because of irregular nature of the terrain and cost involved. To this Hazarika (2008), recommends that drip irrigation can increase quality of crops and yield under undulating landscape as is the case for communities located around the Lake. This would also contribute to optimum use of on-farm water management practice. Mohammed *et al.*, (2014) posit that the cost of irrigation is a major challenge to the use of irrigation in Nigeria.

Farmers in communities farther from the Lake basically irrigate land using water pumping machines or the use of buckets to fetch water from boreholes to the farms. For communities around the Lake only men use buckets since they are stronger while a few with farms along the banks of the Lake also irrigate. Thus generally, irrigation infrastructure is not available in the district. It may be in this light that Manyeruke and Mhandara, (2013) assert that the low level of irrigation infrastructure has made agriculture vulnerable to CVCC. Also irrigation from streams would also be erratic as most streams dry up during the dry season when irrigation activity is most needed. Harvest of rain water would be most useful in their peculiar case. Terracing would also be useful as this would help them to take advantage of the terrain rather than be restricted by it in helping to improve their crop yield. In the short term, the formation of farmer associations could help them collectively mobilize funds for community owned water pumping machines to pump water uphill. This would however be challenged by the distance of farms from the Lake. If long term capital intensive irrigation intervention takes a prime place in efforts to deal with water deficits, then in the short run, increases in crop output would depend on other adaptation techniques rather than irrigation in communities close to the Lake.

Use of agro-chemicals as an adaptive strategy does not seem to be a popular adaptation technique in both clusters of communities. More than 60% of eleven communities out of the twelve did not use agro-chemicals. This is partly because farmers considered the cost of agro-chemicals as fertilizers, weedicides, etc to be high. The influence of agro-chemical prices on farmers ability to adopt it is confirmed by Egyir *et al.*, (2014) who established that adoption of modern coping strategies such as the use of agro-chemicals by farmers who had access to capital was higher than those who lacked access. Also most farmers pointed out that they have not experienced increase in the incidence of diseases and pest hence, less urgent the need to engage in the practice. Okonya *et al.*, (2013), also found a similar trend in their study as inability to pay for farm inputs such as fertilizer hampered farmers' adaptation in Uganda. However, this adaptation strategy was predominantly practiced by communities farther away from the lake as against those located around the lake. Communities such as Nkowi and Abororodwom (located around the lake) and Adwampong and Brodekwano (located farther away from the lake) did not engage in the practice at all. However, while communities such as Dededua, Kokodie, Ayuom and Amankwadei located farther away from the lake respectively recorded 40%, 35%, 63% and 11% for the use of agro-chemical, other communities such as Obo, Abaase ,Anyinatease and Pipie old town located around the lake recorded 8%, 25%, 15% and 6% respectively.

The use of crop residue for mulch after harvest was the dominant adaptation practice among smallholder farmers in the Bosomtwe District. The least recorded practice for mulching for all twelve communities was 80% which occurred at Brodekwano, one of the communities farther away from the Lake. Six communities in total recorded 100% response for the practice, out of which three communities (Abaase, Aborodwom, Pipie old town and Anyinatease) were located around the lake while two (Ayuom and Adwampong) were located farther away from the lake.

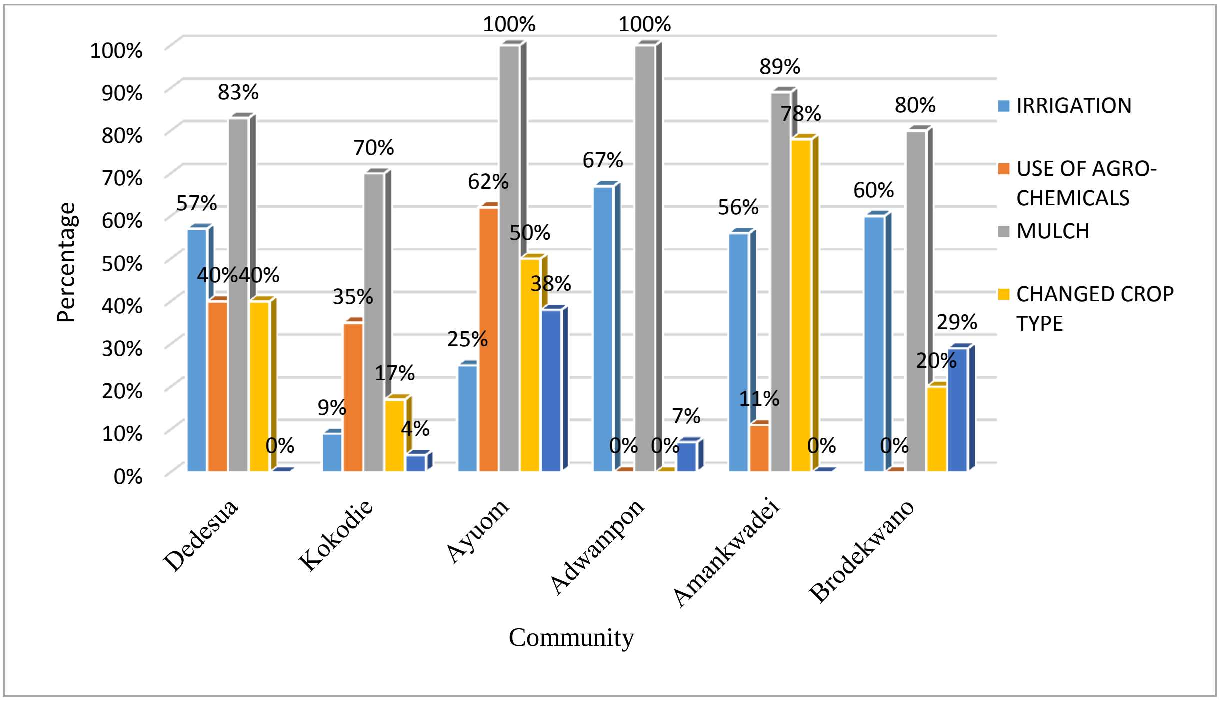
A comparison of the responses revealed that communities located farther away had much lower responses (100% at Ayuom, 100% at Adwampong, 83% at Dedesua, 91% at Kokodie, 89% at Amankwadei and 80% at Brodekwano) as against those around the lake (100% at Abaase, 100% at Aborodwom, 100% at Anyinatease, 100% at Pipie old town, 87% at Nkowi and 90% at Obo). Mulching was hence dominant among communities located around the lake rather than those located farther away from the lake. This is a traditional on-farm activity among smallholder farmers that has proven useful amidst current trends of climate variability in the Bosomtwe District. Codjoe *et al.,* (2013) also found mulching to be the predominant soil fertility strategy without fertilizer among local farmers in Southern Ghana. Garcia *et al.,* (2009) found the practice of mulching to be equally widespread among Andean farmers as it helped increase moisture retention in soils and reduced the amount of tilling required. Key crops cultivated in the district included maize, cassava and plantain. Mulching increases soil fertility and moisture content and also controls weeds (Milder and Scherr, 2011).

Nine out of the twelve communities recorded 40% or less for change in crop type as an adaptive strategy. Four of these were located farther away from Lake Bosomtwe namely Dedesua, Kokodie, Adwampon and Brodekwano, and five found around the Lake namely Nkowi, Abaase, Aborodwom, Anyinatease, and Pipie old town. The remaining three communities were Obo- located near the Lake recording 43% and Ayuom and Amankwadei – located farther away recording 50%, and 78% respectively with Amankwadei recording the highest.

A converse trend is seen in change of crop variety where nine out of the twelve communities recorded 50% or more for change of crop variety as an adaptation strategy. Only Brodekwano and Aborodwom located near to the Lake and Dedesua, located farther away recorded 40%, 40% and 43.3% respectively for the change of crop variety in order to adapt to climate variability in the district. The practice was entirely absent in three communities namely Adwampon, Amankwadei and Brodekwano- all located farther away from Lake Bosomtwe. This practice is therefore skewed towards communities closer to the Lake rather than those farther away. To this the district crop research officer asserted *"there is a high demand for hybrid crops that mature earlier and are drought tolerant"*.

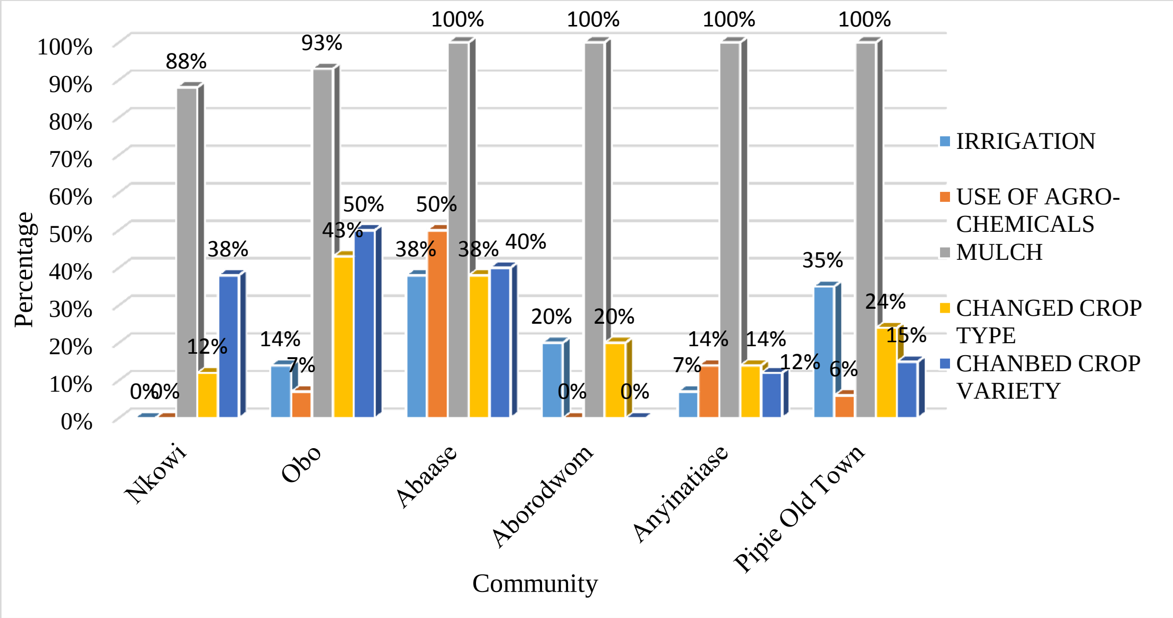
Although farmers indicated that the incidence of disease and pest has not really increased, change of crop variety towards more pest and disease resistant and drought tolerant varieties served as a strategic adaptation anchoring sustainability of crop production in the district. In line with this Mohammed *et al.*, (2014) affirm that the use of improved crop varieties is increasing in Africa because the improved varieties are available and less expensive. This situation among some of the communities in the Bosomtwe District is illustrated in Figure 4.26 and Figure 4.27.

Figure 4.26: Intensification practices among communities farther from Lake Bosomtwe.



Source: Author's construct using field data (2015)

Figure 4.27: Intensification practices among communities close to Lake Bosomtwe



Source: Author's construct using field data (2015)

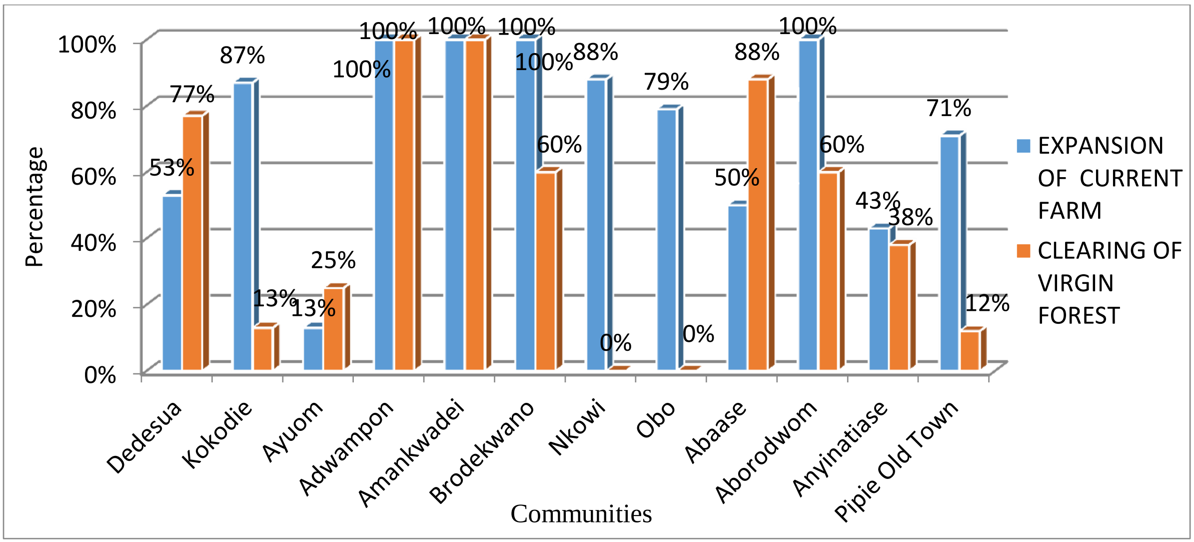
Expansion of farm was relatively prevalent in communities farther away from the Lake as compared to those closer. The rate of forest loss as noted by Chakravarty *et al.*, (2012) can be proxied by increases in agricultural land. The results reveals that most smallholder farmers in these communities have been able to expand their current farms by a few metres. Of the communities farther away from the Lake Brodekwano, Adwampon and Amankwadei recorded 100% of respondents being able to expand their farms in the last fifteen years. Dedesua and Kokodie respectively recorded 53% and 87% of respondents being able to expand their current farms. Ayuom (located farther) however recorded 13% being the lowest for all the twelve communities. This could be attributed to it being surrounded by fast growing peri-urban communities making access land for agriculture more difficult. A respondent retorted that *"the land is finished"*.

Naab *et al.*, (2013), found a similar trend in Northern Ghana explaining that agricultural lands are mostly lost to residential and commercial purposes through urbanization. Hence, the pressures of urbanization have negative implications on predominantly poor farming communities in the Tamale region. Although only Aborodwom had all respondents (100%) expanding their farms among the communities close to Lake Bosomtwe, Nkowi, Obo, Abaase, Anyinatease, and Pipie old town also respectively had 88%, 79%, 50%, 43% 71% which are equally high. The expansion of farms is therefore a practice that is widespread among smallholder farmers in the Bosomtwe District rather than restricted to either of the clusters. Clearing of forests for new farmland was another practice that smallholder farmers in the Bosomtwe District have resorted to in the face of current micro-climate variability. To this practice, Robinson *et al.*, (2013), noted that farm expansion underpinned by such practices as shifting cultivation in many African countries has driven forest loss. Robles, (2013) in agreement puts forth that expansion of farmlands on state and customary lands by smallholder farmers in Mexico, is a key driver of deforestation.

Unlike the expansion of current farms, the study revealed that the clearing of forests for new agricultural lands was more prevalent in communities farther away from the Lake rather than those around the Lake. The two highest recorded for this practice in communities farther away occurred in Adwampon and Amankwadei which had 100% apiece while that of those located around the Lake was 88% and 60% for Abaase and Aborodwom respectively. The two least recorded for those farther away was 13% for Kokodie and 25% for Ayuom while that of those around the Lake was zero for Nkowi and Obo. Hence, communities farther away tend to indulge in this practice more than those around the Lake.

One would have anticipated that communities around the Lake, being most prone to flooding would rather resort to clearing of new farmland. The rugged nature of the terrain around the Lake coupled with rocks as observed in the field in three communities (Aborodwom, Abaase and Anyinatease) had to some extent restricted their ability to expand into virgin forest compared to those in other communities with a comparatively flatter and less difficult terrain. This finding is in sequence with that of the National Report of Turkey (2008) which noted that the mountainous terrain in Turkey restricted agricultural development. Insaidoo *et al.*, (2014) also found that at Offinso and Asankragwa in Ghana, cocoa farmers cleared forests for new cocoa farmlands as the productivity of old farms diminishes. On-farm extensification practices among smallholder farmers is presented in Figure 4.28.

Figure 4.28: On-farm extensification practices in the selected communities.



Source: Author's construct using field data (2015).

It is quite clear that Ghana's climate is changing. Current global anthropogenic emission of carbon dioxide and other greenhouse gases are likely to continue for a while. With its concomitant effect on climate variables as rainfall, temperature and humidity that determine the favorability of micro-climates for agricultural production, crop production is likely to be increasingly adversely affected unless appropriate adaptation action is adopted. The adaptation of smallholder farmers in the Bosomtwe District to CVCC is influenced positively by their income level and the types of crops they cultivated. Smallholder farmers in the Bosomtwe District in adapting to the current vagaries of the climate experienced had resorted to such activities as irrigation, mulching, planting different crops, cultivation of improved crops varieties, use of agro-chemical, expansion of cultivated farm and clearing of virgin forest for new farmlands.

With regard to the second objective of assessing the adaptation practices of smallholder farmers to climate change and climate variability, it was found that farmers had resorted to practices as mulching, use of agro-chemicals, irrigation, change of crop variety, change of crop type, expansion of farms, and opening of new farms in forest. Some of these practices such as mulching and expansion of farms had been dominant in the district while others such as changing of the variety of crop cultivated and use of agro- chemicals had been minimal. In the modified CCFS frameworks (Figure 2.4), there is a two way relationship between the change in agricultural assets and adaptation. In so far as assets for agricultural production are affected by CVCC, adaptation becomes imperative. As traditional farming knowledge is altered due to variations in temperature, onset of rains, rainfall amount and duration, adaption strategies as clearing forest for new farms, mulching, use of agrochemicals and engagements in off-farm livelihood activities become relevant for sustained agricultural production. Practices such as clearing of forest and use of agrochemicals affect land, the biophysical environment conducive for agricultural production. Also the seasonal rainfall and precipitation variation requires that farmers alter their traditional knowledge of the seasons by accepting daily to yearly weather forecasts. Moreover, such practices as opening of farms in forests and on forest frontiers are maladaptive as these release sequestered carbon in trees into the atmosphere.

4.5 AN ASSESSMENT OF ALTERNATIVE LIVELIHOODS OF SMALLHOLDER FARMERS AS AN OFF-FARM ADAPTATION STRATEGY IN THE FACE OF CLIMATE CHANGE

4.5.1 Introduction

In recent times, the attention of development practitioners, policy makers and international organizations have been drawn to climate change induced livelihood vulnerability (Klein *et al.*, 2007*)*). The impact of climate change on livelihoods is anticipated to be greater in Africa compared with other parts of world (Iglesias *et al.*, 2011). This is because climate change is likely to disturb prime sources of food and water, and constrain the continent's supply of food for already poverty stricken and vulnerable communities through droughts, temperature surges and variable rainfall (Nhemachena and Hassan, 2008). Food security of the continent hangs in the balance if livelihoods are not secured and made resilient to reduce the impacts of climate change (Vermeulen *et al.*, 2010). Local livelihoods as well as vulnerabilities are diverse depending on the outcome of socio-economic, demographic and ecological factor interactions (Boissière *et al.*, 2013).

The effect of climate change on livelihoods is revealed through its impact on natural, social, physical and financial assets (Chemnitz and Hoeffler, 2011). Reducing vulnerability implies reducing over dependence on climate related livelihoods especially in the Sahel and Savannah regions (Klein *et al.*, 2007). The study sought to explore the alternative livelihoods of smallholder farmers in the face of climate variability and climate change in the Bosomtwe District. Key areas of concern included alternative income generating activities of smallholder farmers, length of years of engaging in these activities, effects of climate variability on agricultural livelihood and the possibility of switching to alternative income generating activities as primary occupation.

4.5.2 Willingness to Consider Changing Current Occupation

Farmers' disposition to increasingly engaging in alternative livelihoods was ascertained. The likelihood of a farmer devoting more attention and resources to an alternative livelihood activity other than farming was analyzed using the binary logistic regression modelling. Using the Odd ratios for the likelihood of occupation modification, this modelling determined whether farmers were more likely to devote more resources and time to alternative livelihood activities besides farming. Thus respondents were asked to indicate 1 = Yes, the current crop yields encourages them to consider other alternative livelihoods and 0 = No, the current crop yields does not encourage them to consider other alternative livelihoods. The step-wise logistic regression was run in the SPSS software. The first model which was without any predictive variables was the null hypothesis, implying there is no significant difference between the response variables- (Yes and No). This sought to establish that the null hypothesis would be a better way of predicting the outcomes without the inclusion of the independent variables. Conversely, the alternative hypothesis sought to establish that the prediction of the outcome would be better with the inclusion of the independent variables.

The null hypothesis (block 0) showed that overall accuracy of the prediction without the inclusion of independent variables (predictive variables measured at the y= the constant) was 92.7% with a probability value of significance at $P < .000$, and B (EXP) = 0.079. The alternative hypothesis which had the predictive variables added (block 1) had an overall prediction accuracy of 93.3% which was a little higher than the null model at a significant value of P < .000, and a Chi-square value χ^2 = 30.119 at 5 degrees of freedom. The *Nigelkerke* $R^{2,}$ was indicative that the independent variables included in the model offered a 44.6% explanation of the variation in the dependent variable.

There were eight independent variables (non-categorized), entered into the alternative hypothesis equation. However three of them were significant in predicting farmers' disposition to considering alternative livelihood activities other than farming. These independent variables were; the age of the farmer, size of household and security of household food supply. Age was significant in predicting farmers' likelihood of considering alternative livelihood activities because most of the farmers who were young could not envisage any improvement in the current trend of low crop yield in the near future. Another predictive variable was the size of household. Most farmers had household sizes of six or more members. There was hence the need for those who were of age to contribute towards the upkeep of these households. This required a source of income and hence sustainable livelihood. The last significant predicting factor was security of household's food supply. The insecurity of household food supply due to crop failure or poor crop yield consequently necessitated the adoption of alternative livelihood activities to ensure a constant supply of household food.

Age of the farmers, size of household and security of household food supply were significant in the likelihood of predicting the outcome of response variable. These were significant at $P < .030$, $P <.019$ and $P < .012$ respectively. At a 95% confidence interval (CI), these variables had lower to upper CIs for each of the EXP (B) respectively at CI = 1.134—12.524, CI = 1.359—30.224 and CI 1.781—104.561respectively. Six out of the eight independent variables had B (EXP) > 1 of likelihood to predict the outcome of the dependent variable of engaging in other alternative livelihood activities when those independent variables were used on the response variable at; B(EXP) = 1.054—13.644 times (Table 4.6). This implies that the possibility of farmers engaging in livelihood activities besides farming can be predicted by the independent variables at thirteen Odd likelihoods.

Table 4.6: Logistic regression table on likelihood to consider changing current primary occupation

Predictive variables	B	S.E.	Wald	df	Sig.	Exp (B)	95.0% C.I. for EXP(B)	
							Lower	Upper
Age of respondent (A_g)	1.327	.613	4.685	1	.030*	3.768	1.134	12.524
Type of household	17.435	1.504E4	.000	1	.999	3.733E7	.000	.
Marital status of respondent	.708	.456	2.413	1	.120	2.030	.831	4.958
Size of household (S_z)	1.858	.791	5.510	1	.019*	6.408	1.359	30.224
Location of community	-1.783	.998	3.191	1	.074	.168	.024	1.189
Increased expenditure on agricultural inputs	.053	1.070	.002	1	.961	1.054	.129	8.582
Reduced income from agriculture	.623	1.037	.361	1	.548	1.865	.244	14.243
Insecure household food supply (H_{fs})	2.613	1.039	6.326	1	.012*	13.644	1.781	104.561
Constant	-49.068	3.009E4	.000	1	.999	.000		

*** Significant at 0.05**

Source: Author's field data (2015).

The equation generated with the variables inserted is shown in Equation. 1 as;

$$p = \left[\frac{e\{1.327A_g + 1.858S_z + 2.613H_{fs} - 49.068\}}{1 + e\{1.327A_g + 1.858S_z + 2.613H_{fs} - 49.068\}} \right]$$

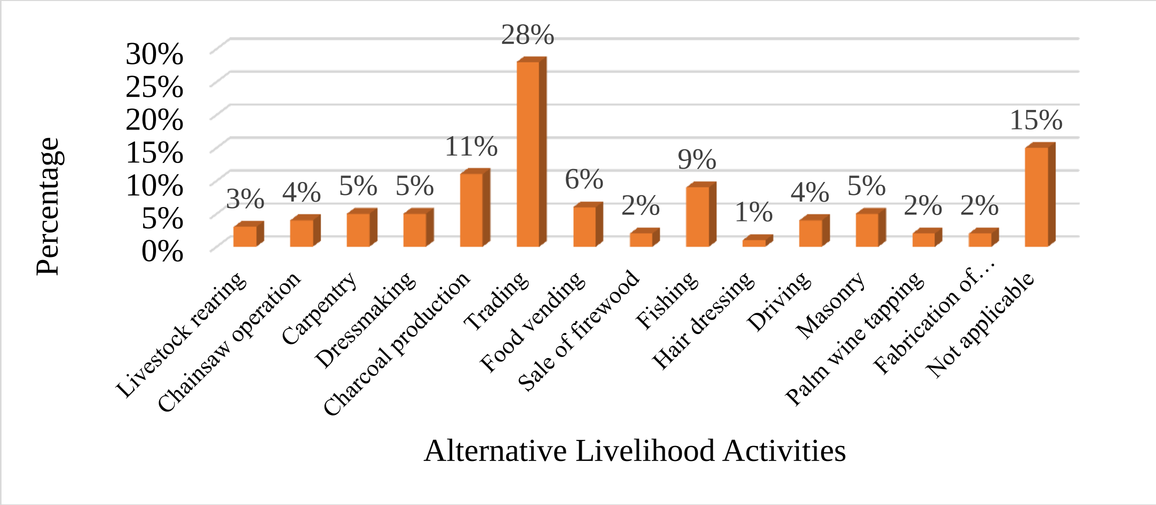
Eqn. l

Thus farmers are thirteen times more likely to continuously engage in alternative livelihood activities besides farming if their crop output remained as it was.

4.5.3 Farmers' Alternative Livelihood Activities

Alternative livelihood activities by smallholder farmers in the Bosomtwe District were varied as can be seen from Figure 4.29. These were basically aimed at diversifying the income sources of smallholder farmers, hence making them less vulnerable to the impact of climate variability.

Figure 4.29: Alternative Income Generating Activities



Source: Author's field data (2015).

These include livestock rearing, chainsaw operation, petty trading, carpentry, masonry, dress making, charcoal production, food vending, sale of firewood, fishing, hairdressing, driving, palm wine tapping and fabrication of aluminum products.

The decision to engage in an alternative livelihood activity for most of the smallholder farmers in the Bosomtwe District was underpinned by current crop yield trends. Thus 61% of respondents had resorted to alternative livelihood activities due to crop failure and low yield. The next highest figure of 24% also engaged in these livelihood activities without any climate related reason while 15% of respondents were not engaged in any livelihood activity. The district coordinator for Women in Agricultural Development-WiAD, explained that *"off-farm income generating activities in the district have increased in the last fifteen years and has been skewed towards trading, logging and small scale mining"*. The latter was however not mentioned by respondents. This could be due to the fact that those who engaged in these activities may not have acquired the legal rights to undertake such activities and hence did not feel safe giving out such information. However, interactions with the key informant revealed that it is one of the major alternative engagements that has emerged in recent years. She adds that *"in view of weather changes, farmers have increasingly engaged in trading, particularly petty trading, processing and sale of gari and soap making"*.

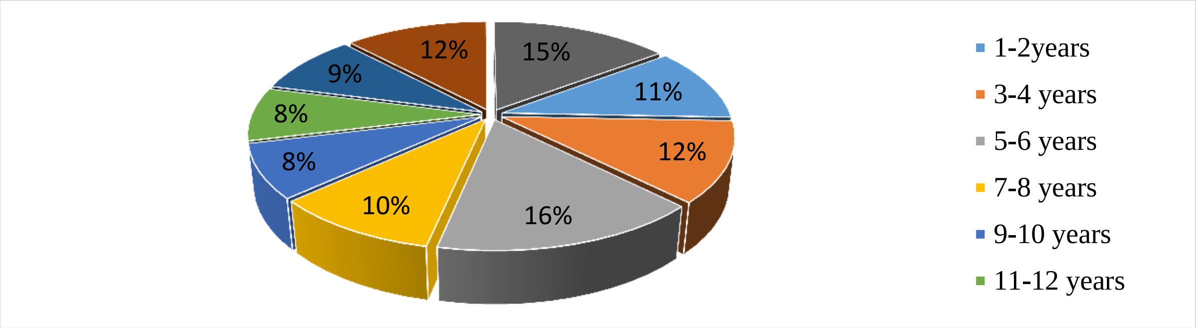
Simbarashe (2013), pointed out that farming in Bikita in Zimbabwe had been adversely affected by climate variability resulting in failure of crops, and low crop yields. Farmers had thereby diversified into alternative livelihood activities such as firewood trade and brick molding. Some smallholder farmers in the Bosomtwe District however pointed out that they were limited in resources to engage in these alternative livelihood activities. It was anticipated that trading would be prevalent in communities located in proximity to the Lake due to its tourist attraction. However, this was not the case. This was because although the lake is a major tourist site, its patronage is seasonal in nature and this does not support robust economic activities in this regard. Also fast growing peri-urban settlements in communities farther away from the lake provides a sustained market for petty trading in such communities.

The study revealed that most smallholder farmers in the district were into petty trading representing 28% of respondents. This, as observed in the communities ranged from the sale basic provisions on table tops to big stores and others that are carried from one community to another. Its predominance was because it requires relatively less capital to commence. Also 15% of respondents did not engage in any alternative livelihood activity. The next highest alternative livelihood activity was charcoal production accounting for 11% of alternative activities. The abundance of trees suitable for charcoal production was found to be the prime driving force for the practice. Charcoal production in the Northern region was graded as the second major occupation to agriculture and also placed second with respect to income generation (Anang and Akuriba, 2011). Agyeman and Lurumuah, (2012) also confirmed commercial charcoal production to be a major source of livelihood in the Northern parts of Ghana. Charcoal production as the second highest alternative livelihood activity is a maladaptive practice which amplifies climate variability. Local climatic conditions can be exacerbated through the release of carbon sequestered in trees into the atmosphere. The 15% of respondents who did not engage in any alternative livelihood activity correspond to findings by Shewmake (2005) who analyzed the vulnerability and impact of climate change in South Africa's Limpopo River Basin. In his study he observed that majority of households did nothing in times of droughts. In the case of smallholder farmers in the Bosomtwe District, they rather resorted to short term coping strategies as borrowing, migrating and changing eating patterns to get by the situation.

Nine percent of respondents engaged in fishing as an alternative livelihood activity due to the presence of rivers such as Oda, Butu, Siso, Supan and Lake Bosomtwe. Food vending was another alternative livelihood activity that was practiced by six percent of respondents. However this was not prevalent because it is usually vibrant in places where secondary and tertiary occupation types prevail which is characteristic of urban centers. Other activities such as masonry, driving, dressmaking, chainsaw operations, carpentry and fabrication of aluminum products are those that require some level of skill. Hence, those who had been able to acquire these skill were the only ones able to engage in related income generation activities as alternative livelihood activities to agriculture.

The number of years for which smallholder farmers had engaged in these alternative livelihood activities were categorize into eight groups as follows: 1 to 2 years, 3 to 4 years, 5 to 6 years, 7 to 8 years, 9 to 10 years, 11 to 12 years, 13 to 14 years and above 14 years. The year period within which majority of farmers had engaged in these activities was 5 to 6 years representing 16%. The next highest was shared by 3 to 4 years and above 14years and accounted for 12% of respondents apiece. This was followed by 1 to 2 years having 11%. This implies that in recent times, farmers were increasingly engaging in alternative livelihood activities. The two lowest recorded were eight percent for the 9 to 10 and 11 to 12 year groups. Smallholder farmers who had been involved in alternative livelihood activities at least within the last 15years in the Bosomtwe District was the sum of the year ranges from 1to 14years was 73%. This is presented in Figure 4.30.

Figure 4.30: Number of years of involvement in alternative income activities



Source: Author's field data (2015).

Probing further to ascertain whether the shift from agriculture to other livelihood activities was likely to persist among smallholder farmers, they were asked if they were still considering other sources of livelihood and the place of agriculture if such livelihood avenues expanded. Up to ninety three percent (93%) of respondents were still considering other sources of livelihood activities other than that which they already practiced and agriculture, while only seven percent were content with their current economic activities-agriculture and current alternative livelihood activity. Of those still considering alternative livelihood activities, 60% said they would keep agriculture as their primary occupation and 33% intended to rather keep agriculture as a secondary occupation if only the alternative livelihood activity has more prospects than agriculture. For the remaining seven percent, this was not applicable. Barrett *et al.*, (2001) espouse that as output from farms decline, farm household in order to reduce risk and vulnerability naturally diversify into off-farm activities. The main reason for diversification in Nigeria as observed by Abimbola and Oluwakemi, (2013) was limited agricultural income.

The role of these alternative livelihood activities was even more crucial in the district as the level of remittances was very low among the farmers. Only 23% of respondents receive remittances and 77% did not. Most of those who received remittances only received it on an average of twice in a year. This contextualizes the relevance of these alternative livelihood activities among smallholder farmers in the Bosomtwe District as being a very critical adaptation strategy. This concurs with the findings of Roncoli *et al.*, (2001) who observed in their study of farmers in Central Plateau in Burkina Faso that non-farm activities was becoming important and already formed part of the main source of income for households. This trend is further made clear in Table 4.7, which is a cross tabulation revealing the possibility of farmers switching to alternative livelihood activities as their main economic activity due to the predictability of rainfall pattern or otherwise if better livelihood opportunities emerge.

Table 4.7: Farmers switching to alternative livelihood activities due to the consistency and predictability of rainfall.

		PERCEIVED RAINFALL PATTERN IN THE LAST 15YRS		
		Consistent and predictable	**Inconsistent and not predictable**	**TOTAL**
CONSIDERATION OF AGRICULTURE AS PRIMARY OR SECONDARY ACTIVITY WITH RESPECT TO ALTERNATIVE LIVELIHOOD ACTIVITY	**Primary occupation**	8 (9%)	83 (91%)	91 (100%)
	Secondary occupation	3 (6%)	47 (94%)	50 (100%)
	Not applicable	2 (19%)	9 (82%)	11 (100%)
	TOTAL	13 (100%)	139 (100%)	152 (100%)

Source: Author's field data (2015).

Only 9% of respondents who intended keeping agriculture as their primary livelihood activity said the rainfall pattern had been consistent and predictable while 91% said it had been inconsistent and unpredictable. This conforms to the findings of Ontonyin and Agyemang (2014) whose study in Northern Ghana indicated that smallholder farmers were increasingly resorting to alternative livelihoods. Those intending to keep agriculture as a primary livelihood activity gave reasons as having comfort in their native communities and lack of finances to venture into the seemingly capital intensive alternative livelihood activities. They also had fears of losing their land, should they quit agriculture. As such they were not considering alternative livelihood activities at all. Of those who intended to switch to alternative livelihood activities as their primary livelihood activity, only six percent perceived the rainfall pattern to be consistent and predictable while 94% perceived it to be inconsistent and unpredictable. This indicates that livelihood activities amidst climate variability are perceived to be threatened, especially those that are climate dependent like smallholder farming.

This gradual trend is stimulated by the fact that annual and seasonal weather patterns had increasingly become very unpredictable. Hence income from agriculture had equally become unstable. Engaging in an alternative livelihood activity was therefore a critical adaptation measure which in the short to medium term helped cushion smallholder farmers from the economic implication of the vagaries of the climate. This is because rural non-farm activities provides alternative economic livelihoods for the rural poor who have limited assets (Bryceson, 2002).

4.5.4 Comparative Analysis of Alternative Livelihood Activities of Smallholder Farmers

A cross tabulation of the location of communities (either located near Lake Bosomtwe or farther away) and alternative activities revealed that some alternative livelihood activities were dominant either in communities close to the Lake or farther away while others were evenly spread in the district. Trading which was the most prevalent alternate livelihood activity was more common in communities farther away (16%) rather than those near the Lake (12%). This trend was due to the fact that communities close to the

Lake had fishing as a dominant alternative livelihood activity which was absent in communities farther away. Engaging in trading does not require any special training or skill and requires less capital hence its high level among smallholder farmers in the district.

However, communities close to the Lake found fishing to be a more attractive alternative livelihood activity. This is due to a generally high demand for fish in households in the district and beyond, and the ease of access to the Lake due to their proximate location. Hence fishing seemed less burdensome and more attractive compared with trading. The decline in their engagement in trading was buffered by fishing activities. Fishing and sale of firewood as alternative livelihood activities recorded higher response in communities near the Lake (two percent for sale of firewood and nine percent for fishing) as compared to those farther away (zero percent apiece). Sale of fire wood was high because it served to provide fuel wood for food vending activities which also recorded approximately five percent in communities close to the Lake compared with one percent in communities farther away from the Lake. Carpentry and livestock rearing were widespread among the communities which are farther away (three percent apiece) rather than in those near Lake Bosomtwe (two percent and zero percent apiece). That of carpentry corresponded to chainsaw activity as a livelihood activity which was equally high in communities farther away than those near (chainsaw: three percent and one percent for communities farther away and those near respectively) the Lake Bosomtwe respectively.

This among other factors can be attributed to the topography of the terrain around the Lake which is rugged and hence difficult to access compared to that of those farther away with a gentler terrain. This seemed to have fuelled carpentry as an alternative livelihood activity in the communities farther away from the Lake due to easy access to timber and wood. The other alternative livelihood activities were evenly distributed in the district regardless of whether the communities were close to the Lake or farther away.

These alternative livelihood activities are usually done concurrently with agricultural activities and only intensified in the minor rainy season (Septembers - October), dry season and when crops do not do well in the major season. When Roncoli *et al.,* (2001) examined farmers' response to drought conditions in Burkina Faso, he found that off-farm alternative livelihood activities were predominant in the dry season when agriculture produce is being sold and hence people have more money and time.

The alternative livelihood activities found in the Bosomtwe District from this study include livestock rearing, chainsaw operation, petty trading, carpentry, masonry, dress making, charcoal production, food vending, sale of firewood, fishing, hairdressing, driving, palm wine tapping and fabrication of aluminum products, small-scale mining with petty trading being the most prevalent. Charcoal production was also prominent and had been sustained by the abundance of trees species for the practice. This is a maladaptive practice that amplifies global climate change by releasing carbon dioxide sequestered by trees into the atmosphere. Smallholder farmers' involvement in alternative livelihood income activities has been high within the last 15 years with the prime objective of securing household income supply. Diversification is a primary means by which many individuals and households reduce risk.

CHAPTER FIVE:

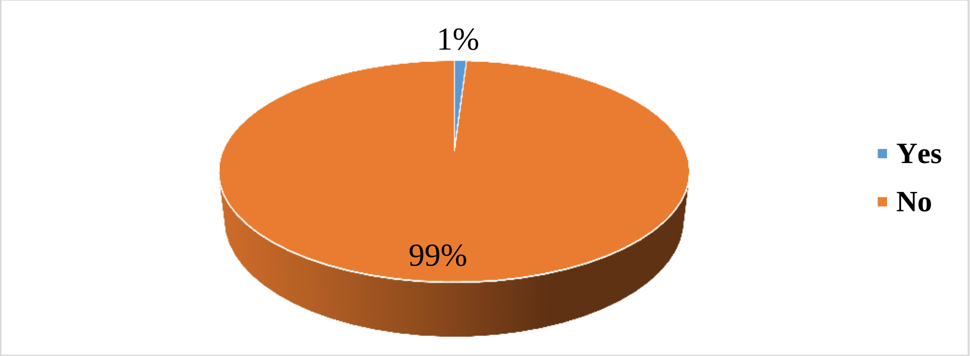
AGRICULTURE BASED CLIMATE CHANGE MITIGATION: THE EVIDENCE

5.1. INTRODUCTION

One of the specific objectives of the study was to assess the agricultural and forest land use potential for REDD+ among smallholder farmers in the Bosomtwe District. Critical areas examined included awareness of REDD+ and its benefits among smallholder farmers in the Bosomtwe District, willingness of smallholder farmers to engage in forest management practices, possible motivation for adoption of REDD+ activities, and land tenure and its potential implication on access to REDD+ benefits. Some of the arguments remain that agriculture is a driver of deforestation in REDD+ (Elbehri *et al.*, 2011).

The study results revealed that awareness of Reduced Emissions from Deforestation and Forest Degradation with conservation and sustainable management (REDD+) and its benefits was diminutive among smallholder farmers in the Bosomtwe District. Only one percent of respondents knew what REDD+ meant, stood for and the benefits thereof for developing countries (and other stakeholders). The remaining 99% had never heard of REDD+ (Figure 5.1). Similarly Reed (2011), found that in Ecuador, most of the country's indigenous populations were indifferent and distrustful of REDD+, in part because they had never heard of it.

Figure 5.1: Smallholder farmers' knowledge of REDD+ in the Bosomtwe District



Source: Author's field data (2015).

According to Madeira (2008), although the focus of international discourse on REDD is on credit design and policy, its success depends on the practicality of implementation in host countries and among local stakeholders such as communities and land owners. This is equally premised on their awareness and understanding of what REDD+ is, and hence to appropriately understanding their role in the implementation of these policies at the local level. Sommerville, (2011) posits that ill-informed stakeholders and beneficiaries could unknowingly sell their carbon rights to others even with a policy of equitable distribution of benefits. It is therefore very necessary that these stakeholders are appropriately educated on what REDD+ is, its associated responsibilities and the accruing benefits accordingly.

5.1.1 Willingness of Smallholder Farmers to Adopt REDD+

Although the potential of achieving climate change mitigation within REDD+ begins with its design, the actualization of its purposes ultimately lies in the ability of grassroot stakeholders and their commitment to this course (Madeira, 2008). Farmer's views were sought about their willingness to trade-off immediate gains of cutting down trees for future REDD+ benefits, trading off future REDD benefits for present gains or utilizing benefits now and planting trees instead. Majority (74%) were willing to utilize immediate benefits of cutting down trees and plant new ones instead, 23% were willing to trade off future benefits of REDD for present gains (without replanting) and only three percent were willing to trade immediate gains of cutting down trees for future benefits. Farmers do not expect to benefit immediately from preservation of trees. Consequently trading off their immediate and primary source of livelihood for benefits that may not be forth coming in the short term does not seem appropriate. Hill (2004), explained that the benefits of planting trees on farms is only realized in the long-term. Farmers were also more willing to cut down the trees because their crops do not do well in the shade and crop yield is increasingly being affected by among other factors climate variability. Issues of illegal logging has also hampered the planting of trees among smallholder farmers in the Bosomtwe District. Leaving economically valuable trees on your farm poses a threat to crops as loggers may cut it down and destroy cultivated crops in the process. Fraser (2015), attests to this stating that some farmers in Ghana for fear of their crops being damaged by loggers destroy tree saplings during cultivation.

When asked about their willingness to be involved in REDD+ activities –with the necessary training, support and materials – 64%, indicated being very willing, 29% indicated being quite willing while only seven percent were not willing. This agrees with findings by Banerjee-Woien, (2010) who asserts that in Indonesia, the willingness of indigenous people was key in determining the success of REDD+ initiatives. The motivation of smallholder farmers in the Bosomtwe District was based on three basic bench marks derived from benefits that are embedded in REDD+ – climate mitigation (81% yes and 19% no), secure agricultural livelihood (95% yes and five percent no) and possible financial benefits (76% yes and 24% no). In-depth interview with District Extension Officers revealed that periodic awareness programmes and field demonstrations are embarked upon to educate farmers on the best farming practices that have agro-forestry components. These programmes are highly patronized by farmers. Also weekly and monthly visits to communities and farm by Agricultural Extension Officers have been planned over the years but challenged by accessibility. It is quite obvious that smallholder farmers in the district keenly have their livelihood at heart as the need to secure agricultural livelihood recorded the highest as a motivating factor for the adoption of REDD+ initiatives.

There was a positive but weak relationship between monthly income and number of trees planted by farmers within the last ten years (Table 5.1). This presupposes that an increase in income of smallholder farmers will result in an increase in the number of trees they plant on their farms. Smallholder farmers' income sources in the Bosomtwe District is not restricted to agriculture as off-farm income sources also contribute to household income. Deductively the more secured farmers are about their income, the more likely they are to plant more trees on their farms.

Table 5.1: Correlation between monthly income and number of trees planted.

		Average monthly income	Number of trees planted in the last ten years
Average monthly income	**Pearson Correlation**	1	.184*
	Sig. (2-tailed)		.023
	N	152	152
Number of trees planted in the last ten years	**Pearson Correlation**	.184*	1
	Sig. (2-tailed)	.023	
	N	152	152

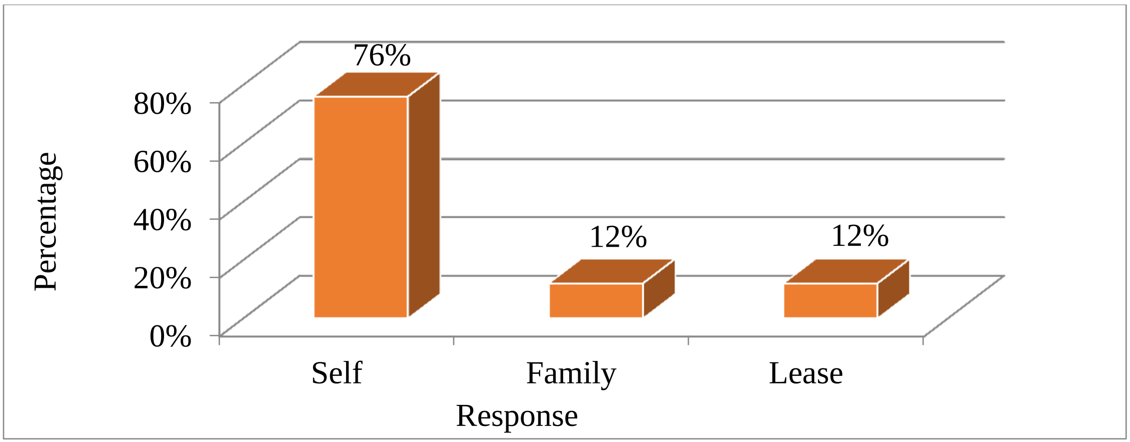
Source: Author's field data (2015).

The descriptive statistics also indicated that most of the smallholder farmers own their agricultural lands and majority of them were very willing to engage in REDD+ activities. The weak relationship between income and number of trees planted indicates that there are other intervening factors that influence the planting of trees on farms. These could be embedded in traditions and customs, the perception of tree-shade hampering crop growth and farming systems that came up during the study but are more qualitatively inclined.

5.1.2 Relationship between Land Tenure Arrangement and REDD+ Benefits

For REDD+ targets to be actualized, equitable distribution of resources and benefits, clear carbon tenure and local participation must be achieved (Tanzania Natural Resource Forum, 2011). Land tenure system in the Bosomtwe District among smallholder farmers as revealed by this study results was predominantly self-owned: 76% of smallholder farmers owned their farmlands, 12% of respondents worked on family lands and 12% on leased lands. This is shown in Figure 5.2. Having secure tenure over the land they cultivate stimulates the farmers' commitment to protect and develop the area contracted to them. Being able to harvest, utilize and market the products derived from the development of their tenured lands are incentives for them to continue doing so not only for their individual benefit in the long term but also to the community and nation in general (Bugayong, 2003).

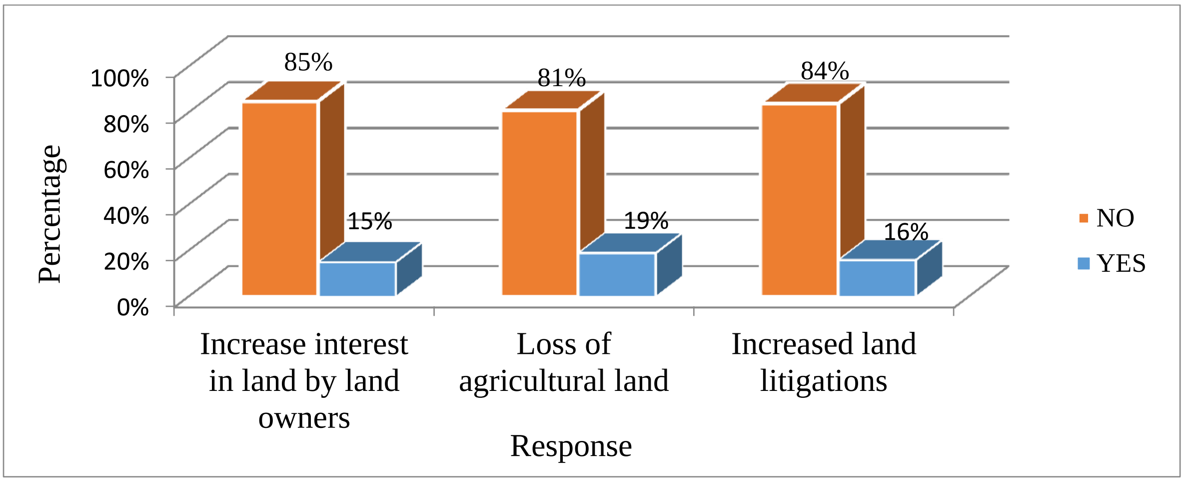
Figure 5.2: Land tenure in the Bosomtwe District.



Source: Author's field data (2015).

This presupposes that farmers have the opportunity to be actively involved if land owners are to be involved as key stakeholders in the formulation and implementation of projects. Rothe and Munro-Faure, (2013), further assert that while tenure related risks will affect the implementation of REDD+, it may also reduce or exacerbate land conflicts by changing value of forests. From Figure 5.3, it can be deduced that there is little anticipation among smallholder farmers with regard to increased interest in farmland by land owners. This is because farmlands are predominantly owned by the farmers themselves and therefore benefits would accrue to them.

Figure 5.3: Tenure implications for access to REDD+ benefits



Source: Author's field data (2015).

Hence, 85% did not anticipate an increased interest in farmland by land owners while 15% did. This trend was equally made manifest in their response on the possibility of increased land litigations due to access to REDD+ benefits with 84% not anticipating an increase in land litigation and 16% anticipating an increase in land litigation. They however noted that the value of agricultural land will increase. Nineteen percent (19%) of respondents anticipated a reduction in agricultural as a result of competing land use changes with the introduction of REDD+ activities while 81% anticipated otherwise. This is shown in Figure 5.3. Those who anticipated a reduction in agricultural land attributed it to the shade that trees provide and the root systems of trees being less favourable for the tilling of land. The majority who indicated no reduction in agricultural land explained that trees were more helpful and improved soil moisture and nutrients which would buffer for reduction in land area due to trees planted.

5.1.3 Smallholder Farmers' Knowledge of the Benefits of Forests

The Forest Investment Program (FIP) - one of the climate funds that target forests and REDD-aimed to attract between US$1 billion and US$2 billion to fund a range of activities, including REDD, sustainable forest management and afforestation activities (Griffiths, 2008). Grieg-Gran (2010) posits that payments for forest conservation must be accompanied by support for other income generating activities and improvement of agriculture as well as agro-forestry.

Although 64% of smallholder farmers were willing to practice agro-forestry 36% were not willing. Of those not willing to practice agro-forestry, 26% were willing to use part of their farms for afforestation, one percent (1%) were willing to use their entire farm for afforestation and 9% were not willing to engage in agro-forestry or afforestation. They however, expressed concerns of the possibility of losing agricultural land through afforestation and agro-forestry. This is because land is scarce and crops do not do well in shade. The Tanzanian Natural Resource Forum (2011) states emphatically that communities that undertake REDD+ commit themselves to forego activities which have a value to them (economic and otherwise), as individuals, households, and communities. Forests provide ecosystem services that includes soil protection, non-timber forest products including food and fiber and climate regulation (UN-REDD, 2010). It was also found that knowledge of smallholder farmers in the Bosomtwe District on the benefits of forests was quite high.

Table 5.2: Smallholder farmers' knowledge of the benefits of forests

THE ROLE OF FOREST/TREES IN CLIMATE	RESPONSE		TOTAL
	YES	NO	
Prevents intense surface heating	90%	10%	100%
Helps in cloud formation (hence rainfall)	43%	57%	100%
Serves as watersheds	92%	8%	100%
Absorbs carbon dioxide (CO_2)	32%	68%	100%

Source: Author's field data (2015).

Up to 90% of smallholder farmers indicated that forests prevent intense surface heating and also serve as water sheds. They espoused that vegetated or forested places tend to have a distinct physical environment and the micro climates of these places are quite distinct from others in terms of temperature, rainfall and winds. More than a quarter (43%) of the respondents also indicated that forests also help in cloud formation (and hence rainfall) and the absorption of carbon dioxide: 32% (carbon sequestration). This local knowledge among smallholder farmers provides strong basis for them to appreciate and accept REDD+ and other related programmes. REDD+ will encourage smallholder farmers to be more committed to activities that will help to conserve and/or rejuvenate forests. Although smallholder farmers in the Bosomtwe District are quite knowledgeable of the benefits of forests, they are faced with the challenge of how to make a living sustainably especially amidst current climate trends. REDD+ will not only serve to secure the livelihoods of smallholder farmers. It will also make it more sustainable and improved through proper environmental resource management, education on proper adaptation practices, potential financial benefits and the actualization of the benefits of forest known to them.

The study set forth with a proposition that smallholder farmers in the Bosomtwe District are not willing to undertake REDD+ initiatives as avenues for benefits and the conservation of carbon stock in trees. Farmers raised concerns on the impact of agro-forestry and for that matter trees on their farming activities. REDD+ as a forest oriented programmes may seem to pose a similar challenge. However training programmes carried out by the district extension officers and traditional ecological knowledge (TEK) which is in tandem with the potential benefits of REDD+ seemed to alley their fears. This will form the basis for the easy adoption of REDD+ initiatives within the Bosomtwe District. Willingness to be involved in any such initiative is also spurred on by ownership of farmland which is prevalently self-owned. They anticipate that benefits will accrue directly to them. Hence, smallholder farmers in the Bosomtwe District are very willing to undertake REDD+ mechanisms as avenues for benefits and conservation of carbon stock in trees.

5.2 PATTERNS OF AGRICULTURAL LAND USE CHANGE

5.2.1 Introduction

Land is the main source of food and fiber for humanity and the backbone of many livelihoods in developing countries, supporting a global population of 7 billion (Smith *et al.*, 2014). Improving land-based carbon stock through land uses is argued to be the most feasible means of achieving global climate change mitigation goals (Noordwijk *et al.*, 2009). One tenth of anthropogenic GHG emissions is from land use change basically through forest changes for agricultural purposes as forests have a high stock of carbon in its trees and pristine soil (PHYS.ORG, 2014). Murphy *et al.*, (2009) put forth that in developing countries, the climate change mitigation potential in forest, agriculture, land use and land use change is very significant and as such must not be overlooked. Mitigation interventions could lead to the displacement of emission instead of actual reduction. Although forest protection programmes can save up to 77 billion tons of CO_2 emissions by 2100, it can also lead to agriculture and other land use patterns resulting in 96 billion tons release of CO_2 (PHYS.ORG, 2014). The mitigation options in the AFOLU sector, consequently must be understood in the light of changes in current and projected land use trends, and its implications for the amelioration of global CVCC (Smith *et al.*, 2014). The study analyzed agricultural land use change trends and their resulting effects on forest cover changes focusing on trends of agricultural land use change and modification prevalent among smallholder farmers and their knowledge of the relevance of agricultural land use and land cover change to climate in the Bosomtwe District.

Pearson's correlation coefficient was used to determine the strength and direction of the relationship between total number of farms owned and the total number of farms converted to other land uses within the last fifteen years as a proxy for agricultural land use change by smallholder farmer in the Bosomtwe District.

Table 5.3: Correlation between total number of farms owned in the last fifteen years and the number that has been changed.

		Number of farms changed	Number of farms owned in the last 15years
Number of farms changed	Pearson Correlation	1	-.255**
	Sig. (2-tailed)		.002
	N	152	152
Number of farms owned in the last 15years	Pearson Correlation	-.255**	1
	Sig. (2-tailed)	.002	
	N	152	152

****. Correlation is significant at the 0.01 level (2-tailed).**

Source: Author's field data (2015).

A correlation between the total number of farms owned by smallholder farmers in the Bosomtwe District in the last fifteen years and the total that had been changed reveals a significant relationship with a *P*-value of 0.002. The Pearson product-moment correlation coefficient reveals that total number of farms owned is slightly and negatively correlated to the number of farms that have been changed in the last fifteen years. The coefficient of determination of -0.26 means 26% of the variation in agricultural land use change among smallholder farmers is influenced by the number of farms owned. This implies that a unit increase in the number of farms will lead to a decrease in the number of smallholder farmlands converted into other land uses. Conversely, 74% can attributed to other factors as location of farmland, topography, and tenure, etc.

5.2.2 Trends of Agricultural Lands Use Change among Smallholder Farmers

The study results revealed that 90% of respondents had two or more farms while only 10% had just one farm. Smallholder farmers with two and three farms over the last fifteen years respectively, were 40% and 38%. These were the two highest figures and represented 78% of total respondents. The remaining 10%, 11% and one percent of respondents respectively had one farm, four farms and five farms. The multiplicity of farms insulates household from economic and climate shocks that threaten the household's food and income supply. It also provids them the opportunity to practice fallow system, safeguarding the sustainability and productivity of their farms. This is clearly reflected in their land use change patterns. Agricultural land use change was generally low among smallholder farmers in the Bosomtwe District as 66% of respondents had not converted any of their farms to other land uses. The minority (34%) had changed farmland to other land use with 33% of respondents changing one farm and one percent of respondents changing two of their farms to other land use. Hence, the rate of land use change among smallholder farmers in the district was not high.

The pattern of agricultural land use change considered in tandem with ownership of land revealed that of the 34% of respondents who had change their land use from agriculture, 22% was used for residential purposes while 12% was used for commercial purpose including recreation. The pattern of land use change from agriculture to residential was high for self-owned lands (16%) compared with that of family ownership (three percent) and lease (three percent). Quasem (2011) found that in Bangladesh, agricultural land converted under self-ownership was mostly put to residential land uses. For family and lease owned lands, conversion from agriculture to residential recorded three percent (for each) while conversion from agriculture to commercial (recreation) was one percent for each. This is because the development of commercial infrastructure- particularly recreational is more capital intensive and not very profitable in the short to medium term. The presence of the Lake as a tourist site in proximity to the Kumasi metropolis has been a key driver of land conversion for commercial land use particularly around the Lake. The prevalence of agricultural land use is typical of a rural to peri-urban environment with limited or nascent economic opportunity (OECD, 2009). Arable land is increasingly becoming scarce and expensive due to rapid peri-urbanization development and arable land is being lost mostly to residential and commercial activities.

Table 5.4: Cross Tabulation of Pattern of Agricultural Land Use Change and the Location of Communities.

		Land use change			
		Residential	Recreational	Not applicable	Total
Proximity to Lake Bosomtwe	Farther	18%	1%	32%	51%
	Near	6%	9%	34%	49%
	Total	24%	10%	66%	100.0%

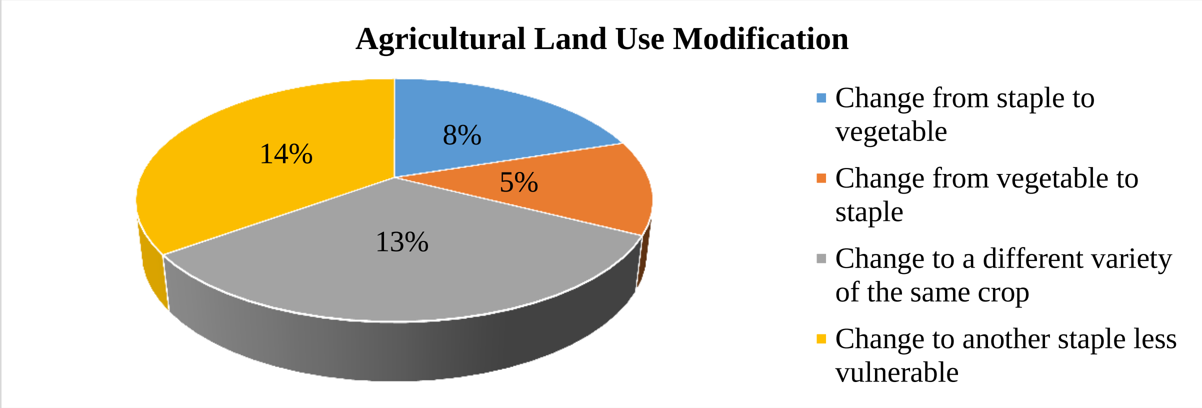
Source: Author's field data (2015).

The trend of agricultural land use change was influenced by the location of the community as agricultural land use change for communities located farther away from Lake Bosomtwe was skewed towards residential purpose while that of communities located around the Lake was towards recreational purpose. Agricultural land use change was also high among communities farther away compared to those closer. This was attributed to the difference in the topography which is flatter in communities farther away as compared to those located around the Lake. The study revealed that 18% of agricultural land in communities farther away had been changed to residential use while one percent was for recreational use. On the contrary, agricultural land change in communities located around the Lake recorded nine percent for recreational use and six percent for residential use. Lake Bosomtwe as a major tourist site in Ashanti region has drawn investors to the area, fuelling the growth of recreational infrastructure and hence this resultant agricultural land use change pattern. The location of farms in proximity to other land uses as entertainment, industry and shopping centers attract land developers who bid high prices for farmlands (Azadi *et al.,* 2010; Quasem, 2011).

5.2.3 Trends of Agricultural Land Use Modification

Most (60%) of the smallholder farmers had not modified their land use at least within the last 15years while 40% had undertaken some form of land use modification shown in Figure 5.4. These consist of a change from staples to vegetable, vegetable to staples and change to a different variety of a particular crop and from one staple to another less vulnerable. Their respective proportions are shown in Figure 5.4.

Figure 5.4: Agricultural land use modification in the Bosomtwe District



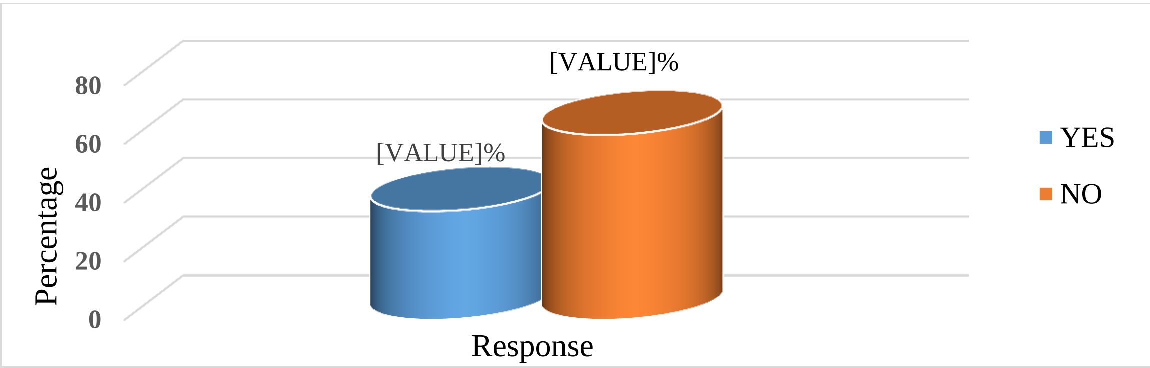
Source: Author's field data (2015).

The pattern of agricultural land use modification in response to the vagaries of the climate predominantly involved changing the crop cultivated from one staple to another that was less vulnerable. This represented 14% of the responses in this regard. The second prevalent agricultural land use modification involved changing the variety of a crop cultivated to a different variety of the same crop that is either early maturing or tolerant of harsh weather conditions. A few farmers (8%) changed their crops planted from vegetables to staples and much fewer (5%) also resorted to the cultivation of staples in place of vegetables (Figure 5.4). The response indicated that agricultural land use modification was not a common change in livelihood strategy and the trend was skewed towards staples which constitute basic household food supply. This point was buttressed by the fact that 77% of farmers were into the cultivation of staples in the Bosomtwe District. This finding supports the study by Ezekiel *et al.*, (2012) in Nigeria that identified that no relationship existed between climatic variability and cassava yield. Consequently, farmers were increasingly cultivating cassava in place of other vulnerable crops. Cassava is particularly tolerant of poor soils and has several robust varieties that can withstand harsh conditions (Gyau, 2015). Other factors could underpin these changes as the economic value of crops at a particular point in time, the vulnerability of a crop, availability and access to improved varieties and the ability to irrigate are all factors that influence farmers' decision to modify their land use (Asfaw and Lipper, 2011).

5.2.4 Implication of Settlement of Agrarian Lands

The study results revealed that only 37% of respondents were constrained from expanding farms while 63% indicated otherwise (Figure 5.5). The majority (63%) were not constrained because most farmers had more than one farm and practiced mixed cropping. This safeguarded them from the repercussions of loss of agricultural land to other land use purposes. They were hence less vulnerable amidst the current land use change pattern. Agricultural land conversion usually leads to the complete loss of agricultural land. In the absence of this, extensification practices are still possible. More so, one could still get land through lease for agricultural purposes. Once household food supply was not constrained by such modifications and household labour was enough to cater for household consumption demands, there was no need for such modifications as espoused in the Chayanovian theory (Hammel, 2005).

Figure 5.5: Land use change constraining expansion of farms



Source: Author's field work, 2015.

A cross tabulation of location of communities and constrains of engaging in extensification in Table 5.5 reveals that of those constrained from expanding their farms, 25% were farther away from Lake Bosomtwe while 12% were located near the Lake. The study thus revealed that agricultural land use change is not constraining farmers' ability to engage in extensification either by expanding farms or clearing new farmlands to a lesser degree which is at variance to the second proposition set for this study.

Table 5.5: Location of community and constrains in farm extensification.

LOCATION OF COMMUNITY	SETTLEMNT OF AGRARIAN LAND AND FARMERS ABILITY TO EXTENSIFY		TOTAL
	YES	NO	
FARTHER	25%	26%	51%
NEAR	12%	37%	49%
TOTAL	37%	63%	100%

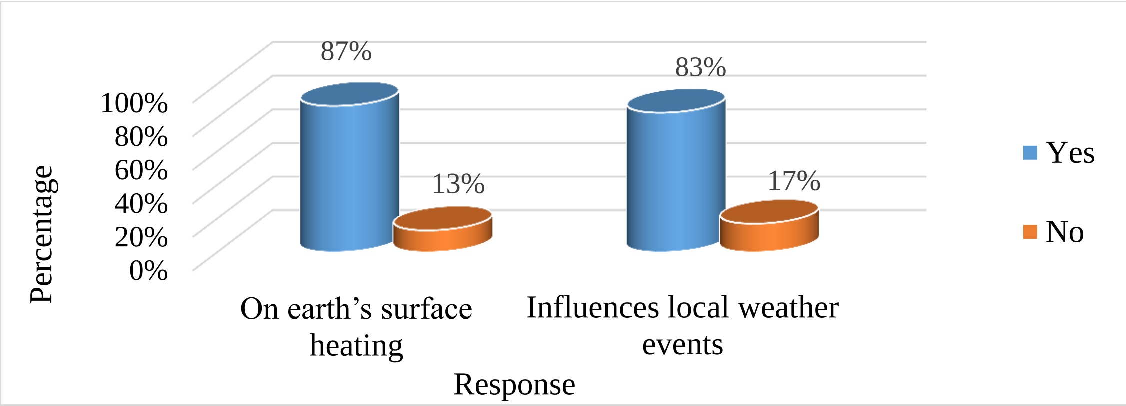
Source: Author's field work, 2015.

The topography of land around the Lake as undulating as it is poses a major challenge to the change of agricultural land to other land uses. Change of land from agriculture around Lake Bosomtwe might require much capital compared to other communities located further away. Hence such farms are disadvantaged especially if they will not generate any financial returns in the long run. This explains why agricultural land use change around the Lake is skewed towards recreation rather than residential use. In tandem with this Azadi *et al.*, (2010) found in China that the vast majority of farmland conversion was prevalent in areas with slopes less than 15 degree. This is because the cost of levelling the land for other land use deters land users and potential buyers from such practices. Discussions with the District Planning Officer revealed that agricultural land-use change to other land uses is rapid in the peri-urban environments but much slower in the rural areas. This is in accordance with this study as eleven of the twelve study communities had population figures less than 1,000 and hence considered rural. It is however quite clear that arable land is generally decreasing relative to other land uses in the district.

5.2.5 Relevance of Conserved Agricultural Land and Land Cover Change to CVCC

Majority of the respondents (87%) indicated that agricultural land use affects surface warming from the earth surface while 13% said otherwise (the albedo effect) explaining that farms devoid of trees are hotter (have high temperature). The majority explained that this is because the land is not properly covered or shaded while those with trees or on forest frontiers are cooler (have low temperature). In the tropics, changes in the rate of evapotranspiration is related to changes in surface albedo which varies correspondently with land use change (Brown *et al.*, 2000; Kvalevag *et al.*, 2012).

Figure 5.6: Effects of agricultural land use and land cover change



Source: Author's field data (2015).

Again, 83% of respondents indicated that land use change had affected the pattern of weather related events. The transition from forest to agricultural and subsequently to other land uses had reduced forest cover around some communities. Winds were therefore stronger compared with the past making communities vulnerable. Also, deforestation and some patterns of land cover change are identified as a local driver of CVCC consequently resulting in climate change manifest locally in droughts, inconsistent and unpredictable rainfall patterns referenced to the modified CCFS framework (Figure 2.4). Respondents also indicated that land cover influences temperatures, explaining that forested areas are less warm compared with places with little or no forest cover. To this Betts *et al.*, (2007) emphasized that reforestation (or avoided deforestation) in the tropics results in a cooling effect through sequestration of atmospheric carbon, increased evaporation and cloud cover.

In assessing the pattern of agricultural land use change by smallholder farmers in the Bosomtwe District, the study revealed that the number of farms owned by farmers influenced agricultural land use change among smallholder farmers in the Bosomtwe District. Hence agricultural land use change was generally low among smallholder farmers and the pattern when considered in tandem with ownership revealed that changes among farmers who owned the lands was high for conversions to residential use as compared those to recreational use. The same trend prevailed for family owned lands and lease. Although an analysis of the Bosomtwe District micro climate revealed change, this does not greatly influence agricultural land use pattern in the district as was postulated for the study. Land use change has been minimal because land in itself is a form of security. Also, the economic costs and returns of developing land in some parts of the district has served as a deterrent factor. In the Bosomtwe District, these drivers have rather been restricted by topography and economic factors. Climate change has rather increased the value of land as a form of security. Also, most of the smallholder farmers have not modified their land use at least within the last 15years. Agricultural land use modification is hence quite small and the trend is skewed towards cultivation of staples which constitute basic household food supply.

Through smallholder farmers' adaptive response, variations occur in agriculture and forest land use patterns evident in the modified CCFS framework (Figure 2.4). Land use change and or modification occurs based on the potential present and future economic returns of agricultural land vis a vis that of other land uses. In the Bosomtwe District, conversion of forest to agricultural land is of high economic value in the short term while conversion of land to commercial is not economically prudent in the short term. Also, agricultural land was seen as a form of security and hence, deters conversion to other land uses except for that towards secondary forest through fallow. Traditional ecological knowledge (TEK) of the benefits of trees was found to be in synergy with the benefits of REDD+. Hence, REDD+ and agricultural land use as related to adaptation, were in themselves mitigation measures. They should be pursued through policy interventions in response to CVCC since they also are related to the agricultural production assets as depicted in the modified CCFS framework (Figure 2.4).

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

This final chapter presents a summary of the key findings of the study and policy recommendations. Climate variability and climate change has taken center stage in global development discourse due to its impact across various sectors. Its potential to undermine development efforts locally and internationally has necessitated the adoption of appropriate policies for effective mitigation and adaptation. The agricultural sectors of developing countries must harness their potentials and take advantage of all available opportunities to secure food production amidst already pressing challenges as increasing population, loss of arable land to other land uses, low production technology and opportunities as well as an inherent vulnerability to CVCC itself.

In order to substantiate the need for the adoption of appropriate mitigation and adaptation measures for sustainable agricultural production, the study was guided by five specific objectives. Firstly, the study analyzed the trends of climate variability and climate change in the Bosomtwe District for a 30 year period (1981to 2011). Secondly, it examined smallholder farmers' adaptation strategies to climate variability in the Bosomtwe District. Thirdly, the study assessed the alternative livelihoods of farmers in the face of climate variability and climate change. Again the agricultural and forest land use potential for REDD+ among farmers in the District was assessed. Finally, the study assessed the agricultural land use change and modification patterns among smallholder farmers in the face of climate variability.

In order to achieve these objectives, the simple random sampling technique was used to sample a total of 152 smallholder farmers for the study. These respondents were selected from twelve communities which were randomly sampled from 66 communities in the district. Six of these communities were located around Lake Bosomtwe while the remaining six were located farther away from it. In-depth interviews and questionnaires were the main methods and tools for data collection from key informants and respondents respectively. Both descriptive and inferential statistical tools of the SPSS and Excel software were used for the analyses of the quantitative data gathered; whereas content analysis, drawing systematic conclusions from the in-depth interviews was the method used for the analysis of the qualitative data gathered. The major findings of the study are summarized as follows:

6.1.1 Trends of Climate Variability and Climate Change

It was observed that temperature and rainfall in the Bosomtwe District from 1981 to 2011 had been inconsistent and unpredictable. The onset of rainfall for the rainy season has changed significantly and its distribution has also varied. Generally, there has been shifts in the peak rainfall months of the major and minor season. Some years also experienced a unimodal rainfall regime instead of bimodal as was confirmed by findings of Codjoe and Owusu, (2011). Temperatures have also increased, significantly affecting maize yield. Consequently, farmers have not been able to adequately prepare for the onset of rains. The year to year variation in rainfall has left farmers in a dilemma of what to expect in subsequent years.

6.1.2 On-farm and Off-Farm Adaptation Practices of Smallholder Farmers

Prevailing adaptation practices in the Bosomtwe District were irrigation, use of agro-chemicals, mulching, change of crop type, change of crop variety, expansion of farm and opening of new farm in forest. The most prevalent practice was mulching due to its ecological and agricultural benefits. This practice is quite a general practice as opposed to irrigation which was more skewed towards communities proximate to Lake Bosomtwe. Economic and geographical factors have to a large extent influenced the adoption of these adaptation practices in the district resulting in a mosaic of practices across the district. The opening of new farms in forest was particularly a maladaptive practice as it releases carbon sequestered in trees into the atmosphere. Mulching was the most famous adaptation practice in all communities although communities around the lake practiced it more than those farther away from the lake. Other adaptation strategies such as, change of crop type and use of agro- chemicals were also prevalent in the communities closer to the lake. Adaptation practice such as irrigation, use of agro-chemicals, change of crop variety, expansion of farms and opening of farms in forests and forest frontiers were prevalent in communities farther away from the lake.

Off-farm adaptation practices had keenly been involvement in alternative livelihood activities. These have played a key role in lessening farmers' vulnerability to the vagaries of the climate. They include trading, driving, lumbering, fishing, charcoal production, food vending and other activities that are less capital intensive and require less labour commitments. Some alternative livelihood activities were dominant either in communities close to the Lake or farther away while others were evenly spread in the district. Trading which was the most prevalent alternate livelihood activity was more common in communities farther away and fishing was prevalent in communities around the lake. The study also revealed that some of these alternative livelihood activities complemented each other. Food vending for example was prevalent in communities close to the lake, complemented by harvest and sale of firewood while carpentry was also dominant in communities farther away from the lake complemented by chain saw activities. Other livelihoods activities such as masonry, driving, fabrication of aluminum products and hairdressing were not skewed to any of the clusters. These had augmented income from agriculture to ensure a sustained household income supply. However with increased variability of the climate, smallholder farmers are inclined to replace agriculture as a primary livelihood activity with these alternative livelihood activities.

6.1.3 The Potential for Reducing Deforestation and Forest Degradation with Conservation and Sustainable Forest Management among Smallholder Farmers

The role of stakeholders in sustainable forest management in forest regions cannot be overemphasized. However, in the Bosomtwe District, knowledge of REDD+ among smallholder farmers was low. Based on traditional ecological knowledge on the benefits of forest which was in agreement with REDD+ environmental and ecological benefit, farmers were however very willing to be involved in REDD+ and related programmes. Some were already engaged in agro-forestry practices. They foresaw it as a means of mitigating micro-climate variability, resulting in a more sustained agricultural economy through sustainable forest use, management and conservation practices. With the predominant tenure being self-ownership, farmers foresaw benefits of REDD+ accruing to them with little room for loss of agricultural land and land litigations.

6.1.4. Agricultural Land Use Change and Modification Patterns among Smallholder Farmers

The trend of agricultural land use change seemed to be influenced by the location of the community. Agricultural land use change for communities located farther away from Lake Bosomtwe was skewed towards residential use while that of communities located around the Lake is towards commercial use. Arable land was being lost mostly to residential and commercial activities. Also most of the smallholder farmers had not modified their land use at least within the last 15years. Agricultural land use modification was hence quite small and the trend was skewed towards staples which constitute household basic food supply.

6.2 CONCLUSIONS

This study provides the fundamental basis necessary for a wider investigation of adaptation within the agricultural sector and its inherent potential for the mitigation of CVCC. The interconnection between agriculture and climate change and variability focusing on adaptation, livelihoods, and mitigation nexus must still be explored. Through a systematic mixed method approach of data collection and analysis, the study has paved the way for further research. The evaluation of on-farm and off-farm adaptation practices provides the basis for further assessment of the link between the two in other parts of the country. The study also assessed the potentials inherent in agriculture for climate change mitigation and concludes that with appropriate policy interventions and programmes, agriculture can contribute to the mitigation of climate change through effective adaptation, forest and land use practices. This would enable Ghana to have access to REDD+ related benefits to further develop and sustain the agriculture and forestry sectors.

The study objectives, hypothesis and propositions which guided the study were satisfactorily certified by the findings and results. The trends of CVCC in the district had been manifest in various ways, making smallholder agriculture vulnerable and hence necessitating adaptation. The adoption of alternative livelihoods to agriculture had proven very useful as smallholder households had become more resilient to climate related shocks and stresses. Agricultural and forest land use potentials in the district present an opportunity for local level mitigation action in the Bosomtwe District through agricultural and forest land use modification and change.

The study failed to reject its null hypothesis that there is no statistically significant relationship between temperature variability and crop yield. It was proposed that farmers are not willing to undertake REDD+ mechanisms as avenues for benefits and conservation of carbon stocks in trees. With respect to the findings it was realized that more than 80% of farmers were willing to engage in REDD+ activities, motivated by benefits that could accrue to them with environmental and forest conservation. It was also proposed that the pattern of land use change was constraining farmers' ability to adapt to CVCC. Conversely, it was found that agricultural land use change was not constraining farmers' ability to adapt to CVCC as more than half (63%) were not constrained with respect to extensification practices in the Bosomtwe District.

6.3 POLICY RECOMMENDATIONS

This final section of the study elaborates the relevant polices that appropriate institutions are to consider in fashioning climate change adaptation and mitigation policies and programmes in the Bosomtwe District. It is quite clear to smallholder farmers that the need to adapt effectively and contribute to climate change mitigation is imperative and crucial. Being an agrarian district, such changes and variations in climate have remarkable implication for agriculture and the local economy. The following recommendations are made for apposite institutional considerations.

6.3.1 Investments in Communications

Government through the Ghana Meteorological Agency must ensure that information and communication technology tools are put at the core of all agricultural discourse from the national to grassroot levels. District level modeling of rainfall and temperature trends is needed to ensure institutional alertness and preparedness. There is the urgent need for farmers to have access to and utilize relevant weather information in their endeavors. The Ministry of Food and Agriculture in conjunction with the Regional Meteorological Service should therefore collaborate with telecommunication companies to be able to communicate yearly, monthly, weekly and daily weather forecast to farmers of particular regions and districts through self-phones. Other channels include radio station, community information centers and local authority and structures. This can also be used to expand farmer’s awareness of opportunities as crop varieties, agroforestry, crop shares and insurance among others. This requires investment in communication that enforces inter-sectorial and intra-sectorial flow of knowledge both upward and downwards among the Forestry Commission, Ministry of Food and Agriculture, NGOs in agricultural research and innovation, academia, National Disaster Management Organization and farmers. This will enable them to make more precise decisions on the onset of rains, crop types and varieties and the appropriate farming technologies, practices and systems suited to particular years, landscapes and ecological environments and be adequately prepared for unforeseen contingencies.

6.3.2 Adaptation and Livelihoods: A Holistic Approach

Government through the Ministry of Environment and Natural Resources must adopt a policy approach that is holistic and complementary to avoid duplication of efforts. Such policies must seek to maximize local resources and knowledge to enable farmers and their livelihoods to adapt to and mitigate climate change. This must encompass on-farm adaptation, alternative livelihoods, land use planning, sustainable resource use and management and disaster management. This can be done through participatory approaches ensuring that farmers’ capacity is built with access to resources to initiate and implement sustainable practices in the short run when shocks and stresses are encountered. The development of adaptation strategies should be linked to local practices to improve the effectiveness of autonomous adaptation measures. It is imperative to implement and/or broaden policies that seek to directly or indirectly encourage farmers’ adoption of crop insurance, crop shares, subsidies, access to credit and other incentives that motivate farmers to adopt improved crop varieties.

6.3.3 Local Participation in REDD+ and Environmental Resource Management

The Forestry Services Division should promote the practice of REDD+ among smallholder farmers through education to whip up and sustain interest in the strategy. Building on traditional ecological knowledge (TEK) such as benefits of forest and its relevance to micro-climatic conditions in the implementation of REDD+ programmes will ensure that they are embraced and sustained. Farmers seeing themselves as custodians of natural resources and recipients of fiscal and non-fiscal benefits accruing from their sustainable management will contribute to the sustainability of REDD+ projects. Research should not only focus on the development of resilient crop varieties but also on agro-ecological systems which through management practices are in themselves resilient and robust. There is also the need for policy to be directed towards the protection of marginal agricultural lands to ensure continuous local and regional food supply and encourage proper special planning of other land use practices. Hence it is necessary to designate these areas in the development plan for agricultural or recreational uses rather than residential or commercial.

6.3.4 Collaboration Forums

The Department of Geography and Rural Development should organize yearly collaborative fora that bring policy makers, academicians and grassroot stakeholders such as farmers, District Forestry and Agricultural Officers on a common platform. This will help bring to the fore critical areas of climate change, adaptation and mitigation strategies coming up through numerous research findings such as these and the likes to help create a more congenial environment for participatory and informed policy conceptualization, formulation and implementation.

6.3.5 Limitations of the Study and Issues for Further Studies

Due to constrain of time and resources, other areas of research interest that emanated from the study could not be pursued. Building on findings of the influence of the landscape on adaptation practices and agricultural land conversion, it is recommended that further studies be pursued to further validate the veracity of these finding in light of the hypothetical statements: “there is no significant relationship between the gradient of the landscape and the number of on-farm adaptation practices explored to adapt to climate change” and “there is no significant relationship between the gradient of the land and the rate of agricultural land conversion for other land uses”.

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APPENDIX

SAMPLE QUESTIONNAIRE

DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

1.Respondents's relation with head of household	1.Head [ ] 2.Spouse [ ] 3.Daughter/son [ ] 4.Parents [ ] 5.Other (specify) [ ]
2. Gender of household head	1.Male [ ] 2. Female [ ]
3. Age of household's head	1. 20-35 years [ ] 2. 36-45 years [ ] 3. 46-55 years [ ] 4. 56-65 years [ ] 5. 66-75 years [ ] 6. 76+ years [ ]
4. What is your hometown and region of origin?	**Hometown Region**…….
5. Head of Household's educational level	1. No formal education [ ] 2. Primary [ ] 3. JHS/Middle Sch. [ ] 4. SHS/Tec/voc [ ] 5. Tertiary [ ] 6. Other, (specify)
6.Marital Status of head of household	1. Married [ ] 2. Single [ ] 3. Widow/widower [ ] 4. Divorced [ ]
7. Size of Household ***(A household is a person living alone or a group of people who eat from the same pot) GLSS, 2005/06.***	1. 1-5 [ ] 2. 6-10 [ ] 3. 11-15 [ ] 4. 16-20 [ ] 5. 20+ [ ]
8. Type of Household If a multiple household, which of these members constitute your household?	1. Single Household [ ] 2. Multiple Household [ ] 1.Couple only [ ] 2.Parents with children [ ] 3.Couple and other relatives [ ] 4.Parents, children and other relatives [ ]

HOUSEHOLD ECONOMIC ACTIVITIES

9. Main (Primary) occupation	1.Farming [ ] 2.Teaching [ ] 3.Wood processing [ ] 4.Chainsaw operation [ ] 5.Carpentry [ ] 6.Dressmaking [ ] 7.Charcoal Production [ ] 8.Herbal Medicine production [ ] 9.Trading [ ] 10.Food vending [ ] 11.None [ ] 12.Others (specify)
10. Secondary occupation	1.Farming [ ] 2.Teaching [ ] 3.Hair dressing [ ] 4.Chainsaw operation [ ] 5.Carpentry [ ] 6.Dressmaking [ ] 7.Charcoal Production [ ] 8.Masonary [ ] 9.Trading [ ] 10.Food vending [ ] 11.None [ ] 12.Others (specify)
11. What type of crops do you cultivate? If farming is your primary/secondary occupation	1.staples [ ] 2. vegetables [ ] 3.staples, vegetables and other [ ] 4.staples and vegetables [ ] 5.other [ ]
12. What is the average monthly income of the household? ***Amount could be asked in seasons or years and convert into monthly income***	GH¢………………………………………
13. How will you describe your monthly income?	1. Adequate [ ] 2. Inadequate [ ]
14. How often do you receive remittances from relatives who are not part of your household?	1. Daily [ ], 2.Weekly [ ], 3. Monthly [ ] 4. Every three months [ ] 5. Half a year [ ] 6. Yearly [ ] 7. No remittance [ ]
15. How will you describe the frequency of your income?	1. Regular [ ] 2.Not regular [ ] If not regular why……… …………………………………………

16. How much does your household spend on these items monthly and what percentage of your monthly income is spent on each of them?

Total monthly expenditure GH¢……………………………………………

All expenses on the listed items plus all other expenses should add up to the total monthly expenditure.

Total monthly expenditure should not be greater than total monthly income range in Q12.

Item	Amount	Freq	%
Food *(rice, maize, meat, fish, vegetable milk, egg oil etc)*			
Water (*for cooking, drinking and bathing)*			
Rent			
Electricity			
Energy(*charcoal, firewood, LPG*)			
Education *(fees, books ,uniform*)			
Health care (*Orthodox & Herbal NHIS inclusive)*			
All other expenses			

A. TO ANALYSE THE TRENDS OF CLIMATE VARIABILITY IN THE BOSOMTWE DISTRICT

17. What do you understand by climate variability and climate change? ***Select all that apply***	1.Change in seasonal Rainfall characteristics	
	2.Flooding	
	3. Change in temperature characteristics	
	4. Change in solar radiation	
	5. Other (specify)	
18. What is the level of your knowledge of climate variability and climate change?	1. Very good knowledge	
	2. Good	
	3. Don't know	
	4. Poor knowledge	
	5. Very Poor	
19. Which of the following effect of climate change and climate variability have you experienced? ***You can choose more than one***	1.Water shortage	
	2.Flooding	
	3.Rising temperature	
	4.Shifts in crop growing season	
	5.Drought	
	5.Other (specify)	
Have you adapted to climate change?	Yes	
	No	
20. How have these affected crops? ***You can choose more than one***	1. Loss of crops prematurely due to weather events	
	2.Crop failure	
	3.Other	
21. Is human causes of climate variability and climate change is prominent?	1.Yes	
	2.No	
	If no what is?	

22. What are the human causes of climate variability and climate change? ***(Can pick more than 1)***	| | Yes | 1.Emission of vehicular fumes 2. Removal of vegetation (deforestation) 3. Bush burning 4. Industrial emission 5.None 6. Other, specify
23. How has the rainfall pattern been in the last fifteen years?	1.Consistent and predictable 2.Inconsistent and not predictable
24. How does vegetation cover affect the elements of weather *viz* temperature and rainfall? ***Select all that apply***	1. High vegetation cover prevent intense surface heating 2. Creates a favorable local climate 3. High vegetation cover enhances cloud formation and rainfall 4.Other
25. How has the rainfall season in itself changed?	1. Rains delay, 2. Rains come earlier than expected 3. Sometimes come earlier than expected and at other times delay.
26. In what ways are these changes affecting your farming activities? ***You can choose more than one.***	1. Waste of seedlings 2. Single successful harvest instead of two 3. Reduced crop yield 4.Other, specify
27. How has climate variability affected agricultural activities? ***You can choose more than one answer.***	1. Delayed land Preparation 2. Delayed Planting periods 3. Increased irrigation activities 4. Adoption of soil nutrient and soil water conservation practices 5. Other (specify)
28. What have you observed about the recent climate variability and change in this community? ***You can choose more than one answer***	1.Increased rainfall intensity 2.Decreased rainfall intensity 3.Increase rainfall frequency

	4.Decreased rainfall frequency	
	5.Increased Temperature	
	6.Decreased Temperature	
	7.Increased Frequency of floods	
	8.Decreased frequency of floods	

B. EXAMINE FARMERS' ADAPTATION STRATEGIES TO CLIMATE VARIABILITY.

29.What is the size of your farm? ***Please write the absolute figures by the answers***	1.Less than 1 acre	
	2.1-3 acres	
	3. 4-6 acres	
	4. 7-9 acres	
	5. 10-12acres	
	6. 13- 15 acres	
	7. 16 and above	
30. Is your farm located close enough to Lake Bosomtwe to be used for irrigation?	1.Located near the Lake	
	2. Located near other source of water	
	3.Not located near source of water for irrigation	
31. Which of the following farming systems do you practice?	1.Mixed farming	
	2. Mix cropping	
	3. Monocropping	
32. In order to adapt to the changing climate which of the following on farm adaptation practices have you done? ***Can choose more than one in descending order of importance using a, b c, d with "a" being the most important.***	1. Extensification	
	2. Increased use of agro chemicals – fertilizers	
	3. Change the variety of crops grown	
	4. Changed the type of crop grown	
	5. Other, specify	
	6 Not applicable	
33. What do you do when your crops fail for lack of water?	1.Relocate farm closer to source of water if located afar off	
	2.Engage in alternative source of livelihood	
	4. Migrate	
	5. Borrow	
	3. Change eating pattern	

34. Which of the following do you practice? (CLIMATE SMART AGRICULTURE)	1.Irrigation [ ] 2.No tillage [ ] 3. Mulch tillage [ ] 4. Not applicable [ ] 4. Other, specify
Has the incidence of pest and diseases increased?	1.Yes [ ] 2.No [ ]
Do you have access to agricultural the following?	(Yes / No) Agricultural extension services [ ] [ ] Improved farming tools and technology [ ] [ ]
35. Have these practices been effective?	1.Yes [ ] 2.No [ ] 3. Not applicable [ ] Explain below:
36. Has these factors facilitated your ability to adapt to the climate variability?	(Yes / No) a. Remittances [ ] [ ] b. Diversified livelihoods [ ] [ ] c. Improved farming practices [ ] [ ] d. Availability of arable land for extensification [ ] [ ] e. Clear Forest for new farm [ ] [ ] If you chose ©, please specify here
37. Have any of the following factors constrained your response to climate variability	(Yes / No) a. Lack of knowledge on the situation [ ] [ ] b. Constrains to expand farm size due to limited land [ ] [ ] c. High cost of agric inputs [ ] [ ] d. Lack of or reduction in remittances [ ] [ ] 5.Lack of access to water [ ] [ ] e. Constrained alternative livelihood opportunity [ ] [ ] f.Other, specify

38. How does climate variability and climate change affect water resources used for agric? ***You can choose more than one answer***	1. Drying up of water sources 2. shrinking of water sources 3. Not applicable 4.Other, specify
39. Which of the following do you practice?	1. Irrigated farming 2.Non irrigated farming
40. What is the most important source of irrigation water for you?	1.Lake 2.Stream 3.Pond 4.Well 5.Borehole 6.River 7.None
41. Is water available year-round from this source?	1.Yes 2.No 3.Sometimes 4. Not applicable
42. Have you changed the location of crop production to have access to water for irrigation?	1.Yes 2.No Explain briefly:
43. Which of the following soil nutrient conservation practices do you engage in?	1. Cover Crops 2. Green Manures and Mulches 3. Compost and Composting 4. Not applicable 5.Other
44. Which other crop management practices in order to optimize water on the farm?	1. Efficient management of irrigation systems 2. Growing crops that require less water 3. Optimizing of irrigation schedules 4. Cultivation of cover crops 5.Not applicable 4. Other, specify

C. AN ASSESSMENT OF THE ALTERNATIVE LIVELIHOOD OF FARMERS IN THE FACE OF CLIMATE VARIABILITY AND CLIMATE CHANGE INDUCED CROP FAILURES

45. Which of the following off farm income generating activities do you also engage in? ***Select all that apply***	1.Livestock rearing	
	2.Chainsaw operation	
	3.Carpentry	
	4.Dressmaking	
	5.Charcoal Production	
	6.Herbal Medicine production	
	7.Trading	
	8.Food vending	
	9.Hair dressing	
	10. Fishing	
	11.Hunting	
	12.Masonary	
	13. None	
	14.Others (specify)	
46. How long have you been involved in these activities? ***Write the absolute figure by the chosen range***	1.0-2 years	
	2.3-4 years	
	3.5-6 years	
	4.7-8 years	
	5.9-10years	
	6.Above 10years	
	7. Not applicable	
47. Which of the following reasons accounts for your choice to engage in those other activities?	1.Crop failure and/or low yield	
	2.Without climate related issued	
	3. Not applicable	
48. Is the current crop yield trend encouraging you consider others alternative livelihoods either?	1.Yes	
	2.No	
	Explain:	
49. If yes which of the following would apply to farming?	1. Primary occupation	
	2. Secondary occupation	
	3.Stopped completely	
	4. N/A	
50. Which of the following do you practice to help improve your livelihood?	1.Farming season irrigation farming	
	2.Year round irrigation	

	farming 4. Dry season irrigation 5.None
51. In which of the following ways has your income or livelihood been affected by climate variability and climate change?	1. Increased expenditure on agric input 2. reduced income from agriculture 3. Insecure household food supply 4.Other(specify)

D. AN ASSESSMENT OF THE AGRICULTURAL AND FOREST LAND USE POTENTIAL FOR REDD IN THE DISTRICT AMONG LAND OWNERS.

52. Who owns your farmland?	1. Myself 2. Family 3. Relative 4. Community 5. Not known 6. Other (specify)
53. Do you know what REDD is?	1.Yes 2.No
54. About 15 years ago how many trees did you have on your farm when you first cultivated it? ***Write the absolute figure by the chosen range***	1.None 2.1to 5 3.6 to 10 4.11 to 15 5. 16 to 20 6. 21to 25 7. 25 to 30 8. Above 30
55. .What types of trees were on the farm?	1.Wawa 2.Odum 3.Mahogany 4.Sapele 5.Onyina 6. Don't know 7.Other (specify)

56. Which tree type was the commonest?	1.Wawa 2.Odum 3.Mahogany 4.Sapele 5.Onyina 6. Don't know 7.Other (specify)
57. What are the average diameters of the trees?	1.Less than 1metre 2.1to 2.9metres 3.3to 4.9metres 4. 5metres and above 5.Less than
58. Presently how many trees do you have on your farm? ***Write the absolute figure by the chosen range***	1.None 2.1to 5 3.6 to 10 4.11 to 15 5. 16 to 20 6. Above 20
59.Who cuts the trees?	1. Yourself 2. Legal loggers 3. Illegal loggers 4. Unknown 5.Other (specify)
60. In the last 15 years how many trees have you planted on your farm deliberately? ***Write the absolute figure by the chosen range***	1.None 2.1to 5 3.6 to 10 4.11 to 15 5. 16 to 20 6. Above 20
61. Are there any tree planting programmes for farmers in the district? ***(List below the organization or institutions responsible for these tree planting programmes)***	1.Yes 2.No If yes specify the programmes:
62. Do you practice any of the following forest conservation practices?	(see table below)

	Yes	No
1. Agroforestry		
2. Regenerate timber trees		
3. Plantation development		
4. Enforcement in forest reserves		
5. Regeneration of		

	off-reserve areas		
63. How do trees help to mitigate climate change?		Yes	No
	1. High vegetation cover prevent intense surface heating		
	2. Creates a favorable local climate		
	3. High vegetation cover enhances cloud formation and rainfall		
	4.Serves as watersheds		
	5.Absorbs carbon dioxide		
64. Do you know that you could benefit financially from planting or preserving trees on your farms?	1.Yes		
	2.No		
65. What would motivate you to be committed to planting and preserving trees on your farm?		Yes	No
	a.Climate mitigation		
	b.Secured agric livelihood		
	c.Financial benefits		
	d.Other (specify)		
66. Which of the following are you willing to do?	1. Trade-off immediate gains of cutting down trees for future benefits		
	2. Trade-off future benefits for presents gains		
	3. Utilize immediate benefits and plant new trees instead		
67. Which of the following are you willing to involve actively in?	1. Buy and Plant seedling.		
	2. Plant if only seedlings are free		
	3. Plant if required by law		
	4. Will not plant at all		

68. Anticipating the direct benefits of tree planting and preservation which of the following are you willing be committed to?	1.Change completely to forest [ ] 2. Use part for forest [ ] 3. Agroforestry [ ] 4. Change to cash crops such as cocoa [ ] 5.None [ ] ***Indicate how much land (in hectors or acres) you are willing to consign.***
69. Which of the following could access to REDD benefits lead to?	1. Increased interest in land use by land owners [ ] 2. Lose of agric land [ ] 3. Increased land litigations [ ] 4. Increased value of land [ ] 5.Other, (specify)
70. Given the necessary training, material and support, to what extent are you willing to be involved in forest management?	1. Very willing [ ] 2. Quite willing [ ] 3. Not willing [ ]
71. In your own opinion what should be done to ensure sustainable forest management of the forest?	……………………………………… ……………………………………… ……………………………………… ………………

E. AN ASSESSMENT OF THE PATTERNS OF LAND USE CHANGE BY FARMERS IN THE FACE OF CLIMATE VARIABILITY

72.Does the settlement of agrarian/arable lands have any impact on agricultural activities?	1.Yes [ ] 2. No [ ]
73.How is agric land use and land cover change of relevance to climate change and climate variability?	1.Influences surface heating — Yes / No 2.Influences the absorption of carbon dioxide — Yes / No Explain:

74. How do you respond to the settlement of the agrarian/arable lands?		Yes	No
	1. Constraining the ability to extensify		
	2. Encouraging you to adopt soil and water preservation practices		
	3. Forcing you to change farm farming systems		
	4. Not related to agric activities		
	5.Other(specify)		
	If you chose (3) specify below		
75. How many farms have you had in the last 15 years? Sum the farm sizes in acres	1.One		
	2. Two		
	3.Three		
	4. Four		
	5. Five or more		
76. What is the total number that has been changed? **Indicate the total size changed in acres**	1.One		
	2. Two		
	3.Three		
	4. Four		
	5. Five or more		
	6.None		
77. Which of the following use was it put to?	1. Abunu and abusa		
	2. Residential,		
	3. Sold		
	5.Commercial-stores		
	6. Rent		
	6.Not applicable		
	7. Other(specify)		
78. Indicate the key drivers of deforestation that persist in the district ***(in order of importance from using a, b c, d with "a" being the most persistent)?***	1.Charcoal extraction		
	2.Legal Logging		
	3.Illegal Logging		
	4.Agric expansion		
	5.Infrastructural development		
79. Which of the following land modification practices have you engaged in order to adapt to climate change? ***Can choose more than one.***	1. From subsistence to cash,		
	2. From cash to subsistence		
	3. From staples to vegetables		
	4. From vegetables to staples		
	5. To a different variety of the same crop		
	6. From staples to a different staple		

	7.No land modification
80. What was the reason for such changes?	1. Secure livelihood 2. Improve prospects from agric activities 3. Not applicable 3.other(specify)
81. Which of the following have you engaged in the last ten years due to the variable climate?	1. Intensification 2. Extensification 3. Both 4.None
82. How would you describe the ease of acquiring agric land for other land use?	1. Very Easy 2. Easy 3. Difficult 4. Very Difficult Why:
83. Which land use change is the most prevalent?	1.Agric to commercial 2.Agric to residential 3.Agric to recreational 4.Agric to forest 5.Other(specify)

SAMPLE INTERVIEW GUIDE

Name of Institution:...

Name of Respondent:...

Rank/ Position of Respondent:..

1. How has climatic conditions in the district been?

....

2. How will you describe the relationship between rainfall and crop yield the district?
   1. Very strong [ ] 2.Strong [ ] 3. Weak. [ ] 4.Very weak [ ] 5.Not at all [ ]

Explain……………………………………………………………………………………..
…………………………………………………………………………………………
…………………………………………………………………………………………

5. Is your institution doing something to aid farmers with respect to climate change and climate variability?
 1. Yes [ ] 2. No

6. If yes what is your institution doing or has done to aid farmers with respect to climate change and climate variability?
....
....
....

7. Give details of your institution's activities?
…………………………………………………………………………………………
…………………………………………………………………………………………

8. How would you assess the patronage of these programmes by farmers?

1. Highly patronized [ ] 2. Moderately patronized [ ] 3. [ ] 4.Poorly patronized [ ]

5. very poorly patronized [ ]

9. How will you describe the cooperativeness of the local people with your institution's activities?

1. Highly cooperative [ ] 2. Cooperative [ ] 3. Low cooperative [ ] 4. Not cooperative at all [ ]

10. What information does your institution provide to farmers on the linkages between climate change, subsistent agriculture and sustainable natural resource management?

....
....

11. Prior to these programmes, what adaptation practices persisted?

....
....

12. How effective were these mitigation and adaptation practices?

....
....

13. What role has differences in proximity to Lake Bosomtwe and other water sources played in farmers' mitigation and adaptation practice in the district?

....

14. What mal-adaptation practices are known to prevail among subsistent farmers in the district?

....

15. What kind of support are you providing for conservation agriculture and improved natural resources governance in the district?

....

16. What channels of communication are used to reach subsistent farmers in the district?

....

17. Has the incidence of pest and diseases increased in the last 15years? Yes .... No........

18. How often do you visit the communities?

....
....

19. What trainings and support on the adoption of climate smart agriculture, REDD and other climate smart agriculture techniques are you currently offering?

....

20. What special programme on REDD strategies are predominant in the district?

....

21. How successful have these programmes been?

....

22. How have the farmers responded to these programmes?

1. Very cooperative [ ] 2. Cooperative [ ] 3. Low cooperative [ ] 4. Not cooperative at all [ ]

23. What benefits are there for farmers who adopt these strategies?

....
....

24. What other programmes are you undertaking that support farmers to implement actions that reduce deforestation?

....
....

25. What is been done to improve farmers' acceptance of these programmes?

....
....

26. What other organizations in the district are working with farmers on climate change?

....

27. Which is the key driver of deforestation in the district?

(From the most prevalent to the least prevalent using 1 as most prevalent and 4 as least prevalent)

Charcoal extraction	
Legal Logging	
Illegal Logging	
Agric expansion	
Infrastructural development	

28. How is agricultural land use changing in the district?

....

29. What are the main factors accounting for this trend?

....
....

30. How would you describe the rate of agricultural land use change into others land uses in the district?
    1. Very rapid [ ] 2.Rapid [ ] 3.Slow [ ] 4.Very Slow[ ]
31. How has climate change and variability contributed to agricultural land use modification?

....
....

32. Which particular modifications persist in the district?

....

33. Is agricultural land use increasing, decreasing in area and intensity?

....
....

34. How is agricultural land use increasing or decreasing in relation to residential, forest cover, recreational and commercial?

....
....