UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCE

VULNERABILITY AND ADAPTATION OF FARMING HOUSEHOLDS TO CLIMATIC AND NON-CLIMATIC STRESSORS IN SEMI-ARID GHANA

BY

STEPHEN OMARI

(10047359)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE DEGREE

INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES

JULY, 2018

DECLARATION

I, Stephen Omari hereby declare that except for references to other people's works which have been duly acknowledged, this thesis is the result of my independent research conducted at the Institute for Environment and Sanitation Studies, College of Basic and Applied Sciences, University of Ghana, Legon, under the joint supervision of Prof. Samuel Nii Ardey Codjoe, Dr. Elaine Tweneboah Lawson, and Dr. Benedicta Fosu-Mensah. I also declare that as far as I know, this thesis has neither in part or in whole been published nor presented to any other institution for an academic award.

……………………………………..

STEPHEN OMARI Date: ....

(Student)

……………………………………

PROF. SAMUEL NII ARDEY CODJOE Date: ....
(Principal Supervisor)

…………………………………….

DR. ELAINE TWENEBOAH LAWSON Date: ....
(Co-Supervisor)

……………………………………..

DR. BENEDICTA YAYRA FOSU-MENSAH Date: ....
(Co- Supervisor)

ABSTRACT

Since the latter part of the 20th Century to date, climate change has received considerable global attention due to its threats on all sectors of the global economy, particularly agriculture. Sub-Saharan Africa, for which Ghana is part, is considered as most vulnerable to the impacts of climate change and variability due to its low adaptive capacity and dependent on predominantly rain-fed agriculture. Farmers in Ghana and beyond are not only prone to climatic stressors but also to non-climatic stressors. Studies have been conducted across a range of geographical settings about how climate change adversely affect the activities of farming households. Though insightful, there are, however, few examples of how climatic and non-climatic stressors influence vulnerability and adaptation decisions of farming households.

Using the Lawra District in northwest Ghana, this thesis examines the vulnerability and adaptation of farming households and communities to climatic and non-climatic stressors. The study employs both quantitative and qualitative approach, including semi-structured questionnaire interviews, participatory methods, expert interviews, meteorological information and soil samples to explore the wide range of stressors shaping the activities of farming households in the district. The results demonstrate that, without prompting, farmers cited a range of climatic and non-climatic conditions that affect farming and household activities. Male and female farmers differ in their perception of the severity of perceived stressors, and this is likely to affect their adaptation decisions. The results also demonstrate that farmers know the causes and the effects of the stressors they cited. The results, further, show that scientific information did not always support farmers' perception of climate change. The results from the vulnerability assessment reveal households within and across communities differ in their vulnerabilities to climatic and non-climatic stressors. The results reveal that the farmers utilised various adaptation strategies contingent on the perception of climatic and non-climatic stressors and that the effects of climate change may not be the reason why farmers utilised certain adaptation strategies. Using binary logistic regression, the results reveal that membership of a social group, use of fertiliser, crop diversity and communication diversity are key determinants of farmers' adaptation to non-climatic stressors and that the same, as well as age, determine adaptation to climatic stressors. The results indicate that farmers' adaptation to climate change is not in isolation from institutional supports. The farmers' ability to adapt to climate change is also tied to supports from traditional authority, extended family system, friendship, community and governmental and non-governmental institutions. The study recommends that governmental and non-governmental institutions should invest in agricultural as well as non-agricultural activities to improve the socio-economic state of the farmers. Policymakers need to formulate adaptation policies that target both climatic and non-climatic stressors and that such policies should also consider the vulnerability of men as well. Formal and informal institutions should work synergistically, through programmes, to enhance natural, human, social, financial and physical capitals of farmers.

DEDICATION

To my children, Kwaku, Adwoa and Kwame.

ACKNOWLEDGEMENT

First, I would like to thank the Almighty God for His abundant grace on me. Second, I am most grateful to my supervisors, Prof. Samuel Nii Ardey Codjoe, Dr. Elaine Tweneboah Lawson, and Dr. Benedicta Fosu-Mensah for their professional guidance, advice, patience and constructive comments with which they guided this work.

I am very appreciative of START/ASSAR for their financial contributions to make this work better. I am also grateful to Staff and students of the Institute for Environment and Sanitation Studies (IESS) of the University of Ghana, Legon for their academic supports from the start of my PhD studies. I also thank the management and staff of Presbyterian University College, Ghana (PUCG) for their contribution and guidance throughout my PhD studies.

I wish to thank the chiefs, elders, officials and study participants of the study communities and district for their warm reception and for sharing their experiences with me. I am also grateful to Yaya Abdul Hamid, Albert Songmeh and Bernard Anvuur-Billy, Philip Bargouh, John Bosco, Joseph Oppong Peprah and the other enumerators for helping in the data collection. I sincerely appreciate the support of Samantha Osei Bonsu, Fuad Taminu and Samuel Bruce for helping in the data input and analyses.

Finally, I wish to thank my family and friends for their support, especially, my wife, Kwakoa Osei, my mother, Mercy Pomaa, my aunt, Rebecca Owiredu Amoafo, my sisters, Miriam Agyemang and Mariam Aku, my brothers Enoch Amoafo Frimpong and Patrick Ampadu, my uncle, Amos Anom Amoafo, and my friends, Bennet Ntiamoah and Andrew Sackitey.

TABLE OF CONTENTS

Contents **Page**

LISTS OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADI	Adaptive Capacity Index
ASSAR	Adaptation at Scale in the Semi-arid Regions
DfID	Department for International Development
EI	Exposure Index
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FDG	Focus group discussion
GHG	Greenhouse gas
GMA	Ghana Meteorological Authority
GSOP	Ghana Social Opportunities Project
GSS	Ghana Statistical Service
HH	Household
HHH	Household head
HHM	Household Member
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KII	Key informant interview
LDA	Lawra District Assembly
LEAP	Livelihood Empowerment against Poverty
LSD	Least Square Difference
MESTI	Ministry of Environment, Science, Technology and Innovation
MLGRD	Ministry of Local Government and Rural Development
MMD	Metropolitan, Municipal and District
MMYE	Ministry of Manpower, Youth and Employment
MoFA	Ministry of Food and Agriculture
MoGCSP	Ministry of Gender, Children and Social Protection
NADMO	National Disaster Management Organisation
NGO	Non-governmental organisation
NHIA	National Health Insurance Authority
NHIS	National Health Insurance Scheme
OECD	Organization for Economic Co-operation and Development
OVI	Overall vulnerability index
RESULT	Resilient and Sustainable Livelihood Transformation

SDG	Sustainable Development Goal
SI	Sensitivity Index
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
VSLA	Village Savings and Loan Associations
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

There is overwhelming evidence from the scientific community that the earth's climate is changing at an unprecedented rate due to historical emissions of greenhouse gases (GHGs) from natural and human activities (Berrang-Ford *et al*., 2011; IPCC, 2014). Human activities such as deforestation and burning of fossil fuel have been implicated as the dominant drivers of climate change since the Industrial Revolution (Costello *et al*., 2009). Global manifestations of climate change and variability, including changes in droughts, floods, storminess, wildfires and heat waves, are already affecting human societies and ecosystems (Xie *et al*., 2014).

Climate change is real, and its impact is global. Climate change impacts are already being experienced in every part of the world (Wilbanks & Kates, 2010). Impacts of climate change and variability are more detrimental to developing countries than developed countries (Huq *et al*., 2004; IPCC, 2014a; Mendelsohn *et al*., 2006; Smith *et al*., 2009). Climate change has adverse effects on all sectors of economic development including water resources, agriculture and food security, forestry, housing, tourism, manufacturing and health as well as ecosystem services upon which these sectors depend (IPCC, 2007a). However, agriculture, which is the primary occupation of the world's poorer, remains most vulnerable to climate change (Li *et al*., 2016).

Global climate models (GCMs) have revealed that even if socioeconomic development remains unchanged, global average temperatures are expected to rise between 1.1 and 6.4

°C and shift in precipitation patterns by 2100 (IPCC, 2007a). Studies indicate that during the last 50 to 100 years, mean temperature levels over Africa increased, whereas total precipitation declined (IPCC, 2007a; Niang *et al.*, 2014). Temperatures in Africa are projected to rise faster than the global average increase during the 21st century whereas precipitation is expected to decrease in northern and the sub-Saharan Africa (SSA) by mid-21st century (Niang *et al.*, 2014). For West Africa, the mean temperature is expected to rise between 2ºC and 4ºC while 22 percent increase in the frequency of extreme wet seasons is expected by the end of 2100 (Codjoe *et al.*, 2012). The projected increase in temperature and shift in precipitation are expected to influence water resources (quantity and quality), food systems and food production (Thornton *et al.*, 2014), and subsequently food security.

Within developing countries, sub-Saharan Africa (SSA) is considered as the most vulnerable to climate change even though the region contributes the least GHG emissions (Canadell *et al.*, 2009). The vulnerability of the SSA is due to the low adaptive capacity of the population, frequent natural disasters such as droughts and floods, and over-dependence on rain-fed agriculture (Huq *et al.*, 2004; Niang *et al.*, 2014; Stringer *et al.*, 2009; Vogel, 2005). Climate change and variability are projected to shorten growing seasons and result in reduced yields of major cereal crops in SSA (Niang *et al.*, 2014). With agriculture being the backbone of African economies, contributing about 40 percent of foreign exchange (Ludi, 2009) and providing 65 percent of full-employment (Pretty *et al.*, 2011), a decline in agricultural productivity will ultimately affect other sectors such as education, health, and transport.

In addition, SSA is vulnerable because of its geographical location and climatic conditions (Mendelsohn *et al.*, 2006). The climate of Africa ranges from humid equatorial at the equator, through tropical and semi-arid in the middle of the region, to sub-tropical

Mediterranean-type climates (UNESCO, 2012). About two-thirds of Africa is either arid or semi-arid, and this is home to more than 300 of the 800 million Africans (UNESCO, 2012). In general, arid and semi-arid regions are considered as one of the hotspots where climate change is potentially significant (O'Brien *et al*., 2004). Indeed, semi-arid environments are sensitive to global changes because of their fragile ecosystems (Huang *et al*., 2012). Semi-arid areas also experience rare precipitation, frequent drought and damaging but episodic floods conditions (Lin, 1999; Tschakert *et al*., 2010).

Climate change and related hazards have adverse effects on people whose livelihoods directly depend on natural resources, especially smallholder farmers (Harvey *et al*., 2014; Kabote *et al*., 2014; Schirmer *et al*., 2013). On the global scale, smallholder farmers manage 80 percent of small farms and provide an estimated 80 percent of food consumed in the developing world (IFAD, 2013). In SSA, smallholder farmers account for 73 percent of agricultural producers (Morton, 2007), and this means that the economy of most African countries hinges on the production decisions of these farmers. Because of the crucial role that smallholder farmers play in the provision of food, any reduction in agricultural productivity will have adverse effects on food security, nutrition, income and well-being of the farmers (Harvey *et al*., 2014) and even non-farmers.

Ghana is not insulated from the impacts of climate change and related hazards. The country is situated in a complex climatic region which is affected by tropical storms, and the influence of the Atlantic Ocean and the Sahel (MESTI, 2013). The country has experienced a rise in temperature and a decrease in mean annual rainfall over the last decades, and these trends in temperature and rainfall are projected to continue (MESTI, 2013). The south of the country is predicted to experience increased precipitation while the north will become drier (Tschakert *et al*., 2010). Climate extremes such as drought and floods have been recorded during the past decades (Tschakert *et al*., 2010) and have accounted for about 67 percent of total disaster occurrences in the country over the past 30 years (NADMO/UNDP, 2012).

Ghana's domestic economy is typical of most SSA countries due to its over-dependence on agriculture. The agricultural sector contributes about 35 percent of gross domestic product (GDP), generates about 40 percent of the foreign exchange earnings, and employs over 55 percent of the population (Fosu-Mensah *et al.,* 2010). Smallholdings constitute about 90 percent of farms and account for 80 percent of total agricultural production (Chamberlin, 2008). The agricultural sector in Ghana is climate-sensitive because it is mainly rain-fed. Major crops grown in Ghana require an appreciable amount of water during growth, and erratic rainfall and persistent drought conditions have often resulted in the low production of these crops (Antwi-Agyei *et al*., 2012).

Climate change is not experienced in isolation; instead, it occurs within the broader context of multiple, non-climatic conditions (Füssel & Klein, 2006; O'Brien & Leichenko, 2000; Tschakert, 2007; Wilbanks & Kates, 2010). Non-climatic stressors are a wide range of environmental, economic, social, demographic, technological, and political factors that may interact with climate change to increase vulnerability and reduce adaptive capacity because of resource deployment to competing needs (Lioubimtseva & Henebry, 2009). Vulnerable regions and households face multiple stresses that affect their exposure and sensitivity as well as their capacity to adapt (IPCC, 2007a; Lioubimtseva & Henebry, 2009; Reid & Vogel, 2006). Therefore, assessing the vulnerability of regions or households to climate change should be done within the context of multiple, non-climatic stressors.

To address the impacts of climate change and variability, adaptation is widely recognised as one of the critical response strategies (Adger *et al*., 2007; Füssel, 2007). The other is mitigation. Mitigation is a set of steps undertaken to confine global climate change by reducing activities that contribute to GHG emissions, increasing carbon sinks and increasing the use of renewable energy sources (IPCC, 2007a). Adaptation refers to an adjustment in a system in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007a). Scholars have identified adaptation as the better option because past and current levels of greenhouse gases will continue to change the climate in the next few decades; and that due to lag times in the climate and biophysical systems, the positive impacts of current mitigation efforts will take several decades to fully manifest (Füssel & Klein, 2006).

Adaptation is not only an option but a necessary action that must be undertaken so that those experiencing the impacts of climate change can survive. Adaptations are essential in dealing with the impacts of climate change (Smit & Wandel, 2006; Stringer *et al*., 2009). Adaptation is not a new concept to farmers in Africa (Vogel, 2005). Farmers have employed various adaptation strategies, such as altering agricultural patterns and settlements, to survive the impacts of climate change. Adaptation to current climate variability can also increase resilience to long-term climate change (Adger *et al*., 2007). However, adaptations are not isolated from other decisions but occur in the context of multiple stressors (Adger *et al*., 2005). The extent to which farmers will be able to work and survive in a multi-risk dimensional environments dictated by the presence of climatic and non-climatic stressors will be significantly influenced by the success of those exposed in adapting to changing conditions (Cradock-Henry, 2011; Meinke *et al*., 2009; Wilk *et al*., 2013).

1.2 Statement of the problem

The agricultural sector, in Ghana and beyond, is inherently dependent on climatic and non-climatic stressors. For instance, an increase in temperature will lead to increase in soil evaporation and transpiration in plants. This will subsequently affect the amount of soil moisture and available soil nutrients needed for the growth of plant. Low rainfall will profoundly affect livestock production through the reduction in the availability of pasture and feed crops (Thornton, 2010). Increase in temperature will adversely affect milk production in livestock (Thornton, 2010). The decrease in the yield of certain staple crops is likely to occur as a result of the combined effects of temperature and precipitation changes on water supply and crop phenology (Wang *et al*., 2011). However, according to Ochieng *et al*. (2016), climate change and variability have differential effects on crop production with temperature producing negative effects on staple crops but a positive effect on tea production while the vice versa is true for rainfall (Ochieng *et al*., 2016).

Non-climatic factors have been noted to affect agriculture, and in some cases, more profoundly adverse effects than climatic factors. According to Boansi (2017), the reduction in the yield of cassava in Togo is not only influenced by prolonged drought during tuber-formation and root thickening but also by producer prices, pest and diseases. Bhatta *et al*. (2016) noted that market-related forces and resource issues are stronger drivers of changes in farming practices in the past decades than climatic factors. In the agricultural settings, any adverse effect on crop and animal production will affect the wealth and well-being of farming communities as well as sectors that depend on agriculture.

Understanding vulnerability to the effects of climate change and related hazards is crucial as it allows policymakers to devise a host of targeted strategies and policies to manage the effects and reduce vulnerability. Attempts have been made to analyse the vulnerability of farming households to climate change in Ghana, Africa and beyond (Dasgupta & Baschieri, 2010; Deressa *et al*., 2008; Etwire *et al*., 2013; Shah *et al*., 2013). Though informative, these studies focused mainly on climate hazards and without considering the role of non-climatic factors in determining the vulnerability of farming households. However, farmers in Africa work in multi-dimensional risks environment that is influenced by many factors beyond climate change and variability (Antwi-Agyei *et al*., 2017; Nyantakyi-Frimpong & Bezner-Kerr, 2015; Tschakert, 2007). Thus, focussing on climate change only could curtail understanding of the role of non-climatic stressors or combination of climatic and non-climatic stressors in defining the vulnerability of farming households.

Studies on the impacts of climate change have outlined a host of adaptation strategies employed by farmers in Ghana and elsewhere (Codjoe *et al*., 2012; Maddison, 2007; Olayemi, 2012; Stringer *et al*., 2009; Yaro, 2013). The adaptation strategies of farmers occur in response to multiple stressors that reconfigure access to resources required for the response (McDowell & Hess, 2012). Therefore, understanding adaptation to a wide range of stressors is critical to unravelling the complex nature of vulnerability. Where studies have attempted to attribute adaptation strategies employed by Ghanaian farmers to multiple stresses, for example, Codjoe *et al*. (2012), Antwi-Agyei *et al*. (2014) and Yaro (2013), they have done those studies with regard to only climatic stressors. Though informative, these studies have focussed on climate change only, and therefore, provided little information about how farmers adapt to exposure to non-climatic stressors. However, adaptations could be triggered by the perception of climatic stressors or non-climatic stressors or both (Adger *et al*., 2005). This study seeks to contribute to the ongoing debate on climate change adaptation by seeking to explore farmers' adaptation to a multiple range of climatic and non-climatic stressors. Since impacts associated with a hazard is context-specific, the results from these studies cannot be generalised for all farming communities in Ghana.

In summary, despite considerable studies on the impacts of climate change on agriculture as well as those whose economic activities evolved around agriculture, there has not yet been sufficient examination of the vulnerability and adaptation of smallholder farming households to climate change and other interacting stressors. This study aims to contribute to deepening understanding of the issues raised by focusing on how activities of farming households in the semi-arid areas of Ghana revolve around exposure to climatic and non-climatic stressors.

1.3 Research Objectives

The main objective of this study is to explore the role of climate change and non-climatic stressors in shaping the vulnerability of farming households, and the adaptation strategies that are used by these households in semi-arid Ghana. The specific objectives are to:

1) Examine current and future perceptions and ranking of climatic and non-climatic stressors by farmers, and how these differ by sex of household heads;
2) Compare actual and perceived climatic and non-climatic stressors;
3) Investigate exposure, sensitivity, adaptive capacity and vulnerability of farming households to climatic and non-climatic stressors;
4) Assess the different adaptation strategies utilised by farming households in relation to climate change and non-climatic stressors;
5) Establish the relationship between vulnerability and adaptation to climatic and non-climatic stressors; and
6) Explore the role of local institutions in strengthening the adaptive capacity of farming households and reduce vulnerability to climate change and non-climatic stressors.

1.4 Significance of the study

Smallholder farmers in the semi-arid environment are exposed to both climatic and non-climatic stressors which may contribute to their vulnerability, perception and adaptation choices of farming households and communities. This thesis broadens understanding of the drivers of vulnerability of farmers in the semi-arid and provides decision-makers with evidence-based information to enhance the design and implementation of more targeted and appropriate climate adaptation policies.

Climate change may not be the only determinant of choices of adaptation strategies employed by farmers. There may be other multiple non-climatic stressors that interact with climate change and related hazards to inform the farmers' choices of adaptation methods. This thesis contributes to the current scientific debate by increasing understanding of the role of each stressor in influencing farmers' choices of adaptation methods.

Understanding how farmers perceive climate change is a prerequisite for the implementation of an effective adaptation policy (Nhemachena *et al*., 2014; Yaro, 2013). However, there are marked differences in how farmers perceive and respond to climate change and related hazards. The differences in perception and response may be due to gender and social differences existing among farmers at both community and household levels. This study provides insights into how gender and social variation contribute to both perception and response to climate change. This thesis focuses on farming households in the Lawra District of Upper West Region of Ghana. This region is considered the poorest in the country (GSS, 2015) and one of the vulnerable areas to climate change and variability (Antwi-Agyei *et al*., 2012). The environmental and socio-economic conditions of the region are typical of most semi-arid environment of Africa and therefore, the outcome of this is both crucial and appropriate.

This thesis increases understanding of local strategies and innovations employed by the different farmer groups in coping with and adapting to climate change and variability for policy development and implementation. The study provides insight into how climate-induced risks influence the determinants of wellbeing among different social groups in Ghana. This study also provides evidence-based information to help policymakers to provide the necessary adaptive strategies that work for the majority of farmers in semi-arid areas.

1.5 Organization of chapters

This thesis comprises of eight chapters. Chapter 1 introduces the study with the background and problem statement, research objectives, hypothesis, and significance of the study. Chapter 2 presents a comprehensive review of existing literature relevant to the study with reference to sub-Saharan Africa as a whole and Ghana in particular. This chapter reviews peer-review articles on vulnerability, adaptation and perception of farming households in Ghana and beyond with respect to climate change and other non-climatic factors. In addition, this chapter reviews the literature on various frameworks that have been used to quantify vulnerability, adaptation and perception of farmers in relation to climate change and non-climatic stressors.

Chapter 3 provides information on the study area and also the methodological approaches adopted by this study to assess the vulnerability, adaptation strategies and perception of farming households in the study district. In this chapter, the study area was thoroughly described. Chapter 4 is devoted to exploring the perception of farmers in term of climate change and non-climatic stressors affecting their farming and household activities. This chapter also analyses meteorological data and soil samples to provide the scientific bases of farmers' perception of climate change and non-climatic stressors. Chapter 5 explores how farmers' perception of climatic and non-climatic stressors could be supported by actual and scientific information. Chapter 6 analyses the exposure, sensitivity, adaptive capacity and vulnerability of households and communities in the study district. The characteristics of the least vulnerable household and the most vulnerable household in each study community are described in this chapter. Chapter 7 presents the assessment adaptation strategies employed by farmers in relation to their perception of specific climatic and non-climatic stressors affecting their farming as well as household activities. In Chapter 8, the components used to determine vulnerability are linked to adaptation to understand how these components explain the decision to adapt or not to adapt. Chapter 9 explores the role of governmental and non-governmental institutions, identified by sampled farming households, in enhancing the adaptive capacities of farming households and communities to reduce vulnerability and improve utilisation of existing and innovative adaptation strategies. Chapter 10 provides the summary, conclusion and recommendations for significant issues of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews pertinent literature on climate change and climate-related hazards, other stressors to which farmers are exposed, vulnerability and adaptation choices to establish conceptual and theoretical frameworks for exploring the research objectives of the study. The chapter identifies gaps in existing literature that inform the objectives and methodology of the study. This chapter is organised into six sections with each section related to one objective of the study. Sections 2.2 to 2.4 outline current and future climate change and variability and associated impacts agricultural development globally, SSA and Ghana, respectively. These are followed by Section 2.5, which outlines the concept of vulnerability to climate change and non-climatic factors. In Section 2.6, the approaches for assessing vulnerability are reviewed. Section 2.7 is devoted to describing adaptation to climate change and factors influencing households' and communities' adaptation to climate change. Section 2.8 outlines the concept of perception and its influence in determining households' utilisation of available adaptation options. The penultimate section reviews the role of institutions (public and private) in enhancing adaptive capacity, promoting adaptation and reducing households' vulnerabilities, and the final section concludes the chapter.

2.2 Global climate change and variability

It is now unequivocal that the climate of the earth has been changing and will continue to change. This change is in response to increasing emissions of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxides from natural and anthropogenic influences. Many of the observed changes in the climate of the earth are unprecedented since the mid-20th Century (Berrang-Ford *et al*., 2011) and these have been attributed, primarily, to human activities such as deforestation and burning of fossil fuel. Increasing concentrations of GHGs beyond the absorptive capacity of the Earth has led to the warming of the Earth's atmosphere (Canadell *et al*., 2009; Dilling *et al*., 2015; Füssel & Klein, 2006; Haines *et al*., 2006; IPCC, 2013; Leiserowitz, 2006; Teshome, 2016). Global and regional manifestations of the warming including extreme changes in precipitation and temperature, as well as increases in the frequency and severity of other climatic events are already affecting the quality of the environment and human life (IPCC, 2013; Xie *et al*., 2014).

Climate change is a change in the average value of a climate variable over a long-term period. Hope (2011) defined climate change as any long-term significant regional change in measures of climate variables. The author noted that the variations in the climate variables must be statistically significant in the measurement of either the mean state or variability in the average weather for a given geographical area. The Intergovernmental Panel on Climate Change (IPCC) refers to defined climate change as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2007b, p. 78). Climate variability denotes variation in the mean state and other statistics of the climate beyond that of individual weather events.

Climate change has both beneficial and detrimental effects on human well-being and the quality of the environment. However, the detrimental effects tend to outweigh the beneficial ones. The pronounced adverse impacts have made climate change one of the most severe challenges affecting humanity. Studies have shown that the impacts of climate change and variability have geographical, demographic and sectoral dimensions (Jonsson & Lundgren, 2014; Porter *et al*., 2014). Climate change is said to have adverse impacts on people who live in countries with low adaptive capacities and are highly dependent on climate-sensitive socio-economic activities such as rain-fed agricultural systems (Das, 2016; Kima *et al.*, 2015; Mendelsohn *et al.*, 2006; Stringer *et al.*, 2009).

2.3 Climate change and variability in SSA

Africa contributes the least to the total global greenhouse gas emissions in per capita terms (Hope, 2009) but it is the hardest hit and the most vulnerable to the adverse impact of climate change and vulnerability (Canadell *et al.*, 2009; Codjoe *et al.*, 2012; IPCC, 2007a). The susceptibility of Africa is attributed to its low adaptive capacity and the centrality of rain-fed agricultural activities (Boko *et al.*, 2007; Huq *et al.*, 2004; Lobell *et al.*, 2011; Niang *et al.*, 2014; Stringer *et al.*, 2009; Tschakert, 2007). Agriculture is the backbone of most African economies, contributing about 40 percent to foreign exchange (Ludi, 2009) and providing employment for most Africans (Pretty *et al.*, 2011). Mendelsohn *et al.*, (2006) noted that African's vulnerability to climate change is due to its geographical location, climatic and socio-economic conditions. Most African countries have high poverty levels and are located in the tropical and sub-tropical latitudes where temperatures are already high.

Among the regions of Africa, the SSA is considered the most vulnerable to climate change and variability (Connolly-Boutin & Smit, 2016; Kotir, 2011; Tschakert, 2007). Africa is currently warmer than it was 100 years ago (Hope, 2016; Kotir, 2011; Niang *et al.*, 2014). There has been an upward trend in temperatures in the last 100 years over Africa, with warming rates of 0.5ºC (Niang *et al.*, 2014). Regarding future trends, temperatures of most parts of the continent are projected to rise faster than the global average during this 21st century (Boko *et al.*, 2007; Niang *et al.*, 2014). However, the future upward rise in temperatures is projected to occur in West Africa for two decades than the global average (Niang *et al*., 2014).

Studies have indicated different characteristics of rainfall variability across Africa over the past decades. Over the past decades, some parts of North Africa have experienced decreases in the amount of rainfall during summer, while other parts have experienced increases in the amount of rainfall during winter (Radhouane, 2013). Rainfall is projected to exhibit negative trends in North Africa by the end of the 21st century (Niang *et al*., 2014). In West Africa, a decline in rainfall and a significant increase in the number of warm spells have been observed over the course of the 20th century (Boko *et al*., 2007; Niang *et al*., 2014). The region is projected to experience wetter seasons with a delay in the onset of raining season by the end of the 21st century (Niang *et al*., 2014).

In East Africa, rainfall has exhibited a contrasting pattern in the past decades. Rainfall trends have been more favourable in the northern parts and negative trends in the southern parts (Boko *et al*., 2007). Some parts of East Africa, such as Uganda, Kenya and South Sudan, are expected to experience a decline in the amount of rainfall (Niang *et al*., 2014). According to Kotir (2011), southern Africa has seen an increase in the amount of rainfall, but with occasional dry periods in some countries, such as Angola, Namibia and Malawi, over the past 40 years. However, rainfall is projected to decline in most parts of southern Africa by the end of the 21st century (Niang *et al*., 2014).

2.4 Effects of climate change and variability on agriculture in SSA

Climate change has profound adverse effects on water availability. Access to water of adequate quantity and quality is essential for sustainable agriculture and also linked to achieving all the Sustainable Development Goals (SDGs). Changes in temperature, rainfall and extreme events will result in a significant change in the hydrologic cycle and ultimately affect annual run-off and recharge of groundwater. A decline of up to 50% in the yearly run-off is expected in most countries in western and southern African regions (NASAC, 2015). With water availability linked to socioeconomic development and well-being of societies, any adverse impacts of climate change on water resources will have damaging repercussions on the African population.

Climate change and variability will have a negative influence on crop productivity. Most of the commonly cultivated crops in SSA, such as maize and millet, are highly sensitive to high temperatures above 30°C during the growing seasons (NASAC, 2015). Blanc (2012) estimated that weather changes have an overall negative impact on the yield of cassava, finger millet, maize and sorghum. Mean change in yield of all crops across Africa is projected at -8% by the next four decades with mean yield change for wheat, maize, sorghum and millet projected at -17%, -5%, -15% and -10%, respectively. No significant change in mean yield for rice, cassava and sugarcane.

Ramirez-Villegas & Thornton (2015) estimated the impacts of rising temperatures and decreasing precipitation on crop production in Africa and concluded that the effects vary substantially by crops and regions. According to the authors decline in suitable areas for the production of bean, maize, banana and finger millet will be severe for many West African countries and less severe for East and South African countries due to a high temperature above the optimum level. The suitable areas to produce pearl millet, sorghum and yam will decline for many African countries with decreases in precipitation.

Livestock production contributes significantly to the economy of SSA and climate change could compound the already existing problems that negate livestock development in the continent. Climate change and variability will influence livestock production in several ways such as changes in production and quality of feed crops and rangeland (Thornton, 2010; Weindl *et al*., 2015), In addition, heat stress directly or indirectly impairs milk production (via reducing feed intake) and reproductive performance during periods of seasonal infertility (Baumgard *et al*., 2012; Weindl *et al*., 2015). Prolong high temperature, warm and humid conditions may influence metabolic rate, change the distribution of diseases, and induce high mortality (Thornton, 2010).

2.5 Climate change and variability in Ghana

Ghana is not immune to the effects of climate change and variability. The climate of the country is tropical and is typical of most sub-Saharan African countries due to Ghana located a few degrees above the Earth's equator. The climate varies across the entire country, and it is significantly influenced by the North-East Trade Winds (NETW) and the South West Monsoon Winds (SWMW) that interact to give rise to the Inter-Tropical Convergence Zone (ITCZ) that is responsible for weather variability (Stanturf *et al*., 2011). The NETW, also called the to dry dusty harmattan winds, blows from the Sahara desert and covers much of the country between December and March, lowering the humidity and visibility, and also creates hot days and cold nights in the North (GSS, GHS, & ICF International, 2014). The SWMW from the Atlantic Ocean brings moisture. The onset of rains usually starts between April and June, and the cessation of rains occurs between October and November. Changes in rainfall and temperatures determine the wet and dry seasons.

The country is divided into six agro-ecological zones defined by their climate, vegetation and soil types, and these have implications on the kind of farming activities farmers can engage. These agro-ecological zones running from the north to the south are Sudan Savannah Zone, Guinea Savannah Zone, Transition Zone, Semi-deciduous Forest Zone, Rain Forest Zone and the Coastal Savannah Zone. Climate change has differential impacts across the country. The mean annual rainfall ranges from 800 mm in the Coastal Savannah Zone to 2,200 mm in the Rain Forest Zone. The northern part of the country, which contains Sudan and Guinea Savannah Zones, is characterised by one rainfall season that begins in May, peaks in August, and lasts until September. However, the southern part (rainforest and coastal savannah zones) and the middle part (deciduous and transition zones) record two rainy seasons from April to July and from September to November (FAO, 2005; MESTI/EPA, 2015).

The country has experienced a progressive rise in temperatures and these trends in temperature and rainfall are expected to continue into the future (Bawakyillenuo *et al*., 2016; Codjoe *et al*., 2012; Dumenu & Obeng, 2016; MESTI, 2013). Historical records showed that the rate of change in minimum temperature for the period 1960 to 2010 was 2% for the southern and middle parts of Ghana and 37% for the northern part (MESTI/EPA, 2015). The projected mean temperature for Ghana shows that mean temperatures are likely to increase by 1.02°C, 1.5°C and 1.8°C, by 2040, 2060 and 2080 respectively. Mean minimum temperatures over the Coastal Savanna Zone are projected to increase by 1.1°C, 2.5°C, 1.9°C, by 2040, 2060 and 2080 respectively. Mean monthly maximum temperature is expected to rise by 1.2°C and 2.1°C by 2040 and 2060, respectively (MESTI/EPA, 2015).

An analysis of two-decade rainfall records from weather stations across for all six agro-ecological zones showed a variable rate of change in observed rainfall (MESTI/EPA, 2015). The rate of change ranges from 333% for the southern, 112% for middle to 431% for northern parts of Ghana (MESTI/EPA, 2015). Decadal rainfall change is negative for the middle part at 2.8%, but positive for southern at 13% and northern at 3.3% (MESTI/EPA, 2015). There is uncertainty associated with rainfall for the future. The country is expected to experience an increase in the intensity of high-rainfall events and an overall decrease in the number of rain days around the same period (Bawakyillenuo *et al*., 2016). Rainfall across the country has been projected to decrease by 2.9% in 2040, followed by a slight increase in 2060 by 1.1% and later drop in 2080 by 1.7% (MESTI/EPA, 2015). Also, the country is predicted to experience increased and decreased precipitation in the South and the North, respectively (Codjoe *et al*., 2012; Tschakert *et al*., 2010; Yaro *et al*., 2015). Studies have shown that the direct manifestations of climate change and variability in Ghana include erratic rainfall, floods, and increases in the intensity of extreme weather events (EPA, 2011; MESTI, 2013; Tschakert *et al*., 2010). Each of these manifestations has direct and indirect impacts on the wellbeing of the people, the environment and, ultimately, on the economy.

2.6 Effects of climate change and variability in Ghana

Climate change and variability have serious implications for every sector of the Ghanaian economy, particularly the agricultural sector. Agriculture remains the mainstay of the Ghanaian economy contributing about 20.1% of gross domestic product (Ministry of Finance, 2017); employing more people than any other sector (MoFA, 2013); and generating 40% of the foreign exchange earnings (Fosu-Mensah *et al*., 2010). The rural economy is dominated by the agricultural sector, with 90% of the population depending on the sector for survival (Stanturf *et al*., 2011). The agricultural sector of the country is the most vulnerable to climate change, and associated hazards as the sector are over-dependent on rainfall. The sector is dominated by smallholder farmers who cultivate on less than 2 hectares (MoFA, 2013) and responsible for about 80% of agricultural output (Asante & Amuakwa-Mensah, 2014). In the midst of climate change, these smallholder farmers continue to use rudimentary farming technologies, and this has contributed to declining agricultural production.

Comparatively, northern Ghana, which comprises the Northern, Upper East and Upper West Regions and occupies approximately 47% of the total land size of the country, is considered most vulnerable to climate change (Antwi-Agyei *et al*., 2012; Dietz *et al*., 2004). Northern Ghana has a semi-arid climate, and therefore, it is much drier than southern Ghana (Dietz *et al*., 2004), due to the proximity of the area to the Sahel and the Sahara desert. The area is estimated to be the poorest in the country with a poverty rate between 44.4% in Northern Region and 70.7% in Upper West Region (GSS, 2015). The region has a rural population; a high proportion of economically-active people in climate-sensitive agricultural activities; higher mortality rate; and a higher illiteracy rate than the rest of the country (GSS *et al*., 2014). It is also considered as the "most food-insecure, risk-prone and conflict-ridden area of the country" (Dietz *et al*., 2013, p. 17). Therefore, northern Ghana provides a suitable case-study context to explore vulnerability and adaptation strategies of farming households to climate change and other stressors.

2.7 Non-climatic stressors and associated effects on agriculture

Non-climatic stressors are as critical in shaping farming systems and adaptation decisions as climate change. In the context of agriculture and this study, non-climatic stressors are non-meteorological factors that have the potential of influencing agricultural activities and therefore, shaping policies and programmes of stakeholders. African farmers reported that non-climatic challenges significantly affect farming practices than climatic stressors (Nyantakyi-Frimpong & Bezner-Kerr, 2015). Scholars continue to debate the significance of climatic drivers relative to non-climatic forces (Bhatta *et al.*, 2016). Farmers in North America recognised production cost, pest and diseases, governmental policies, credit, technology, markets, consumers' acceptance and competition from other farm products as non-climatic stressors affecting the farming activities (Belliveau *et al*., 2006).

According to Tschakert (2007) farmers in Sahelian region identified ill-health, food prices, low harvest, lack of money, poor housing, death of livestock, lack of water, lack of seeds, lack of credit, theft of livestock and household assets, cost of marriage and lack of training as some of the non-climatic stressors affecting their livelihood activities and that these farmers did not consider climatic stressors in their risk assessments. Farmers in Ghana identified similar non-climatic stressors as affecting their activities (Antwi-Agyei *et al*., 2017; Nyantakyi-Frimpong & Bezner-Kerr, 2015).

Using market forces, Boansi (2017) noted that price has a profound influence on the yield of cassava and that an increase in the producer price of beans relative to cassava encourages farmers to allocate more resources into beans production and fewer resources into cassava production. Cabas *et al*. (2010) observed a statistically significant relationship between crop yields and input use, and crop yield and area planted. The authors continued noted that average crop yields increase with decreasing input, and also decrease with increase planted area as additional land is put into production. Use of technology results in 1% increase in the yield of corn and wheat and 0.6% increase in soybean (Cabas *et al*., 2010). Removal of fertiliser prices resulted in increased use of fertiliser, increase crop production area and an increase in income of Malawian farmers (Komarek *et al*., 2017).

The relationship between human health and agricultural production is bidirectional. On the one hand, the health of people influences agricultural output. Poor human health reduces work performance, reduces income and productivity (Hawkes & Ruel, 2006). Farming households with invalid or convalescing people would have to divert a portion of the money for farm investment into seeking medical attention for the household member. Also, there would be a reduction in the labour force for farm work. On the other hand, healthy food improves health and in the long run, improve household income. Food of poor quality affects the health of farming households, which in turn affect the ability of farming households to engage in farming activities.

2.8 Perception of climate change and other stressors

Every living organism has an innate ability to perceive changes in its environment. This ability is recognised as one of the life processes that differentiate a living organism from a non-living thing. Living organisms rely on their sensory systems to gather and interpret changes in their environment and ultimately respond to those changes. The word "perception" comes from the Latin word *perceptio* means receiving or collecting, *percipere* means "to obtain or to perceive". Perception is a way in which organisms understand the world. It is about how organisms interpret and organise sensory information to produce meaningful experiences about the environment.

Perception is the way in which an individual gathers processes and interprets information from the environment. An organism recognises an array of information in its environment but will take actions on that information that it deems a priority. Information that is considered unimportant will be relegated to the background. Thus perception plays a vital role in the human decision-making process.

In climate change adaptation literature, perception is considered as a prerequisite to individual's response to changes in the environment (Codjoe *et al*., 2014; Fosu-Mensah *et al*., 2010; Maddison, 2007; Simelton *et al*., 2013; Yaro, 2013). Fosu-Mensah *et al*. (2010), argued that policymakers must take into account farmers' knowledge and perception of climate change, their potential adaptation measure and possible barriers to such adaptation. This assertion is also echoed by Yaro (2013) and Simelton *et al*. (2013) who indicated that to adapt or not hinges upon farmers' knowledge and perception of the local climate. Codjoe *et al*. (2014) noted that the perception of climate change informs adaptation strategies utilised by coastal communities in southern Ghana. Maddison (2007) noted that adaptation involved two sequential processes: first perceiving that a change in a condition has occurred and second, deciding whether to take actions to respond to the change.

Though perception is recognised as vital to the adoption of adaptation or coping strategies, studies on climate change have produced conflicting conclusions on whether farmers' perception and knowledge of climate change concur with scientific information of climate change. Yaro (2013) noted that Ghanaian farmers' perception of climate change parameters was in agreement with the recorded meteorological information. Kusakari *et al*. (2014), indicate that the perception of majority farmers in northern Ghana in relation to changes in climatic conditions in their local environment did not significantly deviate from the scientifically observed trends and phenomena. In a study comparing local people perception to scientific climatic observations, Manandhar *et al*., (2015) noted that between 61% and 86% of households in northern Thailand correctly predicted changes in rainfall pattern.

On the contrary, Simelton *et al*. (2013) observed that farmers' perception of rainfall events were at odds with meteorological evidence and that these discrepancies may be due to farmers inability to recall recent events than events that occurred decades ago. The authors also noted that farmers were able to predict rainfall events correctly provided the occurrence of the rainfall events coincide with other memorable events. Swe *et al*., (2015) also confirmed that farmers' perception and knowledge of trends in temperature and rainfall could not be established with statistical analyses of temperature and rainfall data obtained from meteorological stations in Myanmar.

Perception of changes in the environment is not uniform across households, communities and nations. Perception also varies between individuals in the same household or different households located within the same geographical area. Some factors influence the ability of people to perceive and adapt to changes in their environment. A study by Debela *et al*. (2015) reveals that the level of perception of smallholder farmers in Ethiopia is greatly influenced by the age, education level, livestock holding, access to climate information and extension services. The authors indicated that farmers with a high level of education are more likely to interpret climate information better and apply the necessary actions to reduce the negative impacts of climate change. Access to support from extension service increases the level of perception.

Highly educated households can read and understand climate change and related issues and therefore prioritise adaptation or coping strategies to minimise their vulnerability to climate change (Manandhar *et al*., 2015). A study conducted by Gbetibouo (2009) in Limpopo Basin, South Africa, reveals that level of education and access to irrigation decrease farmers' perception of changes in rainfall while farming experience and access to extension service increase probability of perceiving changes in the trends of temperature. However, a study by Teshome (2016) noted that education, age and gender were not significantly related to knowledge and perception of changes in temperature and rainfall among households.

2.9 Concept of Vulnerability

The concept of vulnerability is fundamental to human-environment research (Wu *et al*., 2002). The term vulnerability originated from Latin *vulnerabilis* from Latin *vulnerare* 'to wound', from Latin *vulnus* 'wound' (Kelly & Adger, 2000, p. 328). The Oxford Dictionary of English (Second Edition, 2006) defines vulnerability from vulnerable to mean "exposed to the possibility of being attacked or harmed, either physically or emotionally".

Vulnerability can mean "potential to suffer". Originally, vulnerability was rooted in the study of risk-hazard and geography (Füssel, 2007a; Luers *et al*., 2003). Currently, vulnerability is a central concept in natural hazards and disaster management, ecology, public health, poverty and development, secure livelihoods and famine, sustainability science, land change, and climate impacts and adaptation research (Füssel, 2007a). To understand the concept of vulnerability in climate change literature, this section explores the various terms and approaches relevant to the study of vulnerability.

Vulnerability has multiple definitions and therefore, has no universal meaning for the term (Table 2.1). The numerous definitions associated with vulnerability emerged from the fact the vulnerability has broader application in many disciplines of study. It should be noted that even within the same discipline, the term may be defined differently. In economic literature, vulnerability is defined as the degree to which an economy is adversely affected by external shocks such as changes in trade policy, exchange rate fluctuations, or shifts in commodity prices (Briguglio *et al*., 2009; Leichenko *et al*., 2014). It is much related to poverty issues (Luers *et al*., 2003). In health literature, vulnerability is regarded as "the potential risk of developing certain diseases or suffering from environmental hazards" (Grabovschi *et al*., 2013, p. 1). Within geography, vulnerability is the "measure of the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted, on account of its nature or location, by the impact of a particular disaster hazard" (United Nations, 1997, p. 76).

Table 2.1: Some definitions of vulnerability in literature

Definitions	Source
"The threat to which people are exposed."	(Gabor & Griffith, 1980)
"The degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude."	(UNDRO, 1980)
"The capacity to suffer harm and react adversely."	(Kates, 1985)
"the differential capacity of groups and individuals to deal with hazards based on their positions within physical and social worlds."	(Dow, 1992)
"The potential for loss of property or life from environmental hazards."	(Cutter, 1996, p. 529)
"The state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt."	(Adger, 2006, p. 268)
"The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard."	(Wisner *et al*., 2004, p.11)
Vulnerability is the degree to which a person, system or unit is likely to experience harm due to exposure to perturbations or stresses.	(Kasperson & Kasperson, 2005)
"The degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes."	(IPCC, 2007, p. 6).

2.9.1 Vulnerability: theoretical views

Theoretically, from the different definitions of vulnerability in the climate change literature, three divergent understandings of vulnerability are evident: vulnerability as exposure to a hazard, vulnerability as social condition (a measure of resilience to hazards), and vulnerability as the integration of potential exposures and societal resilience.

Vulnerability as exposure to the hazard (or biophysical vulnerability) has arisen from an approach based on assessments of hazards and their impacts, in which the role of human systems in mediating the outcomes of hazard events is downplayed or neglected (Brooks, 2003). This approach to understanding vulnerability has its root in physical sciences. Füssel (2007a) identified this approach as risk-hazard approach and can be better investigated through internal factors such as topography, environmental conditions and land cover; and external factors such as severe storms, earthquakes and sea-level change. Kelly & Adger (2000) and Soares *et al*. (2012) regarded the biophysical vulnerability approach as an end-point analysis. The biophysical approach respond to research questions such as, "What are the expected net impacts of climate change in different regions?" and "What are the benefits of climate change mitigation?" (Füssel, 2007a).

Biophysical vulnerability assessment approach attempts to assess the level of damage that a given environmental stress causes on both social and biological systems. It is sometimes known as an impact assessment (Tesso *et al*., 2012). Here, vulnerability is defined as a "function of exposure to exogenous biophysical threats: physical stimulus is itself the departure and vulnerability of the system described in terms of the outcome" (Cradock-Henry, 2011, p. 29). Biophysical vulnerability has been described as 'outcome vulnerability' (O'Brien *et al*., 2007) or 'wounded soldier' approach (Kelly & Adger, 2000).

The limitation of this approach is the assumption that environmental or biophysical factors contribute significantly to vulnerability and that socioeconomic factors do not. The reason for the biophysical approach is that, for instance, farmers are vulnerable to factors that affect their livelihood options and that these factors are climate change, soil infertility, soil degradation, topography, and water stress among others. Socioeconomic factors that also define a farmer's adaptive capacity are irrelevant and remain constant. However, two farming households may face the same climatic or environmental conditions but may vary by socioeconomic factors.

Vulnerability as social condition (or vulnerability as a state) is rooted in social sciences and humanities and focuses on the social, economic and political status of individuals or groups (Füssel, 2007a; Opiyo *et al*., 2014; Tesso *et al*., 2012). It has arisen from studies of the structural factors that make human societies and communities susceptible to damage from external hazards (Brooks, 2003). This approach indicates that individuals or groups within a household and community differ in their vulnerability to climate change due to differences regarding age, gender, income, education, wealth, health status, access to credit, political power, access to information and technology, land ownership, and social networks. In other words, socio-economic vulnerability is about social and economic inequalities.

Social vulnerability is determined by factors such as poverty and inequality, marginalisation, food entitlements, access to insurance, and housing quality (Brooks, 2003; Wisner *et al*., 2004). Deressa *et al*. (2008, p. 2) noted that the approach mainly "identifies the adaptive capacity of individuals in a household or community based on their internal characteristics". According to Füssel (2007a), socioeconomic vulnerability can be better understood through internal and external factors. The internal factors include household income, social networks, access to information; and the external factors include national policies, international aid and economic globalisation. Changes in the internal and external factors can affect vulnerability.

Studies by Brouwer *et al*. (2007) and Willroth *et al*. (2012) are examples of this approach. In their study in communities along River Meghna in southeast Bangladesh, Brouwer *et al*. (2007) concluded that households with lower income and low access to productive natural resource asset were more vulnerable to flooding. Willroth *et al*. (2012) revealed that social network and income diversification decrease vulnerability of households in Khao Lak, a fishing community, and Ban Nam Kham, a farming community, to post-tsunami shocks in Bangladesh.

The limitations of this approach are the assumption that all other factors, such as environmental and climatic factors, are considered to be constant and without any significant influence on the vulnerability. However, in reality, this does not appear to be so. Households and communities are influenced by both socioeconomic and environmental factors (Deressa *et al*., 2008). Ignoring the importance of the environmental factors distorts the measurement of vulnerability. Socioeconomic approach implies that decision-makers might not consider exogenous environmental factors and their associated contribution to vulnerability in the design and implementation of programmes and policy to increase adaptive capacity and reduce the vulnerability of farming households.

Integrated vulnerability assessment approach combines both socioeconomic and biophysical approaches to determine vulnerability. It tries to correct the flaws identified in biophysical and socioeconomic approaches (Deressa *et al*., 2008; Füssel, 2007a; Opiyo *et al*., 2014). This approach, thus, assesses the combined effects of biophysical and socioeconomic factors. The approach assumes that vulnerabilities of households or societies are determined by the interplay between environmental and socioeconomic factors. The main limitation is that there is no standard method for combining the biophysical and socioeconomic indicators (Tesso *et al*., 2012).

The IPCC (2007a) definition that vulnerability is a function of exposure, sensitivity and adaptive capacity requires integration of both socioeconomic and biophysical approaches.

Exposure mostly denotes environmental factors while the sensitivity and adaptive capacity denote socioeconomic factors. The integrated approach has been employed by some studies to analyse vulnerability (Opiyo *et al*., 2014; Piya *et al*., 2015). Piya *et al*. (2015) incorporated climate change and related hazards with socioeconomic factors to analyse the vulnerability of households in Nepal. Opiyo *et al*. (2014) utilised environmental factors, such as temperature, rainfall, drought, flood and wind, and integrated these with socioeconomic factors, such as age, gender, marital status, remittance and credit, to determine the vulnerabilities of rural households.

2.9.2 Components of vulnerability

Vulnerability involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or society (Wisner *et al*., 2004). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system". (IPCC, 2007, p. 6). Thus, vulnerability may be thought of as the extent to which a system is exposed to a stressor; the system's sensitivity to the stressor; and the system's adaptive capacity to cope with and recover from a change in the stressor (Stringer *et al*., 2009).

Vulnerability is place-based and context-specific, and factors that make one household, community or region may be different from another (Wolf *et al*., 2013). Conceptually, vulnerability is a function of exposure, sensitivity and adaptive capacity (Adger, 2006; IPCC, 2007a). This concept of vulnerability is the one adopted for this study. However, the relationship between the terms remain ambiguous (Brooks, 2003). Exposure is an external dimension of vulnerability whiles sensitivity, and adaptive capacity is internal dimensions of vulnerability (Corobov *et al*., 2013). In this sense, exposure and sensitivity increase vulnerability while adaptive capacity decreases it. Exposure indicates the nature, extent, duration and frequency of climate change and related hazards such as droughts, floods, storms, changing distribution of temperature and rainfall over a geographic area (Ide *et al.*, 2014; Murthy *et al.*, 2015; Teshome, 2016). These climate change and related hazards could adversely affect people, livelihoods, ecosystem functions and services that are located in such a geographic area (IPCC 2014).

According to O'Brien, *et al.* (2004) exposure relates to the extent to which a particular system or a household or community may be exposed to climatic stresses. Cardona *et al.* (2012) refer to exposure as the characteristics of an area in which hazard events may occur and that people and economic resources that are not located in potentially dangerous settings will not be vulnerable. Exposure to any climate condition depends on where people live and how they construct their settlements, communities and livelihoods (Brooks, 2003). Ide *et al.* (2014) and Teshome (2016) relate exposure to climate change with temperature and rainfall. With the increase in exposure, in this case, increase in the change in temperature and rainfall and also increase in the occurrence of climate-related hazards, will make people, especially, farmers more vulnerable to climate change. Increase temperature leads to increase the rate of evaporation of water which in turn reduce soil moisture and amount of surface waters available for farming and household use.

Several studies have shown that smallholder farmers are not only exposed to climate change and variability but also by non-climatic factors or stressors (Antwi-Agyei *et al.*, 2017; Füssel & Klein, 2006; Nyantakyi-Frimpong & Bezner-Kerr, 2015; O'Brien *et al.*, 2004; Tschakert, 2007). Climate stressors relate to changes in meteorological conditions (such as temperature, precipitation, and wind) as well as changes in sea level, landslides, flooding, or drought. Non-climatic stressors relate to a wide range of environmental, economic, social, demographic, technological, and political factors that affect the exposure and sensitivity components of vulnerability cultural, political (Antwi-Agyei *et al*., 2017; Füssel & Klein, 2006), physical and environmental factors that increase the vulnerability of households or communities.

The socioeconomic factors may include rising prices, economic downturn, crimes/theft, migration, death, poor roads, access to the market, access to health facilities, access to irrigation facilities, credit/loans and access to agricultural inputs. Political factors include poor governance, war, corruption, regulatory barriers, and political network. Environmental factors include bushfires, deforestation, pollution (land, water, and air), and availability/access to natural resources. Cultural factors include farming practice, land tenure systems and inheritance. The physical factors include the location of the farm (lowland, highland, closeness to a water source), farm size, and type of housing.

Sensitivity is the extent to which a given system responds to climate change and related hazards (Adger, 2006; Kelly & Adger, 2000; Murthy *et al*., 2015). A sensitive system is one that is highly responsive to climate change and non-climatic factors (Füssel & Klein, 2006). The sensitivity of a system to climate change denotes the "degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)" (IPCC, 2007a). In general, sensitivity increases the effect of exposure on people and a system, and therefore the more adverse the impact would be. Sensitivity may be influenced by socioeconomic and ecological conditions of the system. In their study of the impact of climate change on rural households in Kenya, (Opiyo *et al*.,

2014) noted that shortage of food, limited availability of water and pasture resources and conflicts increase household vulnerability to climate change.

In climate change literature, adaptive capacity denotes that ability of a system to change to cope with and recover from the effects of climate change (Adger, 2006; IPCC, 2007b; Murthy *et al*., 2015; Teshome, 2016). *Ceteris paribus*, adaptive capacity correlates negatively with vulnerability. Adaptive capacity and coping ability are used interchangeably, though, the two terms have different meanings with respect to timescale. Adaptive capacity is linked to long-term strategies while coping ability refers to short-term strategies (Smit & Wandel, 2006). The capacity to adapt can change over time and depends on several factors including economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology (IPCC, 2007a; Smit & Wandel, 2006). These determinants of adaptive capacity vary from one country, community, social group and individual to another and they are also dynamic (Smit & Wandel, 2006). The scale of adaptive capacity may be interdependent. For instance, the ability of a household to withstand specific stress is greatly influenced to some degree by socioeconomic processes in the community, and at subnational and national levels (Smit & Wandel, 2006).

According to Vogel and O'Brien (2004) (cited in IPCC, 2012), vulnerability is multi-dimensional, differential, scale-dependent and dynamic. It is multi-dimensional and differential because it varies across physical space and among and within social groups. What makes a household or a community different from another, and what makes one social group, say, livestock farmer, vulnerable may be different from crop farmer. Vulnerability is scale-dependent because it varies across units of analysis such as households, communities, regions or nations. The differential nature of vulnerability is as a result of changes in the biophysical and socio-economic conditions of a particular household, community or region (Smit & Wandel, 2006). These conditions also change with time. The primary objective of vulnerability assessments is to identify people or places that are most susceptible to harm and to identify vulnerability-reducing actions (Luers, 2005).

2.10 Adaptation

The concept and practice of adaptation are not new to human society (Kotir, 2011). With the growing recognition of the adverse impacts of climate change and climate variability on societies as well as on ecosystems, various response strategies have been given attention within the development discourse. Adaptation and mitigation are two response strategies employed to respond to the adverse impacts of climate change (Adger *et al*., 2007; Aleksandrova *et al*., 2014; Baird *et al*., 2014; Connolly-Boutin & Smit, 2016; Füssel, 2007b; IPCC, 2014; Meinke *et al*., 2009; O'Brien *et al*., 2009; Smit & Skinner, 2002). Füssel (2007b) identified compensation as the third response strategy. Mitigation refers to steps undertaken to confine global climate change by reducing activities that contribute to GHG emissions, increasing carbon sinks and increasing the use of renewable energy sources. Adaptation refers to an 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, 2007a). Compensation involves the transfer of payments from countries that contribute that disproportionately contribute to climate change to those who are disproportionately affected by it (Füssel, 2007b).

Many scholars, however, identified adaptation as the best response strategy in the context of climate change (Baird *et al*., 2014; Füssel & Klein, 2006). Füssel & Klein (2006) proffered some reasons why adaptation is the best option. According to the authors, climate change is expected to continue as the results of past GHG emissions and the inertia of a climate system; the benefits of adaptation is immediate whilst that of mitigation will take several decades to fully manifest; adaptation can be undertaken at local and regional scale, and it is less dependent on the actions of others, and adaptation reduce risks associated with current climate change. In an attempt to broaden understanding, this section presents the various definitions of adaptation and explore the approaches to assessing adaptation to climate change.

Adaptation involves change. The Oxford Dictionary of English (Second Edition, 2006) refers to adaptation as the action or process of adapting or being adapted. Adaptation is derived from old Latin (in the 13^{th} century) and French (in the 16^{th} century) word *adaptatio* to mean the action of adapting (Simonet, 2010). Adapt originated from late Middle English, from French *adapter*, and from Latin *adaptare* (to adapt to), from *ad-* 'to' + *aptare* from *aptus* 'fit' (Simonet, 2010).

Like vulnerability, adaptation has different meanings and interpretations to different people and disciplines. For instance, in ecology, adaptation refers to the inherited trait that increases an organism's chance of survival and reproduction in a particular environment (Arms, 1996) or the physical changes that allow an organism to survive in a given environment (Cunningham & Cunningham, 2006). In social science literature, adaptation refers to "adjustment by individuals and the collective behaviour of socioeconomic systems" (Saon, 2015, p. 472). In psychology, adaptation is "the process of unceasing interaction between man and the ever-changing world within which he evolves" (Simonet, 2010, p. 3). See Table 2.2 for other definitions of adaptation. Notwithstanding the differences in the above definitions, it is clear that adaptation is closely linked to coping and adaptive capacity.

Table 2.2: Some definitions of adaptation in literature

Definitions	**Sources**
"The process of deliberate change, often in response pressures and changes that affect people's lives".	(Stringer *et al*., 2009, p. 749)
"A process, action or outcome in a system (household, community, group, sector, region, country) for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity".	(Smit & Wandel, 2006, p. 282)
Actions taken to moderate the adverse effects of climate change.	(Füssel & Klein, 2006).
"Adjustments in ecological, social, economic systems in response to actual or expected climatic stimuli, their effects or impacts".	(IPCC, 2001, p. 879; Smit *et al*., 2000, p. 225)
"Actions targeted at the vulnerable system in response to actual or expected climate stimuli with the objective of moderating harm from climate change or exploiting opportunities."	(Füssel, 2007a, p. 265)
"Changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change."	(IPCC, 2001)

In agriculture, adaptation to climate change is already taking place. Adaptation is place- and context-specific (IPCC, 2014b). That is adaptation varies across scale (household, community or region) and also depends on the type of stressors. Adaptation strategies adopted in one place may not be effective in another place. The conceptual framework for adaptation for this thesis relies on the first three questions pose by Smit *et al*. (2000, pp. 224,) recommend researchers to focus on answering four (4) questions: "adapt to what?

Who or what adapts? How does adaptation occur?" The fourth question posed by the authors is "how good is the adaptation?"

Adaptations are made with respect to the type of stressor that an individual household, community or region faces and that the stressor varies with time and space (Smit *et al*., 2000). Several scholars have noted that farmers in SSA are not always confronted with a single stressor but with multiple stressors that are climatic and/or non-climatic in nature and interacting to compound the vulnerability of the farmer (Codjoe *et al*., 2012; Kihupi *et al*., 2015; Morton, 2007; Nyantakyi-Frimpong & Bezner-Kerr, 2015; O'Brien *et al*., 2009; Olayemi, 2012; Tessema *et al*., 2013). However, most adaptation studies in SSA have focused mainly on farmers' response to climatic stressors (Codjoe *et al*., 2012; Kihupi *et al*., 2015; 2009; Olayemi, 2012; Tessema *et al*., 2013). Focusing on climatic stressors only clouds understanding of the importance of non-climatic stressors in adaptation strategies of African farmers. This thesis addresses this knowledge gap by linking each adaptation or coping strategy to a specific stressor faced by the farmers and therefore, answering the question, adapting to what?

Smit *et al*. (2000) posited that studies on adaptation should always consider the unit that is employing an adaptation strategy. The unit of analysis could be an individual, a community, a region, a nation, an ecosystem or across different scales. For example, in the study of the response of farming communities to drought and floods, Codjoe *et al*. (2012) selected farmers (male and female, fishers and charcoal producers. The study revealed that these individuals respond differently to the same climatic conditions. Adaptation to even the same stressor differs across households, communities, regions and nations due to differences in adaptive capacities which are influenced by socioeconomic, cultural and natural resource conditions.

Women play a central role in households- and community-based adaptation initiatives. In SSA, women and girls are responsible for collecting water for household use, 80% of food production, household food security (Midgley *et al*., 2012). However, cultural practices restrict most African women's access to property, finance and technologies that would have enhanced their adaptive capacity and therefore, improving their overall condition in life.

Climate change literature relate this question to the types, forms and timing of adaptation (Bawakyillenuo *et al*., 2016; Berrang-Ford *et al*., 2011; Codjoe *et al*., 2012; Eakin *et al*., 2014; Huq *et al*., 2004; Maddison, 2007; Shackleton *et al*., 2015; Smit & Skinner, 2002; Smit & Wandel, 2006; Stringer *et al*., 2009; Wilbanks & Kates, 2010). Autonomous adaptations (also referred to as spontaneous adaptation or reactive) is undertaken by individuals in response to past and current changes in climatic events without the intervention of public policy (Huq *et al*., 2004). Autonomous adaptation, therefore, occurs naturally and as and when the climate condition changes. On the other hand, planned adaptations are undertaken by deliberate public agency and are based on the awareness that conditions are about to change or have changed, and therefore some actions are needed to minimise losses or benefit opportunities (Bawakyillenuo *et al*., 2016; Codjoe *et al*., 2012; Huq *et al*., 2004).

Adaptation could be either anticipatory and responsive, tactical and strategic (Codjoe *et al*., 2012; Smit & Skinner, 2002) and public and private (Tompkins & Eakin, 2012). Anticipatory adaptation (or proactive) "involves deliberate decisions to prepare for potential adverse impacts before a climatic event or trend occurs, while responsive (or reactive) adaptation is undertaken after the event or trend has been observed" (Codjoe *et al*., 2012, p. 435). Autonomous and planned adaptations are considered as responsive and anticipatory adaptations, respectively. In the tactical adaptation, the farmer makes adjustments within a season as a response to changes in climatic conditions. Strategic adaptations relate to "structural changes in the farm operation or changes in enterprises or management that would apply for a subsequent season, or a long-term" (Smit & Skinner, 2002, p. 94). Private adaptations are actions taken by individuals or households or private entity while public adaptations are initiated and implemented by the government (Tompkins & Eakin, 2012). According to Adger *et al*., (2005), private adaptation actions which aim to benefit individuals may, in the long run, benefit the public and that some of the actions may be constraint by institutional structures and regulations.

2.10.1 Adaptation practices in SSA and Ghana

The extent to which the net impacts of climate change and related hazards will be beneficial or detrimental to farmers in SSA will depend on the success of the adaptation or coping strategies employed (Asfaw *et al*., 2014; Berry *et al*., 2006). In agriculture, adaptation is not a new phenomenon in African farming communities as farmers have always lived with climate uncertainty and have developed a diverse range of strategies to cope with this uncertainty (Reid *et al*., 2013; Vogel, 2005). Whereas climate change is a global phenomenon, adaptation is mainly location-specific and context-specific. Climate change literature is replete with various adaptation strategies employed by African farmers in the face of climate change and variability.

In Tanzania, Mary & Majule (2009) identified the adaptation strategies employed by farmers in Kamenyanga and Kintinku villages in the Manyoni District in Singida Region to include early land preparation and planting to avoid competition for labour, burying and burning of crop residues to increase soil fertility and control crop pests, using contour ridges to reduce soil erosion and retain soil moisture, planting mixture of crops and varieties to spread risks, and altering timing and location of cropping activities. A study by Kihupi *et* *al*., (2015) revealed that the adaptation strategies implemented by farmers in semi-arid areas of Tanzania in response to temperature and rainfall variability include use of drought-resistant varieties, irrigation, crop diversification, change in planting dates, application of agrochemicals, use of early maturing varieties, and agriculture diversification. Additionally, the farmers are also involved in non-farming activities such as petty trading, hairdressing, dressmaking, fishing, construction activities, and brewing.

In Ethiopia, Tessema *et al*., (2013) found out that farmers in East Hararghe Zone have introduced tree planting, early planting, irrigation, water harvesting, use of early-maturing plants, terracing, non-farming activities, and praying. According to Olayemi (2012), crop farmers in Ondo State of Nigeria response to climate change by employing early and delay planting, early harvesting, mixed farming and cropping, mulching, construction of fire track, use of drought-resistant varieties, use of improved varieties and cultivars, improved storage facilities, irrigation, soil conservation, migration, and non-farming activities.

Studies on climate change in Ghana have shown that the adaptation strategies used by farmers are not entirely different from those from SSA. Farmers across the country response to climate change by use of improved crop varieties, prayers, livestock rearing, engage in non-farming activities, migration, use of irrigation facilities, mixed cropping, tree planting, agricultural inputs, seasonal migration, use of traditional knowledge, rainwater harvesting, changing planting dates, and fertilizer application (Ahmed *et al*., 2016; Bawakyillenuo *et al*., 2016; Codjoe *et al*., 2012; Fosu-Mensah *et al*., 2010; Stanturf *et al*., 2011; Yaro, 2013).

However, some of the adaptation practices employed by farmers may have unintended negative consequences on humans and the environment (Magnan *et al*., 2016). According to Barnett and O'Neil (2010), adaptation is complex and an action taken may fail to meet its objectives and may even increase vulnerability. This can result in maladaptation. For instance, the felling of trees to use as firewood for cooking or to sell to generate income can result in deforestation, a contributor to climate change. the application of fertilizer and manure to boost food production can increase the nutrient load in water bodies and ultimately result in eutrophication. Farmers who migrate to southern Ghana, during the dry season, in search of non-farming income-generating ventures are likely for face various hardships such as living in dilapidated buildings and becoming victims of social vices.

Farmers in Ghana and beyond do not only adapt to climate change, but also to non-climatic stressors. Nyantakyi-Frimpong & Bezner-Kerr (2015) observed that farmers in northern Ghana utilised round ridging and inter-row cultivation to control weeds, *zai* pits technology and trash lines to restore soil fertility and moisture, and manure and compost to restore soil fertility. Ahmed *et al*. (2016), noted that farmers in Ghana use adaptation strategies such as seed preservation, livestock keeping, rainwater harvesting, charcoal making and selling and social network to counteract non-climatic stressors such as water scarcity, land degradation and poor soil fertility. However, this study did not explicitly link the adaptation strategies to specific non-climatic stressors and knowledge about how specific stressors influence the choice of adaptation strategies will provide an important step in guiding policymakers in the design and implementation of well-tailored adaptation policy and programmes. This thesis seeks to fill this knowledge gap by linking farmers' adaptation to specific climatic and non-climatic stressors.

2.10.2 Factors influencing the choice of adaptation strategies

As indicated earlier, adaptation is critical to coping with the negative impacts of climate change and other related hazards. However, the ability of farmers to adapt to climate change and variability in hinged upon a number of factors ranging from perception of climate change (Esham & Garforth, 2013; Piya & Lall, 2013) to non-climatic factors to socio-economic factors (Abdulla *et al*., 2009; Bhatta *et al*., 2016; Esham & Garforth, 2013; Feola *et al*., 2015; Mugi-Ngenga *et al*., 2016; Piya & Lall, 2013).

Climate change and non-climatic factors are known to influence the adoption of response strategies. Bhatta *et al*. (2016) noted that farmers change their agricultural practices in response to changes in climate change and related hazards, such as less rainfall, drought, increasing temperature, cyclones and floods, as well as non-climatic factors such as pests and diseases, low yield and policy changes. Esham & Garforth (2013) indicated that perception of climate change has a positive influence on the level of adaptation among farmers in Sri Lanka. In rural Ghana, studies have shown that farmers employ different adaptation strategies in response to drought and flood conditions (Codjoe *et al*., 2012).

Age of a household head has been found to significantly influence the level of adaptation such that the older people are seen to have more experience and can utilise various adaptation strategies to address changes affecting farming activities (Mugi-Ngenga *et al*., 2016). However, Shiferaw & Holden (1998) indicated that there is a negative correlation between age and level of adaptation and that younger people may be willing to take the risk of adopting new technologies in relation to adaptation than older people. Younger people are also likely to engage in climate-related activities with the ultimate aim of reducing the impact of climate change (Salehi *et al*., 2015). Gender is also another determinant of adaptation. However, there is no clear-cut effect of gender factor with regard to adaptation. Female-headed households are found to have a lower level of adaptation due to socio-cultural and institutional barriers (Berman *et al*., 2015; Hassan & Nhemachena, 2008; Mugi-Ngenga *et al*., 2016).

On the contrary, Nhemachena & Hassan (2007), using multinomial logit (MNL) and multinomial probit (MNP) models, reveal that female-headed households are more likely to adapt to climate change because women do much of the agricultural work in rural Africa. Mugi-Ngenga *et al*. (2016) used multinomial and binary logistic regression models to predict the influence of socioeconomic characteristics on the level of adaptation to climate variability. The authors noted that socioeconomic and agronomic factors such as average size of land under maize; farming experience; household size; and household members were statistically significant in determining the choice of adaptation.

2.11 Institutional role and adaptation

Aside from perception, institutions are essential in shaping adaptation to climate change. Institutions are recognised as structures and mechanisms of social order and cooperation governing the behaviour of a set of individuals within a given human collectivity (Agrawal, 2008; North, 1990). According to Hodgson (2006, p. 2), institutions are be defined as "systems of established and prevalent social rules that structure social interactions". Institutions constrain and enable human actions or behaviours through the imposition of rules (Hodgson, 2006; North, 1990). Institutions may also help individuals and communities to interpret scientific information and design and implement adaptation strategies, including the provision of innovative technologies to reduce vulnerability (Amaru & Chhetri, 2013). According to (Yaro *et al*. (2015), institutions, especially, traditional African institutions in rural communities are essential in the sense that they provide the framework within which capacities of local people can be exercised in their adaptation to climate change.

Adaptation to climate change and variability is a function of dissemination of information and provision of resources between various institutions and communities with mandates/activities to enhance adaptive capacities (or improve adaptation strategies) and ultimately reduce vulnerabilities (Agrawal, 2008; Amaru & Chhetri, 2013; MESTI, 2013). Institutions are categorised as public (local agencies and local governments), private (service organisations and private businesses) and civic (membership organisations and cooperatives) and these are further grouped as formal or informal (Agrawal, 2008).

In Ghana, there are a number of international, national and private institutions or organisations with mandates/activities to enhance adaptive capacity and ultimately to reduce the vulnerability of communities and households to climate change and variability (MESTI, 2013). Some of these institutions may have core mandates that are strictly political, such as the modern political system of governance (elected or appointed governments) and traditional political systems (chieftaincy institutions). Also, some of these institutions may not have offices within the communities that require their support and therefore liaise with other rural-based or district-based institutions with similar mandates to channel their supports.

In rural Ghana, the institutions are formal and informal and may include religious institutions, local countries, traditional institutions, family networks, clan/elders networks, community-based organisations, farm-based organisations, and women's groups (Yaro *et al.*, 2015). To understand how farmers cope with the adverse effects of climate change and variability, it is essential to recognise the role of institutions in influencing behaviour and also challenges that these institutions face in executing their mandates. Understanding the role of institutions is key to providing sustainable and long-term interventions for reducing vulnerabilities among farming households and communities.

The Ghana National Climate Change Policy report (MESTI, 2013) provides a list of institutions or organisations with mandates in climate change. These institutions include the

Metropolitans, Municipals and District Assemblies (MMDAs), Ministries, Departments and Agencies (MDAs), non-governmental and civic organisations, and private institutions (including financial institutions). The report also documented various legal and regulatory frameworks that regulate institutional and human actions to reduce the adverse impacts of climate change across multiple scales.

2.12 Conceptual framework for the study

Based on the theoretical framework and literature review, the study adopts an integrated vulnerability approach to explore the vulnerability and adaptation of farming households in the Lawra District, Ghana to climatic and non-climatic stressors. According to the framework, farming households work in a multi-dimensional risk environment characterised by the interaction between climatic and non-climatic stressors to influence vulnerability and adaptation decisions. The framework takes as its starting point the definition of vulnerability as a function of exposure, sensitivity and adaptive capacity (Figure 2.1). That is, vulnerability is the manner and degree to which a farming household is exposed to climatic and non-climatic stressors to which is it sensitive, and the capacity to adapt to these stressors. The components of exposure and sensitivity create potential impacts and increase the vulnerability of households, while adaptive capacity decreases it. *Ceteris paribus*, a high degree of exposure or sensitivity and low adaptive capacity would suggest the farming household is more vulnerable; and a low degree of exposure or sensitivity and high adaptive capacity would mean the farming household is less vulnerable.

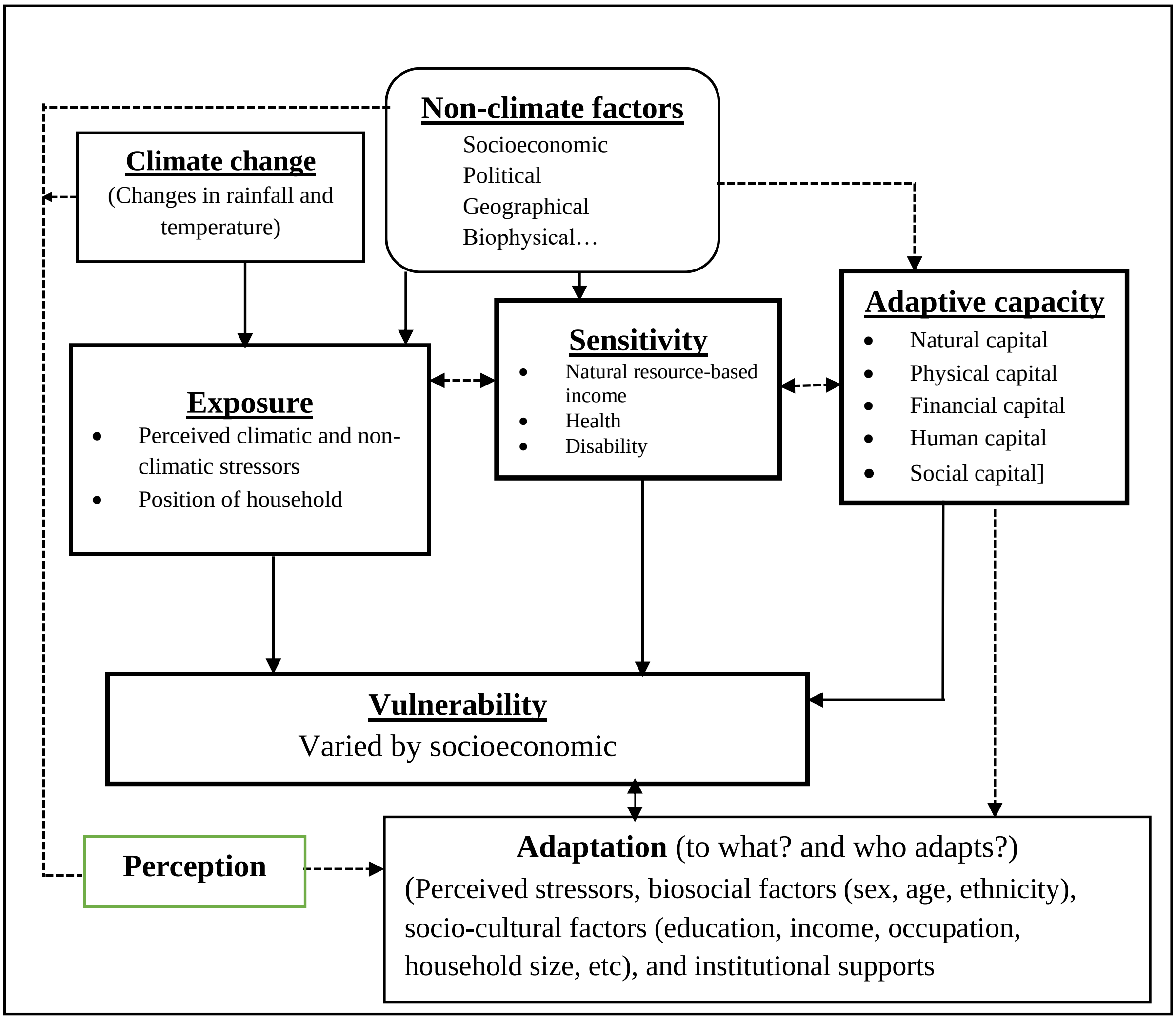

Figure 2.1: Conceptual framework: Household vulnerability to multiple stressors

Source: Author's construct.

Exposure-sensitivity, in this context, denotes the degree to which the farming household experiences stress and the nature of the unit of exposure (that is farmer's awareness and location of household). It refers to the interaction of the farming household with climatic and non-climatic stressors perceived by the farmer to have occurred and affecting his/her farming activities. For instance, a farming household that is over-dependent on rain-fed farming with a source of income from non-farm or off-farm income generating activities is more exposed and sensitivity to erratic rainfall or drought than a farming household facing the same stressors but also relying on off-farm activities.

Adaptive capacity, in this context, is the ability or capacity of the farming household to adjust to climatic and non-climatic stressors to take advantage of opportunities or to cope with the consequences of these stressors. Adaptive capacity is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time (Smit & Wandel, 2006). In this study, the adaptive capacity of an individual is defined by the livelihood assets expound by DfID (1999) and (Scoones, 1998). These assets or capitals are fundamentally affected by prevailing stressors (DfID, 1999). The adaptive capacity of individuals or households is shaped and constrained by social, political, and economic processes at higher scales (Smit & Wandel, 2006).

The framework also seeks to account for the influence of climatic and non-climatic stressors in defining adaptation decisions of farming households. The framework seeks to ask the questions, who adapt and to what? Fundamentally farmers are not indifferent to the changes in the local environment but respond to these changes in various ways. Farmers' adaptation decisions are influenced by their perception of climatic and non-climatic stressors, individual socioeconomic conditions (adaptive capacity) and support from local institutions operating in the area. As noted by Maddison (2007), for adaptation to take place, farmers must first perceive a change in a condition before deciding whether to take action to respond. Adaptation strategies if implemented well will reduce households' vulnerability to climate change and non-climatic stressors.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter presents a description of the study area and the methodology employed in the study. Under the description of the study area, the chapter details the geographical location, climate, vegetation, geology demographic and the socioeconomic settings of the district and the selected communities. Second, the chapter captures the various methods and techniques used in this study including the research design, sampling, data collection methods, instruments as well as the limitations encountered. Finally, the chapter describes how the data collected are processed, analysed and presented.

3.2 The study area

The study was conducted in the Lawra District of the Upper West Region of Ghana and involved six rural farming communities. The study area was purposively selected based on it being located in the poorest (GSS, 2015), and one of the most vulnerable regions of the country to climate change and variability (Antwi-Agyei *et al*., 2012). The study district is also one of the two districts (the other being neighbouring Nandom District) for the broader project, "Adaptation at Scale in the Semi-arid Regions (ASSAR) in Ghana. The ASSAR project seeks to strengthen understanding of the processes and factors that impede adaptation and maintain vulnerability in semi-arid areas of Africa and Asia.

3.2.1 Location and size

Lawra District is one of the eleven districts in the Upper West Region and one of the 260 metropolitan, municipal and districts (MMDs) in Ghana. The region was created in 1983 out of the Upper Region, which was formerly part of Northern Region until 1960 (GSS, 2013) when the country had attained independence and had become a republic without sovereignty control by the British. The district was created from the Legislative Instrument (L.I) 1434 of 1988 (PNDCL 207, Act 462). In 2012, with the coming into force of the Legislative Instrument 2099, Nandom District was carved out of the Lawra District to create two separate districts (LDA, 2013).

The district (Figure 3.1) is situated in the north-western corner of the Upper West Region and between Latitude 9º83″N and 11ºN, and Longitude 1º25″W and 2º45″W. It is bounded on the north by the Nandom District, on the North and West by the Republic of Burkina Faso, on the south-east by Lambussie-Karni District, and to the south by Jirapa District (Essegbey *et al*., 2016; GSS, 2014). The closeness of the district to Burkina Faso allows for transboundary movement of people and goods and services between the district and francophone communities in Burkina Faso.

The district has area councils which are Lawra, Babile, Zambo and Eremon Area Councils, with the traditional administration under the Lawra Traditional Council (LDA, 2013). It has a total area of 527.37 km^2, and this accounts for about 2.8 percent of the region's entire land area, estimated at 18,476 km^2 (GSS, 2014). Lawra is the traditional and administrative capital of the district.

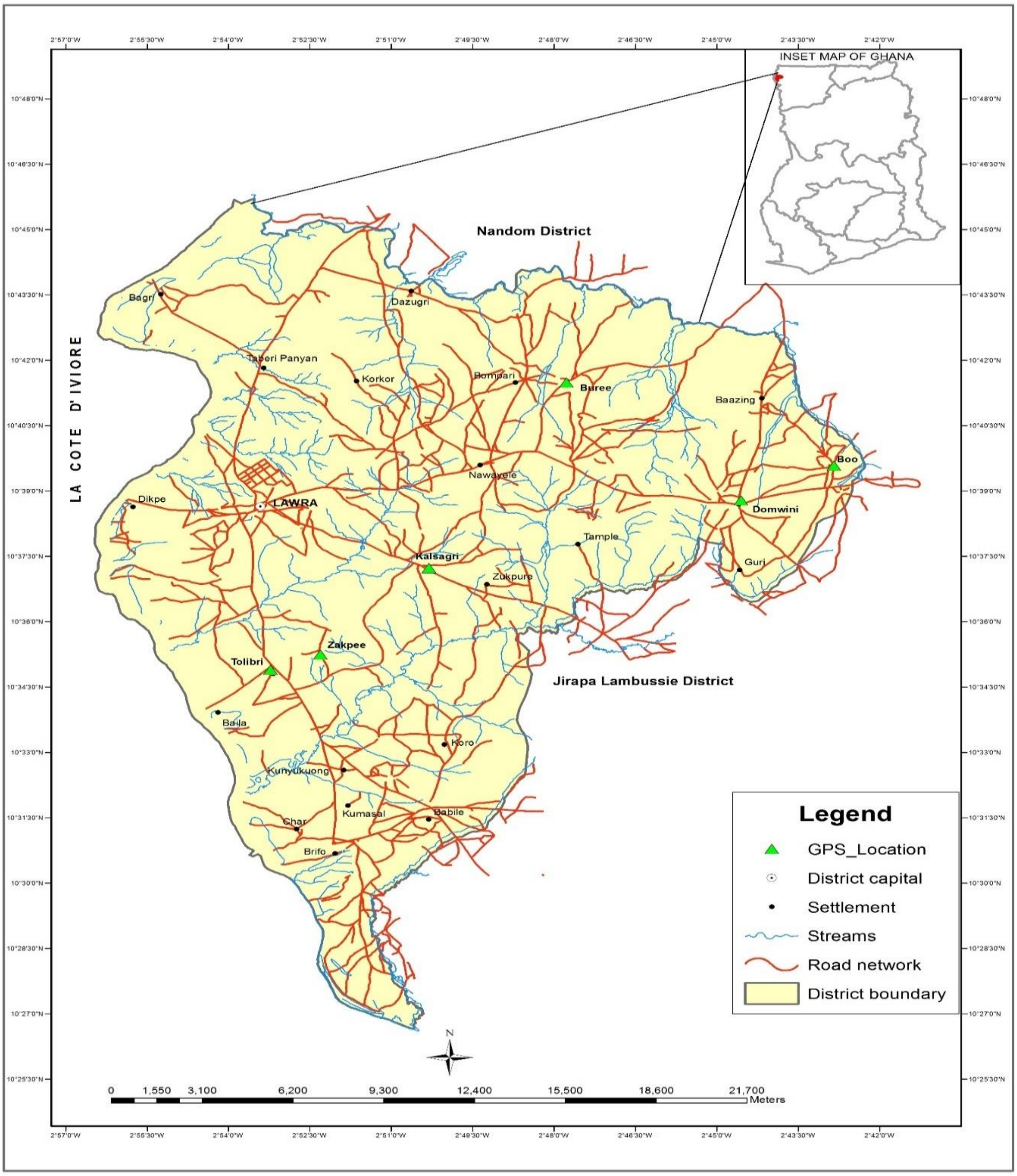

Figure 3.1: Map of Lawra District showing the selected study communities.

3.2.2 Vegetation and climate

As a result of diverse climate conditions and natural vegetation, Ghana has six agro-ecological zones: rainforest, coastal savannah, semi-deciduous forest, transitional zone, Guinea savannah and Sudan savannah zones. The study area is located within the Guinea savannah zone. The mean annual temperature of the District ranges from 27°C to 36°C, with

February and April being the hottest (GSS, 2014). Climatic changes of late, however, affect the weather pattern. Between April and October, the Tropical Maritime air mass blows over the area, which gives the only wet season in the year (GSS, 2014). This weather results in the district having one farming season and hence leading to the youth migrating to the south during the prolonged dry season (LDA, 2013).

The vegetation of the district is characterised by short grasses and few woody plants. Most trees in the District consist of drought and fire-resistant trees such as baobab (*Adansonia digitata*), dawadawa (*Parkia biglobosa*), shea trees (*Vitellaria paradoxa*) and acacia (*Acacia albida*). The vegetation is very congenial for livestock production, which contributes significantly to household incomes in the District (GSS, 2014; LDA, 2013). The prolonged dry season has a profound influence on the vegetation. Vegetation becomes dry and prone to burning. The burning of grass leaves most areas patchy and bare. Consequently, the torrential early rains cause soil erosion. Bush burning reduces the vegetative cover and increases the rate of transpiration and this affects average annual rainfall totals (LDA, 2013).

3.2.3 Relief, drainage, geology and soils

The District is gently rolling with a few hills ranging between 180 and 300 metres above sea level. It is drained by the Black Volta River, to the west forming a boundary between the District and the Republic of Burkina Faso. The Black Volta River has several tributaries in the district; notably amongst them are the Kamba/Dangbang, Nawer and Duodaa (GSS, 2014). These water bodies if utilised for irrigation could offer agro-based employment for the youth who migrate to the south in search of non-existing or high-risk jobs during the dry season.

Geologically, the rock formation in the District is primarily Birimian with dotted outcrops of granite. The District mineral potential is mostly unexplored. However, recent mineral prospecting in the area indicates the presence of Gold in appreciable quantities worth mining. As a result of a well-developed fracture pattern in the rocks, the potential for obtaining groundwater in the district is very high. This accounts for the 90% success in borehole drilling activities in the district (LDA, 2013). The soils in the district consist mostly of laterite soils. These are developed from the Birimian and granite rocks which underlie the area. There are also strips of alluvial soils along the floodplains of the Black Volta as well as sandy loams along some of its tributaries (GSS, 2014; LDA, 2013).

3.2.4 Demographic and socioeconomic characteristics

The report of the 2010 Population and Housing Census put the population of Lawra District at 54,889, which represents 7.8% of the population of the Upper West Region. The females constitute 52% and the males 48%. The district is predominantly rural (88.2%). The principal settlements are Lawra (the district capital), Babile, Boo, Dowine, Kunyukuo, Koninob No. 1, Nawayele, Bagri, Batani, Eremon and Baadi (GSS, 2014). The district is more youthful (under 15 years accounting for 41.0% of the population) and a small proportion (7.3%) aged 65 years and above. The age-dependency ratio for the district is estimated at 93.6, which is higher than the regional ratio of 91.0. The age-dependency ratio is higher in the rural areas (97.8) than in the urban areas (67.1).

The district has a total of 9,200 households with an average household size of 6 persons per household. The household size for rural areas is higher (6.2) than for urban areas (4.5). A large proportion (47.4%) of households practices an extended family system followed by a nuclear family system (21.1%). Male-headed households constitute 26.6% of headship, while female-headed households represent 8.4% (GSS, 2014). This is because the district is mostly a patriarchal and patrilineal society and even, by the customs and tradition, widows are not allowed to head a household.

In terms of marital status, the married constitutes 50.1%, the single 37.6%, widowed 9.6%, divorced 1%, informal/consensual union 0.9%, and the separated 0.7%. With regard to literacy, there are more illiterate (54.8%) than literate (45.2%), with the male population being more literate (59.7%) than the female population (41.3%). Among the married, 74.7 percent have no education, while about 22 percent of the never married have never been to school (GSS, 2014).

With regard to religious affiliation, 61% professed to the Christian faith, followed by traditional (26.3%) and Islam (6.6%). About 5.7% of the population is not affiliated with any religion. A majority (46.3%) of Christians professed to belong to the Roman Catholic denomination. A higher number of secondary and vocational schools in the district were built and operated by the Roman Catholic Church until the Government of Ghana took over the operation after independence. The predominant ethnic group is Dagarti (also called Dagaba, Dagaaba, Dagarti, Lobi-Dagarti or Dagari) (van der Geest, 2011).

A large proportion (79%) of the population is economically active, while 21% are not economically active (GSS, 2014). Agriculture accounts for 80% of the district economy, followed by commerce/service (18.2%) and industry (0.8%) (LDA, 2013). Subsistence agriculture is engaged by 83.5% of households, with a little over 90% of rural households and 47% of urban households involved in it. The people practice mixed farming at the subsistence scale (GSS, 2014), in which crop farming is combined with animal husbandry. Most households maintain compound farms which are situated in the immediate surroundings of their compounds. The types of crops cultivated by the farm households include maize (*Zea mays*), millet (*Pennisetum glaucum*), yam (*Dioscorea spp.*), sorghum (*Sorghum bicolar*), groundnut (*Arachis hypogea*), Bambara beans (*Vigna subterranea*), beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*) and rice (*Oryza sativa*). These crops are grown mostly for household consumptions, and the surpluses are either processed for sale or sold in unprocessed form during market days. Animal production is undertaken by the people to supplement income from crop farming. The type of animals kept by the people includes cattle, sheep, goats, poultry and pigs (GSS, 2014; LDA, 2013).

Other farm households undertake non-farming activities such as pito-brewing, pottery, basket and cloth weaving, shea butter processing, rice processing, stone quarrying (van der Geest, 2011). Fishing is practised on the Black Volta River, which forms the border between Ghana and Burkina Faso and then Ghana and Cote d'Ivoire, to provide protein and also to supplement the meagre income earned in crop farming. Farmers also practice dry season farming on lands located a few metres from the Black Volta River.

3.2.5 Selection and description of study communities

The six rural communities used in this study were purposively selected with support from the District Office of the Ministry of Food and Agriculture (MoFA). The communities were selected based on their relevance to the study. The experts from MoFA also indicated that these communities were highly exposed to climate change,predominantly farming communities, different farmers use different adaptation strategies, willingness of the communities to participate in the study and easy road access to communities. A description of socioeconomic characteristics of the six selected communities are below:

Tolibri

Tolibri is located in the southern section of the district. Its distance is about 9 km from the district capital, Lawra. The village is situated on the Lawra-Nadowli-Wa road. The village comprises a cluster of compound houses that are separated by a large track of lands that serve as farmland for houses in the village. Crop farming and animal keeping are the predominant livelihood activities in the village. Compound farming is the conventional type of farming in the village. Compound farming is practised on lands surrounding the farmers' houses. Crop farming is predominantly rain-fed, and the principal crops grown include guinea corn, maize, millet, groundnut and yam. The village is headed by a chief.

There is no irrigation facility in the village. However, dugouts have been constructed to harvest and store rainwater for domestic and livestock use during water stress periods like the harmattan season. Some inhabitants either travel southwards to engage in non-farming activities or practice dry season farming by relocating farms closer to the Black Volta River where the surrounding soils are still moist during the dry season. Non-farming activities practised by the inhabitants include dressmaking, hairdressing, pito-brewing, fried beans/cowpea cake (*koose*) making, dawadawa paste making, petty trading, masonry, carpentry and drinking bar operation. These activities are dominated by women.

None of the houses in the village is connected to the national electricity grid, even though the electric power lines pass through the village. There is no health centre (clinic) or market in the village. For medical attention, the inhabitants either go to the District Government Hospital at Lawra or the health centre at Babile. For trading, the inhabitants go to the market at either Lawra or Babile. There is no school in the village. Children of school going age have to go to Kunyukuo (a nearby village) to attend a primary school. There are four boreholes with only two functioning properly in the village.

Zakpee

Zakpee is located south of Lawra off the Lawra-Nadowli-Wa road and about 3 km from Tolibri. Like other villages in the district, the people in Zakpee are predominately farmers. Compound farming is the conventional type of farming in the village. In addition to crop farming and animal rearing, some inhabitants, mostly women, engage in non-farming income generating activities such as pito brewing, fried beans/cowpea cake (*koose*) making and dawadawa paste making. There are no schools in the village, and school children have to walk for about 3 km to Kunyukuo or 6 km to Kalsagri to attend school. The road network is poor and not tarred. The village is not connected to the national electricity grid. Like Tolibri, there are no hospitals or health centre at Tolibri and people had to commute to Lawra or Babile to access a health facility. There are four boreholes with only two functioning in the village.

Kalsagri

Kalsagri is a farming village linking Lawra to Jirapa. The village is about 6 km from Lawra, the district capital. The primary occupation is farming and rearing of livestock. Compound farming is the common type of farming in the village. Non-farming activities engaged by the inhabitants include teaching, pito brewing, fried beans/cowpea cake (*koose*) making, dawadawa paste making, petty trading, carpentry and masonry. The non-farming activities are engaged by a few inhabitants who are mostly women. The community is connected to the national electricity grid. The community has a primary High School. The road network is good and tarred. There are five boreholes with one not functioning in the community.

Buree

Buree is predominantly farming village. Compound farming is the common type of farming in the village. The inhabitants also keep livestock as a form of security and also a source of additional income. There is no non-farming activity observed in the community. The village is located at about 7 km off the Lawra-Dowine road. Altogether, this village is about 15 km from Lawra. The village has neither a school nor health centre. School children had to walk or ride (bicycle) for about 4 km to Danko to attend school. For medical attention, inhabitants have to go to Danko, Lawra or Dowine. The community is not connected to the national electricity grid. There are three boreholes with only one functioning in the village.

Dowine

Dowine is located at the intersection of Lawra, Jirapa and Nandom, and about 17 km from Lawra. The village is much closer to Jirapa in the Jirapa District (roughly 12 km) than Lawra. The roads linking Dowine to Lawra; Dowine to Jirapa; and Dowine to other villages are poor, untarred and dusty. The inhabitants of this village are predominately farmers, and they practice compound farming. The principal crops grown by the farmers included maize, Guinea corn, beans, Bambara beans, millet, sorghum and yam. The livestock reared by the inhabitants include goats, sheep, cattle, Guinea fowl and pigs. Some inhabitants engage in non-farming activities such as petty trading, fried beans/cowpea cake (*koose*) making, dawadawa paste making, selling of alcoholic and non-alcoholic beverages, garment making, hairdressing, masonry, carpentry and teaching. The village has a health centre and a primary school. The village is connected to the national electricity grid. There is no market centre in the village and inhabitants have to go to either Tizaa (Jirapa District), Boo, Lawra or Babile to trade. The village has nine boreholes, but six were functioning correctly at the time of data collection.

Boo

Boo is a village located at about 3 km from Dowine and about 21 km from the district capital, Lawra. Like other villages in the district, inhabitants in this village are predominately farmers with compound farming being common. Farmers also farm on owned lands at a distance from houses in the village. The principal crops cultivated by the farmers include millet, sorghum, maize, Guinea corn, beans, Bambara beans and yam. The livestock reared by the inhabitants include goats, sheep, cattle, Guinea fowl and pigs. The inhabitants also engage in non-farming activities such as dawadawa paste making, *koose* making, shea butter making and masonry. The village is not connected to the national electricity grid even though the electric power lines pass through the village to Hen the next community. The village has a school, a health centre and a market centre. There are nine boreholes with one not functioning in the village.

3.3 Methodology

3.3.1 Research design

This study used an explanatory sequential mixed method design involving two phases (Creswell, 2003; Ivankova, Creswell, & Stick, 2006). The design started with quantitative collection and analysis followed by qualitative data collection and analysis. This approach was adopted because of the stated objectives of the research and because climate change is a complex issue. This approach allowed for the analyses of the challenges facing farm households in the study communities. The quantitative approach was used to collect information from respondents in order to get a general understanding of the research problem. The qualitative approach was used to provide in-depth explanation and understanding of the problem by exploring the views from participants. The qualitative approaches such as focus group discussion were used in constructing the seasonal calendar and establishing the various factors affecting farm households in the study.

Various scholars such as Gentle *et al*., (2014), Haque *et al*., (2012), Kalaugher *et al*., (2013), Teshome (2016) and Thorlakson & Neufeldt (2012) used mixed methods approach to assess the impacts of climate change on farming communities in Nepal, Bangladesh, New Zealand, Ethiopia and Kenya, respectively.

3.3.2 Reconnaissance visits to selected communities

In order to enter each of the selected communities, the service of a staff member of Department of Social Welfare (DSW) at the Lawra District Assembly was engaged (the officers of MoFA were not available for this exercise). The staff from DSW was selected because of his knowledge of the local terrain; ability to speak the Dagarti dialect; involvement with the registration for the National Health Insurance Scheme (NHIS) and Livelihood Empowerment against Poverty (LEAP). Meetings were arranged with the chiefs and elders of their respective communities through the Assembly member. The meetings were held within the compound of the chief's palace of each community. The purpose of the community entry was to seek the consent of the communities and to inform members of the communities of the objectives of the research.

3.3.3 Training of enumerators

Enumerators for the study were made up of two teachers from each study community as well as an Agricultural Extension Officer from the District Agricultural Office and an officer (who doubled as a translator) from the Social Welfare Department of the district. Two graduates from the Presbyterian University College, Ghana were also recruited for the exercise. Enumerators comprised males and females who lived in the study communities.

A workshop was organised to train enumerators so that the enumerators would be familiar with questions contained in the survey instruments. The training was done for two days at the Lawra District Assembly.

3.3.4 Primary data collection

3.3.4.1 Household questionnaire administration

The smallest unit of analysis was the farm household and was defined as a household for which the primary economic activity of the household head was agricultural production. The administration of the questionnaire at the household level started with the determination of the sample size and then the selection of households. The sample size was determined taking into consideration the characteristics of the population under study as well as the objectives of the study. According to GSS (2014), 83.5% of the 9,200 households in the district engaged in agriculture. Thus, there were 7,682 agricultural households in the district. Using the formula described by Rose, Spink & Canhoto (2015), the sample size was determined:

$$n = \frac{4pq}{d^2} \qquad \text{(eqn 1)}$$

Where *n* is the required sample size, *p* is the proportion of the population having the characteristics of interest (in this case, farm households), *q* is (1 – *p*), and *d* is the degree of precision. The *p* was determined to be 0.835, and *d* is 0.05. Substituting these figures into equation (1), yielded an *n* value of 220. The value was considered as the minimum number of households to constitute the study population for the household survey. Dividing the value of *n* by 6, which was the number of study communities, gave a value of 36.7. The value was rounded off to give the final sample size of 40 and was used for each study communities.

In each of the selected communities, households for questionnaire administration were selected purposively. The Assembly member of each community assisted in selecting the households. Only household heads were selected as respondents. A household head was defined "as a male or female member of the household recognised as such by the other household members" (GSS, 2014 p. 12). Where a household head (male) was absent from the house for more than six months, his spouse was considered as the head and therefore was interviewed. In some cases, female spouses were reluctant to be interviewed until they received approval from the husbands via phone call. In most cases, the research team requested the presence of the spouse of the male head during the interviews. Rather than leaving the questionnaire for the respondents to complete themselves, the research team went through the questions with the respondents and filled according to the responses from the respondents. This strategy was employed because the more than half (54.8%) of the population had no formal education (GSS, 2014).

The information contained in the questionnaire (Appendix A) included relevant demographic and socioeconomic information of the farmers' household; farmer's perception of the local climatic and non-climatic stressors (or worries); the influence of these perceived stressors on farming and household activities; causes of the perceived stressors; coping or adaptation strategies employed to counter these perceived stressors; and factors hindering the adoption of the response strategies. With regard to perception, the questionnaire was structured in a way that no specific climatic and non-climatic stressor was listed or discussed with the farmers. Rather than *a priori* assumption of climatic and non-climatic stressors, farmers were asked to make a list of the stressors or worries that they perceive to affect their farming and households activities. In the same manner, the questionnaire was designed to exclude the list of possible coping/adaptation strategies farmers could employ. Instead, farmers were asked to list the possible strategies they used to counter each perceived stressor. This approach allowed each respondent to independently indicate the number and nature of stressors affecting his or her household without the influence of the research team.

The questionnaire for the household survey was first pre-tested to allow the research team to know the likely challenges to be encountered during the main survey exercise. The pretesting also allowed the researcher to refine and update the questions. Pretesting was conducted in all selected communities from the 8th to 12th February 2016. The main challenges encountered during the pretesting exercise included meaning of some of the words in the Dagarti language (for example, words like stressors and vulnerability); who should be considered as a child of the head (this was because there are children in a number of households who are not biological children of the husband/wife); duration of the questionnaire (this was found to be about 1.5 hours long); some wives refusing to participate in the absence of husbands (or seeking permission, via mobile phone, from husbands who have temporarily migrated), inability to recall the exact quantity of crops harvested in the past 10 years; the actual farmland under cultivation; refusal of some households to participate in the exercise even though their houses had been selected; and the distance of some houses from the centre of the community (because of the scattered nature of settlement enumerators had to walk or ride for long distance to reach some selected houses).

The main household survey was conducted from July 2016 to October 2016. The geographical location and elevation/slope of each selected house were determined using a GPS (Garmin® eTrex 10). This was important in the determination of vulnerability status of each household (*see* Chapter Six).

3.3.4.2 Focus group discussions

Focus group discussions were conducted using a checklist of questions (Appendix B). The questions included types of farming practices, factors affecting farming and household activities, ranking of the factors, who are vulnerable in the community, adaptation strategies employed by farmers, challenges encounter in implementing these strategies, and the type of support farmers receive from government/NGOs for the household survey. The researcher moderated the discussions throughout the discussion period.

Two types of focus group discussion were conducted. The first FGDs were held during the reconnaissance study. The second FDGs were conducted for community members who did not belong to the chief/elder groups. In all, 24 FGDs (4 from each community) were conducted with between 7 and 13 participants drawn from different socioeconomic backgrounds according to gender and age. The age dependency definition was used to categorise the participants were grouped into older men, older women, younger men and younger women. In this study, old people were defined as people who were 65 years and above, and young people were those below 65years. These age categories were chosen from the assumption that all persons aged 65 years and older do not work or cannot work and are therefore dependent on the economically active groups whilst those aged 15 - 64 years work and not dependent on others (GSS, 2014). Responses were both written and recorded. The FDG was conducted in November 2016. The two types of FGDs were conducted to improve participation of people who were deemed not to belong to people with authority in each community.

3.3.4.3 Key informant interviews

Key informant interviews (KII), based on the responses received from the household survey and focus group discussion, were conducted to update some of the qualitative data. KII was conducted to solicit information qualitatively from experts and officials of local organisations, governmental and non-governmental institutions with objectives relating to climate change and adaptation in the district. The organisations or institutions were purposively selected. The institutions included community-based organisations, farm-based organisations, the District Assembly, the District Health Management Team (DHMT), ESOKO and Resilient and Sustainable Livelihood Transformation (RESULT) projects. In addition, the chief or regent of each community was interviewed. The interviews were conducted in December 2016 and January 2017 and recorded using a voice recorder. The interviews were conducted mostly in the English Language by the researcher and a retired MoFA officer. The interviewees were asked the same questions in an orderly manner, and the interview continued until a point of data saturation was reached when no new information was obtained. The recorded voices were transcribed and given to the interviewees for their input and clarification. A change was proposed by one of the interviewees with respect to distribution of subsidised fertilisers. The interviews were coded by the researcher and two research assistants. The themes and subthemes were input into the ATLAS ti software and analysed.

3.3.4.4 Soil Sampling

To evaluate farmers' perception of soil quality in their farms, soil samples were collected from four randomly selected farms per study community to give a total of 24 soil samples. This was done during the pre-planting season in January 2017. On each selected farm, soil samples were collected from six (6) sites from a depth of 0 -15 cm using a soil auger. The six soil samples were put into a pail and mixed thoroughly, and then a single soil subsample was taken from the resultant mixture for analysis. Each sample was labelled indicating the site code and the GPS reading. The soil samples were sent to the Ecological Laboratory of the Institute for Environment and Sanitation Studies (IESS) of University of Ghana for analyses. The soil samples were air-dried, ground and then sieved through a 2 mm sieve to obtain a uniform soil sample.

Total nitrogen (TN) in soil was determined using Kjeldahl digestion, distillation and titration. Organic carbon (OC) and organic matter (OM) were determined by following modified Walkley-Black wet oxidation procedure as described by Nelson and Sommers (1982). Available phosphorus (AP) was determined by spectrophotometer by following Olsen and Sommers (1982) method. The electrical conductivity (EC) of the soil was determined with the conductivity meter (HACH Sension 5 model). Available potassium (AK) was determined using flame photometry. Soil pH was determined in a 1:2 suspension of soil to water ratio with pH meter (WTW model pH 523) equipped with the combination electrode type (Type E 50).

3.3.5 Secondary data

A 30-year daily meteorological data (1984 – 2014) recorded at the Babile Meteorological station (Agromet) were obtained from the Ghana Meteorological Authority (GMA). Babile is a community within the Lawra District were the GMA has temperature and rainfall recording station. There is another station at Lawra, but the researcher could not make use of the data because of a lot of missing data. The Babile Agromet station had 2.4% data gaps (about 266 days of missing data), and since the other meteorological stations in the region are very far (more than 50 km) from the study communities, the researcher decided to use the Babile data (Amekudzi *et al*., 2015). At the time of writing this thesis, the meteorological data for the years 2015, 2016 and 2017 had not been completed by the meteorological agency. The information obtained from the analyses of meteorological data was used to support the observations of farmers, in the study area, concerning the local climate.

In addition, census information from the Ghana Statistical Service was collected to understand the socioeconomic status and other relevant information about the study district. Relevant information from the annual reports of the Lawra District Assembly as well as non-governmental organisations with mandate within the Lawra District was also used in this thesis.

3.3.6 Ethical Approval

Ethical clearance for all survey instruments for this study was obtained from the Ethics Committee of the College of Basic and Applied Sciences (ECBAS) of the University of Ghana in March 2016. The clearance was approved by the committee in June 2016. Ethical consideration is necessary since the research involves human participants who have different sensitivities and the need to safeguard the wellbeing of the participants during the research process. The objectives of this study, the associated risks and compensation were thoroughly explained to all participants. Participants were also informed that there were no monetary benefits associated with agreeing to participate in this study and that participation was voluntary. Participants were informed of their rights to withdraw from the research at any time without any penalty. Also, participants were assured that the information obtained would be treated as confidential and anonymous.

In addition, participants were given the opportunity to ask questions relating to the research. For those participants who could not read, a member of the household or community (who is familiar with the participant) was asked to read and explain every information to the participant.

3.3.7 Method of analysis

In order to accurately analyse the information or data obtained, different data capturing and data analysis software were used. This is due to the nature of the data collected. Qualitative data started with coding by three coders. The themes were generated from the data and not identified in advance. The themes generated and analysed using ATLAS.ti version 7, a qualitative data analysis software. Quantitative data from the household questionnaire were coded, input and analysed using the Statistical Package for the Social Sciences (IBM® SPSS® Statistics) version 22 for Windows® and Stata® for Windows® version 13.1. Rainfall and temperature data were analysed using Instat+® for Windows® version 3.036. Instat+ is a statistical package developed by the University of Reading, UK for analysis of climatic data.

3.3.7.1 Perception analysis

Content analysis technique was used to analyse the qualitative parts of the questionnaire. Altogether, a broad spectrum of stressors was listed, and those with similarities were grouped into one stressor. For instance, *low rainfall, less rainfall* and *little rainfall* were grouped under "low rainfall". *Poverty, low income, no income, little income, financial problems*, *lack of money* and *lack of income* were denoted as "lack of money". The responses to the perception of stressors elicited from the sampled farmers were grouped into climatic and non-climatic stressors, and the number (frequency) of farmers citing each stressor was computed. The ranking of a stressor relative to the other stressors by each farming household was determined. Each household was asked to rank each stressor cited on the scale of 1 (most important) to 10 (least important). The average ranking for each stressor for all households was determined and then overall ranking computed with the stressor with the lowest average ranking assigned ranking number 1, and so on using the ranking formula in Microsoft Excel (version 2016) to compute the final ranking of each stressor relative to the other stressors in the pool. The ranking was computed separately for male and female respondents, and later for all respondents to give the overall ranking. The ranking denotes the relative importance of one stressor with respect to other stressors in the pool.

3.3.7.2 Vulnerability analysis

Vulnerability status of households was assessed using indicators or proxy variables based on literature and incorporated into the household survey instrument. The selected indicators were categorised into exposure indicators, sensitivity indicators and adaptive capacity indicators as described in the next subsection.

Exposure contributes positively to vulnerability of a household to climate change and variability. Higher elevation is usually associated with higher rainfall and lower temperature, and vice versa (Flesch & Reuter, 2012; Lee *et al*., 2013; Ogwang *et al*., 2014; Shi *et al*., 2008). Given the lack of meteorological data at household and community levels, proxy variables were used to represent exposure components. In this study, it was hypothesised that individual household in a community is exposure to stressors and therefore, the number of perceived stressors by a household was used as a proxy for climatic and non-climatic stressors. The higher the elevation of a house, the lower the temperature level that the house would experience, and hence, the lower the exposure value. The higher the number of different stressors or worries mentioned by the household the higher the exposure and vice versa (Table 3.1).

Sensitivity contributes negatively to vulnerability reduction. In this study, sensitivity indicators were represented by five proxy variables namely share of household income from natural resources; affected household (whether household was considered by the head as most affected in the community); proportion of household members fallen ill in the past 12 months; length of illness and proportion of household member with disability (Table 3.1). A higher proportion of income from natural resource-based will increase household sensitivity as these sources are dependent on climate change.

Table 3.1: Indicators or proxy variables for sensitivity component

Indicators[1]	Unit	Expected sign[a]
Exposure index		
Elevation of HH	Metre	(-)
Stressors faced by HH (number)	Number	(+)
Sensitivity index		
Share of natural resource-based income	Percentage (%)	(+)
HH is affected most by stressors	Dummy:1 = yes and 0 = no	(+)
HHM falling ill in last 12 months (%)	Percentage (%)	(+)
Length of illness	Months	(+)
HHM with disability	Dummy:1 = yes and 0 = no	(+)

[1] At the community level, the mean values were computed and used in the analysis. [a] The hypothesised relation of the indicator, with positive indicating that a higher value of the indicator is likely to increase sensitivity, while negative means lower sensitivity. HH (household); HHH (household head); HHM (household members)

Climate change has negative impacts on the health of people (Haque *et al.*, 2013). Poor health negates productivity and also cause a household to divert available resources (including income) to seek medical attention instead of channelling into boosting productivity. Besides, ill-health of a member would result in a reduction of labour strength because a health member who could have supported production would have to attend to the sick member. Thus, a healthier household has lower sensitivity. The length of illness measured the number of days a household member was ill and therefore could not engage in farming and household activities. The higher the length of illness, the more sensitive the household. A household with a member being ill was expected to be more sensitive to climate change.

The proportion of the higher the share of household income from natural resource the higher the sensitivity. The higher the share of household income from non-natural resource-base the lower the sensitivity. The healthier the household head over the last 12 months the lower the sensitivity. The higher the proportion of household members falling sick in the last 12 months, the higher the sensitivity. The higher the total number of days a household member was sick and therefore, could not engage in farming or productive activities the higher the sensitivity. People with disability are considered to be one of the most vulnerable people in the community (Tschakert *et al*., 2013). Therefore, if there was a household head with a disability, then that household was considered to be more sensitive. Also, a household that identified itself as being the most vulnerable compared to all households in the community was assumed to be very sensitive.

Adaptive capacity correlates negatively with vulnerability. Adaptive capacity is identified adaptive capacity as a function of a household's possession of social, natural, human, financial and physical capitals (DfID, 2004; Fraser *et al*., 2011). Indicators for the determinants of adaptive capacity used in this study were referenced from other vulnerability studies (Notenbaert *et al*., 2013; Opiyo *et al*., 2014; Tibesigwa *et al*., 2016).

Social capital assets were assessed in seven ways: membership of associations or social groups, access of formal extension advice, access to weather information, access to credit facility, household head's involvement in active politics, the number of extended relatives of household head residing in other households in the community, and the number of close friends of the household head in the community (Table 3.2). The associations that a farmer belong included formal and informal association such as farmer-based associations, community-based association and faith-based associations. It was assumed that a household that belongs to an association or a social group was well-positioned to cope with adverse effects of climate change. In addition, a social group provides a platform for members to share information and also pull resources together to help members in times of need. Members of an association could provide farmer-to-farmer extension services. Households belonging to one or more association were scored 1, those belonging to no association were given a score of 0.

Access to weather information could be through the use of radio, television, phone (texting) or farmer-to-farmer interaction. Access to weather information enhances adaptive capacity and hence, reduces a household's vulnerability to climate change (Wood *et al*., 2014). A household having access to weather information was scored 1, and the one without access was scored 0. Access to formal extension advice helps farmers to learn new methods of managing farming activities. A household that received a visitation from agricultural extension officers in the last 12 months was scored 1, and a household that did not receive such visitation was scored 0.

Access to credit facility enables farmers to receive necessary resources or funds to boost production and hence, increase their adaptive capacity and reduce their vulnerability. Farm credit facility helps farmers to diversify their livelihood strategies inside and outside the agricultural sector (Stanturf *et al*., 2011). A household with access to credit was scored 1 while a household without access in the last 12 months was scored 0. Affiliation to a political party can be positive or negative. A household with the head affiliated to a political party was assumed to benefit from agricultural intervention/support programme implemented by government compared to a household seen to be apolitical. In this study, it was assumed that household with affiliation to a political party and actively involved with party politics would have an advantage compared to a nonpartisan household. A household with head involved in active politics was assigned a score of 1, otherwise 0.

Relatives and friends could provide some support, such as financial, food and other material support, in times of need. Household head with friends or extended relatives within the same community may be able to maintain productivity without institutional support during harsh environmental and developmental conditions (Fraser *et al*., 2011). In this study, it was assumed that the higher the number of relatives of a household head in other households within the same community, the higher the household's adaptive capacity and therefore, the lower the household's vulnerability to climate change and stressors. Likewise, the higher the number of close friends the household head had in the community, the higher the household's adaptive capacity and hence, the lower vulnerability to climate change and other stressors.

Natural capital assets were assessed using three (3) indicators: size of farm holding, ownership of farmland, and the number of different kinds of fruit trees a household owns (Table 3.2). It was assumed that a household with a larger land under cultivation is more likely to grow more crops and have more grains harvested to meet the family food requirement than a household with a smaller land under cultivation. Land ownership status is defined as the type of land tenure system under which the household is operating. Land inherited was given a score of 1 while land that was either purchased/rented was given a score of 0.

Owning a fruit tree is seen as important for the household to meet their nutritional requirement. Fruits could be sold to raise additional income. Fruit trees provide shades when the sun is high, help reduce evaporation of soil moisture, provide a barrier against windstorm and prevent soil erosion (Cardona *et al*., 2012). The higher the number of fruit trees owned, the more healthy the household is assumed to be and there the higher the adaptive capacity.

Human capital asset refers to the "skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives" (DfID, 1999: p. 7). A human capital asset was assessed using seven (7) proxy indicators: household size, the gender of household head, the age of household head, household age dependency ratio, literacy ratio, the proportion of household member with valid health insurance, and number of years household head has been farming (Table 3.2). Household size refers to the number of people living with the respondent. It presents the availability of labour in the household. It can influence a household's adaptation to climate change. Croppenstedt (2003) argued that a larger household means that a larger household size enables the adoption and intensive use of available technologies. Also, a larger household size means household members could engage in off-farm activities to generate additional income without significantly affecting household labour for on-farm activities (Tessema *et al*., 2013).

Age, gender and years in farming of a household head is important in determining the vulnerability of the household to climate change. Age presents two contrasting factors for vulnerability. Households headed by older persons are more likely to be vulnerable as they cannot cope with stresses compared with the younger ones. On the other hand, older household heads are argued to have more farming experience and accumulated knowledge of changes in the environment than younger ones (Debela *et al*., 2015). However, in this study, adaptive capacity was assumed to associate negatively with age. Gender is an important demographic factor in determining an individual's rights of access to resources in pursuit of particular adaptation options (Morchain *et al*., 2015). It is argued that women are often constrained from accessing resources due to prevailing cognitive, social and cultural limitations (Perez *et al*., 2015). Households headed by women are seen as more vulnerable than households with men as heads. In this study, a dummy variable was used with male = 1, when the head of the household is a male and male = 0 when the head is a female. Years in farming was considered as a proxy for farming experience. The higher the number of years in farming, the lower vulnerability.

The dependency ratio is defined as the ratio of the number of household members who are aged less than 15 years and more than 64 years to those who are aged from 15 years to 64 years (GSS, 2014). The dependency ratio is a measure of economic burden the productive members of the household have to bear. The higher the dependency ratio (measured in terms of percentage), the less the adaptive capacity and the more vulnerability the household. Literacy ratio relates a person's ability to read and write a simple statement with understanding (GSS, 2014). Literacy has been established to reduce the vulnerability of households by increasing their capabilities and access to information crucial to adopting and implementing available adaptation options (Opiyo *et al*., 2014). Therefore, a household with higher literacy ratio assumed to have a higher adaptive capacity than a household with a lower literacy ratio.

Table 3.2: Indicators or proxy variables for adaptive capacity component

Adaptive capacity[1]	Unit	Expected sign[a]
Social capital		
Membership of social group	Dummy:1 = yes and 0 = no	(+)
Access to formal extension advice	Dummy:1 = yes and 0 = no	(+)
Access to weather information	Dummy:1 = yes and 0 = no	(+)
Access to credit facility	Dummy:1 = yes and 0 = no	(+)
HHH belongs to active politics	Dummy:1 = yes and 0 = no	(+)
Number of relatives in the village	Number	(+)
Number of friends in the village	Number	(+)
Natural capital		
Farm holding size	Hectare (Ha)	(+)
Ownership of farmland	Dummy: 1 = inherited, 0 = otherwise	(+)
Number of different of fruit trees owned	Number	(+)
Human capital		
HH size	Number	(+)
HH head: male	Dummy: 1 = yes and 0 = no	(+)
Age of HHH	Years	(-)
HH dependency ratio	Percentage (%)	(-)
HH literacy ratio	Percentage (%)	(+)
Proportion of HHM with NHIA	Percentage (%)	(+)
HHH years of farming	Years	(+)
Financial asset		
Ownership of livestock	TLU	(+)
Remittances received	Dummy:1 = yes and 0 = no	(+)
HHM working on farm (%)	Percentage (%)	(+)
HHH engaged in off-farm activities	Dummy:1 = yes and 0 = no	(+)
Income diversity	Index	(+)
Physical capital		
Crop diversity	Number	(+)
Transport diversity	Number	(+)
Communication tool diversity	Number	(+)
Use irrigation facilities	Dummy:1 = yes and 0 = no	(+)
Access to electricity	Dummy:1 = yes and 0 = no	(+)
Use of fertilizer	Dummy:1 = yes and 0 = no	(+)

[1] At the community level, the mean values were computed and used in the analysis. [a] The hypothesised relation of the indicator, with positive indicating that a higher value of the indicator is likely to increase adaptive capacity, while negative means a likely lower adaptive capacity. HH (household); HHH (household head); HHM (household members); TLU (Tropical Livestock Unit): cow = 0.70; sheep/goat = 0.10; pigs = 0.20, fowl = 0.01.

Possession of valid health insurance (NHIA) was assumed to make the household less vulnerable to climate change and its related effects. Health insurance reduces the financial burdens of households with regard to health care, and therefore, households can channel their limited funds into acquiring input to boost farm production. In this study, health insurance was measured by the proportion of household members with valid NHIA cards at the time of data collection. The higher the proportion of households with health insurance, the higher the adaptive capacity and hence, the lower the vulnerability of that household.

Financial capital asset refers to the financial resources that the household possesses and use to meet its livelihood objectives. Ownership of livestock was assumed to provide some financial support for households because livestock has high liquidity value (Table 3.2). Livestock could be sold to provide need funds to support household or farming activities. In this study, livestock was measured using the tropical livestock units (TLU) described by (Jahnke *et al*., 1988). The authors assigned TLU conversion factor of 1.00 to a camel, 0.70 to a cow, 0.50 to a donkey, 0.2 to a pig, 0.1 to a goat/sheep, and 0.01 to poultry (chickens). The number of each animal owned by a household was multiplied by its corresponding conversion factor to arrive at the value of the livestock owned in term of TLU. The higher TLU was assumed to mean that the household was a wealthy one.

Financial assets of households were also assessed using remittances that the household received from friends and or relatives in the last 12 months (Table 3.2). A household that received remittances was scored 1, and a household that did not receive any remittance was scored 0. The number of household members working on the farm was also used to determine the financial asset of the household. It was assumed that a higher the number of farm labour from the household, the well-endowed the household was. The reason was that if the source of labour from household was small, then the household had to hire farm labour from elsewhere and that would translate to a reduction in savings. Households with members also engaged in off-farm activities are better equipped to cope with climate-related hazards than households with members entirely engaged in farming (Thorlakson & Neufeldt, 2012). Household engaged in off-farm activities was assigned a score of 1 and a household with no off-farm activities was assigned 0. Income diversity was measured as the numbers of different sources that a household considered to contribute to overall income. The higher the number, the higher the diversity and therefore, the better the household in the face of climate-related hazards.

Physical capital asset relates to the basic infrastructure and producer goods needed to support household's livelihoods (DfID, 1999). The physical capital was assessed using crop diversity, transport diversity, communication diversity, access to irrigation facility, access to electricity/solar, and use of fertiliser (Table 3.2). In this study, crop diversity was calculated as the number of different crops grown per household. Crop diversity is viewed to correlate positively with a higher adaptive capacity of a household (IFAD, 2009). It also implies that the household has a wider choice of food crops to consume to meet dietary requirements.

Transport diversity was calculated as the number and the corresponding different types of means of transport of a household. Households which had no means of transport scored 1, those owning bicycle scored 2, motorcycle scored 3, car scored 4, and a bus scored 5. The number of each means of transport was multiplied by the corresponding score to determine the overall index for transport. Communication diversity was measured as the number of different communication device own by a household. Communication devices are tools for efficient transmitting or dissemination of weather information as well as farming activities (Naab & Koranteng, 2012). A household without a communication device was scored 1; those with phone scored 2; with radio was scored 3, and those with television scored 4. The overall household communication diversity was calculated by summing up the scores of the different types of communication devices owned.

Access to irrigation facility. Households with access to irrigation facilities were scored 1 whereas those without were scored 0. Households with electricity or solar were scored 1 whereas those without were scored 0. Households that applied fertiliser were scored 1, whereas those who did not apply were scored 0.

The normalisation of indicators and determination of vulnerability

The values of the selected indicators have different units of measurement, and therefore, they are not compatible. To ensure compatibility in the construction of the vulnerability index, the values of indicators were normalised to nullify the effect of their units of measurement and also to have a relative position within the range of 0 to 1. Values were normalised using the max-min approach described by Iyengar & Sudarshan (1982) and adopted by OECD (2008). If the indicator X_i had a positive relationship with the resulting component index, the normalised values were computed using equation 1.

$$Normalised\ Xi = \frac{Xi - min(X)}{max(X) - min\ (X)} \qquad \text{(equation 1)}$$

Where *Xi* is the value of indicator corresponding to household or community *i*; *min(X)* is the minimum value of the indicator *X* across selected communities; and *max(X)* is the maximum value of the indicator *X* across selected communities. If the indicator *Xi* had a negative relationship with the resulting component index, then its normalised values were computed using equation 2.

$$Normalised\ Xi = \frac{\max(X) - Xi}{\max(X) - \min(X)} \qquad \text{(equation 2)}$$

After normalisation of indicators, the next step was to assign weights to the indicators. Weighting in this study indicates the relative importance or contribution of each selected variable or indicator. There are a number of ways used to determine the weight to be assigned to an indicator. Heltberg & Bonch-osmolovskiy (2010) assigned equal weights to each indicator in their study on the vulnerability of geographical zones of Tajikistan. Assigning equal weight assumes that all variables are worth the same or contribute the same to vulnerability. Corobov *et al*. (2013) also assigned equal weights in their study of the vulnerability of areas in the Dniester River Basin in Moldova to effects of climate change. The method of simple averages gives equal importance for all indicators, and this leads to underestimating or overestimating the contribution of some indicators to overall vulnerability. In assigning unequal weights to indicators, Brooks *et al*. (2005) and Antwi-Agyei *et al*. (2013) used expert judgement, Opiyo *et al*. (2014) and Tesso *et al*. (2012) used principal component analysis (PCA), Heltberg & Bonch-Osmolovskiy (2010) used fuzzy logic, and Murthy *et al.* (2015) used the method described by Iyengar & Sudarshan (1982) to generate weights for the indicators. This study also adopted the method described by Iyengar & Sudarshan (1982) in computing vulnerability index.

It is assumed that there are *M* households, *K* indicators of vulnerability, and X_{ij} (i = 1, 2, 3,…*M*; j = 1,2,3 ….*K*) is the normalised score. The overall vulnerability index of *ith* household Y_i, is assumed to be a linear sum of X_{ij} as:

$$Y_i = \sum_{j=1}^{K} W_j X_{ij} \qquad \text{(equation 3)}$$

Where W ($0 < W < 1$ and $\sum_{j=1}^{K} W_j = 1$) is the arbitrary weight reflecting the relative importance of the individual indicator. The weights are assumed to vary inversely with the variance over the households in the respective indicators of vulnerability. That is, the weight, W_j, is determined by:

$$W_j = \frac{c}{\sqrt{var\ (X_{ij})}} \qquad \text{(equation 4)}$$

Where *c* is the normalised constant and can be obtained below

$$c = \left[\sum_{j=1}^{K} \frac{1}{\sqrt{var\ (X_{ij})}}\right]^{-1} \qquad \text{(equation 5)}$$

Assigning weights in this manner ensures that large variation in any of the indicators will not unduly dominate the contribution of the rest of the indicators and distort inter-household comparisons. The overall vulnerability index (OVI) was computed as the net effect of exposure (EI), sensitivity (SI) and adaptive capacity (ADI) indices (Heltber & Bonch-Osmolovskiy, 2011) as follows:

$$OVI = \frac{1}{3}\big(EI + SI + \ (1 - ADI)\big) \qquad \text{(equation 6)}$$

The implication of equation 6 is that a higher net value indicates a higher vulnerability to stressors and vice versa. The value of OVI was computed to lie between 0 and 1, with a higher OVI indicating a higher vulnerability.

A k-means cluster analysis was performed on the overall vulnerability indices of households to group households into three (3) vulnerability categories: *less*, *moderately* and *highly*. Households in the same cluster are homogenous to each other and heterogeneous to households in another cluster.

Analysis of variance (ANOVA) is a parametric test used to infer means with three or more groups. A one-way ANOVA was adopted to test for statistically differences between and among the study communities. The dependent variables were the indices of exposure, sensitivity, adaptive capacity and vulnerability. The independent variables were the study communities. Where significant differences occurred, the least significant difference (LSD) and Duncan post-hoc tests were performed to separate the means of the various communities with regard to adaptive capacity, exposure, sensitivity and vulnerability indices. The analyses were performed at a significance level of 5%.

3.3.7.3 Analysis of adaptation

Binary logistic regression was performed through SPSS to assess prediction of adaptation (dependent variable) as a function of the independent variables. Using the variables or components used to compute the vulnerability index (in this study) as independent variables, a binary logistic regression model was used to predict the outcome of adaptation to stressors (dependent variable). This study employed the binary logistic regression because the responses of the dependent variable were dichotomous (either farmer adapts, or the farmer did not adapt).

The logistic model considers the relationship between a binary dependent variable and a set of independent variables that are categorical or continuous. The logistic model for 'k' independent variables (x_i, x_2, x_3, …, x_k) is given by

$$Logit\ P\ (x) = \alpha + \sum_{i=1}^{k} \beta_i x_i \qquad \text{(equation 7)}$$

Exp (β_i) indicates the odds ratio for a person having characteristics i versus not having i, while β is the regression coefficient, and α is a constant.

3.3.7.4 Analyses of rainfall and temperature

In order to ascertain and validate the perception of farm households and communities with respect to the local climate, rainfall and temperature data obtained from the Ghana Meteorological Agency were analysed. A number of rainfall and temperature variables were generated with respect to perception of climatic stressors by sampled farmers. Temperature variables generated were trends of mean minimum temperature and mean maximum temperature. A number of rainfall and temperature variables were generated with respect to perception of climatic stressors by sampled farmers. Rainfall variables generated included the trend of annual rainfall, trend of the number of raining days, seasonal variation in rainfall, onset of raining season. The onset of the raining season defined the starting of the growing season or successful planting dates (Amekudzi *et al*., 2015). Onset of raining season was defined as the accumulation of 25 mm of rainfall within a 5-day period, followed by a period of no more than seven or more consecutive dry days in the following 30 days (Laux *et al*., 2008) starting from the first day of April (Amekudzi *et al*., 2015). A raining day was defined as any day that the amount of rain was at least 0.1 mm. Date of first rains in the year was defined as the first day of the year with at least 0.1 m of rain. The difference between the dates of first rains in the year and onset of raining season defined the risk of planting. Cessation of rains (or end of the raining season) was defined as 'any day from 1st September after which there are 21 or more consecutive days of rainfall less than 50% of the crop-water requirement' (Omotosho *et al*., 2000). The difference between the onset of the raining season and the cessation of the raining season defined the length of rainy season.

3.4 Conclusions

This chapter has provided a detailed description of the study area, mainly, the location of the selected study communities. The chapter has also described and justified the various methods used to collect both primary and secondary data relevant to the study. Climate change and variability is a complex problem and has differential effects on households and communities located in the same or different agro-ecological zones. The complex nature of climate change and its differential impacts on various sectors of the economy requires the integration of various methods to understand the challenges posed by climate change entirely. This study, therefore, employed a mixed-method approach that integrated both quantitative and qualitative methods for validation and broadening understanding of the complex nature of climate change and variability. The next chapter presents the results of the analyses of farmers' perception of climatic and non-climatic stressors in the study area based on objective one.

CHAPTER FOUR

CURRENT AND FUTURE PERCEPTIONS, AND RANKING OF CLIMATIC AND NON-CLIMATIC STRESSORS BY FARMING HOUSEHOLDS

4.1 Introduction

This chapter explores the climatic and non-climatic conditions or factors the farmers perceived as affecting their household and farming activities. This chapter relates to the first objective of the study, which is to identify current and future perceptions and ranking of climatic and non-climatic stressors by farmers, and how these differ by sex of household heads. The chapter is constructed into three sections. It begins with the analyses of farmers' perception of climatic and non-climatic stressors in the study area. This is followed by a discussion in section two and then the conclusion in section three.

4.2 Perception of current climatic and non-climatic stressors

Household heads identified seven climatic stressors and twenty-two non-climatic stressors (Table 4.1). The household heads were made up of 70.4% (n = 169) male and 29.6% (n = 71) female. The main climatic stressors identified by household heads were rainfall-related concerns (low rainfall, heavy rainfall, short duration of rains and late onset of rains), high temperatures and strong wind. The main non-climatic stressors identified by the household heads included lack of money, poor soil fertility, low yield, lack of agricultural tools, cost of fertiliser and ill-health.

The most mentioned stressor was low rainfall, followed by lack of money, death of livestock, poor soil fertility and late onset of rains. The least mentioned stressor was the cost of education. When the result was disaggregated into sex of heads, male-headed households identified all 29 stressors while female-headed households identified 28 stressors (excluding lack of irrigation facility).

Table 4.1: Perception of current stressors based on the sex of farmers

Perceived stressors		**Percentage of farmers**[1]		
		Male (*n* = 169)	**Female (*n* = 71)**	**Overall**
Climatic	Dust	3.0	4.2	3.3
	High temperatures	10.1	15.5	11.7
	Late onset of rains	21.9	15.5	20.0
	Low rainfall	63.9	54.9	61.3
	Heavy rain	4.7	4.2	4.6
	Short duration of rains	17.2	15.5	16.7
	Strong wind	4.1	7.0	5.0
Non-climatic	Bushfire	5.3	2.8	4.6
	Agricultural tools (lack)	7.1	2.8	5.8
	Crop pests	10.7	1.4	7.9
	Felling of trees	3.0	2.8	2.9
	Education (cost)	2.4	1.4	2.1
	Fertilizer (cost)	14.2	15.5	14.6
	Fertilizer (lack)	11.8	8.5	10.8
	Ill-health	9.5	7.0	8.8
	Inadequate drinking water	8.3	5.6	7.5
	Insufficient food	7.1	7.0	7.1
	Irrigation facility (lack)	4.1	NA	2.9
	Electricity (lack)	5.9	5.6	5.8
	Money (lack)	50.3	47.9	49.6
	Support (lack)	2.4	2.8	2.5
	Livestock (death)	30.2	14.1	25.4
	Livestock (diseases)	17.8	14.1	16.7
	Livestock (theft)	8.9	2.8	7.1
	Low yield	16.0	16.9	16.3
	Poor accommodation	1.2	8.5	3.3
	Poor soil fertility	26.6	18.3	24.2
	Post-harvest losses	4.1	7.0	5.0
	Seed failure	0.6	7.0	2.5

[1] Percentages exceed 100% due to multiple responses. NA means the group of farmers did not identify the stressor. (*Source*: Computed from household questionnaire interviews, 2016)

The most mentioned stressor by the male-headed households was low rainfall, and this was followed by lack of money, death of livestock, poor soil fertility, and late onset of rains. The least mentioned stressor by male-headed households was seed failure. Similarly, low rainfall was identified by female household heads as the most important stressor, followed by lack of money, poor soil fertility, low yield, and late onset of rains. The least mentioned stressor among female farmers were crop pests and cost of education.

4.3 Ranking of current climatic and non-climatic stressors

The ranking of stressors indicates the relative importance of specific stressors with respective to the others. In addition, by ranking, the farmers were able to reveal the severity or level of damage stressors cause their farming and household activities. The lower the ranking, the higher the severity of the stressor on farming household activities. Among the climatic stressors, low rainfall was ranked the highest and therefore, causes the highest damage to their farming activities, followed by late onset of rains (Table 4.2). both male-headed and female-headed households gave the same ranking for all the climatic stressors.

Table 4.2: Ranking of perceived stressors by farmers at the household level

Perceived stressors		**Ranking**		
		Male	**Female**	**Overall**
Climatic	Dust	7	7	7
	High temperatures	4	3	4
	Late onset of rains	2	2	2
	Low rainfall	1	1	1
	Heavy rain	5	5	5
	Short duration of rains	3	4	3
	Strong wind	6	6	6

(*Source*: Computed from household questionnaire interviews, 2016)

Table 4.3 reveals the ranking of non-climatic stressors by the respondents. The ranking differs across sex of respondents, with the male-headed households ranking lack of money highest whilst the female-headed households ranking insufficient food the highest. Thus, male-headed households also identified lack of money as a stressor causing severe damage whilst female-headed households considered insufficient food as a bane on their farming and household activities. Though men provide grains for the entire family, it is the woman who must ensure that food is always available for the family to consume. The farmers revealed the ability of a household to provide sufficient food for the beyond the next harvesting season indicate the level of productivity of the household.

While the death of livestock was the second most ranked by male farmers; low yield was second most ranked by the female farmers. The closest ranking stressors by both farmers (ranking difference of 0) was cost of education. The least ranked stressors by male and female farmers were poor accommodation and crop pests, respectively.

Table 4.3: Ranking of non-climatic stressors by farmers at the household level

Perceived stressors	**Ranking**		
	Male	**Female**	**Overall**
Bushfire	15	18	18
Agricultural tools (lack)	20	12	17
Crop pests	8	21	13
Felling of trees	18	16	19
Education (cost)	13	13	11
Fertilizer (cost)	4	6	4
Fertilizer (lack)	7	11	8
Ill-health	11	15	10
Inadequate drinking water	9	3	6
Insufficient food	14	1	7
Electricity (lack)	17	20	20
Money (lack)	1	5	1
Irrigation facility (lack)	19	-	21
Support (lack)	10	19	15
Livestock (death)	2	8	5
Livestock (diseases)	6	17	8
Livestock (theft)	12	14	12
Low yield	5	2	2
Poor accommodation	22	7	14
Poor soil fertility	3	4	3
Post-harvest losses	16	9	9
Seed failure	21	10	16

(*Source*: Computed from household questionnaire interviews, 2016)

4.4 Farmers' perception of causes of climatic and non-climatic stressors

Table 4.3 presents the opinions of the farmers about the causes of each stressor that they perceived. It can be seen from the results that some stressors cause other stressors. This information suggested the possible interactions among the stressors. For instance, felling of trees, which was perceived as a stressor, was acknowledged by the farmers as the cause of low rainfall; heavy rainfall; late onset of rains; short duration of rains; strong wind; lack of money; post-harvest losses and poor soil fertility. Lack of money, another perceived stressor, was cited as the cause of perceived stressors such as high cost of education, poor accommodation, lack of fertiliser, lack of agricultural tools, lack of irrigation facility and ill-health. Low rainfall could result in the soil becoming drier causing the soil to become less fertile. This makes the soil more prone to erosion by the wind which further reduces soil fertility, low yield and ultimately, result in food shortage.

As envisaged, farmers cited supernatural powers as the cause of changes in climate variables (low rainfall, late onset of rains, heavy rainfall, short duration of rains, high temperatures, strong wind) and other non-climatic stressors (such as ill-health, low yield and death of livestock). This, indeed, is not surprising, when one considers that, 86.7% (n = 208) of farmers are Christians, 12.9 (n = 31) are indigenous African religious practitioners and 0.4% (n = 1) are Muslims. Indeed, God is seen as the creator of all things and the main provider of good and bad fortunes. God brings good fortunes to those who obey and do His will and punishes those who go astray. The belief in supernatural powers as a cause of climate change is likely to influence the farmers' desire to utilise available adaptation options since supernatural activities are beyond their control.

Table 4.4: Household heads' opinion about the causes of climatic stressors

Perceived stressors		**Causes**
Climatic	Low rainfall	Bush burning; God; felling of trees; climate change; bad weather; nature[m]
	Heavy rainfall	Bad weather; felling of trees; God; nature[m]
	Late onset of rains	Bush burning; felling of trees; bad weather; God; nature
	Short duration of rains	Bad weather; felling of trees; God; nature; bush burning
	High temperatures	Bad weather; God; nature
	Strong wind	Felling of trees; God; nature
	Dust	Bad road[m]
Non-climatic	Poor accommodation	Lack of money
	Education (cost)	Lack of money[m]
	Bushfire	Hunting[m]; bad farming practices
	Crop pests	Bad weather; climate change; God; nature; poor storage, lack of money
	Fertilizer (cost)	No governmental support[m]
	Death of livestock	Bad weather; nature, livestock diseases; lack of veterinary services; poor feeding; God; insecure road[m]; accident[f]
	Felling of trees	Bad farming practices; need for fuelwood
	Insufficient food	Bad weather; low yield; post-harvest losses; death of livestock
	Ill-health	God; lack of money; malaria[f]; poor drinking water[f]; old age
	Money (lack)	Death of livestock; felling of trees; bush burning; household size; no governmental support; lack of credit facility, ill-health; bad weather; low yield; lack of alternative jobs;
	Livestock (diseases)	Free-range system; lack of veterinary services; poor feeding
	Support (lack)	No governmental support
	Fertiliser (lack)	Cost of fertiliser; no governmental support; lack of money
	Irrigation facility (lack)[m]	No governmental support; lack of money
	Low yield	Bad weather; God; poor soil fertility; seed failure
	Electricity (lack)	No governmental support
	Post-harvest losses	Felling of trees; poor soil fertility; poor storage facility
	Inadequate drinking water	Bush burning; dysfunctional boreholes; household size; bad weather; no governmental support
	Poor soil fertility	Bush burning; over farming; high cost of fertiliser; felling of trees; lack of money
	Livestock (lack)	Lack of money; lazy people becoming thieves[f]; free-range system
	Agricultural tools (lack)	Lack of money; No governmental support
	Seed failure	No governmental support

[m] Cited by only male heads
[f] Cited by female heads.
(Source*: Computed from household questionnaire interviews, 2016*)

.

Felling of trees, which according to the farmers, was caused by bad farming practices (such as bush burning and clearing land for farming) and need for fuelwood, was identified as the cause of low rainfall, heavy rainfall, late onset of rains, short duration of rains, strong wind, lack of money, post-harvest losses and poor soil fertility. Fuelwood (used by 90.4% of farmers) is an indispensable source of energy for food preparation since there was no liquefied petroleum gas (LPG) station within the Lawra District. The nearest LPG stations are located in the Nandom and Jirapa Districts. Fuelwood is free, and the high price of gas as well as the distance to the nearest gas station make it a disincentive to farming households to cook with LPG. The assertion that felling of trees causes climate change indicates that the farmers understand the scientific bases of climate change. It also means that the farmers know they are also contributors to climate change. Felling of trees drives climate change through the release of CO_2 stored in living plants and soil into the atmosphere, eliminating natural sinks of CO_2, and decreasing evapotranspiration. Cutting down trees for fuelwood or make way for farming causes erosion and increases soil infertility. Also, loss of soil moisture due to increase rate of evapotranspiration will affect soil microorganisms which are essential in the cycling of nutrients. Trees act as windbreakers, and therefore, loss of trees contribute to the destruction of crops and houses. With the loss of soil moisture and soil fertility, crop production will fall, and this will have a rippling effect on household income.

Farmers noted that bad weather or a natural process was responsible for poor rainfall (low, heavy, short and late), high temperature, crop pests, the death of livestock, insufficient food, lack of money and low yield. The consequence of low rainfall is low soil moisture content, and this subsequently will affect the number of crops to be harvested (low yield) and stored for household consumption. Insufficient food will cause farming households to change diet or reduce daily food consumption, and this will ultimately affect the nutritional requirement of the households. Also, low yield will mean little or no food surplus to be sold at the market to increase households' income, and this will, also, affect the nutritional requirement of non-farming households. Low income will affect farmers' ability to purchase required agricultural inputs for the next farming season. When crop production falls due to bad weather, farmers either have to sell their livestock or seek off-farm income generating ventures. However, bad weather also impedes livestock production. Low rainfall causes poor pasture production around the farm compound or village. The farming households have to move their livestock to areas with enough pasture, and this implies that there would be fewer hands to work on the farms.

Bush burning, which was considered to be caused by hunting and bad farming practices, was implicated by the farmers as the cause of low rainfall, late onset of rains, short duration of rains, poor soil fertility, and inadequate drinking water. Hunters usually set fire to cause animals to leave the burrow. Farmers also set fire to burn plant residues during land preparation for farming. Burning results causes felling of trees, which in turn, drives climate change. Bush burning causes soil erosion, destroys soil microorganisms and reduces the amount of soil nutrients. This view about bush burning and its effect on soil fertility was supported by an official of the Ministry of Food and Agriculture at the Lawra District as he said:

> *The natural law is that plants must die naturally for the important nutrients in plants to return to the soil and therefore burning kills the microorganisms that are to decompose the dead plants in the soil this prevent the nutrients from entering the soil. We have asked the farmers to stop burning, but they still do it. (MOFA official, Lawra)*

Lack of money was seen by the farmers to be the cause of the high cost of education, poor accommodation, lack of fertiliser, lack of agricultural tools, lack of irrigation facility and ill-health. Meanwhile, farmers indicated lack of money to be caused by factors such as the death of livestock, felling of trees, lack of government supports, lack of credit facility, ill-health, lack of alternative jobs and bad weather. Resources are increasingly becoming scarce, and therefore, there are economic prices attached to resources that, hitherto, were in abundance and free. Without money, farmers would not be able to purchase farming inputs (fertiliser and tools) to boost crop production to sell to increase household income. Poor farmers are most likely to have difficulties buying drugs or even renewing their health insurance. According to an official of MoFA, Lawra District, the financial institutions are reluctant to provide credit facilities to individual farmers, because of the unpredictable nature of rains these days. However, the facility is available to farmers in groups such as the groundnut farmers groups, so that the cost of the loan could be shared among the farmers in the group. Individual farmers have difficulties paying up the loan.

The farmers identified lack of government support as the lack of money, high cost of fertiliser, lack of fertiliser, lack of electricity, inadequate drinking water and lack of agricultural tools. Analysis of the household survey revealed that only 8.3% (n = 20) of farmers received support from the government during the bad times. Governmental institutions are considered as the formulators and implementers of policies and programmes that would help farmers to overcome challenges they encounter in their locality. For instance, supports to farmers through subsidised fertilisers would go a long way to help increase crop productions.

The free-range system of animal rearing and lazy people were implicated to be responsible for the theft of livestock by 7.1% (n = 17) of farmers. Under free range, animals are allowed to roam freely outdoor rather than confined in pens. According to the farmers, this system contributed to theft of livestock and spread of livestock diseases. In the case of the link between lazy people and theft of livestock, the following statement summed up the issue:

> *Nowadays, many young people do not want to work. They are lazy people, and all they know is to steal our guinea fowls and sheep. Everybody in this village has this problem. I cannot curse them because now I am a Christian. I always leave it up to God. One day when their cups are full, they would learn sense. (Married woman, 41 years, Dowine village, FGD)*

The farmers implicated free-range rearing of livestock to be the cause of death of livestock. One other observation was that livestock, particularly fowls and sheep, were occasionally knocked down by vehicles. It was observed that some livestock was always found resting on the untarred road and remained there even when cars and motorcycles were approaching. Due to the dusty nature of the roads, drivers approaching may not see the animals lying on the way.

4.5 Who is the most affected by the perceived stressors?

Table 4.4 provides the responses of sampled farmers about the most affected people to the stressors they perceived. From the table, a greater proportion of the respondents identified farmers to be the most affected by the stressors and followed by old people. Women, in general, were found to be the third most affected group of people in the study area, followed by widows, children and people with disability. This result confirmed climate change literature that indicated that the elderly, women, children and people with disability are vulnerable to climate change.

Lazy people were mentioned by the households to be one of the most affected people in the study area, concerning the perceived stressors. Lazy people were implicated by one of the households as people who steal livestock and therefore, contributed to the outcome of one of the perceived stressors.

Table 4.5: Households' response to who is the most affected by the perceived stressors

Most affected groups	**% of household heads**	
	Female (n = 71)	**Male (n = 169)**
Livestock keepers	-	1.2
Children	18.3	4.7
Disabled people	9.8	2.4
Everybody	1.4	1.2
Farmers	29.6	53.8
Lazy people	2.8	-
Men	2.8	-
Myself	4.2	-
Old people	8.4	15.4
Landless farmers	-	2.4
Widows	14.1	7.1
Women	8.5	11.8

(Source*: Computed from household questionnaire interviews, 2016*)

4.6 Perception of future climatic and non-climatic stressors

Farmers are not only vulnerable to past and current changes in their perceived stressors but also future changes in these stressors. The knowledge of the future occurrence of these stressors would help farmers as well as stakeholders in designing and implement better responsive strategies to counteract the associated impacts of stressors in the future. Farmers in the study area anticipated the likely occurrence of some of the stressors. In the household survey instrument, farmers were asked to state which of the perceived stressors they perceive would occur in the next ten years. Altogether, 20 of the 29 perceived stressors would, according to the farmers, reoccur in the next ten years (Table 4.5). The farmers mentioned that lack of agricultural tools; cost of education; seed failure, heavy rainfall, poor accommodation; dust; irrigation facility (recall that female farmers did not perceive this stressor); felling of trees and lack of support would have been tackled and therefore, would not occur in the future. Majority of farmers (40.0%, $n = 96$) cite low rainfall, followed by lack of money (12.9%, $n = 31$), short duration of rains (11.3%, $n = 27$), late onset of rains (8.8%, $n = 21$), and low yield (5.4%, $n = 13$).

Regarding gender, both male and female farmers predicted 16 stressors. Male farmers did not predict the future occurrence of bushfire, lack of electricity, post-harvest losses and strong wind. Similarly, female farmers could not predict lack of fertiliser, high temperatures and theft of livestock. The reason that could be attributed to the inability of female farmers to predict the future occurrence those stressors is that women are traditionally not in the rearing of livestock as well as the distribution of fertiliser. The fertiliser supplying offices are mostly located at Lawra (the District capital) which is quite a distance from the communities. However, a higher proportion of both groups of farmers predicted the future occurrence of low rainfall, followed by lack of money and short duration of rains.

Table 4.6: Farmers' prediction of future stressors

		% of household heads		
	Perceived stressors	**Female (n = 71)**	**Male (n = 169)**	**Overall (n = 240)**
Climatic	High temperatures	N/A	3.0	2.1
	Late onset of rains	5.6	10.1	8.8
	Low rainfall	33.8	42.6	40.0
	Short duration of rains	11.3	11.2	11.3
	Strong wind	2.8	N/A	0.8
Non-climatic	Bushfire	1.4	N/A	0.4
	Cannot predict	N/A	1.2	0.8
	Fertilizer (cost)	2.8	1.2	1.7
	Fertilizer (lack)	N/A	1.2	0.8
	Insufficient food	2.8	3.0	2.9
	Ill-health	2.8	1.8	2.1
	Livestock (disease)	2.8	1.2	1.7
	Lack of money	16.9	11.2	12.9
	Livestock (death)	4.2	3.6	3.8
	Livestock (theft)	N/A	1.2	0.8
	Low yield	7.0	4.7	5.4
	Lack of electricity	1.4	N/A	0.4
	Inadequate drinking water	1.4	0.6	0.8
	Post-harvest losses	1.4	N/A	0.4
	Poor soil fertility	1.4	2.4	2.1

(Source*: Computed from household questionnaire interviews, 2016*)

4.7 Discussion

Perception of stressors is critical; it is a first step in the adaptation process (Maddison, 2007) Farmers in the study area identified and ranked a wide-range of climatic and non-climatic stressors that they deemed to affect their farming and household activities adversely, and also, shape their vulnerability. The findings are parallel to that of studies conducted in Ghana (Ahmed *et al*., 2016; Antwi-Agyei *et al*., 2017; Nyantakyi-Frimpong & Bezner-Kerr, 2015; Westerhoff & Smit, 2009), in Africa (Mubaya *et al*., 2012; Reid & Vogel, 2006; Tschakert, 2007) and beyond (Belliveau *et al*., 2006; Bhatta *et al*., 2016; McCubbin *et al*., 2015; McDowell & Hess, 2012; O'Brien *et al*., 2004; Odgaard *et al*. 2011) that farmers work in a multi-dimensional risk environment shaped by both climate change and non-climatic conditions. These stressors interact with one another in a complex and sophisticated manner to heighten farmers' and farming households' vulnerability (O'Brien *et al*., 2009; Westerhoff & Smit, 2009).

Agriculture is inherently dependent on rainfall and temperature. The farmers identified a wide range of rainfall-related concerns as low rainfall, heavy rainfall, short duration of rains and late onset of rains. Low rainfall was cited by more than half (50%) of farming households. This means that farmers in northern Ghana are much concerned about the nature of rainfall as it significantly affects their livelihood options. Previous studies have confirmed the observation of these climatic stressors by the farmers (Antwi-Agyei *et al*., 2017; Yaro, 2013). According to Yaro (2013), smallholder farmers from the coastal savannah zone of Ghana reported declining rainfall, variable rainfall, highly unreliable rainfall, shorter rainy season, occasional excessive rains, rising temperature, extreme heat, unpredictable hot season, strong winds, and extreme events such as drought and floods as affecting their farming activities. Antwi-Agyei *et al*. (2017) noted that farmers in northern Ghana are affected by lack of rainfall, high temperature, drought and floods which alter their livelihood activities.

The main non-climatic stressors identified by the farmers included lack of money, poor soil fertility, low yield, lack of agricultural tools, cost of fertiliser and ill-health. The perception of the farmers concerning non-climatic stressors concurred with results of other works in Ghana and other African countries. For instance, Nyantakyi-Frimpong & Bezner-Kerr (2015) reported that farmers in northern Ghana perceived non-climatic stressors such as high food prices, inadequate labour, lack of credit facilities, poor human health, seed failure, poor soil fertility and cost of input as endangering their farming activities. Tschakert (2007) noted that farmers in Senegal identified poor housing conditions, lack of water, cost of education, livestock theft, lack of credit, lack of seeds, poor human health, lack of money and death of livestock as some of the non-climatic stressors negatively influencing their activities.

Money has a direct bearing on farmer's ability to purchase needed agricultural inputs and also meet daily household's needs. However, the poverty level among smallholder farmers in northern Ghana and the study communities is high, with poverty rate between 44.4% in Northern Region and 70.7% in Upper West Region (GSS, 2015). Without money, farmers will not be able to buy improved seeds, fertiliser, hire farm labourers, access tractor service and other agricultural inputs to boost crop yield. Low crop yield will also affect the farmer's ability to generate income from crop production. This could lead to a situation called a vicious cycle, where one trouble leads to another trouble to aggravate the first.

The results reflect gender role on the perception of stressors. Within the same agro-ecological zone exposed to the same climatic and non-climatic stressors, women and men have conflicting views about the severity of the stressors they are exposed. While male-heads were more concerned about lack of money, women were more concerned about insufficient food, as a most damaging stressor. The findings resonate with many studies on vulnerability which found women having divergent views from men with regards to the severity of stressors (Ajibade *et al.*, 2013; Antwi-Agyei *et al.*, 2017; Tschakert, 2007). Traditionally, in Ghana and many other countries in sub-Saharan Africa, women are responsible for cooking food and men are responsible for making money available to purchase household needs (Ajibade *et al*., 2013; Jost *et al*., 2015). Women are also interested in securing food availability in times of climate change to prevent hunger (Jost *et al*., 2015). With adaptation to climate change being contingent on the perception, the differences in perception of stressors among male and female farmers have implications on adaptation policies (Yaro, 2013).

The results empirically demonstrate that farmers had a deeper understanding of the causes of the various stressors that affect the farming and household activities. Most of the identified causes of the perceived stressors could be linked to anthropogenic activities for which the farmers themselves were culpable. For instance, the causes of all rainfall-related concerns were, identified by the farmers, as bush burning and felling of trees. The farmers set fire on the land either as part of the land preparation for farming or hunting of bushmeat. Farmers clearing land of trees to make way for farming and also, harvesting fuelwood (mostly by women) for cooking contribute to deforestation which eventually leads to increasing rate of carbon dioxide generation and decreasing rate of carbon dioxide assimilation. The causes of climatic stressors observed by the farmers are parallel to that reported by farmers in Senegal (Tschakert, 2007) and Zambia and Zimbabwe (Mubaya *et al*., 2012).

Another observation revealed by the results was the farmers attributing the causes of the climatic stressors to non-climatic stressors. The farmers, unknowingly and independently, revealed the possible interaction between stressors. This supports the concept that non-climatic stressors interact with climatic stressors, in multiple ways, to exacerbate livelihood security and existing vulnerability of farming households (Mubaya *et al*., 2012). These observations have implications for climate change policies and development. Lessening the seriousness or severity of one stressor will assuage other stressors.

The findings suggest that farmers were deep-rooted in the belief in supernatural powers as responsible for changes in climatic condition. This is reasonably so because all farmers prophesied to be affiliated to either Christian, Muslim or African traditional believer. This conception by the farmers is in line with the findings from other studies (Debela *et al*., 2015; Yaro, 2013). The belief in supernatural powers as a cause of climate change is not likely to urge farmers to utilise available adaptation options since supernatural activities are beyond their control.

4.8 Conclusion

This chapter has shown that, farmers in the study area identified both climatic and non-climatic stressors as impeding their farming activities. This implies that farmers in the study area work in an environment shaped by multiple climatic and non-climatic stressors. The results, further, revealed the existence of gender differences about the severity of stressors, and this will affect adaptation policy and planning. The next chapter presents the results of the analyses of rainfall, temperature and soils sample to verify the perception of farmers.

CHAPTER FIVE

COMPARING ACTUAL AND PERCEIVED CLIMATIC AND NON-CLIMATIC STRESSORS

5.1 Introduction

This chapter attempts to explore how actual scientific information can explain farmers' perception of climatic and non-climatic stressors. In this chapter, the state of the local climate, concerning trends in rainfall and temperature is presented. The choice of rainfall and temperature data is two-fold. First, the two are necessary elements shaping farming season and activities in the study area. Second, these two are the only climatic variables available at the nearest weather station in the study area. The choice of soil quality is because it is the only non-climatic stressor that the study could rely on at the time of data collection. This chapter is divided into six sections. The first section introduces the chapter, and this is followed by the second section dedicated to presenting the results of trends in rainfall. The third and fourth sections present the results of the trends in temperature and soil quality test, respectively. The fifth section discusses the results, followed by the last section which concludes the chapter.

5.2 Rainfall variability

Meteorological data from Babile station show that there have been some changes in climate in the study areas (Figure 5.1). There was a total of rainfall of 30,608.7 mm recorded over 2,240 raining days within the 31-year period (the year 1984 to 2014). The average rainfall within this period was 987.4 mm per year or 2.8 mm per raining day. The total annual rainfall varied from 565.5 mm to 1,274.1 mm. Though there is a decreasing trend in rainfall, there is no statistically significant trend of rainfall over the years. The correlation between rainfall and time is also insignificant. This confirmed the perception of 61.3% (n = 147) of sampled farmers who observed a decrease in the amount of rainfall (low rainfall) over the decades. Rainfall was erratic in sporadic surges and halts with some years recording rainfall below 800 mm (1984, 1990, 2004, 2007 and 2008) and some other years exceeding 1,200 mm (1995, 1999 and 2000), and this agrees with majority of farmers (65.8%, n = 158) who observed changes in the amount of rainfall (low and heavy rains) over the last decades. Within the last decade, only five years (2005, 2006, 2009, 2010 and 2011) recorded total annual rainfall above the annual average.

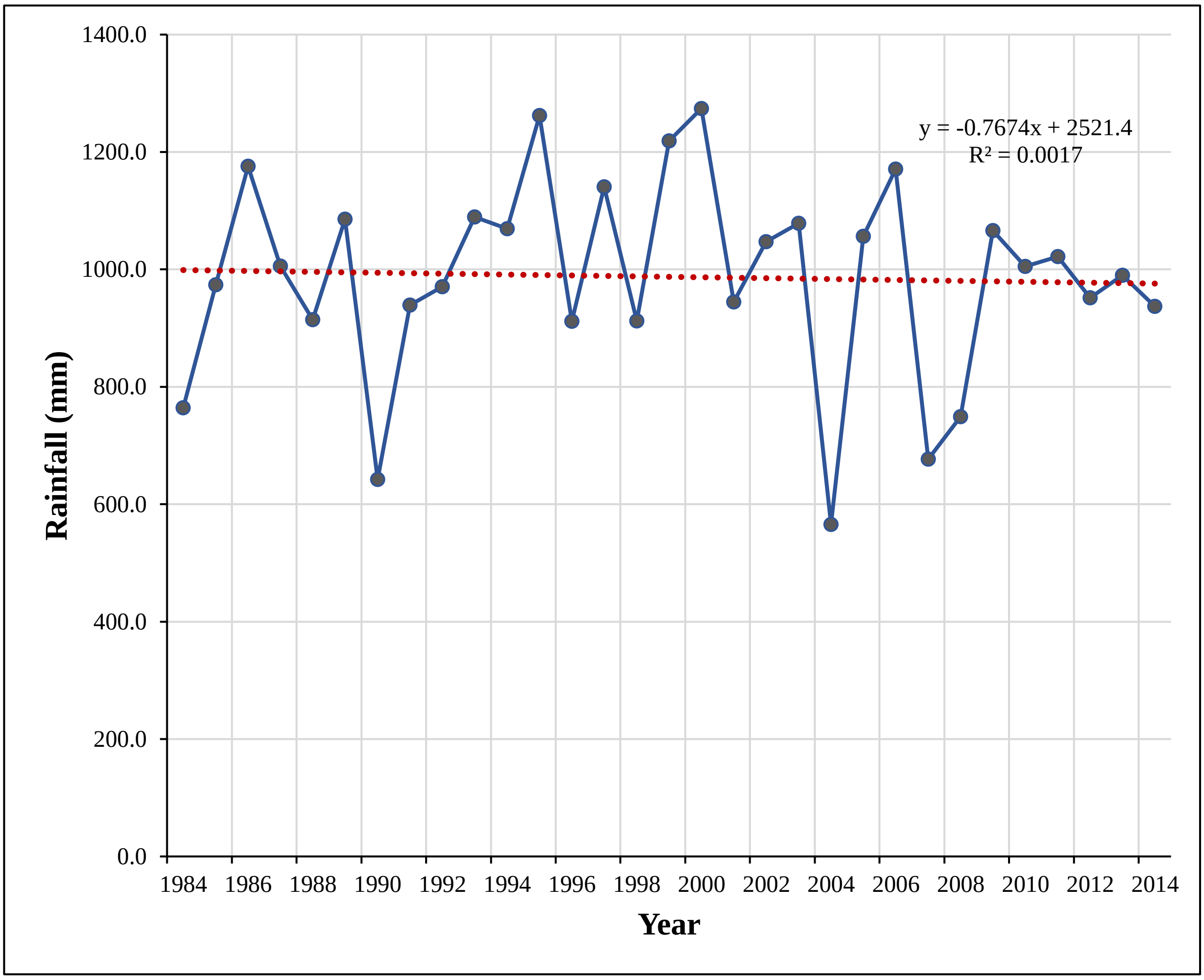

Figure 5.1: Annual rainfall trend for Babile station (1984 - 2014)

Source: Data obtained from Ghana Meteorological Agency, Accra.

Seasonal trend analysis was done to see the variations among the seasons. The seasonal rainfall pattern for the district is unimodal and ranged from April to October, with the highest rainfall in August (Figure 5.2). This showed that there is only one wet season in the district and it starts around May and ending around September. Thus, there are seven months of dry season. Lowest rainfall occurred in December and January which is within the harmattan season. This means that the farmers have more months in the year that they would not be able to engage in farming activities and therefore, they either have to migrate southwards, practice dry season farming near the River Black Volta or engage in off-farm activities in their communities.

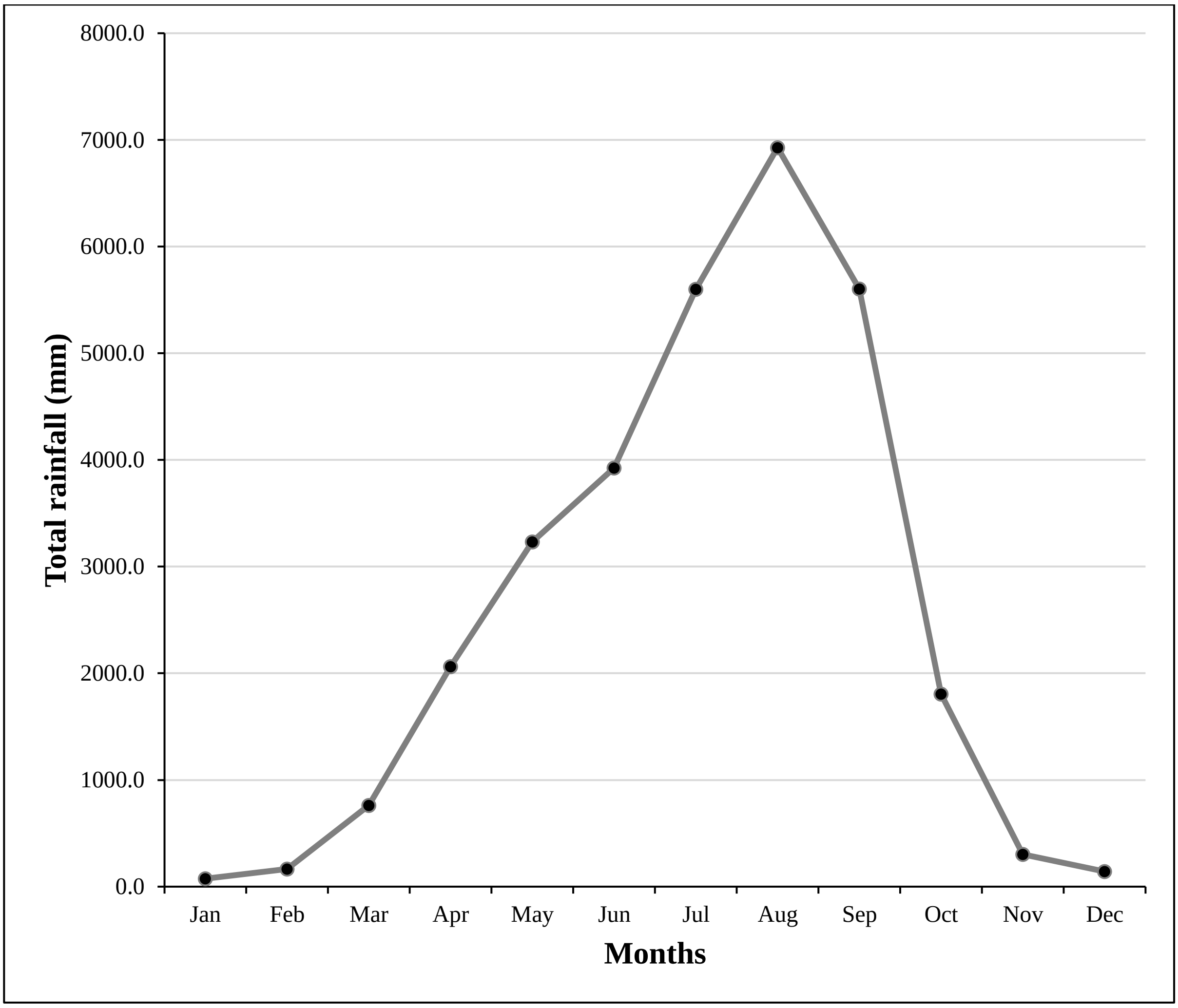

Figure 5.2: Seasonal variations in rainfall for Babile station (1984-2014)

Source: Data obtained from Ghana Meteorological Agency, Accra.

The results of the rainfall data for Babile indicated that the number of raining days (wet days) had decreased sharply over the last three decades, with a negative gradient or coefficient of 0.6645 and the R^2 of 0.2284 (Figure 5.3). Between 1986 and 2014, the number of raining days decreased by 26 days. The highest number of raining days was recorded in 1989 (96 days) and the least number of raining days was recorded in 1984 (38 days). The year 1984 and 1985 were within the periods of 1980 and 1985 when Ghana experienced the worst drought conditions in history (Jarawura, 2014). This supports the claim by 16.7% (*n* = 40) of the farmers that they have experienced short duration of rains over the past years.

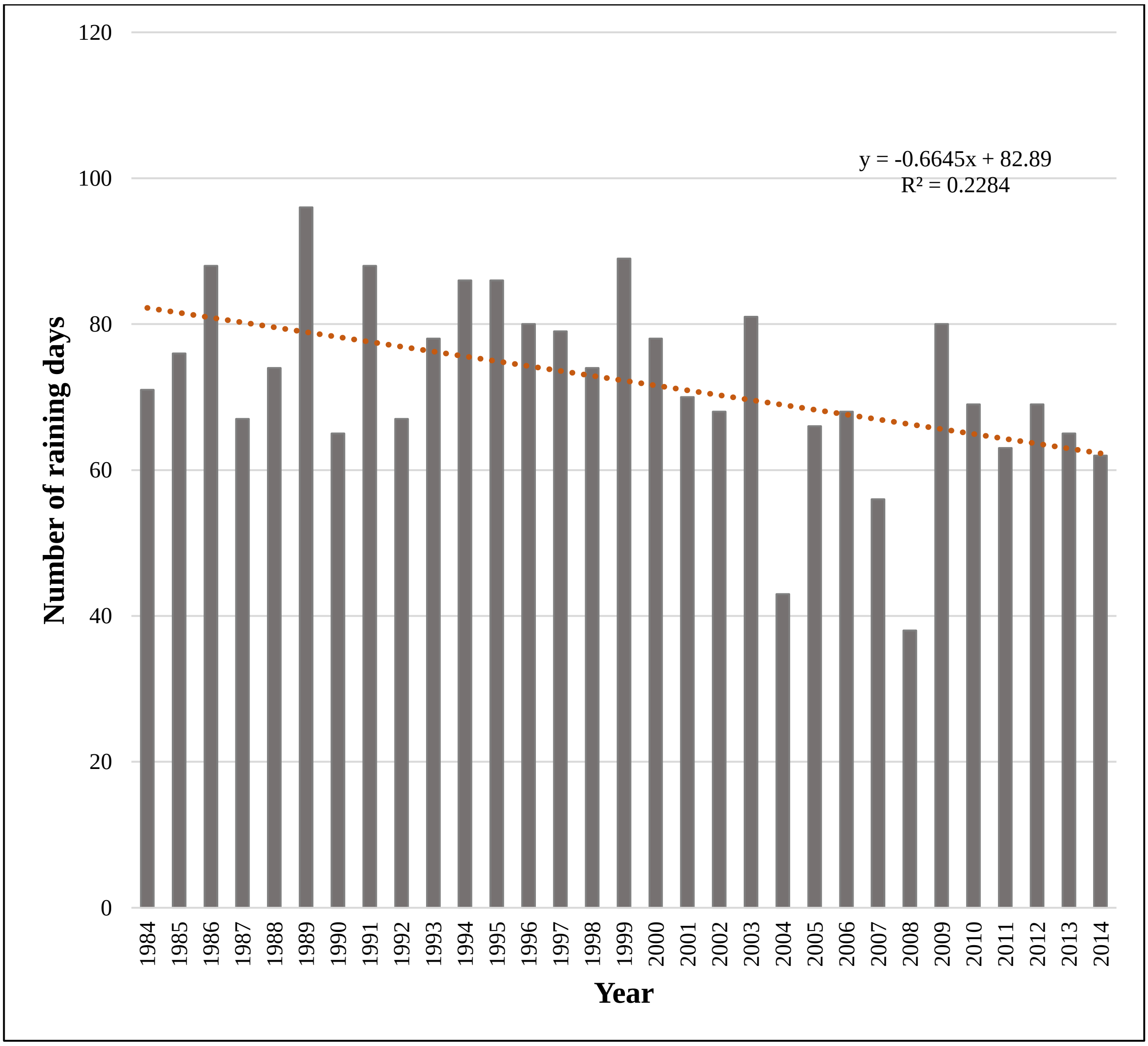

Figure 5.3: Trend of the number of rain days for Babile station (1984-2014).

Source: Data obtained from Ghana Meteorological Agency, Accra.

Table 5.1 shows the onset of rainfall, the cessation of rainfall and the length of rainy season for the Babile station. Farmers need information on the onset of raining season, cessation of raining season, length of season and availability of crop varieties (duration varieties) to better plan for their farming activities. The results revealed that onset of raining season ranged from 122^{nd} day of the year 2000, 2006, 2007, 2012 and 2013 (1^{st} May) to 190^{th} day of the year 1989 (8^{th} July), with the mean onset date occurring on the 139^{th} day (18^{th} May). The cessation of growing season ranged from the 245^{th} day of the year 2004, 2007 and 2008 (1^{st} September) to 326^{th} day of the year 1995 (21^{st} November), with the mean cessation data occurring on the 293^{rd} day of the year (19^{th} October). The length of the rainy season ranged from 100 days (less than four months) in 1984 to 195 days (6 and half months) in 1995. The mean length of the rainy season was computed to be 153 days (about five months). Length of rainy season has implications on the type of crops farmers can cultivate. Early onset of the rains means that crops requiring an extended length of growing season could be cultivated, and late onset of the rains means crops with short length growing season could be cultivated. The results agreed with 20.0% (n = 48) of farmers who perceived late onset of rains (late onset of rains) but did not agree with 16.7% (n = 40) of farmers who perceived short duration of rains (decrease length of rainy season).

Table 5.1: Onset and cessation dates and length of season for Babile station (1984-2014)

	Onset of rainfall		Cessation of rainfall		Length of rainy season (days)
Year	**Days**	**Date**	**Days**	**Date**	
1984	147	26-May	247	03-Sep	100
1985	134	13-May	294	20-Oct	160
1986	124	03-May	302	28-Oct	178
1987	185	03-Jul	300	26-Oct	115
1988	175	23-Jun	292	18-Oct	117
1989	190	08-Jul	302	28-Oct	112
1990	128	07-May	256	12-Sep	128
1991	145	24-May	298	24-Oct	153
1992	153	01-Jun	295	21-Oct	142
1993	124	03-May	293	19-Oct	169
1994	131	10-May	317	12-Nov	186
1995	131	10-May	326	21-Nov	195
1996	140	19-May	301	27-Oct	161
1997	156	04-Jun	309	04-Nov	153
1998	138	17-May	293	19-Oct	155
1999	135	14-May	306	01-Nov	171
2000	122	01-May	307	02-Nov	185
2001	139	18-May	302	28-Oct	163
2002	158	06-Jun	299	25-Oct	141
2003	147	26-May	308	03-Nov	161
2004	135	14-May	245	01-Sep	110
2005	125	04-May	300	26-Oct	175
2006	122	01-May	305	31-Oct	183
2007	122	01-May	245	01-Sep	123
2008	130	09-May	245	01-Sep	115
2009	128	07-May	313	08-Nov	185
2010	141	20-May	296	22-Oct	155
2011	147	26-May	295	21-Oct	148
2012	122	01-May	290	16-Oct	168
2013	122	01-May	298	24-Oct	176
2014	126	05-May	299	25-Oct	173

Source: Data obtained from Ghana Meteorological Agency, Accra.

5.3 Temperature variability

The results of the analyses of temperature data indicated that the mean annual maximum temperatures ranged from 33.3°C to 35.3°C, with the mean value of 34.7°C (Figure 5.4). The mean annual minimum temperatures ranged from 20.9°C to 23.0°C, with the mean value of 22.3°C. The results indicated a decreasing trend for mean annual minimum temperatures with a coefficient of negative 0.0038 and R^2 of 0.0064, and an increasing trend for mean annual maximum temperature with a positive coefficient of 0.0009 and R^2 of 0.0441. This confirms the perception of 11.7% (n = 28) of farmers who reported high temperatures over the last decades.

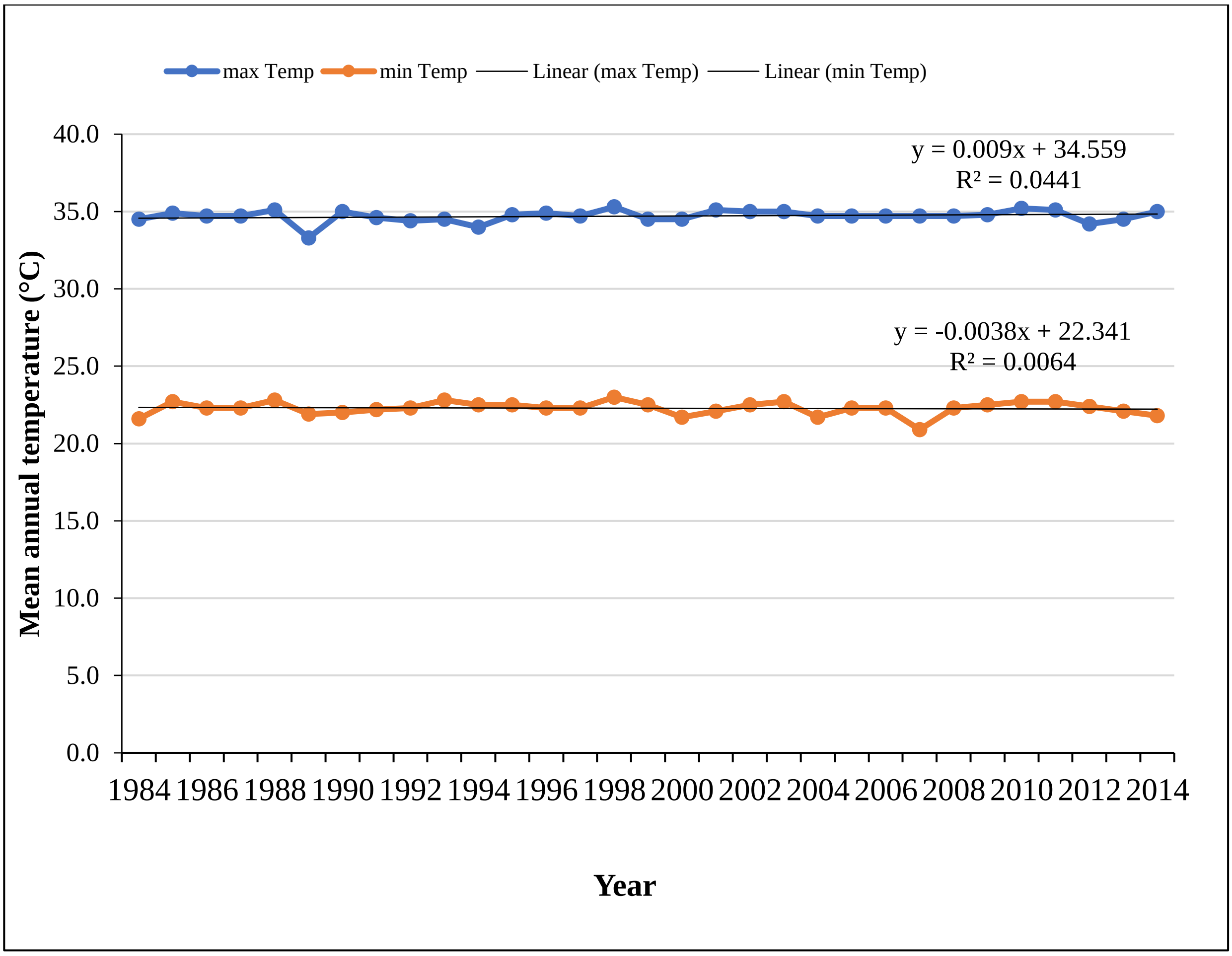

Figure 5.4: Mean annual minimum and maximum temperature trends (1984-2014).

Source: Data obtained from Ghana Meteorological Agency, Accra.

5.4 Soil quality

To ascertain the veracity of farmers' claim that soil quality was poor or low, soil samples from four selected farms in each study community were analysed. Table 5.2 shows the results of farm soil samples. The levels of the soil organic carbon and available phosphorus are low. Soil organic carbon, another measure of soil organic matter, gives an indication of organic constituents of soil in various stages of decomposition of tissues from dead plants and animals. Low levels indicate low soil fertility and could be due to loss of soil material by erosion, over-cropping or bad farming practices such as burning.

The pH measures soil acidity or alkalinity, and it influences agricultural production. It affects the availability of essential soil metals and activities of soil organisms. The pH value of the study area ranged from 5.1 to 6.7, with a mean value of 5.9. This means that the soil in the study area ranged from mildly acidic to normal and this can support most crops cultivated in the study area. A pH value of less than five will result in imbalances in nutrient levels and therefore, will require the addition of lime to reduce the level of acidity. It affects the availability of essential soil metals and activities of soil organisms (Amara, Patil, Kamara, & Saidu, 2016).

The results of the soil tests did not agree with 24.2% (n = 58) of farmers who perceived poor soils fertility. This could be attributed to the fact that soil samples were collected from parts of farmers where fertilisers were not applied and only leguminous crops such as groundnut and cowpea) were cultivated. Leguminous crops are known to have a mutualistic relationship with rhizobacteria that colonise the roots of these crops and help fix atmospheric nitrogen into nitrate. In addition, farmers in the study communities practice mulching and this practice increase soil organic matter content.

Table 5.2: Mean value of soil parameters of soil samples from study communities

	Sample communities					
Soil quality parameter	**Boo**	**Buree**	**Dowine**	**Kalsagri**	**Tolibri**	**Zakpee**
pH	5.60	5.70	5.90	6.00	5.80	6.10
% Organic carbon	1.80	1.60	0.90	1.40	1.50	1.60
Ca (cmol+/kg)	1.40	2.00	2.60	2.60	2.20	3.30
Mg (cmol+/kg)	0.50	1.30	1.60	1.80	1.40	3.30
K (cmol+/kg)	0.20	0.20	0.20	0.20	0.20	0.20
Na (cmol+/kg)	0.30	0.30	0.20	0.30	0.30	0.40
CEC (cmol+/kg)	4.00	5.20	6.60	6.60	5.50	9.00
Avail. Phosphorus (ppm)	10.10	11.50	15.50	10.30	11.60	8.50

Samples collected from 4 farms in each community. Centimoles of positive charge per kilogram of soil (cmol+/kg), numerically equal to milliequivalents per 100 g of soil (me/100g). Parts per million (ppm)

5.5 Discussion

Rainfall, temperature and soil are important elements necessary for agricultural activities. Rainfall and temperature, in this study, are used to represent climatic stressors whiles soil quality represent non-climatic stressor. Rising temperature and decreasing rainfall will have serious repercussions for agricultural production (Ramirez-Villegas & Thornton, 2015) Temperature has effects on agricultural production as well as the natural ecosystems in which farmers work. Grain crops, which are the primary crops cultivated by farmers in Ghana, and SSA as a whole, have optimum temperatures beyond which yields would be affected significantly (Asante & Amuakwa-Mensah, 2014). Soil is the source of nutrients for plants. It is home to many organisms that improve the quality of soil and make crop production possible.

In this study, the onset of raining season was defined as the accumulation of 25 mm of rainfall within a 5-day period, followed by a period of no more than seven or more consecutive dry days in the following 30 days starting from the first day of April (Amekudzi *et al*., 2015; Laux *et al*., 2008). This indicates the day of the year after which planting is possible. Cessation of rains (or end of the raining season) was defined as ‘any day from 1 September after which there are 21 or more consecutive days of rainfall less than 50% of the crop-water requirement’ (Omotosho *et al*., 2000, p. 873). The difference between cessation date and onset date defined the length of rainy season. Farmers need information on the onset of raining season, cessation of raining season, length of season and availability of crop varieties (duration varieties) to better plan for their farming activities (Dodd & Jolliffe, 2001).

The results of the state of the local climate indicate that climate change is, indeed, happening and that there are decreasing and increasing trends in rainfall and temperature, respectively. These were consistent with the perception of farmers about low rainfall and high temperature. Thus, farmers were capable of perceiving changes in climate and therefore, they can successfully implement strategies to counteract climate change if given the needed support. With agriculture being inherently dependent on rainfall and temperature, the concerns of the farmers about these climatic stressors is understandable. The results of the present study concur with those obtained by Gbetibouo (2009) who found that the perception of farmers in the Limpopo Basin, South Africa agreed to climate records.

Scientific data could not support Farmers' perception of some stressors. For instance, the farmers perceived that the quality of the soil was low. However, this was not consistent with the soil test conducted, and the reason could be that the soil samples may not have been collected from the farms of those who perceived low soil quality. Also, the soil samples were collected from the farm where the farmers do not apply fertiliser. These farmers mostly used to cultivate leguminous plants, such as groundnut, beans and cowpea. These plants are known to have a mutualistic relationship with nitrogen-fixing bacteria that tend to increase soil fertility.

5.6 Conclusion

This chapter has detailed the results from the analyses of rainfall and temperature data as well as soil tests. The results revealed increasing trends in temperature and a decreasing trend in rainfall. This revelation has serious repercussion on the economic activities of farmers since farming activities in Ghana, and sub-Saharan Africa is mostly rainfed. The results of decreasing rainfall and increasing temperature concur with farmers who perceived low rainfall and high temperature, respectively. This implies that farmers' own experiences and perceptions are critical in aiding them to adapt, even in the absence of weather information.

However, farmers' perception about the state of soil quality and scientific data are not consistent. This implies that perception of farmers could not always be right. The next chapter presents the results and discussion of farming households' vulnerability.

CHAPTER SIX

EXPOSURE, SENSITIVITY, ADAPTIVE CAPACITY AND VULNERABILITY TO CLIMATIC AND NON-CLIMATIC STRESSORS

6.1 Introduction

This chapter relates to the third objective of the study which is to *investigate exposure, sensitivity, adaptive capacity and vulnerability of farming households to climatic and non-climatic stressors*. The chapter is constructed into four sections. Section 6.1 briefly introduces the chapter. Section 6.2 presents the results of exposure, sensitivity, adaptive capacity and vulnerability indices of all selected households in the study area. Section 6.3 attempts to compare the study communities concerning the components of vulnerability. Section 6.4 provides the nature and characteristics of the most vulnerable and the least vulnerable households in each study community. The penultimate section (6.5) discusses the results of the preceding sections. Section 6.6 concludes the chapter.

6.2 Vulnerability status of households

Table 6.1 shows that adaptive capacity index, with a mean value of 0.233, contributed the most to vulnerability (82.2%), while exposure index, with a mean value of 0.030, contributed the least to the outcome of vulnerability (6.5%). Sensitivity index, with a mean value of 0.033, contributed 11.3% to the outcome of the vulnerability of households. The contribution of each index may be attributed to a number of proxy indicators used to define the index. The more proxies used in the analysis, the greater the contribution. In the analysis, 28 proxy indicators were used for adaptive capacity index while 2, and 5 proxies were used for sensitivity and exposure indices, respectively.

Table 6.1: Contribution of components of vulnerability

Components	Min.	Max.	Mean (± s.d.)	Number of proxy variables	% contribution
Exposure index	0.010	0.058	0.030 ± 0.008	2	6.5
Sensitivity index	0.004	0.094	0.033 ± 0.015	5	11.3
Adaptive capacity index	0.096	0.415	0.233 ± 0.056	28	82.2

(*Source*: Computed from household questionnaire interviews, 2016)

The result of the cluster analysis grouped households into three vulnerability categories: *less*, *moderately* and *highly* (Table 6.2). Category 1 comprises 22.5% (n = 54) considered as less vulnerable. The households in this category are highly exposed, less sensitive and have the highest adaptive capacity to withstand the effects of the stressors in the study area. Category 2 consists of 45.8% (n = 110) of households that are less exposed to stressors and considered as moderately vulnerable. Category 3 comprises 31.7% (n = 76) of households that are highly sensitive, have the lowest adaptive capacity, highest vulnerability index and therefore, considered as highly vulnerable.

Table 6.2: Descriptive statistics of vulnerability categories

Vulnerability category	% of HH	Mean index (± s.d.)			
		EI	SI	ADI	OVI
Category I (Less)	22.5	0.032 ± 0.010	0.021 ± 0.010	0.308 ± 0.037	0.249 ± 0.013
Category 2 (Moderately)	45.8	0.029 ± 0.008	0.033 ± 0.012	0.237 ± 0.023	0.275 ± 0.007
Category 3 (Highly)	31.7	0.030 ± 0.008	0.041 ± 0.015	0.176 ± 0.029	0.299 ± 0.009

(*Source*: Computed from household questionnaire interviews, 2016)

6.3: Vulnerability status of communities

Table 6.3 presents the exposure and sensitivity indices of the study communities. The results revealed that exposure index differs significantly amongst the study communities ($F = 49.37, p < 0.01$). Elevation was hypothesised to correlate negatively with exposure index whiles number of stressors correlates positively with the same. Households in Buree, Kalsagri and Tolibri faced more stressors (≥ 4) than households in the other communities. Households in Dowine recorded a higher elevation (≥ 300 m) than households in other communities. Recording a higher elevation and lower number of stressors implies lower exposure of households in a community. Thus, households in Boo are classified as the least exposed households because they recorded a lower number of stressors and higher elevation.

The results revealed that sensitivity index also differs significantly amongst the study communities ($F = 11.318, p < 0.01$). All the proxy variables of sensitivity index were hypothesised to correlate positively with sensitivity and hence, vulnerability. Thus, a higher value of any of these variables will increase sensitivity and subsequently, increase vulnerability. All households in the study area are somewhat affected by climate change because the main economic activities, farming, are climate-sensitive. However, not all households depend on farming and raising of livestock. About a quarter (25%) of households engage in non-farm economic activities. Income from non-farming activities will cushion farmers when rainfall is erratic, or crop production becomes lower than expected. The results reveal that more than 90% of the income of households in Buree and Zakpee are from natural resource-based activities. This implies that farming households in these two communities are highly sensitive to climate change than households in the other communities. Majority of households (85%) are adversely affected by stressors in Tolibri compared to 37.5% of households in Dowine and Zakpee being affected. Majority of households in Zakpee (91.3%) had never fallen ill in the last 12 months, and therefore, in the case of illness, farmers from this community could be considered less sensitive. Households in Dowine were less sensitive to climate change and non-climatic stressors while households in Zakpee were highly sensitive to the same.

Table 6.3 Description of exposure and sensitivity indices of study communities

Indicators	Communities[1]					
	Boo	Buree	Dowine	Kalsagri	Tolibri	Zakpee
Exposure						
Elevation of HH (m)	297.6	283.2	301.3	273.4	270.5	263.5
Number of stressors faced by HH	3.1	4.0	3.7	4.3	4.2	3.0
Sub-index of exposure	**0.018**	**0.044**	**0.025**	**0.042**	**0.050**	**0.026**
Sensitivity						
Share of natural resource-based income (%)	75.9	90.7	77.0	73.4	86.8	94.2
HH is affected most by stressors (%)	45.0	62.5	37.5	65.0	85.0	37.5
HHM falling ill in last 12 months (%)	18.1	29.2	13.2	18.3	21.9	8.7
Length of illness (months)	1.3	1.9	1.2	1.8	1.7	0.3
HHM with disability (%)	15.0	17.5	12.5	5.0	2.5	5.0
Sub-index of sensitivity	**0.067**	**0.111**	**0.066**	**0.041**	**0.055**	**0.030**

[1] values are mean of all households in respective communities.
(*Source*: Computed from household questionnaire interviews, 2016)

Illnesses, as well as disability, impede farming activities by creating divided attention among household members. A household with an individual who is ill, convalescence or disabled (hearing, speech, sight or mobility) will have to divide time caring for the sick and tending the farm. In addition, farmers will have to divert part of the money meant for farming to taking care of the sick or disabled person. This action will reduce the household's investment in the farming activities. These variables (illnesses and disability) increase vulnerability. Every household in the study area has an individual either ill or disabled. Regarding illness, households in Zakpee are better off than households in the other study areas. Households in Tolibri have fewer members with disabilities. Altogether, households in Buree are highly sensitive whiles households in Zakpee are the least sensitive.

Except for age and dependency ratio, all proxy variables for adaptive capacity index positively correlate with adaptive capacity and negatively correlate with vulnerability index. Table 6.4 presents the adaptive capacity indices of the selected study communities. Households in Dowine recorded the highest adaptive capacity index while households in Zakpee recorded the lowest adaptive capacity index. This implies that households in Dowine are more likely to withstand the adverse effects of stressors than households in Zakpee. Dowine recorded the least vulnerability index, and therefore, households in this community are considered as the least vulnerable while households in Zakpee are the most vulnerable.

The vulnerability index of Zakpee was the highest, followed by Boo and then Buree. This implies that Zakpee was the most vulnerable community amongst the six selected communities in the study area. Dowine recorded the lowest vulnerability index among the six selected communities. Thus, Dowine was the least vulnerability community.

The results revealed that adaptive capacity differs significantly amongst the study communities($F = 6.14, p < 0.01$). The results, further, demonstrated that vulnerability differs significantly among the study community ($F = 9.679, p < 0.01$).

Table 6.4: Description of adaptive capacity and vulnerability indices for study communities

Proxy variables	Study communities[1]					
	Boo	Buree	Dowine	Kalsagri	Tolibri	Zakpee
Membership of social group (%)	45.0	57.5	37.5	57.5	45.0	42.5
Access to extension advice (%)	0.0	42.5	12.5	27.5	67.5	10.0
Access to weather information (%)	10.0	40.0	30.0	35.0	72.5	22.5
Access to credit facility (%)	0.0	5.0	12.5	22.5	5.0	2.5
HHH belongs to active politics (%)	25.0	35.0	32.5	17.5	32.5	2.5
Relatives in the village (number)	14.5	4.4	10.1	6.3	5.3	7.4
Friends in the village (Number)	4.4	2.2	4.2	2.8	3.8	3.8
Farm holding size (ha)	2.4	3.5	3.8	3.2	4.0	2.9
Ownership of farmland (%)	82.5	85.0	97.5	97.5	100.0	100.0
Fruit trees owned (Number)	1.0	1.3	1.6	1.4	0.9	0.8
HH size (number)	4.7	5.9	7.3	6.8	6.9	6.0
HH head: male (%)	52.5	70.0	70.0	80.0	70.0	80.0
Age of HHH (years)	51.7	51.7	51.5	54.6	54.3	48.5
HH dependency ratio	50.3	78.0	67.0	71.6	60.0	94.0
HH literacy ratio	44.5	25.9	46.4	46.9	43.5	23.4
HHM with NHIA (%)	84.0	93.2	84.2	98.7	97.7	97.2
HHH years of farming	24.7	30.0	28.4	28.6	30.3	28.6
Livestock ownership (TLU)	1.0	1.4	2.1	1.0	0.9	0.5
Remittances received (%)	62.5	25.0	50.0	27.5	17.5	15.0
HHM working on farm (%)	67.9	63.5	64.7	59.4	54.9	57.1
HHH engaged in off-farm activities (%)	20.0	12.5	25.0	35.0	17.5	2.5
Income diversity	4.6	4.1	5.1	5.2	4.4	4.0
Crop diversity index	3.9	4.6	4.7	4.5	4.5	4.2
Transportation diversity index	1.9	2.9	2.7	2.4	2.5	2.2
Communication diversity index	3.0	3.1	4.7	4.0	3.7	3.0
Use irrigation facilities (%)	5.0	2.5	0.0	2.5	0.0	5.0
Access to electricity (%)	20.0	7.5	37.5	95.0	5.0	0.0
Use of fertilizer/manure (%)	30.0	47.5	37.5	82.5	75.0	57.5
Adaptive capacity index	**0.291**	**0.390**	**0.531**	**0.515**	**0.448**	**0.259**
Vulnerability index	**0.794**	**0.765**	**0.560**	**0.567**	**0.658**	**0.797**

[1] values are mean of all households in respective communities
(*Source*: Computed from household questionnaire interviews, 2016)

Figure 6.1 revealed the proportion of less, moderately and highly vulnerable households in each community. It showed that Dowine, which is the least vulnerable community, recorded the highest proportion of households (> 40%) within the less vulnerability category while Zakpee, the most vulnerable community, recorded the highest proportion of households (>60%) in the highly vulnerability category. Kalsagri, Boo and Buree recorded the highest proportion of households (≥50%) in the moderately vulnerability category. Tolibri and Zakpee were the two communities with the majority of households (≥ 40%) within the highly vulnerability category while Buree, Kalsagri and Boo had more households (≥ 50%) within the moderately vulnerability category. Generally, except for Dowine, all other communities had fewer households in the less vulnerability category than the other two categories.

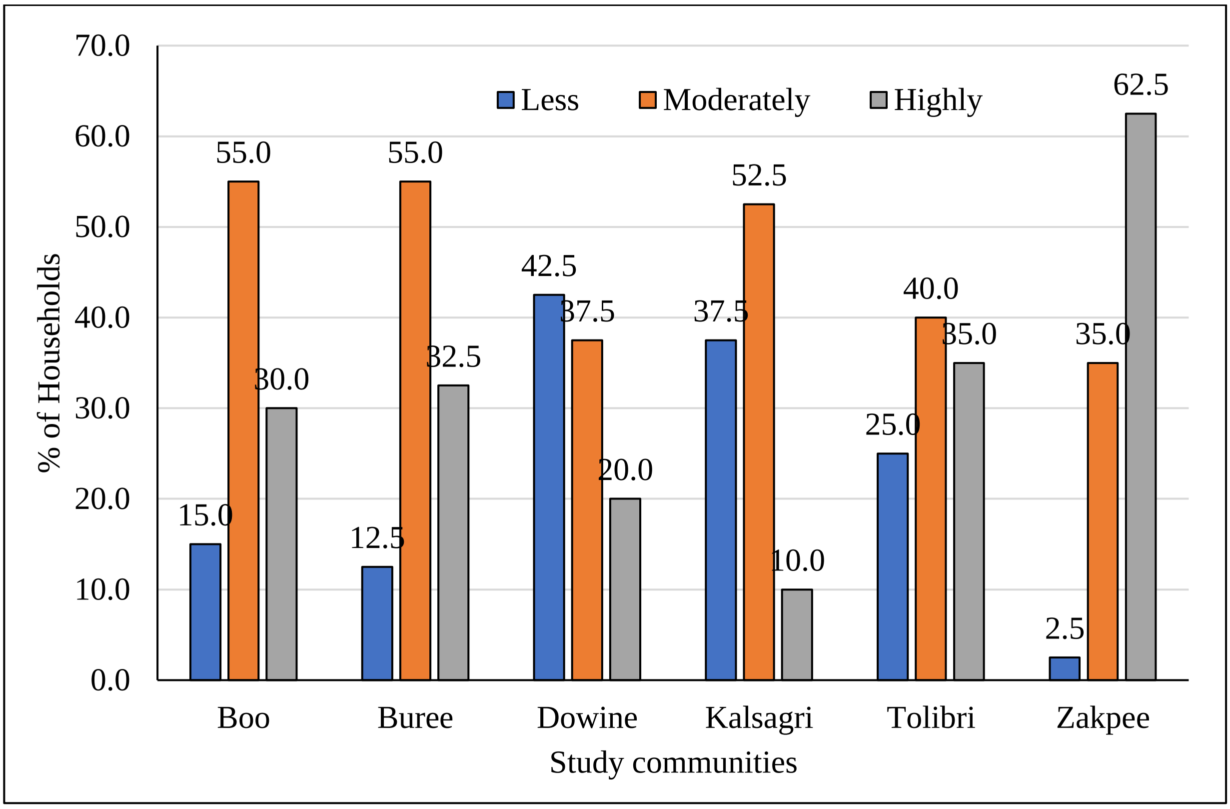

Figure 6.1: Households of different vulnerability categories in the study communities

6.4 Characteristics of most and least vulnerable households in communities

This section provides a detailed description of the most vulnerable households and the least vulnerable households in each of the study communities. The section begins with the description of the households from the least vulnerable community and ends with the most vulnerable community. An analysis of the household survey showed that the household with the highest OVI (least vulnerable) was located in Dowine while the household with the lowest OVI (most vulnerable) was located in Tolibri. The characteristics of the least vulnerable household and the most vulnerable household in each study community are presented in the next section.

6.4.1 Least vulnerable and most vulnerable households in Dowine

The least vulnerable household in Dowine, recorded an OVI value of 0.206, was headed by a 42-year-old married Christian man. The head is a professional teacher with a Diploma in education. At the time of this study, he had enrolled to pursue a degree in education. He is the head teacher of the local basic school. He is also a unit committee member of Dowine Electoral area.

> The house is located at an elevation of 300 m above sea-level. The household size is 12. All members of the household have valid NHIA card. Only 1 member of the household fell ill in the last 12 months. Eight (8) members of the household can read and write giving a literacy rate of 66.7%. Though the household has access to improved drinking water, the same cannot be said about the toilet facility. The house uses a toilet facility in another house which is located at about 200 m. The head has been into farming for the past 20 years and cultivates three crops (groundnut, Bambara beans and yam) on 3-acre inherited farmland. Application of fertiliser is usually employed in the cultivation of groundnut and Bambara beans. Yam is grown for consumption while Bambara beans and groundnut are for both sale and consumption. The head also rears goats, fowl and guinea fowl. The household owns three different fruit trees (mango, orange and pawpaw). The wife and children frequently pick firewood from the bush. The wife does not own a farm but works on her husband's farm and also sells provisions. The head receives a visitation from agricultural extension officers at least twice in a year. Household possesses two television set (connected to satellite decoders), a radio, and three mobile phones. These are used to receive weather information from various media networks. The

mobile phones are used to receive calls, text messages and mobile money. The means for transport for the household is a motorcycle. The house is connected to electricity. The household has access to credit facility for farming and also receives remittances from other relatives residing outside the region. The household is in debt. The head is a member of the Ghana National Association of Teachers (GNAT), by virtue of his teaching occupation, and the community Village Saving and Loan Association (VSLA). The head has 13 relatives and 5 friends in other households in the community. According to the head, he receives support from the government and some NGOs. The 5 main challenges facing the household are low rainfall, poor soil fertility and low credit facility to support farmers. The head does not consider his household as most affected by climate change but thinks women farmers are most vulnerable.

The most vulnerable household in Dowine, with an OVI value of 0.314, fared better than 2.1% (n=5) of all households in the study communities. Thus, the household was the 235th least vulnerable household in the entire study communities. This household is headed by a 60-year-old single and disabled Christian woman. This head has never attended school/formal education.

The house is located at an elevation of 298 m above sea-level. The household is made up of 3 members (including the head). All members of the household have valid NHIA card. Only 1 member of the household fell ill in the last 12 months. Only one member of the household has had formal education up to JSS/JHS. The literacy rate of the household is 33.3%. The household has access to improved drinking water from a borehole which is located at about 400 m from the house. The household does not have access to an improved toilet facility and therefore practice open defecation or uses a toilet facility in another household located at about 200 m. The head has been into farming for the past 20 years and cultivates three different crops (groundnut, beans and millet) on 1-acre inherited farmland. The household does not practice dry season farming. The household does not own livestock and fruit tree. This household picks firewood from the bush for cooking. No fertiliser or manure was used during the past farming seasons. The household does not have access to extension service and weather information. The household neither possesses a communication device (radio, TV or phone) nor means of transport. Though this household is located in the community with extensive electricity coverage, the housed is not connected to the national grid. None of the household members engages in off-farm activities. No member of the household migrates during non-farming seasons. All household income comes from natural resource-based sources. No remittance is received by this household. The head is not associated with any community-based social group but receives some support from governmental and non-governmental institutions. The head is not actively involved in political party activities. The head has 40 relatives in other households in the communities but has no friends. These relatives provide support for the household. According to the head, harvest crops are not enough and therefore, the household experience food shortage before the next harvesting season. The main challenges facing this household are lack of money and inadequate accommodation.

6.4.2 Least vulnerable and most vulnerable households in Kalsagri

The least vulnerable household, with an OVI value of 0.225, is also the fifth least vulnerable household overall. The household is headed by a 55-year-old Christian married man who had formal education up to primary school.

The house is located at an elevation of 271 m above sea-level. The household is made up of 7 members (including the head). All members of the household have valid NHIA card. None of the household members fell sick during the last 12 months. Dependency rate for the household is 16.7% while 3 of the household members can read and write. The household has access to both improved drinking water (from a borehole which is located about 150 m from the house) and an improved toilet facility (pit-latrine with slab). The head has been into farming for the past 40 years and cultivates seven different crops (yams, groundnut, maize, beans, millet, soya beans and Guinea corn) on 4-acre inherited farmland. The household does not practice dry season farming. The household own livestock (goats and fowls) and fruit tree (mango). The members of the household pick firewood, shea nuts, bush meat from the bush. Fertilizer is always used in farming. The household had two visitations from an agricultural extension officer in the last 12 months. The household has communication devices (radio and phone) to access weather information and also contact loved ones. A bicycle is the mean of transport for this household. The household has access to electricity and tractor service. The spouse of the head has her farm on which she grows groundnuts, millets, and beans to support the family. Whereas the head is not engaged in off-farm activities, a member of the household is a salaried worker. None of the household members migrates during non-farming seasons. About 85.7% of household income comes from natural resource-based sources. No remittance is received by this household. The head is associated with 1 social group and therefore receives credit facility for farming. The head is not actively involved in political party activities. The head has 62 relatives and 23 friends in other households in the communities. The quantity of harvested crops are enough to meet the family food requirement up to the next harvesting season. The main challenges facing this household are low rainfall, poor roads, crop pests, lack of support, and heavy rainfall.

The most vulnerable household, with an OVI value of 0.298, was ranked 21st most vulnerable household overall. This household is headed by a 49-year-old married man with no formal education.

> The house is located at an elevation of 279 m above sea-level. The household is made up of 7 members (including the head). All members of the household have valid NHIA card with the head and another member of the household using it to seek medical attention in the last 12 months. Dependency rate for the household is 0% while 2 of 7 of the household members can read and write. The household has access to both improved drinking water (from a borehole which is located more than 100 m from the house) and an improved toilet facility (pit-latrine with slab). The head has been into farming for the past 30 years and cultivates four different crops (yams, beans groundnut and maize) on 3-acre inherited farmland. The household does not practice dry season farming. The household own livestock (2 goats). The members of the household pick firewood from the bush. Application of fertiliser is practiced in this household. The household did not have visitation from agricultural extension officer in the last 12 months and did not receive weather information. The household does not own any communication device. The household does not have any means of transport, no access to tractor service and irrigation facility. However, the house is connected to electricity. Only one member of the household engages in off-farm activities during the off-farm season. The household does not have access to a credit facility. The household is food sufficient. About 80% of household income comes from farming activities. There are 5 relatives and 2 friends of the head residing in the community. The head is not involved in active politics and does not belong to any social group. The main challenges facing this household are lack of money and death of livestock.

6.4.3 Least vulnerable and most vulnerable households in Boo

The least vulnerable household in Boo, with an OVI value of 0.222, was ranked the third least vulnerable household overall. This household is headed by a 59-year-old Christian widowed woman with education up to tertiary. She is a teacher in the community.

> The house is located at an elevation of 299 m above sea-level. The household is made up of 3 members (including the head). All members of the household have valid NHIA card with none seeking medical attention. Dependency rate for the household is 50% while 2 of 3 of the household members can read and write. The household has access to improved drinking water (from a borehole which is located about 200 m from the house) and unimproved toilet facility (pit-latrine without slab). The head has been into farming for the past 25 years and cultivates different four crops (groundnut, rice, millet, beans and maize) on 4-acre inherited farmland. The

> household practices dry season farming by growing pepper, garden eggs, beans and tomatoes. The household own livestock (fowls, goats and a sheep) and fruit tree (mango, cashew, guava, and akee apple). The members of the household pick firewood, shea nuts and dawadawa. Application of fertiliser is practised in this household. The household did not have visitation from agricultural extension officer in the last 12 months but receive weather information. The communication devices owned by the household are radio, mobile phone and television. The head also owns a refrigerator. The household has a motorcycle and a bicycle as means of transport. The household has access to tractor service, irrigation facility and electricity. The head engages in off-farm activities such as full-time teaching and part-time work with NGOs and state institutions (such as Electoral Commission's projects). A member of the household engages in off-farm activities by travelling southwards to work, especially during the off-farm season. The household does not have access to a credit facility. The household is not food sufficient and therefore had to buy food from the market at Boo or Tizaa (near Jirapa). Half (50%) of household income comes from off-farm engagements. The head also receives remittances from relatives living outside the community. The head is involved in active politics and also a member of GNAT and a savings/loan group. The head has 50 relatives and 13 friends in other households in the community. The main challenges facing this household are the cost of fertiliser and, low rainfall.

The most vulnerable household, with an OVI value of 0.301, was ranked the 19th most vulnerable household overall. This household is headed by a 90-year-old Christian widowed woman with education up to primary school.

> The house is located at an elevation of 289 m above sea-level. The household size is 7 (including the head). The head and 5 other members have no valid NHIA card. In the last 12 months, the head and three other members of households have fallen ill and have sought health attention at Boo and Dowine health centres. Dependency rate for the household is 75% while 28.6% of the household members can read and write. The household has access to improved drinking water (from a borehole which is located at less than 100 m from the house) but not an improved toilet facility (pit-latrine without slab) within the house. The head has been into farming for the past 65 years and cultivates 5 crops (millet, beans, groundnut, Bambara beans and maize) on 5-acre inherited farmland. The household does not practice dry season. The household own livestock (donkeys, sheep, goats and fowls) but no fruit tree. The members of the household pick firewood, shea nuts and dawadawa. Application of fertiliser is not practised by this household. The household did not receive a visitation from an agricultural extension officer in the last 12 months but did not receive weather information. The household does not own any communication device. The household has no means of transport. The household has no access to tractor service, irrigation facility and electricity. Neither the head nor other

household members engage in off-farm activities. No member of the household travels southwards to work, especially during the off-farm season. The household does not have access to a credit facility. The household is not food sufficient and therefore had to buy food from the market. Three-quarters of household income comes from on-farm engagements. The head receives no remittances. The head is not involved in active politics but is a member of Christian Women Association at Boo. The head has 10 relatives but no friends in other households in the community. The main challenges facing this household are lack of income, low yield, high temperature, late onset of rains and no electricity.

6.4.4 Least vulnerable and most vulnerable households in Tolibri

The least vulnerable household in Tolibri, with an OVI value of 0.240, is also the 8th least vulnerable household amongst all households in the study communities. This household is headed by a 55-year-old Christian married man with secondary education.

The house is located at an elevation of 272 m above sea-level. The household size is 16 (including the head). All members of the household have valid NHIA card. However, none of the household members fell ill in the 12 months. Dependency rate for the household is 33% while 25% of the household members can read and write. The household has access to improved drinking water (from a borehole which is located at greater than 100 m from the house) but not an improved toilet facility (pit-latrine without slab) within the house. The head has been into farming for the past 30 years and cultivates 5 crops (groundnut, maize, beans, sorghum and yam) on 6-acre inherited farmland. The household does not practice dry season. The household own livestock (pig, goat and fowls) and fruit tree (mango). The members of the household pick firewood, dawadawa, shea nut and bush meat. Application of fertiliser is practised by this household. The household receives a visitation from an agricultural extension officer in the last 12 months. The household receives weather information. The household owns mobile phones, radio and TV. The means for transport for the household are motorcycle and bicycle. The household has no access to tractor service and irrigation facility. Electricity is supply via solar panel system and diesel-operated generator. The spouse of the household head owns a farm. The head and 2 other members were engaged in off-farm income-generating activities. A member of the household travels southwards during the off-farm period. The household does not have access to a credit facility. The household is not food sufficient and therefore supplement the diet by buying from the Lawra or Babile markets. Household income comes from crop farming, animal rearing, salaried jobs (household member), remittances and petty trading (head and spouse). Just over half (57%) of household income comes from natural resources-based sources. The head is not involved in active politics but is a member of a community-based group. The household receives supports from government and NGOs. The head has 5 relatives and 3 friends in other households in the community. The main challenges facing this household are lack of income, low yield, low rainfall and death of livestock.

The most vulnerable household in Tolibri, with an OVI value of 0.323, is also the most vulnerable household overall. This household is headed by a 40-year-old Christian widow with no formal education background. She lives with 2 other relatives.

The house is located at an elevation of 270 m above sea-level. All members of the household have valid NHIA card. Literary and dependency rates are both zero. All members of the house fell ill in the last 12 months and spent 37 days seeking medical attention. The household has access to improved drinking water (borehole) in the community and an unimproved toilet facility (pit latrine without slabs) within the house. The head has been into farming for the past 5 years (since the demise of the husband) and cultivates 5 crops (groundnut, sorghum, Bambara beans, maize, and beans) on a 2-acre inherited farmland. Two members of the house support the farming activity. No fertiliser is usually employed in farming. No livestock is reared. Firewood is often picked to prepare food. The household does not possess a fruit tree, a communication device or bicycle. No visitation from extension officer and no weather information is received. The house is not connected to electricity. No member is involved in off-farm activities. No remittance is received and crops harvested are not enough to last until the next harvest. The head does not belong to any social group but has 3 relatives and 2 friends in the community. No support is received from government and NGOs. The three main challenges facing this household are low rainfall, poor soil fertility and inadequate drinking water. The head considers her household as the most vulnerable household in Tolibri but thinks that widows and children are vulnerable.

6.4.5 Least vulnerable and most vulnerable households in Buree

The least vulnerable household in Buree, with an OVI value of 0.250, was the 20th least vulnerable household overall. This household is headed by a 41-year-old married man living with a wife, 5 children and a brother.

The house is located at an elevation of 296 m above sea-level. The head attended school up to JSS/JHS. All household members have valid NHIA, but none (including the head) has been ill in the last 12 months. The household has a dependency ratio of 67% and literacy ratio of 12.5%. Like most household in the community, this household depends on borehole which is about 100 m from the house. Members of the household have access to an improved toilet facility which is located in the house. The head is not involved in politics. He does not belong to any social group but has 3 friends and 5 relatives residing in other households in the community. In relation to farming activities, the head of the house has been farming for the past 25 years with 88% of farm labour coming from the house. The area of land under cultivation in the 2015 and 2016 farming seasons was 4 acres. The household cultivates about 4 acres of land for six different crops (millet, groundnut, yam, maize, Bambara beans, and beans). Farming is done with the application of fertiliser. In 2015, this household harvested maize (3 bags), millet (3 bags and 30 bowls), yam (50 tubers), beans (1 bowl), groundnut (3 bags) and groundnut (6 bowls). The household also harvests 2 bowls of pepper, 1 bowl of tomatoes and 4 bowls of okra. This household keeps livestock and has 7 cattle, 7 sheep, 26 goats, 2 pigs, 5 fowls, a turkey and a duck. The wife visits the bush or wild to collect fuelwood, dawadawa and shea nuts. The household owns 3 fruit trees. About 93.3% of household income is from natural resource-based. The 6.7% of non-natural resource-based income comes from remittances from 2 relatives who migrate to Kumasi to work during the dry season. The household does not have access to formal extension service but does have access to weather information using a radio. This household also owns a motorcycle and 3 bicycles to aid transport. The household does not have access to electricity. The main challenges confronting this household are poor rainfall (low and late), an infrequent supply of fertiliser, theft and death of livestock and rampart bush burning. Regarding adaptation, the household uses manure (to cope with an adequate supply of fertiliser) and veterinary medicine (to cope with ill-health of livestock).

The most vulnerable household in Buree, with an OVI value of 0.322, is the 3rd most vulnerable household overall. This household is headed by a 76-year-old Christian widow who has no living biological children.

The house is located at an elevation of 286 m above sea-level. The head has never attended formal education. She has a valid NHIA but has never fallen ill in the last 12 months. The source of water for this household is a borehole which is located more than 200 m from the house. The household either practices open defecation or use an unimproved toilet facility located in another household (located about 100 m). The head is not involved in active politics and does not belong to any social group. She has a friend and 10 relatives in other households in the community to provide her with some support during hard times. The head is not engaged in non-farm activity but cultivates 2 crops (groundnut and maize) on 1-acre farmland which was acquired through leasing. In 2015, the household harvested 1 bag of groundnut, and 15 bowls of maize were not enough to last up to the next harvesting. The household does not keep livestock or own fruit trees. The source of energy for cooking comes from fuelwood. Income for the household is entirely from natural resource-based source. The household does not have access to extension service. This household has no communication device, no means of transport, and no access to electricity. The main challenges facing this household are low rainfall and lack of money to support farming activities. This household does not apply any strategy to cope with the challenges.

6.4.6 Least vulnerable and most vulnerable households in Zakpee

The least vulnerable household, with an OVI value of 0.252, was also the 17th least vulnerable household overall. This household is headed by a 43-year-old Christian married man, with no formal education.

> The house is located at an elevation of 264 m above sea-level. The household size is 6 (including the head). All member of the household has valid NHIA cards. However, none of the household members fell ill in the last 12 months. The household has a dependency rate of 100% and a literacy rate of 16.7%. The household has access to an improved water source (borehole). The household uses a pit-latrine with slab (unimproved). The household cultivated six different crop types (maize, groundnut, millet, Bambara beans, beans and rice) on 5-acre inherited farmland. The head has been farming for the past 20 years. Dry season farming is not practised. Farming is mainly rain-fed. The household uses fertiliser in farming. The household raises fowls and goats purposely to sell to supplement household income. The women in the family pick firewood, dawadawa and shea nuts while the men hunt for bush meat. The household owns a mango tree. The head of the household has access to formal extension service, weather information, tractor service and irrigation facility. The household owns a mobile phone and a bicycle. This household is not connected to electricity. The spouse of the head does not own a farm. The head is not involved in off-farm activities, but the wife brews pito for sale at the community and the Babile market. Three members of the household travel southwards during the dry season to work to raise money to purchase need inputs for the next farming season. The quantity of harvest crops is enough to meet the nutritional requirement of the family up to the next harvest. Two-thirds (66.7%) of household income comes from natural resource-based sources. The other sources come from the pito brewing and remittances. There are 10 relatives and 8 friends of the head living in other houses in the community. The head is apolitical and does not receive support from the governmental and non-governmental institutions. The challenges facing the household include low rainfall, crop pests, lack of money, poor soil fertility, poor drinking water and theft of livestock.

The most vulnerable household in Zakpee, with an OVI value of 0.317, is the 237th most vulnerable household overall. This household is headed by a 60-year-old Christian widow, with no formal education.

The house is located at an elevation of 262 m above sea-level. The household size is 5 (including the head). All members of the household have valid NHIA cards. The head and another member contracted malaria and had to spend 29 days recuperating. There is no dependent. Only 1 person can read and write. The household has access to an improved water source (borehole) but not improved toilet facility. The household practices open defecation. The household cultivated 4 different crop types (maize, groundnut, millet and beans) on 1-acre inherited farmland. The head has been farming for the past 25 years. Dry season farming is not practised. Farming is mainly rain-fed. The household does not use fertiliser in farming. The household does not own any livestock. The women in the family pick firewood for making fire for cooking. The household owns a mango tree. The head of the household has no access to formal extension service, weather information, tractor service, irrigation facility and electricity. The household owns a mobile phone and a bicycle. No member of the household is involved in off-farm activities. No member migrates southwards to work during the dry season. The household is in debt. The household is food insufficient. Household income is entirely from natural resource-based sources. No remittance is received. There are 4 relatives and 3 friends of the head in other houses in the community. The head is politically-neutral and does not receive support from the governmental and non-governmental institution. The challenges facing the household include late onset of rains, lack of money, poor soil fertility and no electricity.

6.5 Discussion

The chapter has investigated the exposure, sensitivity, adaptive capacity and vulnerability of farming households and subsequently, the communities in the study area. Understanding how these components influence vulnerability is vital in providing policymakers with cogent information to design and implement appropriate measures to reduce vulnerability in the study area. Though vulnerability is context-specific, the information provided by this study can help direct policy decisions in areas with similar climate and socioeconomic conditions to the study area.

The results reveal that exposure, sensitivity and adaptive capacity affect farming households in varied ways. Households that are highly exposed and have lower adaptive capacity are most likely to suffer from the effects of climate change. Adaptive capacity is linked to the ability to adapt to climate change (Adger *et al.*, 2005). The results, further, indicate that being the most exposed households does not translate into being the most vulnerable households. For instance, Tolibri was the most exposed but not the most vulnerable community. The results concur with studies by Brooks *et al*. (2005) which noted that those who are exposed are likely to be more prepared to adapt and reduce their vulnerability than those that are not. In addition, being the least exposed does not guarantee to be the least vulnerability as demonstrated by this study. Boo was the least exposed community but ended up being the second most vulnerable.

The results demonstrate that exposure, sensitivity, adaptive capacity and vulnerability indices differed across study communities. Amongst the selected communities, households in Zakpee were the most vulnerable whiles households in Dowine were the least vulnerable. The adaptive capacity of households in Dowine was found to be two times that of Zakpee. The higher adaptive capacity of households in Dowine could be attributed to the presence of a health centre, school, electricity (national grid), more farmers engaged in non-farm income-generating activities and proximity to market centres at Boo and Jirapa. Households in Zakpee lacked these things.

6.6 Conclusion

This chapter analysed the vulnerability of households and communities to climatic and non-climatic stressors by using composite indicators that defined the three components of vulnerability. The findings in this chapter suggest that farming households are vulnerable and that their vulnerability to climatic and non-climatic stressors varies due to their differences in exposure, sensitivity and adaptive capacity. The findings, further, suggest that exposure, sensitivity and adaptive capacity are context-specific. Households that are highly exposed are not necessarily the most vulnerable and vice versa. Adaptive capacity remains a critical component needed to reduce vulnerability to stressors.

This study provides an important step to direct future research in vulnerability to climate change. Future research should attempt to use meteorological data from the household level to define exposure and also fine-tune the methodology employed in this study to characterise farming households in semi-arid environments. Nevertheless, the findings of this study can provide policymakers and stakeholders with evidence-based information to direct climate change policies for farming households in similar climatic and socioeconomic conditions. The next chapter presents the results and discussion of adaptation strategies used by farmers with respect to perceived stressors.

CHAPTER SEVEN

ADAPTATIONS STRATEGIES BY FARMING HOUSEHOLDS

7.1 Introduction

This chapter presents the results and discusses that adaptation strategies utilised by farming households as a response to climatic and non-climatic stressors. The chapter is constructed into five sections. The first section introduces the chapter. The second section presents adaptation strategies used by farming households in response to climatic and non-climatic stressors. This is followed by the third section dedicated to present to results of farmers' opinion of the easiest and most important adaptation strategies. The penultimate section discusses the results, and the final section concludes the chapter.

7.2 Types of adaptation strategies

Table 7.1 shows the grouping of adaptation strategies by households into climatic versus non-climatic stressors, autonomous versus planned adaptation, farm-level versus off-farm adaptation, and reactive versus anticipatory adaptation. It is clear from the results that adaptation is contingent on perception. Out of the 36 adaptation strategies cited by the farmers, 12 were utilised to respond to perceived climatic stressors and 30 for non-climatic stressors. Also, 7 of the adaptation strategies cited were utilised to respond to both climatic and non-climatic stressors. This proves that some strategies are flexible and utilised with or without the perception of climate change. Nonetheless, some adaptation strategies, such as intercropping and crop diversification, were noted to be utilised in response to non-climatic stressors, though one would have expected them to be utilised in response to climate change. Thus, climate change may not be the reason why some farmers utilise certain adaptation strategies to improve agriculture.

Table 7.1: Types and categories of strategies employed by farmers in the study area

Stressor	**Forms of Adaptation**	**Adaptation strategies used by farmers**	
		Farm level	**Off-farm level**
Climatic	Reactive	Enrich soil[a] Practice non-burning method[a] Change sowing dates[a] Dry season gardening[a] Switch to irrigation[p]	Migrate[a] Sprinkle water on compound[a]
	Anticipatory	Relocate farm[a] Plant trees[a,p] Use zai pit system[a] Control burning[a] Use improved crop varieties[a,p]	Plant trees[a,p]
Non-climatic	Reactive	Enrich soil[a] Practice non-burning method[a]	Renovate of house[a] Confine livestock[a] Rely on social networks[a] Buy food/barter[a] Change diet[a] Skip meals[a] Use solar panel/generator/lantern/flash light[a] Use sachet water[a] Migrate[a] Call veterinary/use medicine[a]
	Anticipatory	Diversify crops in farming[a] Apply pesticides[a] Plant trees[a,p] Control burning[a] Use improved crop varieties[a,p] Practice intercropping[a]	Harvest rainwater[a] Plant trees[a,p] Apply pesticides[a] Visit health care centres[a] *Engage in off-farm income generating activities[a] Depend on LEAP[p] Depend on disability fund[p] Rely on social networks[a]

*Many types of income streams used by farming households were identified. [a] Autonomous adaptation strategy, [p] Planned adaptation strategy. (*Source:* Computed from household questionnaire interviews, 2016)

Autonomous adaptation strategies are employed by individual farmer in response to changes occurring in his/her environment without governmental initiative. Planned adaptation strategies require policy direction to alter the adaptive capacity of the farming system or household. The results reveal that farmers employed more autonomous adaptation strategies than planned adaptation.

With regard to where adaptation is taking place, farming households employed more strategies that can be categorised under off-farm adaptation than farm-level adaptation. Farm-level adaptation strategies denote the number of interventions applied on the farm to reduce the adverse effect of climatic and non-climatic stressors. These strategies include enriching the soil, using improved crop varieties, changing sowing dates, using irrigation facility, *zai* pit system and diversifying crops. Off-farm adaptation strategies denote the number of interventions usually employed outside the farm but at the household level to reduce the adverse effects of climatic and non-climatic stressors. These strategies include selling livestock and/crops, housing livestock, relying on relatives and friends, reducing food intake and sleeping under a treated mosquito net. However, adaptation strategies such as planting trees and applying pesticides were employed by the farmers at both the farm and the house. Farmers plant trees on their farms and also around their houses for the same purpose: serve as windbreak.

In terms of timing, the adaptation strategies used by the farming households could be categorised as reactive and anticipatory form of adaptation. Reactive adaptation strategies are usually employed during or after the exposure of specific stressor while anticipatory adaptation strategies are used in preparation for future occurrence of some stressors (Smit & Skinner, 2002; UNFCCC, 2007).

7.3 Adaptation strategies to specific stressors

Table 7.2 and Table 7.3 display the adaptation strategies employed by farming households in response to specific stressors affecting the economic activities. While some strategies, such as the use of improved crop varieties, tree planting and reliance on social networks, were used for multiple stressors, others such as the application of pesticides and the sprinkling of wastewater were utilised for a single stressor. Female farmers did not mention irrigation, *zai* pit system, relocation of farms, walking and using a bicycle as response strategies. Though migration was cited by the female-households, it was not intended to counteract against only climate change and variability, but also against non-climatic stressors. The reason why female-households did not mention migration as an adaptation or coping strategy could be because migration is gendered; men are the ones who migrate leaving the women behind to take care of the home.

The results of the household survey showed that about 57% (*n* = 125) of households that adapt reportedly used improved crop varieties, such as drought-resistant and early-maturing varieties, to counteract low rainfall, short duration of rains, late onset of rains, lack of money and insufficient food. Farmers described using early-maturing maize varieties such as *Obaatanpa*, *Okomaso* and *Oburotia*, which mature within 70 – 90 days instead of the usual 120 – 180-day varieties. These maize varieties also included drought-resistant varieties and were, therefore, suitable to be used in an environment that experience low rains, late rains or short duration of rains duration. Farmers used improved crop varieties to boost food production to ensure food security and also to earned income from the sale of crop surplus.

About 14.6% of households cited changing sowing dates in response to low rainfall, late onset of rains, short duration of rains and heavy rainfall. A focus group participant explained the reasons for the change in planting dates as:

> *"Before the 1980s we used to plant around early March. Later, it shifted to late March and then late April. This year and last year, the rain came in late May. Now it is challenging to know when the rain will start coming. Weather information on radio and even from friends have not been able to give accurate information. The*

rainfall is now unpredictable making it difficult to plan" [Male farmer, Focus Group at Boo, November 2016].

Table 7.2: Farmers' adaptation strategies to specific climatic stressors

Perceived stressors	**Adaptation strategies**[1]
Low rainfall	Practice non-burning method; changing sowing dates; enrich soil; plant trees; use improved crop varieties; migrate[m]; control burning; switch to irrigation; use *zai* pit[m]; practice dry season farming
Late onset of rains	Changing sowing dates; plant trees; use improved crop varieties; migrate[m]
Short duration of rains	Practice non-burning method; changing sowing dates; plant trees; use improved crop varieties; migrate[m]
Heavy rainfall	Plant trees; relocate farm[m]
High temperatures	Plant trees
Strong wind	Plant trees
Dust	Sprinkle water on compound[m]

[m] Cited by only male heads and Not female heads.

[1]Adaptation strategies cited by less than 2 households excluded.

(Source: Computed from household questionnaire interviews, 2016)

Table 7.3: Farmers' adaptation strategies to specific non-climatic stressors

Perceived stressors	**Adaptation strategies**[1]
Bushfire	Practice non-burning method; control burning
Lack of money	Diversify crops in farming; enrich soil; use improved crop varieties; migrate[m]; engage in off-farm income generating activities; rely on

	social network (incl. family and friends); receive LEAP/disability fund
Insufficient food	Diversify crops in farming; use improved crop varieties; engage in off-farm income generating activities; rely on social network (incl. family and friends); change diet/skip meals; buy food/barter
Low yield	Diversify crops in farming; enrich soil; practice intercropping; rely on social network (incl. family and friends); change diet/skip meals
Poor soil fertility	Enrich soil
Fertilizer (cost and lack)	Enrich soil; practice intercropping; engage in off-farm income generating activities; rely on social network (incl. family and friends)
Felling of trees	Plant trees
Crop pests	Practice intercropping; apply pesticides
Lack of support	Engage in off-farm income generating activities; rely on social network (incl. family and friends)
Cost of education	Engage in off-farm income generating activities; rely on social network (incl. family and friends)
Agricultural tools (lack)	Rely on social network (incl. family and friends)
Seed failure	Rely on social network (incl. family and friends)
Post-harvest losses	Apply pesticides
Inadequate drinking water	Harvest rainwater; use sachet water
Lack of electricity	Use solar panel/generator/ lantern/flashlight
Livestock (death/theft/disease)	Confine livestock; call veterinary officers; use veterinary medication
Ill-health	Visit health centre; use medication; use insecticide-treated nets
Poor accommodation	Renovate house

[m] Cited by only male heads and NOT female heads.
[1]Adaptation strategies cited by less than 2 households excluded.
(Source: Computed from household questionnaire interviews, 2016)

Though farming households reported practising crop diversification, by cultivating between 2 and 7 crops (mean = 4) on their farms, only 14% (n = 31) use this strategy to respond to lack of money, insufficient food and low yield. The results of the household survey indicated that farmers cultivated guinea corn, maize, groundnut, Bambara beans, millet, sorghum, yam, beans, rice, and other vegetables. These crops were grown for consumption and sale of groundnut and surplus of other crops to make money to buy agricultural inputs, pay school fees or take care of basic needs. From the survey, this means that the intention of farmers concerning crop diversification was not to respond to climate change.

The household survey indicated that 2% (*n* = 4) of farming households practice intercropping in response to low yield, lack or cost of fertiliser and crop pest infestation. Similar to crop diversification, intercropping was practised by farmers, not in response to climatic stressors. According to the focus group with the community elders, farmers grow more than one crop in an alternate row usually maize/sorghum/millet with groundnut/Bambara beans. This strategy helps to prevent the spread of crop pests and disease and ultimately boost food production. In addition, intercropping of cereals with leguminous crops increases soil fertility through microbial-legume mediated nitrogen-fixation process.

Results from the household survey revealed that about 79% (*n* = 189) of farming households plant fruit trees around their houses and on their farms. About 45% (*n* = 85) of these farming households reported using tree planting in agroforestry as a response strategy to reduce their vulnerability to low rainfall, short duration of rains, late onset of rains, heavy rainfall, high temperature, strong wind and felling of trees. The importance of trees includes providing shade and microclimate, reducing soil erosion, serving as a windbreak, improving aesthetic nature of the surroundings, providing medicinal materials for health improvement and combustible materials (fuelwood) for heating, providing fruits, and serving as early warning indicators of impending rainfall and dry spells.

Farmers utilised soil water conservation methods such as *zai* pit and irrigation facility to respond to low rainfall. *Zai* pit system is an innovative soil fertility and moisture improvement method adopted from neighbouring Burkina Faso and Mali (Nyantakyi-Frimpong & Bezner-Kerr, 2015; Pretty *et al*., 2011). This method involves the farmer constructing a small pit (*zai*) with a diameter of 30 cm and a depth of 15 cm to capture surface runoff. Farmers usually add manure or compost which is decomposed by decomposers such as microorganisms, earthworms and termites. The decomposition process helps to improve soil fertility while the pit design helps to conserve soil moisture and improve soil fertility by preventing loss of nutrients via runoff. The construction of the pit is usually done a few weeks into the sowing period. The study revealed that only 1.4% (*n* = 3) of households that adapted use *zai* pit system. No female-household utilises this system and the time-consuming, and labour-intensive nature of the construction could be attributed to the underutilization of the system among the farmers.

Farming households use soil enrich methods such application of organic fertiliser (compost, manure and mulch) and inorganic fertiliser to respond to low rainfall, poor soil fertility, cost/lack of fertiliser, lack of money and low yield. About 55% (*n* = 132) and 35% (*n* = 76) of households that adapt reported using inorganic fertiliser and organic fertiliser, respectively on their farms to increase soil fertility. Organic fertilisation involves leaving crop residues and animal droppings on the farmland to be decomposed by various decomposers such as microorganisms, termites, fungi and worms. This process helps to improve soil fertility when the essential plant nutrients in the residues return to the soils as part of the broader biogeochemical cycle. Mulching also enhances soil moisture conservation when the crop residues cover the ground and prevent the direct incidence of the sunlight which would have, otherwise, increased loss of moisture via evaporation. A transect walk on some farms in the study areas revealed that farmers discard or dump crop residues on farms to rot to improve soil fertility and soil moisture content.

Farmers capitalise on the presence of the Black Volta River to engage in dry season cultivation of mostly vegetables such as pepper, tomatoes, okra, garden eggs and onion. This practice was reported by about 4% (*n* =10) farming households in Tolibri (which is closer to the Black Volta River). The farmers either cultivate on lands a few distances from the river where the soil is still moist even during the dry season or install micro-irrigation facilities. Another strategy used by farming households was relocating their farms to other places which are not prone to flooding. This adaptation strategy, according to the household survey, is practised by male farmers. The adaptation strategy is uncommon among the farming households as it was reported by a third (33.3%, *n* = 3) of households that perceived heavy rainfall as a threat to their household and farming activities.

The study revealed that farmers employed non-burning farm practices and control burning (construct fire belt) as a response to low rainfall, short duration of rains and bush burning. Both male and female farmers utilised this practice. Non-burning practices help improve soil fertility and moisture. Bush burning during land preparation has been noted as bad farming practice, and farmers are reported discontinuing this practice to control erosion, reduce evaporation of soil moisture, prevent the destruction of lives and properties and preserve grass for cattle grazing.

Farming households have resorted to changing diets or skipping meals (reducing food consumption per day) in response insufficient food and low yield. According to extract from the household survey, farming households change diets by either substituting the crops used to prepare traditional meals or replace the traditional meals entirely. Though about 43% (*n*

= 102) of households revealed to experience food shortage before the next harvest, only 8% (*n* = 18) perceived this as a threat to their households. Of those who received food shortage as a threat, only 28% (*n* = 5) responded by changing diets or skipping meals. Of the 16% (*n* = 39) of households that perceived low yield as a problem, about 8% (*n* = 3) responded by skipping meals. Skipping meals could also be a maladaptation strategy as this could lead to a serious health implication particularly among children, elderly and immune-compromised persons making them more vulnerable to climate change.

Farming household heads reported either they or a household member(s) migrated southwards in response to either low rainfall, late onset of rains or lack of money. Farmers cited migrating to Brong Ahafo, Ashanti and Greater Accra regions to seek either agricultural or non-agricultural job opportunities. The results of the household survey revealed that about 45% (*n* = 109) of households have 217 relatives travelling to other places in Ghana to seek better opportunities mostly during the off-farming season of the study areas. Most of these migrants find it difficult to obtain employment in the formal or governmental sector because of their lack of skills and low educational attainment. They are, therefore, engaged in strenuous and low-income opportunities under deplorable environmental and occupation health conditions. These migrants return before the start of the farming season to help with farm work, bringing with them money, agricultural inputs and personal effects. About 33% (*n* = 79) of households indicated receiving remittances from migrants. The results from the focus group discussion revealed that it is mostly men and young single women who migrate to southern Ghana. Husbands migrate leaving behind their wives to take care of the children, and this increases the daily workload of the women. In this environment, women are the carers of children, collectors and managers of water and firewood, and are responsible for almost all house chores.

The results of the household survey indicated that about 13% (*n* = 28) of households had been received governmental supports through cash transfer instruments such as disability fund and LEAP. Livelihood Empowerment against Poverty (LEAP). LEAP is a social cash transfer programme, launched in 2008 by the government, to provide cash to and pay the premium of health insurance for extremely poor households, consisting of the elderly (aged ≥ 65), people with disabilities and carers of orphans and vulnerable children, across Ghana to alleviate short-term poverty and encourage long-term human capital development (Handa *et al*., 2013). The households reported using LEAP as a response strategy mainly to counteract lack of money.

Households reveal relying on family, friends, other social network groups as well as non-governmental organisations (NGOs) to enable them to counteract against the cost of fertiliser, lack of fertiliser, seed failure, lack of agricultural tools, lack of money, insufficient food, low yield and lack of governmental support. From the household survey, about 92% (*n* = 220), 83% (*n* = 198), 43% (*n* = 136), 24% (*n* = 58) and 19% (*n* = 45) of households claimed to receive various supports from family members (living in other houses in the community or elsewhere), friends, non-partisan social groups (such as Village Savings and Loan Associations (VSLA) and farmers' associations), partisan groups (political party affiliation) and NGOs, respectively. These social networks allow the farmers to receive weather information, agricultural inputs, financial support as well as emotional and spiritual support. Networking also provides opportunities for the farmers to get connected to people in a position of power in the society and therefore, receive assistance during unfavourable circumstances.

Farmers claimed to diversify their income streams by engaging in off-farming activities purposely to enable them cost/lack of fertiliser, lack of money, insufficient food, lack of support and cost of education. Through income diversification, farmers can generate income from different sources to enable them to purchase agricultural inputs, buy food ingredients and pay a tuition fee of the family. Table 7.4 revealed that farmers in the study areas were engaged in multiple non-farming income-generating activities in response to non-climatic stressors. It can be deduced from the results that there were gender differences in off-farm income-generating activities among households in the study area. Women appeared to be better-off than men.

The harvesting and selling trees as firewood by women in the study communities represent another form of maladaptation. Trees are important natural resources with sink and source functions. The sink function comes from the ability of trees to sequester carbon dioxide during growth. Without trees carbon dioxide, produced from natural and human activities, would otherwise rise up and trap heat in the atmosphere leading to global warming. The source function emanates from trees being an important source of soil organic carbon via decomposition of parts of trees. In addition, a tree functions as windbreak controlling the movement of wind and thus, prevent destruction of houses and crop fields from windstorm. Thus, felling of trees for firewood leads contribute to changing climate and related imparts, the very thing the farmers are attempting to adapt.

Table 7.4: Off-farm income generating activities undertaken by sampled households

Off-farm activities	**% of households that adapt (*n* = 220)**
Salaried employment	9.5
Pito brewing[f]	3.6
Daily waged labour	6.8
Rent	1.4
Petty trading[f]	16.8
Garment working	1.4
Fishing[m]/fish mongering[f]	1.4
Repair work[m]	0.9
Milling[m]	0.9
Weaving[m,f]	1.4
Hair dressing[f]	0.9
Shea butter making[f]	2.7
Basket making	0.9
Carpentry[m]	0.9
Sale of alcohol beverage[m]	0.9
Sale livestock	28.2
Sale of harvested crops	17.7
Sale firewood[f]	2.3
Food vendor[f]	1.4
Dawadawa (fermented African locust) paste[f]	1.8
Fried beans/cowpea cake (*koose*) making[f]	1.4
Others[*]	2.3

[m] cited by male respondents, [f] cited by female respondents, [*]Others include all activities cited by less than 2 sampled households.

7.4 Most important and easy to utilise adaptation strategies

Sampled farmers who employ adaptation strategies were asked to indicate which of the adaptation strategies they considered as the most important (Table 7.5). Farmers cited 14 of the 36 adaptation strategies as the most important. Majority of farmers (19.5%, n = 43) indicated that engaging in off-farm income generating activities or enriching the soil (with manure, mulch, compost or fertiliser) was the most important adaptation strategy. Use of improved crop varieties was considered as most important adaptation strategy by 19.1% (n = 42) of farmers while tree planting was seen by 16.4% (n = 36) of farmers as an important strategy. Other important adaptation strategies cited by the farmers were social networks, migration, skip meals, response to ill-health, treatment of livestock, changing sowing dates, use flashlights, used sachet water, confine livestock and buy food/barter for food.

Table 7.5: Farmers' opinion about the most important adaptation strategies

	Percentage of farmers		
Adaptation strategies	**Female (*n* = 67)**	**Male (*n* = 153)**	**Overall (*n* = 220)**
Off-farm activities	17.9	20.3	19.5
Improved crop varieties	17.9	19.6	19.1
Social networks	7.5	2.0	3.6
Migrate	3.0	0.7	1.4
Plant trees	19.4	15.0	16.4
Skip meals	1.5	1.3	1.4
Use health centre	6.0	2.6	3.6
Call vet/use medication	3.0	4.6	4.1
Enrich soil	14.9	21.6	19.5
Change sowing dates	7.5	8.5	8.2
Use flash lights	N/A	0.7	0.5
Use sachet water	N/A	0.7	0.5
Confine livestock	N/A	2.0	1.4
Buy food/barter	1.5	0.7	0.9

NA means the stressor was not identified by the group of farmers.
(*Source*: Computed from household questionnaire interviews, 2016)

Male farmers considered 14 adaptation strategies as most important while female farmers considered 11 strategies as important. Female farmers did not cite confining livestock, using flashlights and using sachet water as important adaptation strategies. The most important adaptation options by both male and female farmers (mentioned by ≥ 10% of the farmers) were using improved crop varieties, engaging in off-farm activities, enriching the soil and planting trees. These four adaptation strategies considered by the farmers were utilised by the farmers to counteract all the perceived climatic stressors and 7 of the perceived non-climatic stressors.

Table 7.6 presents the adaptation strategies farmers considered easiest to use. The farmers cited 16 adaptation strategies. The four strategies were cited by a majority of farmers (≥ 10%) as the most important were also considered as being the easiest to use.

Table 7.6: Farmers' opinion about the easiest adaptation strategies to implement

	Percentage of farmers		
Adaptation strategies	**Female (*n* = 67)**	**Male (*n* = 153)**	**Overall (220)**
Off-farm activities	20.9	20.9	20.9
Improved crop varieties	17.9	15.0	15.9
Social networks	1.5	0.7	0.9
Migrate	4.5	1.3	2.3
Plant trees	19.4	17.6	18.2
Skip meals	3.0	1.3	1.8
Use health centre	6.0	2.0	3.2
Call vet/use medication	1.5	3.9	3.2
Enrich soil	11.9	26.1	21.8
Change sowing dates	6.0	7.2	6.8
Use flash lights	1.5	0.7	0.9
Use sachet water	N/A	0.7	0.5
Confine livestock	N/A	2.0	1.4
Barter	3.0	N/A	0.9
Intercrop	1.5	N/A	0.5
Use pesticides	1.5	0.7	0.9

NA means the stressor was not identified by the group of farmers.
(*Source*: Computed from household questionnaire interviews, 2016)

Both male and female farmers cited an equal number (14 each) of adaptation strategies, they considered as easiest to implement. Use of sachet water and confine of livestock were not cited by female farmers. Male farmers did not cite barter trading and intercropping as the easiest strategies to implement.

7.5 Discussion

Every living organism is affected by changes in its external environment and therefore, develops and implements various response strategies to counteract these changes. Thus, critical to adaptation is the ability of the organism to perceive changes occurring in its environment. An organism that is unable to respond to changes in its environment is likely to suffer and becomes more vulnerable. This section discusses the results for adaptation strategies employed by the farming households in response to stressors they faced as they embark on their livelihood activities. Literature is replete with adaptation strategies implemented by farmers in sub-Saharan Africa and beyond (Bawakyillenuo *et al*., 2016; Berrang-Ford *et al*., 2011; Codjoe *et al*., 2012; Kihupi *et al*., 2015; Tessema *et al*., 2013).

The results show that farmers in north-western Ghana utilise various adaptation strategies to counteract perceived climatic and non-climatic stressors. The adaptation strategies employed by the farmers in response to climate change concur with previous studies by Antwi-Agyei *et al*. (2014), Nyantakyi-Frimpong & Bezner-Kerr (2015) and Codjoe *et al*. (2012) which reported farmers in Ghana using some of the strategies to respond to climate change and related hazards. Information about specific adaptation strategy in response to specific stressor encountered is critical to engaging policymakers to design and implement appropriate adaptation policies for the farmers.

The study showed that adaptation strategies used by the farmers were not in response to perceived climatic stressors but also for perceived non-climatic stressors. In addition, a number of adaptation strategies were employed in response to either a single stressor (such as solar panel for lack of electricity, use of *zai pit* for low rainfall) or multiple stressors (such as use of crop varieties for low rainfall, late onset of rains, short duration of rains, lack of money and insufficient food). Furthermore, the use of specific adaptation strategies, such as *zai pit* and relocation of farms, was gender-specific. Interestingly, *zai* pit system, a strategy to improve soil moisture and fertility, is adopted from neighbouring Burkina Faso indicating the transboundary transfer of knowledge among farmers. This shows that farmer-to-farmer collaboration with farmers from Ghana and those from neighbouring countries should be deepened to foster learning and transfer of knowledge and innovative approaches among the farmers.

The results demonstrate that adaptation strategies used by households can be grouped into autonomous versus planned adaptation and farm-level versus off-farm adaptation. Autonomous adaptation strategies are usually employed as reactions to an individual farmer's response to changes occurring in his/her environment (Codjoe *et al*., 2012; Ncube *et al*., 2016; Tessema *et al*., 2013). These adaptation strategies do not involve the intervention of government or governmental agencies. Planned adaptation strategies are deliberate or conscious policy options aimed at altering the adaptive capacity of the agricultural system or facilitate specific adaptation (Berry *et al*., 2006). The results reveal that most of the adaptation strategies employed by the farming households were autonomous adaptation than planned adaptation, indicating the farmers' proactiveness in dealing with problems affecting their economic activities. The autonomous adaptation strategies utilised by the farmers included enriching the soil with fertiliser and animal dropping, practising non-burning method, changing sowing dates, practising dry season gardening, relying on social networks, buying food, engaging barter trading, changing diet and skipping meals. The planned adaptation strategies which were utilised by the farmers at the insistence of governmental agencies included using irrigation facility, using crop varieties, accessing Disability Fund and LEAP.

With regard to where adaptation is taking place, farming households employed more strategies that can be categorised under off-farm adaptation than farm-level adaptation. Farm-level adaptation strategies denote the number of interventions applied on the farm to reduce the adverse effect of climatic and non-climatic stressors. These strategies include enriching the soil, using improved crop varieties, changing sowing dates, using irrigation facility, *zai* pit system and diversifying crops. Off-farm adaptation strategies denote the number of interventions usually employed outside the farm but at the household level to reduce the adverse effects of climatic and non-climatic stressors. These strategies include selling livestock and/crops, housing livestock, relying on relatives and friends, reducing food intake and sleeping under a treated mosquito net.

7.6 Conclusion

The findings of this study demonstrate that, farmers were able to list the various strategies to respond to stressors that affect their farming and household activities. Adaptation strategies employed by the farmers were contingent on the perception of stressors. Farmers' adaptation decisions were not only to respond to climate change but also to non-climatic stressors. However, a number of adaptation strategies were employed by the farmers but not in response to climatic stressors but to non-climatic stressors. This implies that climate change does not always dictate the adaptation decisions of farmers in northern Ghana.

CHAPTER EIGHT

VULNERABILITY AND ADAPTATION STRATEGIES

8.1 Introduction

This chapter aims to establish the association between the components of vulnerability and adaptation to stressors in the study area. The chapter contains four sections. The introduction section is followed by the results of the binary logistic regression to establish the relationship between the components of vulnerability and adaptation. The third section presents the detailed discussion of the results. Then the last section concludes the chapter.

8.2 Factors influencing households' adaptation

Table 8.1 displays the results of binary logistic regression to assess prediction of adaptation (adapt or not adapt) to stressors as a function of components of vulnerability (independent variables). The logistic regression model was statistically significant, χ^2 (35) = 60.448, $p < 0.05$, and explained 51.0% (Nagelkerke R^2) of the variance in adaptation to stressor. The model parameters indicate that membership of a social group, communication diversity and use of fertiliser were statistically significant in explaining whether a farming household would adapt or not adapt at less than 5% probability level while crop diversity was statistically significant in explaining whether a farming household will adapt or not adapt at less than 10% probability level.

Membership of a social group was a significant positive predictor of adaptation by farming households. This implies that members of a social group was more likely to increase farmer's ability to adapt. The odds of utilising adaptation strategies to counteract perceived stressors was 14.903 times greater for households with heads belonging to a social group as opposed to households with heads not belonging to any group. Belonging to a social group was identified by the farmers as one of the adaptation strategies utilised in response to the adverse effects of the stressors faced. Belonging to a social group afford the members the opportunity to share challenges and experiences associated with their farming activities. Members of a group support each other emotionally, materially, financially and spiritually during hard times. Farmers are more likely to learn and adopt innovative ways of farming when they belong to a group. Members of a group are in an advantageous position to access credit facility and insurances from providers. This is because the cost of the credit facility (principal and interests) could be spread among members to ease repayment.

Communication diversity, in this study, referred to the number of different communication devices owned by a household. It was hypothesised that the use of different kinds of communication devices increases information accessibility and therefore, increases adaptive capacity. An increase in adaptive capacity leads to a reduction in a household's vulnerability. It was also envisaged that households with high communication diversification were likely to adapt compared to households with lower communication diversification. The results indicated that the odd of households' with a higher communication diversity index employing an adaptation strategy was 1.791 time more compared to households with a lower communication diversity index. The farming households, in the study area, used radio, television and mobile phone (e.g. information from ESOKO) to access weather information, market prices and any agricultural information. With these communication platforms and information received, farmers can adequately plan for the farming season.

Table 8.1: Logistic regression of vulnerability and adaptation

Independent variables	**β**	**S.E.**	***p-value***	**Odd ratio{Exp(β)}**
Elevation of HH	0.039	0.042	0.355	1.039
Stressors faced by HH (number)	0.254	0.289	0.379	1.289
Share of natural resource-based income	0.018	0.043	0.675	1.018
HH is affected most by stressors (yes)	-0.909	0.891	0.307	0.403
HHM falling ill in last 12 months (%)	0.022	0.017	0.195	1.022
Length of illness (months)	0.028	0.143	0.842	1.029
HHM with disability	-0.011	0.056	0.847	0.989
Membership of a social group (yes)	2.702	1.022	0.008*	14.903
Access to extension advice (yes)	1.661	1.200	0.166	5.265
Access to weather information (yes)	-1.357	1.023	0.185	0.257
Access to credit facility (yes)	0.260	0.880	0.768	1.297
HHH belongs to active politics (yes)	1.609	1.436	0.262	4.998
Number of relatives in the village	0.036	0.071	0.611	1.037
Number of friends in the village	0.169	0.133	0.203	1.184
Ownership of farmland (inherited)	-1.343	0.941	0.154	0.261
Farm holding size (ha)	-0.395	0.748	0.597	0.673
Number of different of fruit trees owned	0.135	0.645	0.834	1.145
HH size	0.255	0.210	0.224	1.290
HH head: male	0.770	0.893	0.388	2.160
Age of HHH (years)	-0.016	0.039	0.674	0.984
Proportion of HHM with NHIA (%)	-0.091	0.056	0.105	0.913
HH dependency ratio (%)	-0.002	0.007	0.777	0.998
HH literacy ratio (%)	-0.029	0.019	0.126	0.972
HHH years of farming	-0.026	0.041	0.525	0.974
HHM working on farm (%)	-0.011	0.019	0.583	0.989
Ownership of livestock (TLU)	0.069	0.382	0.856	1.072
Remittances received: yes	0.394	1.390	0.777	1.482
HHH engaged in off-farm activities (yes)	-1.400	1.374	0.308	0.247
Income diversity	1.112	0.722	0.124	3.040
Crop diversity	-0.772	0.421	0.067**	0.462
Transport diversity	-0.001	0.407	0.998	0.999
Communication diversity	0.583	0.283	0.040*	1.791
Use irrigation facilities (yes)	-2.170	1.815	0.232	0.114
Access to electricity (yes)	1.770	1.198	0.140	5.870
Use of fertiliser (yes)	-2.404	1.024	0.019*	0.090
Constant	-1.591	14.342	0.912	0.204

Note: HH (household); HHH (household head). * and ** = Significant level at 5% and 10% probability levels, respectively.

Use of fertiliser was identified as an adaptation strategy by farming households in response to low rainfall, lack of money, poor soil fertility and low yield. Use of fertiliser was a significant negative predictor of adaptation by farming households. This implies that households that use fertiliser in farming were less likely to adapt to climatic and non-climatic stressors. The results demonstrate that a household that applied fertiliser was 0.09 times less likely to adapt to perceived stressors compared to a household not applying fertiliser. This could be attributed to the fact that farmers in the study area employ many soil enrichment methods for which fertiliser application was part. The other soil enrichment methods utilised by the farmers included the use of animal droppings and plant residues. Thus, though fertiliser is usually applied to enrich the soil, farmers in this study may not be applying it as an adaptation strategy. Leaving residues of crops or plants on the farm to rot and increase soil nutrient was a common practice among the farmers in the study area. Also, the free-range system of farming was common among livestock owners and allowing livestock to roam freely on farmlands leads to increase soil fertility from droppings of these animals.

The results indicate that crop diversity was a negative predictor of adaptation and that households that cultivate more crops were 0.457 times less likely to utilise an adaptation strategy compared to households that did not cultivate more than one crop on their farmlands. Though all farming households in the study practice mixed cropping, cultivating different crops in the same farmland, only 14% (n = 34) of these households claimed to employ this strategy to counteract perceived stressors (*see* Chapter Seven). This may be attributed to the use of mixed cropping, polyculture or intercropping is a common farming practice in the study area.

8.3 Discussion

The results of this study suggest that membership of a social group, use of fertiliser, communication diversity and crop diversity were the key determinants of adaptation to perceived stressors. Membership of a social group was found to be a significant positive predictor of adaptation to stressors. This implies that farmers who belong to a group are more likely to take up an adaptation strategy to respond to perceived climatic and non-climatic stressors. Members of a group tend to share vital agricultural-related information with their colleagues during group meetings. Membership of a group is an example of social capital and that members can provide their colleagues with financial or material supports during times of hardship. The results are consistent with earlier research findings in Ghana, Ethiopia, Nepal, Mozambique, Malawi and Zambia that noted that farmers belonging to an association or social group were more likely to adopt a strategy compared to those who did not belong to a group (Gecho *et al*., 2014; Mango *et al*., 2017, Ndamani & Watanabe, 2016; Piya & Lall, 2013).

Fertiliser usage was observed to have a negative relationship with adaptation strategy. Farmers using fertiliser were less likely to adapt. In the study area, farmers prefer using organic soil enrichment methods such as animal droppings and compost compared to artificial soil enrichment methods such as fertiliser. Communication devices are important tools to inform and raise awareness. Farmers use communication devices to receive weather and agricultural related information (Jost *et al*., 2015), mobile money and to entertain themselves. The results demonstrate that farmers whose households have a higher communication divert were more likely to adapt compared to households with little or no communication diversity index. Using different communication devices provide households with the opportunity to receive information from a variety of sources to inform them (farmers) and help the farmers plan whether to use anticipatory and reactive adaptation strategies.

The results demonstrate households that cultivated more crops were less likely to improve their adaptation strategies. The results, however, contradict with findings of earlier research which observed that crop diversification had a positive and statistically significant relationship with strategies employed by farming households to improve productivity, income and food security in Zimbabwe (Makate *et al*., 2016). Farmers who practice crop diversification would have more crops for sale to improve household income for future investment on farming activities (Mango *et al*., 2018).

8.4 Conclusion

This chapter has shown that farmers' decision to utilise an adaptation strategy is dictated by a number of factors. The results reveal that membership of a social group, use of fertiliser, communication diversity and crop diversity were the key determinants of adaptation among farmers in northern Ghana. While membership of a social group and communication diversity shown a positive and statistically significant relationship with the decision to adapt to stressors, use of fertiliser and crop diversity exhibited a negative and statistically significant relationship with the same. The implication is the policymakers must endeavour to incorporate these factors in the design and implementation of adaptation policies and programmes for farmers in Ghana. The next chapter relates to the role of local institutions and adaptation of farming households.

CHAPTER NINE

LOCAL INSTITUTIONS AND ADAPTATION

9.1 Introduction

This chapter identified institutions which, according to the farmers, provided various supports to them with regard to their farming activities. The chapter also presented the objectives/mandate of these institutions and the kind of support that they provided the farmers. The chapter is constructed into five sections. The first section introduces the chapter, followed by the second section that identifies the role of informal institutions in the study area. The third section identifies the support that the farmers receive from governmental and non-governmental institutions. The fourth section presents the discussion and the last section concludes the chapter.

9.2 The role of informal institutions

The farmers identified families (nuclear and extended), friends and chiefs as those informal institutions that provide support to increase their adaptive capacities in the midst of challenges that they (farmers) encounter daily. This section describes the roles of these informal institutions in building the capacities of farming households to reduce vulnerabilities to climate change and other stressors. It was found out that these institutions did not work in isolation but liaised/interacted with each other to ensure that the farmers' adaptive capacity was built.

9.2.1 Chiefs and elders

In the Dagaaba society, the chieftaincy institution uses traditional rules, customs and taboos to control and manage natural resources. There are two forms of traditional leadership observed: the chiefs and the *tendaanas* or *tengdaana*. The *tendaanas* are said to be the original settlers and therefore, are the custodians of all lands. Ownership of land is not vested in chiefs or individual families but the *tendaana*. He defines the property rights governing the use of lands, and he makes lands available to families and chiefs. They are considered as the spiritual leaders of the people. According to tradition, the *tendaana* is more important than the chief. They sign any land acquisition document and perform traditional or spiritual sacrifices for the chiefs who are the rulers and have administrative powers over the people.

The Lawra Traditional Area (or *Dagaabaland*) is headed by a Paramount Chief (the Lawra *Na*). The traditional area is divided into divisional areas (each having a chief, *Na*), and each divisional area consists of sections or village in which each is headed by a sub-chief. When a chief is absent or capacitated and therefore, cannot discharge his duties, a regent is appointed to act. An example is the Kalsagri community in which the chief works outside the community and therefore, a regent has been selected as a caretaker. The chiefs or reagents do not own the lands in the communities, but they do introduce people (who need land for farming or other purposes) to the custodians of the land, *tendaanas*, or family heads who have lands to lease some for farming. Comparatively, the chief is the first point of contact for individuals or organisations that intend to transact business with the community. In addition, the chief arbitrates and settles conflicts or disputes among members of the community. The chief is also responsible for sanctioning or cautioning individuals who flout traditional rules. The chief or reagent is assisted by heads of extended families, community development chairperson, Assemblyman (or woman)/unit committee member and any other person of good standing in the community.

About 19.6% of household heads indicated that chiefs and elders of their communities have major roles to play to ensure that farmers are given the necessary supports to overcome challenges associated with climate change. The farmers indicated that chiefs and elders provide various supports such as land for farming and settlement, resolution of conflict among feuding parties, and liaising with other institutions to build the capacity of people in the communities.

Chiefs/regents in all the study communities admitted that they have the responsibility to ensure that farmers in their communities were given the necessary supports to enhance their capacities and also help them (farmers) cope with unpredictable rainfall patterns. However, they (regents/chiefs) claimed that they could not provide financial supports to indigenes or settlers but rely on or liaise with governmental and non-governmental organisations to ensure that farmers are supported. The chiefs with the assistance from the community development chairperson and the assemblyman (woman)/unit community member ensure that people in the community participate in communal activities for the betterment of the community. The chief can sanction or disenfranchise families that flouted traditional directives.

Many chiefs in the district are participants of climate change adaptation training and capacity building programmes instituted by governmental and non-governmental organisations. For instance, the chief of Tolibri is a member of the Climate Change, Agricultural and Food Security (CCAFS) platform initiated by the Consultative Group for International Agricultural Research (CGIAR). According to the chief, the platform provides members with the opportunity to learn and dialogue with one another on the issue of climate change adaptation and other related areas. With the support from the Paramount chief of the Lawra Traditional Council, who is also the chair of the Lawra CCAFS platform, inhabitants, particularly the indigenes, have been admonished to stop the felling of trees but instead plant a tree in memory of the departed or upon the birth of a baby in the family. In addition, farmers have been advised to practice non-burning farming practices and utilise compost or manure in farming instead of the use of chemical soil amendment methods.

As in most societies in northern Ghana, the Dagaaba society is patriarchal. The term *patriarch* refers to a social system in which the father or the oldest male member of the family functions as the legal authority of the family. In this case, the wife/wives and children are subordinates and depend on the male head. Inheritance of lands and other properties is through the male line of the family. Female members, and their descendants, in the family, cannot own land or any natural resource from the patriarchal father's line. This kind of social system (and to a large extent the matriarchal system) relegates women to a lower position in the family; even a younger male child assumes a higher position of power than his older female sibling. This system gives the male members an inordinate or a disproportionately large share of power. According to the chief of Dowine, traditionally, women cannot own or inherit portions of their family lands. When a woman is married, she becomes part of her husband's extended family, and there too she cannot own or inherit land, even when her husband dies. It is believed that when a woman was married off, she joined the husband's extended family and helped the husband on his farm. Livestock rearing is reserved for men only. Over time, due to modernity and Christianity, these traditional norms are changing. Presently, women can access land for farming. However, women do not have exclusive rights to the land. That is, women are allocated lands as tenants but not as owners with the exclusive rights. Also, women can also own livestock. However, a married woman is expected to first help her husband in his farm before attending to her farms. This study reveals that 24.5% (n = 36) of married male-headed households have wives who own farms. Crops harvested from the man's farms were mainly for household consumptions. When a woman harvested crops from her farm, she decided what to do with the harvest. She could choose to add to those in the husband's barns or sell them at the market. The money from the sale of her crops belonged to her. However, most women gave a greater proportion of the money to their husbands to support the family.

9.2.2 The family system

The family is a universal socio-biological institution. It is considered the first and the most important social grouping for individuals and societies (WHO, 1978). It is the basic unit of society. Everyone individual in this world belongs to a family. It is the relationship between at least two people who are related by birth, marriage or adoption. As in most societies in Ghana and beyond, there are two distinct families: nuclear family and extended family. The nuclear family consists of two parents (man and wife) and their dependent children, who are either biological or adopted. An extended family is a family unit that is much larger than the nuclear family. The extended family is composed of many nuclear families existing as one unit. It extends beyond the nuclear family to include grandparents, uncles, aunties, nieces, nephews and other relatives. It is built around a unilineal descent group.

As in almost all human societies, two family structures exist in the Lawra District. A nuclear family is a subset of the extended family system and consists of the married couple/unmarried heads and their biological child/children. However, it is difficult to classify a family in the study area as a nuclear family. The nuclear families were found to include at least a relative of either the husband or the wife. Thus, family structure was seen to be extended than nuclear. The living arrangement, which is similar to most communities in northern Ghana, is such that the house is owned by a male head (father) in this case, patriarchal father. The surrounding land serves as farmland, compound farm, where the family (household) cultivates crops and rear livestock mainly for consumption. When the male children are of age and married, they do not leave their father's house but instead build their houses adjoined to that of their father’s to form a larger compound house. These nuclear families constitute the extended family system headed by the patriarchal father. When the female children are married, they leave their father's house and join their husbands' (who also build houses adjoined to their father's). The male children (with their new families) continue to work with their father (on his land). The harvested crops are stored in the father's barns and under the control of the father. Upon the death of the farmer, the farmland is shared among the male children as their inheritance.

The extended family system enhances individual adaptive capacity. The results revealed that 95.4% (n = 229) of sampled households had at least a member who was not a spouse/biological child but a blood relation of the head or spouse of the head. In addition, each household head had, on the average, eight relatives residing in other households in his residential community. Members of the extended family system support each other, and these minimise the effects of climate change and other stressors that individuals in the family face. When disaster strikes, the victims mostly turn to their relatives in other households in the community. There is a division of labour in the household. Most household chores are shared among the women in the extended family. However, in the nuclear family system, the wife is responsible for executing all household chores ranging from bathing the children to collecting fuelwood from the bush to prepare food. Women in the extended family take turns in doing household chores such as cooking food, collecting fuelwood and collecting water from water sources for domestic use. Women are noted for doing much of the farming activities in the rural settings. Resources are pooled together to support educational and health expenses of each family member. That is, the welfare of each member of the extended family system is the responsibility of not only that member or biological parents of that member but every member of the extended family.

In some cases, though the nuclear families unite to live in the same compound house, resources are not pooled together and shared. Each son, his wife and children consist of a nuclear family within the wider extended family. Farmland is divided among the mature male children, and they farm independently of each other. Produce from each one's farm is for him and his small family and he is not under any obligation to share with his brothers' families. However, it was observed the sons help their old parents on their farms and also donate a portion of produce from their (sons') farms to their parents.

Family members who have migrated southwards in search of better opportunities or temporarily due to the harsh dry harmattan season continued to support those left behind through remittances. The money is used to renew health insurance, purchase needed foodstuff, repair buildings, buy medicine or buy farming inputs. Results from the questionnaire survey indicated that 45.4% (*n* = 109) of respondents had a least a member of the household who had migrated southwards. The preferred destinations of these migrants were found to be Accra, Kumasi, Techiman, Kintampo and Wa. Altogether, 217 members from 109 households (sampled households with a least a migrated member) have migrated southwards either permanently or temporarily. About 72.5% (*n* = 79) of the 109 households received remittances from family members who have migrated. Those who migrated temporarily during the dry season returned home, with needed goods and farming inputs, before the onset of the raining season to support farming activities.

It was revealed from the household questionnaire survey (and the FGDs) that members of households who were unable to migrate engaged themselves in non-farming activities to generate income to support the family. Nearly a quarter (24.5%, *n* = 59) of respondents claimed to have at least a member of their households engaged in off-farm income-generating activities. In addition, 18.8% (*n* = 45) of respondents were involved in off-farm income-generating activities. The proportion of female respondents (22.5%) engaged in off-farm income-generating activities was found to be higher than the proportion of the male respondents (17.2%). At the time of the survey, it was found that majority of the off-farm activities in the district were traditionally reserved for women.

9.2.3 Friends

Friendship is defined in this thesis as a socially-defined set of relationships between at least two people who are not related to each other by birth, marriage or adoption, and are committed to providing each other with mutually satisfying companionship, and reciprocal exchanges of intimacy, emotional, material and monetary support. Friendship is another social institution that enhances the adaptive capacity and hence, reduces the vulnerability of an individual to the impacts of climate change and other related hazards. Results from the household survey revealed that 82.5% (n = 198) of respondents claimed to receive some supports from between 1 and 23 friends residing within their communities. Assistance received from members of the communities could be influenced by mutual contributions/exchange or on altruistic grounds. People usually receive support from others based on their material, spiritual, moral and monetary support to others in time past. An altruistic form of assistance occurs when there is a misfortune, such as a bereavement or destruction of one's house or farm by fire, and the number of victims is small. The altruistic form of assistance is not based on the victims' or beneficiaries' contributions to support other victims of a disaster in the past.

In Kalsagri, Dowine and Boo, for instance, it was observed that some members of these communities had formed a social network system to provide monetary support to each other. This is a form of rotating saving and credit system. This support system is prominent among women who are involved in non-farming income generating activities such as pito brewing and fried beans/cowpea cake (*koose*) making. In this system, about 5 to 12 women team up and contribute an equal amount of money which is given to one member to use. The next week, the same contributions are made and presented to the next member to use. The cycle is repeated until every member of the group has received the monetary contribution. This form of interest-free communal contribution among women in the communities is called *Songtaa* ('let's help one another'). This form of social network allowed each member to purchase expensive personal items which would have been difficult for each member.

Another form of friendship support identified among the farmers in the study communities was the formation of a labour group (or communal labour). This is prominent among the male farmers of the same age groups or social status. The farmers come together to constitute a labour group to support each other during land preparation, sowing and harvesting. This reduces the number of hours each farmer and his family would have spent working on the farm unaided. The group also assists each other in seed acquisition and sharing of information on weather and innovative technologies. The labour group network also facilitates barter system/transaction among the farmers. In addition, they assist those who experience food shortage before the next harvesting season with food loans. The beneficiary farmer is expected to repay with crops that he harvests. The labour group also offer their services to other farmers, who are not members of the group and get paid at the end of the day. The money realised is lent to members during a period of difficulties such as payment of school fees, bereavement or ill-health.

9.3 The role of formal institutions

According to sampled farmers, some formal institutions have, over the year, providing them with various supports to enhance their farming activities and also reduce their vulnerabilities to the adverse effects of climate change and other stressors. These formal institutions are categorised as public and private. The private institutions, in this study, were non-governmental organisations (NGOs) working in the study district with the mandate of reducing farmers' vulnerability and improving their livelihood options. The public institutions are governmental organisations or agencies working in the district. About 9% (*n* = 20) and 19% (*n* = 42) of farmers who adapted claimed to have received support from government and NGOs during bad times, respectively. These private institutions work in a concerted and complementary manner to reduce vulnerabilities associated with the harsh conditions in northern Ghana. When asked to mention the institutions that had supported them in the past, the farmers were unable to identify most of the institutions that provided them with the support. However, the farmers were able to identify the projects or services that they had benefited. The following subsections describe the supports and the institutions that provide the supports to the farmers.

9.3.1 Cash transfer programmes

In 2002, the Government of Ghana formulated the first Food and Agriculture Sector Development Policy (FASDEP I) to modernise the agricultural sector and to make it a catalyst for rural transformation and development. The policy was developed in line with the goal set for the sector in the Ghana Poverty Reduction Strategy (GPRS I). The FASDEP II was formulated to replace FASDEP I after it was realised that the first would not be able to achieve the desired impact on poverty among the players in the sector. The FASDEP II was developed to guide development and investment in food and agriculture in Ghana. The FASDEP II sought to provide a framework guide to enhance the environment for all categories of farmers while targeting poor and risk-prone and risk-averse producers (MoFA, 2007). The FASDEP II has six policy objectives: 1) food security and emergency preparedness; 2) improved growth in incomes; 3) increased competitiveness and enhanced integration into domestic and international markets; 4) sustainable management of land and environment; 5) science and technology applied in food and agriculture development, and 6) improved institutional coordination.

The policy document on FASDEP II is silent on climate change and its impacts on the agricultural sector. However, the development of FASDEP II has been instrumental in the formulation of Livelihood Empowerment against Poverty programme (LEAP), National Health Insurance Scheme (NHIS), School Feeding Programme, Ghana Social Opportunities Project (GSOP) and Labour-Intensive Public Works (LIPW).

According to the respondents (from the household survey and FGDs), they have been receiving money from the government through the Livelihood Empowerment against Poverty programme (LEAP). LEAP is a social cash transfer programme instituted by the Government of Ghana in 2008 to provide cash and health insurance to the poorest and most marginalised groups or households in the country to alleviate short-term poverty and encourage long-term human capital development (Handa *et al*., 2013). The programme is funded by the Government of Ghana with support from the World Bank, United Kingdom Department for International Development (DFID) and the United Nations International Children's Emergency Fund (UNICEF). LEAP eligibility is based on poverty which is defined by the presence in a poor household an individual who is at least an older adult (65 years and above) without support, orphan, severely disabled and cannot work, and pregnant woman or a nursing mother.

LEAP methodologies include cash grant and complementary services especially in the area of health such as registering and paying the premium for the National Health Insurance Scheme (NHIS) and public work supports (LEAP is one of the prerequisites for the Ghana Social Opportunities Project, GSOP) for children over the age of 16 years within an impoverished household. The conditionalities of LEAP include (1) all children within a beneficiary household must attend school; (2) such children must not be trafficked within and outside the community; and (3) pregnant women must attend ante-natal care.

The Department of Social Development (DSD), formerly called the Department of Social Welfare (DSW), of the Ministry of Gender, Children and Social Protection (MoGCSP) was cited by respondents (from household survey and FGDs) as the public or state institutions that have been providing services or supports to enhance farming households' adaptive capacity to cope the adverse effects of climate change and related hazards. The DSD, as part of its mandates, has been responsible for handling social intervention programmes such as the Livelihood Empowerment against Poverty programme (LEAP) and the National Health Insurance Scheme.

Since its inception, LEAP has covered 59 communities with 4,391 beneficiary households in the Lawra District (*Interview with Head of DSW, Lawra*). There are 2,568 persons with disability (PWDs) in the district, and they constitute 4.7% of the entire population in the district (GSS, 2014). Information made available at the time of this study indicated that 888 PWDs have been registered and have benefited from the LEAP. The Lawra Area Rural Bank is the participating bank for the disbursement of money to the beneficiaries.

Another social intervention programme that farmers claimed to have benefited is the Ghana Social Opportunities Project (GSOP) which is managed by the Planning Unit in conjunction with the DSD of the district assembly. GSOP is one of the pro-poor programmes launched by the Government of Ghana, with support from the World Bank, to provide financial assistance to poorer households in the rural settings. Like the LEAP, GSOP was designed to help achieve the goal of the National Social Protection Strategy (NSPS) of providing "policy direction in the protection of persons living in situations of extreme poverty, vulnerability and exclusion from both expected and unanticipated threats to their livelihoods, with a view to making them effective participants in the socio-economic development of the country" (MMYE, 2007).

Unlike the LEAP, GSOP uses the Labour-Intensive Public Works (LIPW) concept where targeted poor rural households are provided with off-farm income-generating opportunities during the non-farming dry season periods from October to February. The selected poor rural households are usually those that are already on the LEAP platform. The selected households are engaged for 6 hours per day in rehabilitation and maintenance of rural feeder and access roads; rehabilitation of dams, dug-outs and irrigation systems; soil and water conservation activities such as tree planting; and any other public work activities with high labour intensive. Payment of wages is usually made every fortnight (2 weeks) after the completion of the work (*Interview with the head of the District Planning Unit*, 2017).

The GSOP has gender considerations in the eligibility of beneficiaries. According to the head of the District Planning Unit, the project demands that women constitute at least 50% of the total workforce; women should not be made to work for more than 6 hours in a day and should be involved in the early part of the day's work; women should not be made to work in high-risk areas; pregnant women should not be made to work on plants or equipment that vibrate; and lactating mothers who are beneficiaries should enjoy at least 3 months maternity leave with full wage.

Another public institution that respondents cited as having provided them with some supports was the District Office of the Ministry of Food and Agriculture (MoFA). The services provided by MoFA included formal extension services, veterinary services, micro-irrigation support, weather information (liaise with Ghana Meteorological Agency), distribution of improved crop varieties and subsidised fertilizers, farm credit facility and training on bushfire prevention (liaise with the district offices of the Ghana Fire Service (GFS), National Disaster Management Organization (NADMO), and the Forestry Commission (FC)). With regard to the credit facility, according to an official of MoFA (*interviewed*), farmers were encouraged to come together and constitute a group. MoFA then guarantees for these groups of farmers, mostly groundnut farmers, to receive financial support from the rural bank. Financial institutions are unwilling to lend money to individual farmers in the district because of the high risks associated with farming. The risks, according to the MoFA official, come from the unpredictable nature of rains, bushfires from the harsh hot weather and crop destruction from pests and diseases. Farmers in groups share the cost of the credit facility.

The challenges facing MoFA in executing its mandates, as enumerated by the official, include inadequate staffing; ageing staff; lack of logistics; political interference; and farmers' refusal to accept new and innovative farming techniques. With regards to the issue of staffing, new staff have not been recruited into the sector to replace the retired ones. Many of the existing staff are old and nearing retirement age. These ageing staffs lack vigour and motivation of move to the farming communities to provide extension services. The office does not have adequate means of transports and office equipment. In addition, there is political interference in the distribution of subsidised fertilisers and other farming inputs. Lastly, many farmers in the district, by their lack of formal education, still consider farming as a culture and not as a business. The farmers always refuse to adopt innovative farming techniques and continue to rely on basic methods passed on to them by their fathers or forbearers.

9.3.2 Improved livelihood options

Farmers claimed (from the household survey and FGDs) to have received support from a governmental and NGOs for the enhancement of their livelihood options. The farmers recalled receiving some livestock, either goats or sheep, in the form of a loan from an NGO under the *Resilient and Sustainable Livelihood Transformation* (RESULT) project. Under this scheme, the beneficiary farmer is expected to increase the number of the livestock received and then return some young livestock same as initially received to the officials of the NGO. The young livestock is given to another farmer to rear over time. The process is repeated until a number of farmers have received livestock through this scheme. After paying off the loan (in the form of returning the younger livestock to RESULT), the farmer is given full property rights over the remaining livestock. The livestock not only act as a potential source of income (when sold) but the droppings are used to enrich the soil of farms. In addition, ownership of livestock is translated as a measure of prestige or affluence in most communities.

RESULT is a 6-year (2012 – 2018) project instituted by the Association of Church-based Development Projects (ACDEP). ACDEP is a Ghanaian non-governmental organisation in partnership with the Canadian Feed the Children (CFTC) with support from the Government of Canada to increase food security and resilience among food insecure and vulnerable households in the Talensi, Bongo, Nabdam, Kassena-Nankana West and Kassena-Nankana Districts in the Upper East Region and Jirapa and Lawra Districts in the Upper West Region. The project also provided farmers with highly subsidised fertilisers and other farming inputs. In addition, the project offers vocational skills training to the women in the areas of soap making, shea butter making and batik. This training is to build the capacities of women to engage in off-farm non-climate sensitive income-generating ventures to augment household income.

9.3.3 Provision of drinking water

In the semi-arid environments like the Lawra District, availability of water for drinking and other purposes, particularly during the dry harmattan season, is paramount to both farmers and non-farmers. Water is an important determinant of what farmers can do at any point in time. Availability of water determines when farming season starts, when farming season ends, the type of crops to cultivate and the kind of animals to rear. The quantity and quality of water available are directly and indirectly linked to achieving the objectives of the Sustainable Development Goals (SDGs), particularly Goal 6 (to ensure availability and sustainable management of water and sanitation for all). Water scarcity affects everyone especially women and children (girl-child). Generally, in most households, women are the collectors and managers of water. Women must ensure that there is enough water available for all domestic purposes. Women have to trek for long distances to the next available water source to provide water for household use. Water scarcity can generate conflicts among households and even communities. Drinking water of poor quality is a source of diseases.

About 95% of sampled households claimed to depend on boreholes as sources of domestic water supply. The remaining households depended on unimproved water sources such as dugout wells and streams. According to the farmers (from the FGDs), the boreholes were constructed by the government of Ghana and some NGOs. The government supported the construction of the boreholes through the GSOP programme, where the people in the communities were engaged in the construction and were paid daily wages. The farmers identified Community Water Project (COWAP) of the Canadian International Development Agency (CIDA), Pronet North, Global Water Initiative (GWI), Catholic Relief Service (CRS) and Care International. At the time of data collection, between 20% and 50% of boreholes in the study communities were found to be dysfunctional and therefore, many households depended on bagged water (sachet) for drinking purposes.

9.3.4 Weather information

Access to timely weather information is critical for the farmers to plan planting strategies and also use crop varieties that are tailored for specific weather conditions in a given time frame. Weather forecasting allows farmers to prepare and apply the necessary strategies to achieve the maximum outcome. Results from the household survey revealed that 35.0% (*n* = 84) of farmers interviewed have access to weather information and these farmers used the information in their farming activities.

The farmers who have access to weather information cited some governmental and non-governmental institutions as the sources of the weather information. For instance, about two-thirds (67.9%) of these farmers claimed to depend on radio stations in Lawra (Westlink FM) or elsewhere (such as Radio Progress and Radio Upper West at Wa) for weather information. These radio stations depended on the Ghana Meteorological Agency, which has weather stations in the Lawra District (at Babile and Lawra) and Wa, the regional capital, for weather forecast which is then relayed to farmers via radio. In addition, 15.5% of the farmers with access to weather information depended on television networks. The farmers used decoders to receive digital satellite broadcasts from numerous television stations from Accra and Kumasi.

Nearly a third (32.1%) of the farmers who have access to weather information, claimed to receive the information on their mobile phones via *ESOKO* platform. *ESOKO* is a non-governmental organisation established in 2005 to provide agricultural information to farmers and to help improve rural farming communities across Africa. *ESOKO* relayed weather forecast to farmers on their mobile phones. All that a farmer needed to do was to call the *ESOKO* call centre (using a short code), and the relevant information requested by the farmer was sent (via SMS) to the farmer's mobile phone. The *ESOKO* platform also allowed farmers to access other agricultural related information such as prices of commodities as well as where to buy seeds and fertilisers at affordable prices.

9.3.5 Provision of subsidised fertiliser and improved seeds

Farmers apply growth promoters, such as inorganic fertilisers, to spur crop production. This study revealed that 55.0% (*n* = 132) of sampled farmers used fertiliser as a response to climatic and non-climatic stressors such as low rainfall, poor soil fertility, cost of fertiliser, lack of fertiliser, lack of money and low yield. Though farmers could purchase fertilizer from the open market or receive from some NGOs, application of fertiliser by farmers has increased since the re-introduction to subsidised fertiliser by the government in the year 2008 after the subsidy programme was suspended in the 1990s following the Structural Adjustment Programme (SAP) (Fearon *et al*., 2015). The distribution of subsidised fertiliser has been a public-private partnership. Private companies (called dealers) applied for a license from MoFA to become distributors of subsidised fertiliser at the district level.

Despite the intention of the programme to provide farmers with fertiliser at subsidised prices to sustain household food security and improve household income, there are challenges associated with the programme. The programme has been highly political with government officials, and political agents involve in the supply and distribution to score political points. Furthermore, the distribution of fertiliser seemed to target farmers associated with the incumbent government instead of its being universally distributed with the apolitical lens. Also, the dealers of fertilisers at the district level complained of the delay on the part of the government to make payment on time. The quote below illustrates the sentiments from a subsidised fertiliser dealer in the district:

To become a dealer, one has to apply with MoFA and given the license to distribute the subsidised fertiliser to farmers at the district level. We buy the fertiliser from the open market at GH¢95.00 or GH¢100.00 per bag. At times, we have to buy the bags from Tamale or Kumasi and bring them to the district to be given to farmers who have the fertiliser coupons at a government agreed price of GH¢57.50. The government then pays the dealer the difference when the dealer submits the coupon and payment request. The government always delays making payment to the distributors, and this affects their work. In addition, the cost of transport and the risks of travelling are not factored in the price to the farmers.

Another support farmers claimed to receive from the government through MoFA was the supply of improved crop varieties. Information from the household survey showed that 57% (n = 125) used improved crop varieties to respond to low rainfall, late onset of rains, short duration of rains, lack of money, and insufficient food. The crop varieties used by the farmers include 90- to 120-day varieties, drought-resistant varieties and pest-resistant varieties. The varieties including early-maturing maize varieties such as *Obaatanpa*, *Okomaso* and *Oburotia* allowed farmers to increase food production in the midst of climate change and variability. These crop varieties were introduced to farmers after trial tests by research institutions such as Savannah Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR). SARI has the mandate to provide farmers in northern Ghana with appropriate technologies to boost food and fibre crop production.

9.4 Discussion

The results show that farmers in the study area recognised formal and informal local institutions as playing various roles in building capacities in the midst of a constellation of stressors shaping their livelihood options. This section discusses the results for roles of institutions in enhancing the adaptive capacities of farmers in the Lawra District.

According to Yaro *et al*.(2015), both formal and informal institutions play synergistic roles to ensure a much conducive environment for farming households to work. The results show that farmers, without prompting, cited chiefs and elders, family (nuclear and extended) and friends as being the informal institutions, and governmental and non-governmental (NGO) organisations as being the formal institutions providing various supports to help them (farmers) cope with the impacts of climate change. The results demonstrate that chiefs and elders of the farming communities ensure that property rights associated with ownership and use of farmlands are not under threat of involuntary seizure or encroachment. The chieftaincy institutions also ensure that local beliefs, customs and taboos that shape individuals in the communities are respected. However, certain customs such as the patrilineal system of inheritance appear as a disincentive to women. In this system, women can neither inherit their fathers' lands nor that of their husbands. This custom gives the men an inordinate power over female members of their households.

The family system, whether nuclear or extended, has been found to be important in enhancing the adaptive capacities. Family members support each other during bad times, such as illness, death and disaster, and good times, such as marriage and the birth of a child. While family support was expected to be altruistic; it was found that there were instances where the support had been reciprocal. In the past, the family system was such that farmlands were collectively own and under the power of a male patrilineal head (grandfather or father). Male-heads lived on the same land and adjoined their houses to that of their fathers to form a large compound house. The people in this compound house farmed on the same land and used the same kitchen. Harvested crops were either shared or collected consumed under the direction of the patrilineal head. Women shared household chores and took care of each other's children. However, modernity is eroding these benefits. The extended family system is gradually giving way to the nuclear family system.

Friendship is another informal institution observed to provide support for farmers to overcome the effects of climate change. Through friendship, farmers were able to provide farmer-farmer extension advice, small loans and communal farm services to one another. Friends also provided altruistic support to each other in times of disaster or misfortunes. However, friendship based on reciprocity could result in the formation of exclusive clubs that would eventually create wealth gaps among farmers.

Farmers in the study district acknowledged receipt of support from government agencies and NGOs. This support according to the farmers included cash transfer support, training, dissemination of weather information and market prices, provision of subsidised fertiliser and improved crop varieties and off-farm vocational skills. Government agencies support for the farmers depended on policies and programmes of the central government. The NGOs support to the farmers were constrained by the mandates of the donor agencies as well as the policies of the government. The sustainability of the support from the formal institutions, particularly at the end of the project cycle was of great concern to the farmers.

9.5 Conclusion

This chapter has shown that institutions, both formal and informal, are important for the farmers to cope with climate change and other factors that impede the progress of local agricultural development. The informal institutions that are important to the farmers in the district are the nuclear family, extended family, chieftaincy and friends. The chieftaincy institutions ensure that property rights associated with ownership and use of farmlands are not under threat of involuntary seizure or encroachment. The chieftaincy institutions also ensure that local beliefs, customs and taboos that shape individuals in the communities are respected. However, certain customs such as the patrilineal system of inheritance appear as a disincentive to women. In this system, women can neither inherit their fathers' lands nor that of their husbands. This custom gives the men an inordinate power over female members of their households.

The family system, whether nuclear or extended, has been found to be important in enhancing the adaptive capacities. Family members support each other during bad times, such as illness, death and disaster, and good times, such as marriage and birth of a child. While family support was expected to be altruistic; it was found that there are instances where the support has been reciprocal. In the past, the family system was such that farmlands were collectively own and under the power of a male patrilineal head (grandfather or father). Male-heads live on the same land and adjoin their houses to that of their father's to form a large compound house. The people in this compound house farm on the same land and use the same kitchen. Harvested crops are either shared or collected consumed under the direction of the patrilineal head. Women share household chores and take care of each other's children. However, modernity has eroded the benefits of this system. The extended family system is gradually giving way to the nuclear family system.

Friendship is another informal institution observed to provide support for farmers to overcome the effects of climate change. Through friendship, farmers have been providing farmer-farmer extension advice, small loans and communal farm services to one another. Friends also provide altruistic support to each other in times of disaster or misfortunes. However, friendship based on reciprocity could result in the formation of exclusive clubs that would eventually create wealth gaps among farmers.

Farmers in the study district acknowledged receipt of support from government agencies and NGOs. This support according to the farmers included cash transfer support, training, dissemination of weather information and market prices, provision of subsidised fertiliser and improved crop varieties and off-farm vocational skills. Government agencies support for the farmers depended on policies and programmes of the central government. The NGOs support for the farmers is constraint by the mandates of the donor agencies as well as the policy of the government. The sustainability of the support from the formal institutions, particularly at the end of the project cycle is of great concern.

CHAPTER TEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

10.1 Introduction

This chapter summarises the major findings and advances recommendations out of the study. Agriculture remains the mainstay of the economy of Ghana and other countries in sub-Saharan Africa. Farming households in Ghana and beyond play critical roles to ensure availability of food all year round. However, these farmers work in a multi-dimensional risk environment influenced by both climatic and non-climatic stressors. These stressors interact to exacerbate the existing vulnerability and influence the adaptation process of these farmers. There is a limited but growing body of literature exploring the role of climatic and non-climatic stressors in determining the vulnerabilities of households as well as adaptation strategies employed by these households.

This study aimed to explore the role of climatic and non-climatic stressors in shaping the vulnerability of farming households, and the adaptation strategies used by these households in semi-arid Ghana. The study used explanatory sequential mixed-method approach to:

1) Identify current and future perceptions and ranking of climatic and non-climatic stressors by farmers, and how these differ by sex of household heads;
2) Compare actual and perceived climatic and non-climatic stressors;
3) Investigate exposure, sensitivity, adaptive capacity and vulnerability of farming households to climatic and non-climatic stressors;
4) Assess the different adaptation strategies utilised by farming households in relation to climate change and non-climatic stressors;
5) Establish the relationship between vulnerability and adaptation to climatic and non-climatic stressors; and

6) Explore the role of local institutions in strengthening the adaptive capacity of farming households and reduce vulnerability to climate change and non-climatic stressors.

10.2 Summary of the major findings

10.2.1 Current and future perception and ranking of climatic and non-climatic stressors

The results from the study indicated that, farmers identified 7 climatic and 22 non-climatic stressors affecting their farming and household activities. The farmers identified low rainfall, heavy rainfall, short duration of rains, late onset of rains, high temperatures, strong wind and dust. The identified non-climatic stressors included lack of money, crop pests, felling of trees, fertiliser (cost/lack), livestock (death, diseases, and theft), low yield, poor soil fertility and post-harvest losses. Male-headed households identified 29 stressors while female-headed households identified 28 (lack of irrigation facility). Thus, perceived stressors were commonly identified by both male- and female-headed households. The results, therefore, confirm with previous studies that farmers in Ghana (Antwi-Agyei *et al*., 2017; Nyantakyi-Frimpong & Bezner-Kerr, 2015), sub-Saharan Africa (Tschakert, 2007) and beyond (Cradock-Henry, 2011) work in a multi-dimensional risk environment characterised by the presence of both climatic and non-climatic stressors.

By ranking, the farmers cited low rainfall as the climatic stressor presenting the greatest challenge to farm productivity as well as household activities. Lack of money was the most important non-climatic stressor affecting farming and household activities. Majority of farmers predicted the occurrence of low rainfall and lack of money in the next decade. Farmers' knowledge of the causes of climatic and non-climatic stressors were informed by scientific information and their belief in supernatural beings. Also, the perceived stressors were, according to the farmers, also caused by other perceived stressors and this, therefore, indicates farmers' understanding of the interconnection among the stressors.

10.2.2 Actual and perceived climatic and non-climatic stressors

Using a 30-year rainfall and temperature data, obtained from the Ghana Meteorological Agency's weather station at Babile, the perception of farmers with respect to rainfall and temperature was compared. The results, further, demonstrated that analyses of the long-term rainfall and temperature trends confirmed farmers' perceptions of the changing state of the local climate. This implies that the farmers without scientific instruments could perceive changing trends of rainfall and temperature. This resonates with Gbetibouo (2009) that the perception of farmers in South Africa agreed to climate records.

In addition, the study attempted to compare the farmers' perception of non-climatic stressors with scientific data. Soil samples were collected from four farms from each of the six communities. The results revealed that farmers' perception of poor soil fertility could not be supported by the results of the soil test. Thus, the study concluded that farmers' perception may not always be explained by scientific information.

10.2.3 Exposure, sensitivity, adaptive capacity and vulnerability to climatic and non-climatic stressors

Using proxy indicator variables, which were based on literature, to defined exposure, sensitivity and adaptive capacity indices, the vulnerability status of farming households and communities in the study district was determined. The indicator variables were normalised, and weights were assigned to the variables to reflect their relative importance to vulnerability index. A k-means cluster analysis was performed on the overall vulnerability index to categorise households and communities into three (3) vulnerability clusters: *less*, *moderately and highly*. The results of the cluster analysis revealed that 22.5%, 45.8% and 31.7% of households belonged to the less, moderately and highly vulnerability clusters, respectively.

Exposure, sensitivity, adaptive capacity and vulnerability indices differed significantly amongst the study communities. Dowine was the least vulnerable community and had the highest proportion of households within the low vulnerability cluster. Zakpee was the most vulnerable community and had the highest proportion of households in the high vulnerability cluster.

10.2.4 Households' adaptations to perceived stressors

The study revealed that 91.7% (n = 220) of farming household adapt to climatic and non-climatic stressors while 8.3% (n = 20) of farming households did not adapt. Farmers' decisions to employ adaptation strategies were influenced by their perceptions. None of the farmers was found to use a strategy to respond to lack of irrigation facility. Out of the 36 adaptation strategies, 12 were used for climatic stressors and 30 used for non-climatic stressors. Majority of the adaptation strategies were used to respond to more than a single perceived stressor. The results demonstrated that 16 adaptation strategies were most important strategies while 17 adaptation strategies were easier to use.

The study, further, reveals that some of the adaptation strategies utilised by the farmers may, in the long run, lead to maladaptation. Continuous felling of trees, especially by women, as firewood for cooking, heating and sale to raise household income will reduce the sink function of the environment to capture and store carbon dioxide from the atmosphere.

10.2.5 Vulnerability and adaptation

Employing the variables used to compute the vulnerability index, the study attempted to link the vulnerability of households to adaptation to stressors. The vulnerability variables were used for the independent variables whiles decision to adapt or not to adapt was used as the dependent variables. Binary logistic regression was performed which revealed that membership of a group, crop diversity, communication diversity and use of fertiliser were key determinants of farming households' adaptation decision. Thus, policymakers and stakeholders must consciously endeavour to incorporate these factors into the design and implementation of adaptation policies.

10.2.6 Institutions and adaptive capacity of farmers

The study revealed that the farmers in the study district did not adapt to climate change in isolation from institutional arrangements and supports. The informal institutions, as identified by the sampled farmers, were chieftaincy, extended and nuclear families, and friendship. The formal institutions were NGOs, private enterprises and governmental agencies with mandates on climate change and operate within the district.

The chieftaincy institutions ensure that beliefs and customs were used to shape people's worldview and their relationship with the supernatural powers and the environment. However, the study revealed that some of the customs were a disincentive to women. For instance, the custom that women cannot inherit family lands tends to reduce the adaptive capacity of women. Families and friends were found to provide various supports to help each other to cope with the harsh environmental conditions in the study area. The supports come in different forms such as spiritual, material, financial and emotional support.

The formal institutions were found to liaise with each other as well as with the informal institutions to ensure that the adaptive capacities of the farmers were enhanced. The private-public partnership exists between the governmental and non-governmental institutions, and this healthy relationship ensures the smooth dissemination of vital information (including weather information), distributions of agricultural inputs, and training of farming households. This is especially so with the distribution of improved seeds and subsidised fertilisers. The operations of the formal institutions cannot be without challenges. The MoFA office in the district expressed challenges of inadequate staffing, ageing staff (aggravated by the suspension of recruitment by the government), inadequate logistics, political interference, and farmers' refusal to accept new and innovative farming techniques.

10.3. Limitations of the study and areas for further research

The vulnerability assessment of households and communities in the study district used the number of perceived stressors as one of the two proxy indicator variables for the exposure index due to the absence of meteorological data at the household or community levels. Though the information provided in this thesis is insightful, future studies should incorporate changes in precipitation and temperature for exposure index. Also, this thesis analysed vulnerability at household and community level within a district in one agro-ecological zone, and therefore, the results did not allow for the perspectives and comparison of households' vulnerability across different scales (households, communities, district and regional) and agro-ecological zones. Future studies across different scales and agro-ecological zones would yield more sound results and have a more significant influence on policy direction.

The other limitation was the use of open-ended questions that did not restrict or limit the number of stressors that sampled farmers could make. Though the information in this study with regards to perceived stressors was insightful and sound, the analyses of responses to open-ended-questions were tedious and time-consuming. Future studies should attempt to incorporate the vulnerability of different social groups in the farming communities to specific stressors.

10.4 Conclusion

The empirical evidence provided in this thesis has led to the following conclusions:

1. Farmers in the Lawra District provided a wide range of multiple climatic and non-climatic stressors that they deemed to have severely affected the farming as well as household activities.
2. Farmers in the district were aware of the causes of the multiple climatic and non-climatic stressors as well as the adaptation strategies needed to be employed to overcome these stressors.
3. Scientific data support Farmers' perception of climate change.
4. The vulnerability of households can be determined and used in policy decision.
5. Exposure, sensitivity, adaptive capacity and vulnerability indices differ significantly across communities. Adaptation strategies utilised by the farmers were not to deal with only climate change but to deal with both climate change and other stressors. However, some adaptation strategies may lead to maladaptation.
6. Membership of a social group is the major determinant of adaptation.
7. Local, governmental and non-governmental institutions influenced the capacity of farmers to deal with the effects of climate change.

10.5 Recommendations

Climate change is real, and its impacts affect farmers in the semi-arid setting. The study has revealed that both climatic and non-climatic factors influenced activities of farming households. It is therefore, recommended that interventions designed, by MoFA and other governmental agencies with mandate in agriculture, to tackling the impact of climate change and variability should also consider and integrate the dynamics of non-climatic factors that could affect farming and other activities in the study area.

Women are considered as most vulnerable and therefore many policy interventions designed and implemented tend to be woman-centred and therefore, relegating the needs of men to the background. However, the results of this thesis have shown that other groups of men are equally vulnerable. Consequently, it is recommended that interventions by governmental institutions such as MoFA and MGLRD, and non-governmental institutions that have the potential to reduce vulnerability and poverty should target both men and women.

Government policies should strengthen existing adaptation strategies practice by farmers to counteract current and future climate change and other stressors. The government of Ghana, through its agencies such as MoFA, should also support farmers' adoption of innovative technologies that have the potential to reduce farm level vulnerabilities as well as household vulnerabilities. Farmers need support for innovative technologies such as the use of irrigation facilities, improve crop varieties, application of fertilisers, and access to up-to-date weather information.

Given that human activities such as felling of trees are the major drivers of climate change and non-climatic stressors (as identified by the farmers), more efforts should be made to implement and enforce environmental protection and conservation policies and by-laws to prevent the continuous destruction of ecosystems so that the services provided by the ecosystems could be secured.

Farmers should join or form associations and groups so that they (farmers) can access financial and material supports from MoFA, MLGRD and other non-governmental institutions that can influence agricultural productivity.

Lastly, the government must, as a matter of urgency, improve activities of its supporting agencies, such as MoFA, Ghana Meteorological Agency (GMA) and National Disaster Management Organisation (NADMO), at the district level. Provision of adequate logistics and recruitment of young and experienced officers to replace the ageing ones at the district level is essential in enhancing the adaptive capacities of farmers to reduce household and farm level vulnerabilities.

REFERENCES

Abdulla, F., Eshtawi, T., & Assaf, H. (2009). Assessment of the impact of potential climate change on the water balance of a semi-arid watershed. *Water Resources Management*, *23*(10), 2051–2068. https://doi.org/10.1007/s11269-008-9369-y

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. https://doi.org/http://dx.doi.org.ezproxy.royalroads.ca/10.1016/j.gloenvcha.2006.02.006

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., … Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linde, & C. E. Hanson (Eds.), *Climate Change 2007: Working Group III: Mitigation of Climate Change* (pp. 717–744). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.004

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, *15*(2), 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Agrawal, A. (2008). *The role of local institutions in adaptation to climate change* (International Forestry Resources and Institutions Program No. Working Paper, # W08I-3). Ann Arbor. Retrieved from http://www.umich.edu/~ifri/Publications/W08I3 Arun Agrawal.pdf

Ahmed, A., Lawson, E. T., Mensah, A., Gordon, C., & Padgham, J. (2016). Adaptation to climate change or non-climatic stressors in semi-arid regions? Evidence of gender differentiation in three agrarian districts of Ghana. *Environmental Development*, *20*, 45–58. https://doi.org/10.1016/j.envdev.2016.08.002

Ajibade, I., McBean, G., & Bezner-Kerr, R. (2013). Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. *Global Environmental Change*, *23*(6), 1714–1725. https://doi.org/10.1016/j.gloenvcha.2013.08.009

Aleksandrova, M., Lamers, J. P. a, Martius, C., & Tischbein, B. (2014). Rural vulnerability to environmental change in the irrigated lowlands of Central Asia and options for policy-makers: A review. *Environmental Science and Policy*, *41*, 77–88. https://doi.org/10.1016/j.envsci.2014.03.001

Amara, D. M. K., Patil, P. L., Kamara, A. M., & Saidu, D. H. (2016). Assessment of Soil Fertility Status Using Nutrient Index Approach. *Academia Journal of Agricultural Research*, *6*(3), 1–15. https://doi.org/10.15413/ajar.2017.0303

Amaru, S., & Chhetri, N. B. (2013). Climate adaptation: Institutional response to environmental constraints, and the need for increased flexibility, participation, and integration of approaches. *Applied Geography*, *13*, 128–139. https://doi.org/dx.doi.org/10.1016/j.apgeog.2012.12.006

Amekudzi, L., Yamba, E., Preko, K., Asare, E., Aryee, J., Baidu, M., & Codjoe, S. N. A. (2015). Variabilities in Rainfall Onset, Cessation and Length of Rainy Season for the Various Agro-Ecological Zones of Ghana. *Climate*, *3*(2), 416–434. https://doi.org/10.3390/cli3020416

Antwi-Agyei, P., Dougill, A. J., Fraser, E. D. G., & Stringer, L. C. (2013). Characterising the nature of household vulnerability to climate variability: Empirical evidence from two regions of Ghana. *Environment, Development and Sustainability*, *15*(4), 903–926. https://doi.org/10.1007/s10668-012-9418-9

Antwi-Agyei, P., Dougill, A. J., & Stringer, L. C. (2014). Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. *Climate and Development*, *5529*(January), 1–13. https://doi.org/10.1080/17565529.2014.951013

Antwi-Agyei, P., Fraser, E. D. G., Dougill, A. J., Stringer, L. C., & Simelton, E. (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography*, *32*(2), 324–334. https://doi.org/10.1016/j.apgeog.2011.06.010

Antwi-Agyei, P., Quinn, C. H., Adiku, S. G. K., Codjoe, S. N. A., Dougill, A. J., Lamboll, R., & Dovie, D. B. K. (2017). Perceived stressors of climate vulnerability across scales in the Savannah zone of Ghana: a participatory approach. *Regional Environmental Change*, *17*(1), 213–227. https://doi.org/10.1007/s10113-016-0993-4

Arms, K. (1996). *Environmental Science*. Orlando, Florida: Holt, Rinehart and Winston, Inc.

Asante, F., & Amuakwa-Mensah, F. (2014). Climate Change and Variability in Ghana: Stocktaking. *Climate*, *3*(1), 78–99. https://doi.org/10.3390/cli3010078

Asfaw, S., Mccarthy, N., Lipper, L., Arslan, A., Cattaneo, A., & Kachulu, M. (2014). *Climate variability, adaptation strategies and food security in Malawi* (ESA Working Paper No. 14–08). *ESA Working Paper No. 14-08.* Rome.

Baird, J., Plummer, R., & Pickering, K. (2014). Priming the governance system for climate change adaptation: The application of a social-ecological inventory to engage actors in Niagara, Canada. *Ecology and Society*, *19*(1). https://doi.org/10.5751/ES-06152-190103

Baumgard, L. H., Rhoads, R. P., Rhoads, M. L., Gabler, N. K., Ross, J. W., Keating, A. F., … Sejian, V. (2012). Impact of Climate Change on Livestock Production. In V. Sejian, S. M. K. Naqvi, T. Ezeji, J. Lakritz, & R. Lal (Eds.), *Environmental Stress and Amelioration in Livestock Production*. Berlin, Germany: Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29205-7

Bawakyillenuo, S., Yaro, J. A., & Teye, J. (2016). Exploring the autonomous adaptation strategies to climate change and climate variability in selected villages in the rural northern savannah zone of Ghana. *Local Environment*, *21*(3), 361–382. https://doi.org/10.1080/13549839.2014.965671

Belliveau, S., Smit, B., & Bradshaw, B. (2006). Multiple exposures and dynamic vulnerability: Evidence from the grape industry in the Okanagan Valley, Canada. *Global Environmental Change*, *16*(4), 364–378. https://doi.org/10.1016/j.gloenvcha.2006.03.003

Berman, R. J., Quinn, C. H., Paavola, J., Berman, R. J., Quinn, C. H., & Identifying, J. P. (2015). Identifying drivers of household coping strategies to multiple climatic hazards in Western Uganda : implications for adapting to future climate change.

Climate and Development, *7*(1), 71–84. https://doi.org/10.1080/17565529.2014.902355

Berrang-Ford, L., Ford, J. D., & Paterson, J. (2011). Are we adapting to climate change? *Global Environmental Change*, *21*(1), 25–33. https://doi.org/10.1016/j.gloenvcha.2010.09.012

Berry, P. M., Rounsevell, M. D. A., Harrison, P. A., & Audsley, E. (2006). Assessing the vulnerability of agricultural land use and species to climate change and the role of policy in facilitating adaptation. *Environmental Science and Policy*, *9*(2), 189–204. https://doi.org/10.1016/j.envsci.2005.11.004

Bhatta, G. D., Aggarwal, P. K., Kristjanson, P., & Shrivastava, A. K. (2016). Climatic and non-climatic factors influencing changing agricultural practices across different rainfall regimes in South Asia. *Current Science*, *110*(7), 1272–1281. Retrieved from http://www.currentscience.ac.in/Volumes/110/07/1272.pdf

Blanc, E. (2012). The Impact of Climate Change on Crop Yields in Sub-Saharan Africa. *American Journal of Climate Change*, *1*(1), 1–13. https://doi.org/10.4236/ajcc.2012.11001

Boansi, D. (2017). Effect of Climatic and Non-Climatic Factors on Cassava Yields in Togo: Agricultural Policy Implications. *Climate*, *5*(2), 28. https://doi.org/10.3390/cli5020028

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., … Yanda, P. (2007). Africa. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution ofWorking Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 433–467). Cambridge, United Kingdom: Cambridge University Press.

Briguglio, L., Cordina, G., Farrugia, N., & Vella, S. (2009). Economic Vulnerability and Resilience: Concepts and Measurements. *Oxford Development Studies*, *37*(3), 229–247. https://doi.org/10.1080/13600810903089893

Brooks, N. (2003). *Vulnerability, risk and adaptation: A conceptual framework. Working Paper 38*. Norwich, UK. Retrieved from papers2://publication/uuid/D2016620-F4DE-4C0A-BE4B-78E8F2701438

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, *15*(2), 151–163. https://doi.org/10.1016/j.gloenvcha.2004.12.006

Brouwer, R., Akter, S., Brander, L., & Haque, E. (2007). Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. *Risk Analysis : An Official Publication of the Society for Risk Analysis*, *27*(2), 313–326. https://doi.org/10.1111/j.1539-6924.2007.00884.x

Cabas, J., Weersink, A., & Olale, E. (2010). Crop yield response to economic, site and climatic variables. *Climatic Change*, *101*(3), 599–616. https://doi.org/10.1007/s10584-009-9754-4

Canadell, J. G., Raupach, M. R., & Houghton, R. a. (2009). Anthropogenic CO2 emissions in Africa. *Biogeosciences*, *6*, 463–468. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.862.1393&rep=rep1&type=pdf

Capela Lourenço, T., Rovisco, A., Groot, A., Nilsson, C., Füssel, H.-M., Van Bree, L., & Street, R. B. (2014). Adapting to an uncertain climate: Lessons from practice. *Adapting to an Uncertain Climate: Lessons from Practice*, 1–182. https://doi.org/10.1007/978-3-319-04876-5

Cardona, O. D., van Aalst, M. K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., … Sinh, B. T. (2012). Determinants of Risk : Exposure and Vulnerability. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, … P. M. Midgley (Eds.), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (A Special). Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Chamberlin, J. (2008). *It's Small World After All: Defining Smallholder Agriculture in Ghana* (IFPRI discussion papers No. 00823). Washington, DC: International Food Policy Research Institute (IFPRI).

Codjoe, S. N. A., Atidoh, L. K., & Burkett, V. (2012). Gender and occupational perspectives on adaptation to climate extremes in the Afram Plains of Ghana. *Climatic Change*, *110*(1–2), 431–454. https://doi.org/10.1007/s10584-011-0237-z

Codjoe, S. N. A., & Owusu, G. (2011). Climate change/variability and food systems: Evidence from the Afram Plains, Ghana. *Regional Environmental Change*, *11*(4), 753–765. https://doi.org/10.1007/s10113-011-0211-3

Codjoe, S. N. A., Owusu, G., & Burkett, V. (2014). Perception, experience, and indigenous knowledge of climate change and variability: The case of Accra, a sub-Saharan African city. *Regional Environmental Change*, *14*(1), 369–383. https://doi.org/10.1007/s10113-013-0500-0

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, *16*(2), 385–399. https://doi.org/10.1007/s10113-015-0761-x

Corobov, R., Sirodoev, I., Koeppel, S., Denisov, N., & Sirodoev, G. (2013). Assessment of Climate Change Vulnerability at the Local Level: A Case Study on the Dniester River Basin (Moldova). *The Scientific World Journal*, *2013*, 1–14. https://doi.org/10.1155/2013/173794

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., … Patterson, C. (2009). Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. *The Lancet*, *373*(9676), 1693–1733. https://doi.org/10.1016/S0140-6736(09)60935-1

Cradock-Henry, N. A. (2011). *Farm-level vulnerability to climate change in the Eastern Bay of Plenty, New Zealand, in the context of multiple stressors*. PhD Thesis, University of Canterbury.

Creswell, J. W. (2003). *Research design Qualitative quantitative and mixed methods approaches* (2nd Editio). London: SAGE Publications, Inc.

https://doi.org/10.3109/08941939.2012.723954

Croppenstedt, A. (2003). Technology Adoption in the Presence of Constraints: the Case of Fertilizer Demand in Ethiopia. *Review of Development Economics*, *7*(1), 58–70. https://doi.org/10.1111/1467-9361.00175

Crowley, T. J. (2000). Causes of Climate Change Over the Past 1000 Years. *Science*, *289*(5477), 270–277. https://doi.org/10.1126/science.289.5477.270

Cunningham, W. P., & Cunningham, M. A. (2006). *Principles of Environmental Science: Inquiry and Applications* (3rd editio). New York, USA: The McGraw-Hill Companies, Inc.

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*. https://doi.org/10.1177/030913259602000407

Das, D. (2016). Changing climate and its impacts on Assam, Northeast India. *Das Bandung Journal of the Global South*, *2*(26), 1–13. https://doi.org/10.1186/s40728-015-0028-4

Debela, N., Mohammed, C., Bridle, K., Corkrey, R., & McNeil, D. (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus*, *4*(1), 236. https://doi.org/10.1186/s40064-015-1012-9

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian Farmers' Vulnerability to Climate Change Across Regional States* (No. 00806). *IFPRI Discussion Paper* (Vol. 00806). Washington DC. Retrieved from http://www.ifpri.org/publication/measuring-ethiopian-farmers-vulnerability-climate-change-across-regional-states

DfID. (1999). *Sustainable Livelihoods Guidance Sheet*. London: Department for International Development.

DfID. (2004). *The impact of climate change on the vulnerability of the poor*. London: Department for International Development.

Dietz, T, Geest, K. van der, & Obeng, F. (2013). Local perceptions of development and change in Northern Ghana. In J. Yaro (Ed.), *Rural development in Northern Ghana* (pp. 19–36). New York, USA: Nova Science Publishers. Retrieved from http://padev.nl/other_output/Dietz_et_al_2013_Development_and_Change_in_Northern_Ghana_PREPRINT.pdf

Dietz, Ton, Millar, D., Dittoh, S., Obeng, F., & Ofori-Sarpong, E. (2004). Climate and Livelihood Change in North East Ghana. In A. J. Dietz, R. Ruben, & A. Verhagen (Eds.), *The Impact of Climate Change on Drylands, with a Focus on West Africa* (Vol. 39, pp. 267–291). Dordrecht/Boston/London: Kluwer Academic Publishers. https://doi.org/10.1007/1-4020-2158-5

Dilling, L., Daly, M. E., Travis, W. R., Wilhelmi, O. V., & Klein, R. A. (2015). The dynamics of vulnerability: Why adapting to climate variability will not always prepare us for climate change. *Wiley Interdisciplinary Reviews: Climate Change*. https://doi.org/10.1002/wcc.341

Dodd, D. E. S., & Jolliffe, I. T. (2001). Early detection of the start of the wet season in semiarid tropical climates of western Africa. *International Journal of Climatology*, *21*(10), 1251–1262. https://doi.org/10.1002/joc.640

Dow, K. (1992). Exploring differences in our common future(s): the meaning of vulnerability to global environmental change. *Geoforum*, *23*(3), 417–436. https://doi.org/doi:10.1016/0016-7185(92)90052-6

Dumenu, W. K., & Obeng, E. A. (2016). Environmental Science & Policy Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. *Environmental Science and Policy*, *55*, 208–217. https://doi.org/10.1016/j.envsci.2015.10.010

Eakin, H. C., Lemos, M. C., & Nelson, D. R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. *Global Environmental Change*, *27*(1), 1–8. https://doi.org/10.1016/j.gloenvcha.2014.04.013

EPA. (2011). *Ghana's Second National Communication to the UNFCCC*. Accra. Retrieved from http://unfccc.int/resource/docs/natc/ghana_second_nationalcommunication_final_version.pdf

Esham, M., & Garforth, C. (2013). Agricultural adaptation to climate change: insights from a farming community in Sri Lanka. *Mitigation and Adaptation Strategies for Global Change*, *18*, 535–549. https://doi.org/10.1007/s11027-012-9374-6

Essegbey, G., Totin, E., Karbo, N., Traore, P. S., & Zougmore, R. (2016). *Assessment of climate change policy and institutional context: The case of Ghana* (No. 164). Copenhagen, Denmark.

Etwire, P. M., Abdoulaye, T., Obeng-antwi, K., Buah, S. S. J., Kanton, R. A. L., Asumadu, H., … Etwire, J. C. (2013). On-farm evaluation of maize varieties in the transitional and savannah zones of Ghana : Determinants of farmer preferences, *5*(6), 255–262. https://doi.org/10.5897/JDAE2013.0462

FAO. (2005). *Fertilizer use by crop in Ghana*. Rome: Food and Agriculture Organisation. Retrieved from http://www.fao.org/tempref/docrep/fao/008/a0013e/a0013e00.pdf

Fearon, J., Adraki, P. K., & Boateng, V. F. (2015). Fertilizer subsidy programme in Ghana: Evidence of performance after six years of implementation. *Jounal of Biology, Agriculture and Heathcare*, *5*(21), 100–107. Retrieved from http://www.iiste.org/Journals/index.php/JBAH/article/view/27076/27758

Feola, G., Lerner, A. M., Jain, M., Montefrio, M. J. F., & Nicholas, K. a. (2015). Researching farmer behaviour in climate change adaptation and sustainable agriculture: Lessons learned from five case studies. *Journal of Rural Studies*, *39*(2015), 74–84. https://doi.org/10.1016/j.jrurstud.2015.03.009

Flesch, T. K., & Reuter, G. W. (2012). WRF Model Simulation of Two Alberta Flooding Events and the Impact of Topography. *Journal of Hydrometeorology*, *13*(2), 695–708. https://doi.org/10.1175/JHM-D-11-035.1

Fosu-Mensah, B. Y., Vlek, P. L. G., & Manschadi, A. M. (2010). Farmers' Perception and Adaptation to Climate Change; A Case Study of Sekyedumase District in Ghana. In *World Food System — A Contribution from Europe* (pp. 1–6). Zurich: International

Research on Food Security, Natural Resource Management and Rural Development. Retrieved from http://www.tropentag.de/2010/abstracts/full/203.pdf

Fraser, E. D. G., Dougill, A. J., Hubacek, K., Quinn, C. H., Sendzimir, J., & Termansen, M. (2011). Assessing Vulnerability to Climate Change in Dryland Livelihood\rSystems: Conceptual Challenges and Interdisciplinary Solutions. *Ecology and Society*, *16*(3), 1–17. https://doi.org/10.5751/ES-03402-160303

Füssel, H.-M. (2007a). Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustainability Science*, *2*(2), 265–275. https://doi.org/10.1007/s11625-007-0032-y

Füssel, H.-M. (2007b). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, *17*(2), 155–167. https://doi.org/10.1016/j.gloenvcha.2006.05.002

Füssel, H.-M., & Klein, R. J. T. (2006). Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change*, *75*(3), 301–329. https://doi.org/10.1007/s10584-006-0329-3

Gabor, T., & Griffith, T. K. (1980). The assessment of community vulnerability to acute hazardous materials incidents. *Journal of Hazardous Materials*, *3*(4), 323–333. https://doi.org/doi:10.1016/0304-3894(80)80004-5

Gbetibouo, G. A. (2009). *Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability The Case of the Limpopo Basin, South Africa* (No. 00849). Washington D.C.

Gecho, Y., Ayele, G., Lemma, T., & Alemu, D. (2014). Rural household livelihood strategies : Options and determinants in the case of Wolaita Zone, Southern Ethiopia. *Social Sciences*, *3*(3), 92–104. https://doi.org/10.11648/j.ss.20140303.15

Gentle, P., Thwaites, R., Race, D., & Alexander, K. (2014). Differential impacts of climate change on communities in the middle hills region of Nepal. *Natural Hazards*, *74*(2), 815–836. https://doi.org/10.1007/s11069-014-1218-0

Grabovschi, C., Loignon, C., & Fortin, M. (2013). Mapping the concept of vulnerability related to health care disparities: a scoping review. *BMC Health Services Research*, *13*(1), 1–11. https://doi.org/10.1186/1472-6963-13-94

GSS. (2013). *GSS. (2013). 2010 Population and Housing Census: Regional Analytical Report-Upper West Region. Accra: Ghana Statistical Service.2010 Population and Housing Census: Regional Analytical Report-Upper West Region*. Accra: Ghana Statistical Service.

GSS. (2014). *2010 Population and Housing Census: District Analytical Report for the Lawra District*. Accra: Ghana Statistical Service.

GSS. (2015). *Ghana Poverty Mapping Report*. Accra.

GSS, GHS, & ICF International. (2014). *Ghana Demographic and Health Survey*. Rockville, Maryland, USA.

Haines, A., Kovats, R. S., Campbell-Lendrum, D., & Corvalan, C. (2006). Climate change and human health: impacts, vulnerability and public health. *Public Health*, *120*(7), 585–596. https://doi.org/10.1016/j.puhe.2006.01.002

Handa, S., Park, M., Darko, R. O., Osei-Akoto, I., Davis, B., & Diadone, S. (2013). *Livelihood Empowerment Against Poverty Program Impact Evaluation*. Chapel Hill. Retrieved from https://www.unicef.org/ghana/gh_resources_LEAP_Quant_impact_evaluation_FINAL_OCT_2013.pdf

Haque, A., Budi, A., Malik, A. A., Yamamoto, S. S., Louis, V. R., & Sauerborn, R. (2013). Health coping strategies of the people vulnerable to climate change in a resource-poor rural setting in Bangladesh. *BMC Public Health*, *13*(565), 1–11. https://doi.org/10.1186/1471-2458-13-565

Haque, A., Yamamoto, S. S., Malik, A. A., & Sauerborn, R. (2012). Households ' perception of climate change and human health risks : A community perspective. *Environmental Health*, *11*(1), 1–13.

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., … Mackinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *369*(1639), 20130089. https://doi.org/10.1098/rstb.2013.0089

Hassan, R., & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(1), 83–104.

Hawkes, C., & Ruel, M. (2006). The links between agriculture and health: An intersectoral opportunity to improve the health and livelihoods of the poor. *Bulletin of the World Health Organization*, *84*(12), 985–991. https://doi.org/10.2471/BLT.05.025650

Heltber, R., & Bonch-Osmolovskiy, M. (2011). *Mapping Vulnerability to Climate Change. Policy Research Working Paper*. Washington, DC. Retrieved from http://econ.worldbank.org

Heltberg, B. R., & Bonch-Osmolovskiy, M. (2010). *Mapping vulnerability to climate change*. Washington, DC.

Hodgson, G. M. (2006). What are institutions? *Journal of Economic Issues*, *40*(1), 1–25. Retrieved from http://www.geoffrey-hodgson.info/user/image/whatareinstitutions.pdf

Hope, K. R. (2011). Climate change in the context of urban development in Africa. In B. Yuen & A. Kumssa (Eds.), *Climate Change and Sustainable Urban Development in Africa and Asia* (pp. 37–55). Berlin: Springer Science & Business Media.

Hope, R. K. (2009). Climate change and poverty in Africa. *International Journal of Sustainable Development & World Ecology*, *16*(6), 451–461. https://doi.org/10.1080/13504500903354424

Huang, J., Guan, X., & Ji, F. (2012). Enhanced cold-season warming in semi-arid regions. *Atmospheric Chemistry and Physics*, *12*, 5391–5398. https://doi.org/10.5194/acp-12-5391-2012

Hulme, M., Doherty, R., Ngara, T., New, M., & Lister, D. (2001). African climate change: 1900 – 2100. *Climate Research*, *17*, 145–168. Retrieved from http://www.intres.com/articles/cr/17/c017p145.pdf

Huq, S., Reid, H., Konate, M., Rahman, A., Sokona, Y., & Crick, F. (2004). Mainstreaming adaptation to climate change in least developed countries (LDCs). *Climate Policy*, *4*(1), 25–43. https://doi.org/10.1080/14693062.2004.9685508

Ide, T., Schilling, J., Link, J. S. a., Scheffran, J., Ngaruiya, G., & Weinzierl, T. (2014). On exposure, vulnerability and violence: Spatial distribution of risk factors for climate change and violent conflict across Kenya and Uganda. *Political Geography*, *43*, 68–81. https://doi.org/10.1016/j.polgeo.2014.10.007

IFAD. (2009). Smallholder Agriculture and Food Security in the 21st Century. In *Proceedings of the 32nd Session of IFADs' Governing Council Round Tables, February 2009 at Rome, Italy*. Rome: International Fund for Agricultural Development.

IFAD. (2013). *Smallholders, food security, and the environment*. Rome.

IPCC. (2001). Adaptation to Climate Change in the Context of Sustainable Development and Equity. In *Working Group II: Impacts, Adaptation and Vulnerability* (Vol. 8, pp. 880–912). Retrieved from http://www.ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap18.pdf

IPCC. (2007a). *Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel*. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.). Cambridge, UK: Cambridge University Press.

IPCC. (2007b). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: Intergovernmental Panel on Climate Change.

IPCC. (2007c). Summary for Policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, … H. L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC. (2013). Summary for Policymakers. In T. F. Stocke, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, … P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. Retrieved from http://centaur.reading.ac.uk/1019/

IPCC. (2014a). Climate Change, Adaptation, and Vulnerability. *Organization & Environment*, *24*(March), 1–44. https://doi.org/http://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf

IPCC. (2014b). Summary for Policy Makers. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, … L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation and Vulnerability - Contributions of the Working Group II to the Fifth Assessment Report* (pp. 1–32). Cambridge, United Kingdom: Cambridge University Press. https://doi.org/10.1016/j.renene.2009.11.012

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods*, *18*(1), 3–20. https://doi.org/10.1177/1525822X05282260

Iyengar, A. N. S., & Sudarshan, P. (1982). A Method of Classifying Regions from Multivariate Data. *Economic and Political Weekly*, *17*(51), 2047–2052. Retrieved from https://www.jstor.org/stable/pdf/4371674.pdf

Jahnke, H. E., Tacher, G., Keil, P., & Rojat, D. (1988). Livestock production in tropical Africa with special reference to the tsetse-afferent zone. In *Livestock production in tsetse affected areas of Africa: The African Trypanotolerant Livestock Network, Proceedings of a meeting held 23-27 November 1987 Nairobi, Kenya*. Nairobi: International Livestock Centre for Africa (ILCA)/International Laboratory for Research on Animal Diseases (ILRAD). Retrieved from http://www.fao.org/Wairdocs/ILRI/x5443E/x5443e04.htm

Jarawura, F. X. (2014). Perceptions of drought among rural farmers in the Savelugu district in the northern Savannah of Ghana. *Ghana Journal of Geography*, *6*, 102–120. Retrieved from https://www.ajol.info/index.php/gjg/article/view/111137/100904

Jonsson, A. C. ., & Lundgren, L. . (2014). Vulnerability and adaptation to heat in cities: perspectives and perceptions of local adaptation decision-makers in Sweden. *Local Environment: The International Journal of Justice and Sustainability*, *0*(0), 1–17. https://doi.org/10.1080/13549839.2014.896326

Jost, C., Kyazze, F., Naab, J., Neelormi, S., Kinyangi, J., Zougmore, R., … Kristjanson, P. (2015). Understanding gender dimensions of agriculture and climate change in smallholder farming communities. *Climate and Development*, *5529*(October), 1–12. https://doi.org/10.1080/17565529.2015.1050978

Kabote, S. J., Mattee, A. Z., Mbwambo, J. S., Nombo, C. I., & Masolwa, L. M. (2014). Rain-Fed Farming System at a Crossroads in Semi-Arid Areas of Tanzania : What Roles do Climate Variability and Change Play ? *Journal of Environment and Earth Science*, *4*(16), 85–101. Retrieved from http://www.iiste.org/Journals/index.php/JEES/article/download/15154/15731.

Kalaugher, E., Bornman, J. F., Clark, A., & Beukes, P. (2013). An integrated biophysical and socio-economic framework for analysis of climate change adaptation strategies: The case of a New Zealand dairy farming system. *Environmental Modelling & Software*, *39*(April), 176–187. https://doi.org/10.1016/j.envsoft.2012.03.018

Kasperson, J. X., & Kasperson, R. E. (2005). *The Social Contours of Risk: Risk analysis, corporations and the globalization of risk (vol II)*. London: Earthscan.

Kates, R. W. (1985). The Interaction of Climate and Society. In R. W. Kates, J. H. Ausubel, & M. Berberian (Eds.), *Climate Impact Assessment: Studies of the interaction of Climate and Society (SCOPE Series)* (pp. 3–36). New York: John Willey. Retrieved from http://rwkates.org/pdfs/a1985.01.pdf

Kelly, P. M., & Adger, W. N. (2000). Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, *47*, 325–352. https://doi.org/10.1023/A:1005627828199

Kihupi, M. L., Mahonge, C., & Chingonikaya, E. E. (2015). Smallholder Farmers' Adaptation Strategies to Impact of Climate Change in Semi-arid Areas of Iringa District Tanzania. *Journal of Biology, Agriculture and Healthcare*, *5*(2), 123–132. Retrieved from http://iiste.org/Journals/index.php/JBAH/article/viewFile/19550/19907

Kima, S. A., Okhimamhe, A. A., Kiema, A., Zampaligre, N., & Sule, I. (2015). Adapting to the impacts of climate change in the sub-humid zone of Burkina Faso , West Africa : Perceptions of agro-pastoralists. *Pastoralism*, *5*(16), 1–14. https://doi.org/10.1186/s13570-015-0034-9

Komarek, A. M., Drogue, S., Chenoune, R., Hawkins, J., Msangi, S., Belhouchette, H., & Flichman, G. (2017). Agricultural household effects of fertilizer price changes for smallholder farmers in central Malawi. *Agricultural Systems*, *154*(March), 168–178. https://doi.org/10.1016/j.agsy.2017.03.016

Kotir, J. H. (2011). Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security. *Environment, Development and Sustainability*, *13*(3), 587–605. https://doi.org/10.1007/s10668-010-9278-0

Kusakari, Y., Asubonteng, K. O., Jasaw, G. S., Dayour, F., Dzivenu, T., Lolig, V., … Kranjac-Berisavljevic, G. (2014). Farmer-perceived effects of climate change on livelihoods in WA West District, Upper West Region of Ghana. *Journal of Disaster Research*, *9*(4), 516–528. Retrieved from https://www.researchgate.net/profile/Samuel_Donkoh/publication/264333819_Farmer-Perceived_Effects_of_Climate_Change_on_Livelihoods_in_Wa_West_District_Upper_West_Region_of_Ghana/links/53d8f94f0cf2a19eee839e47.pdf

Laux, P., Kunstmann, H., & Bárdossy, A. (2008). Predicting the Regional Onset of the Rainy Season in West Africa. *International Journal of Climatology*, *28*, 329–342. https://doi.org/10.1002/joc.1542

LDA. (2013). *The Composite Budget of the Lawra District Assembly for the 2013 Fiscal Year*. Lawra.

Lee, S.-S., Lee, J.-Y., Ha, K.-J., Wang, B., Kitoh, A., Kajikawa, Y., & Abe, M. (2013). Role of the Tibetan Plateau on the Annual Variation of Mean Atmospheric Circulation and Storm-Track Activity. *Journal of Climate*, *26*(14), 5270–5286. https://doi.org/10.1175/JCLI-D-12-00213.1

Leichenko, R. M., McDermott, M., Bezborodko, E., Brady, M., & Namendorf, E. (2014). Economic Vulnerability to Climate Change in Coastal New Jersey: A Stakeholder-Based Assessment. *Journal of Extreme Events*, *01*(01), 1450003–1450032. https://doi.org/10.1142/S2345737614500031

Leiserowitz, A. (2006). Climate Change Risk Perception and Policy. *Climate Change*, *77*, 45–72. https://doi.org/10.1007/s10584-006-9059-9

Li, X., Philp, J., Cremades, R., Roberts, A., He, L., Li, L., & Yu, Q. (2016). Agricultural vulnerability over the Chinese Loess Plateau in response to climate change: Exposure, sensitivity, and adaptive capacity. *Ambio*, *45*(3), 350–360. https://doi.org/10.1007/s13280-015-0727-8

Lin, X. (1999). *Flash floods in arid and semi-arid zones*. *Technical Documents in Hydrology*. *No. 23*. Paris.

Lioubimtseva, E., & Henebry, G. M. (2009). Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. *Journal of Arid Environments*, *73*(11), 963–977. https://doi.org/10.1016/j.jaridenv.2009.04.022

Lobell, D. B., Bänziger, M., Magorokosho, C., & Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change*, *1*(4), 42–45. https://doi.org/10.1038/nclimate1043

Ludi, E. (2009). *Climate change, water and food security - ODI Background Note*. London. Retrieved from http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/4116.pdf

Luers, A. L. (2005). The surface of vulnerability: An analytical framework for examining environmental change. *Global Environmental Change*, *15*(3), 214–223. https://doi.org/10.1016/j.gloenvcha.2005.04.003

Luers, A. L., Lobell, D. B., Sklar, L. S., Addams, C. L., & Matson, P. A. (2003). A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change*, *13*(4), 255–267. https://doi.org/10.1016/S0959-3780(03)00054-2

Maddison, D. (2007). *The Perception of and Adaptation to Climate Change in Africa*. *Policy Researh Working Paper*. Washington, DC. https://doi.org/http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-4308

Magnan, A. K., Schipper, E. L. F., Burkett, M., Bharwani, S., Burton, I., Eriksen, S., … Ziervogel, G. (2016). Addressing the risk of maladaptation to climate change. *WIREs Climate Change*, *7*, 646–665. https://doi.org/10.1002/wcc.409

Makate, C., Wang, R., Makate, M., & Mango, N. (2016). Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. *SpringerPlus*, *5*(1). https://doi.org/10.1186/s40064-016-2802-4

Manandhar, S., Pratoomchai, W., Ono, K., Kazama, S., & Komori, D. (2015). Local people's perceptions of climate change and related hazards in mountainous areas of northern Thailand. *International Journal of Disaster Risk Reduction*, *11*, 47–59. https://doi.org/10.1016/j.ijdrr.2014.11.002

Mango, N., Makate, C., Mapemba, L., & Sopo, M. (2018). The role of crop diversification in improving household food security in central Malawi. *Agriculture and Food Security*, *7*(1), 1–10. https://doi.org/10.1186/s40066-018-0160-x

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research*, *5*(2), 122–129. https://doi.org/10.1016/j.iswcr.2017.04.003

Mary, A. L., & Majule, A. E. (2009). Impacts of Climate Change, Variability and Adaptation Strategies on Agriculture in Semi Arid Areas of Tanzania: The Case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental*

Science and Technology, *3*(8), 206–218. https://doi.org/10.5897/AJEST09.099

Mbilinyi, A. and Kazi, V. (2013). *Impact of Climate Change To Small Scale Farmers : Voices of Farmers in Village Communities in*. *Economic and Social Research Foundation*.

McCubbin, S., Smit, B., & Pearce, T. (2015). Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. *Global Environmental Change*, *30*, 43–55. https://doi.org/10.1016/j.gloenvcha.2014.10.007

McDowell, J. Z., & Hess, J. J. (2012). Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. *Global Environmental Change*, *22*(2), 342–352. https://doi.org/10.1016/j.gloenvcha.2011.11.002

Meinke, H., Howden, S. M., Struik, P. C., Nelson, R., Rodriguez, D., & Chapman, S. C. (2009). Adaptation science for agriculture and natural resource management—urgency and theoretical basis. *Current Opinion in Environmental Sustainability*, *1*(1), 69–76. https://doi.org/10.1016/j.cosust.2009.07.007

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, *11*(02), 159–178. https://doi.org/10.1017/S1355770X05002755

MESTI/EPA. (2015). *Ghana's Third National Communication Report to the UNFCCC*. Accra. Retrieved from http://www.careclimatechange.org/files/CVCA_Kenya_Report__Final.pdf

MESTI. (2013). Ghana National Climate Change Policy.

Midgley, S., Dejene, A., & Mattick, A. (2012). *Adaptation to climate change in semi-arid environment: Experiences and lessons from Mozambique*. Rome: Food and Agriculture Organisation.

Ministry of Finance. (2017). *The Budget Statement of the Government of Ghana for the 2017 Financial Year*. Accra. Retrieved from https://www.mofep.gov.gh/sites/default/files/budget-statements/2017-Budget-Statement.pdf

MMYE. (2007). *National Social Protection Strategy: Investing in people*. Accra. Retrieved from http://extwprlegs1.fao.org/docs/pdf/gha149446.pdf

MoFA. (2007). *Food and Agriculture Sector Development Policy (FASDEP II)*. Accra: Ministry of Food and Agriculture.

MoFA. (2013). *Facts and Figures*. Accra. Retrieved from http://mofa.gov.gh/site/wp-content/uploads/2014/03/AGRICULTURE-IN-GHANA-FF-2012-nov-2013.pdf

Morchain, D., Prati, G., Kelsey, F., & Ravon, L. (2015). What if gender became an essential, standard element of Vulnerability Assessments? *Gender & Development*, *23*(3), 481–496. https://doi.org/10.1080/13552074.2015.1096620

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(50), 19680–19685. https://doi.org/10.1073/pnas.0701855104

Mubaya, C. P., Njuki, J., Mutsvangwa, E. P., Mugabe, F. T., & Nanja, D. (2012). Climate variability and change or multiple stressors? Farmer perceptions regarding threats to livelihoods in Zimbabwe and Zambia. *Journal of Environmental Management*, *102*(January), 9–17. https://doi.org/10.1016/j.jenvman.2012.02.005

Mugi-Ngenga, E. W., Mucheru-Muna, M. W., Mugwe, J. N., Ngetich, F. K., Mairura, F. S., & Mugendi, D. N. (2016). Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya. *Journal of Rural Studies*, *43*(2016), 49–60. https://doi.org/10.1016/j.jrurstud.2015.11.004

Murthy, C. S., Laxman, B., & Sesha Sai, M. V. R. (2015). Geospatial analysis of agricultural drought vulnerability using a composite index based on exposure, sensitivity and adaptive capacity. *International Journal of Disaster Risk Reduction*, *12*, 163–171. https://doi.org/10.1016/j.ijdrr.2015.01.004

Naab, J. B., & Koranteng, H. (2012). *Using a gender lens to explore farmers' adaptation options in the face of climate change: results of a pilot study in Jirapa, Ghana* (No. Working Paper No.17). Nairobi, Kenya. Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/21087/ccafs_wp_17.pdf?sequence=2&isAllowed=y

NADMO/UNDP. (2012). Community resilience through early warning, 1–43. Retrieved from http://www.gh.undp.org/content/dam/ghana/docs/Doc/Susdev/UNDP_GH_SUSDEV_CREW_ProDoc_Final_All.pdf

NASAC. (2015). *Climate Change Adaptation and Resilience in Africa: Recommendations to Policymakers*. Nairobi, Kenya.

Ncube, M., Madubula, N., Ngwenya, H., Zinyengere, N., Zhou, L., Francis, J., … Madzivhandila, T. (2016). Climate change, household vulnerability and smart agriculture: The case of two South African provinces. *Journal of Disaster Risk Studies*, *8*(2), 6–8. https://doi.org/10.4102/jamba.v8i2.182

Ndamani, F., & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola*, *73*(3), 201–208. https://doi.org/10.1590/0103-9016-2015-0163

Nhemachena, C., & Hassan, R. (2007). *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa* (No. IFPRI Discussion Paper 00714). Washington, DC. Retrieved from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/39726

Nhemachena, C., Mano, R., Mudombi, S., & Muwanigwa, V. (2014). Perceptions on climate change and its impact on livelihoods in Hwange district, Zimbabwe. *Jàmbá: Journal of Disaster Risk Studies*, *6*(1), 1–6. https://doi.org/10.4102/jamba.v6i1.123

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, … L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1199–1265). Cambridge, United Kingdom and New York, USA: Cambridge University Press.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge, United Kingdom: Cambridge University Press.

Notenbaert, A., Karanja, S. N., Herrero, M., Felisberto, M., & Moyo, S. (2013). Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. *Regional Environmental Change*, *13*(2), 459–470. https://doi.org/10.1007/s10113-012-0368-4

Nyantakyi-Frimpong, H., & Bezner-Kerr, R. (2015). The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change*, *32*, 40–56. https://doi.org/10.1016/j.gloenvcha.2015.03.003

O'Brien, K. L., Eriksen, S., Nygaard, L. P., & Schjolden, a N. E. (2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, *7*(1), 73–88. https://doi.org/10.1080/14693062.2007.9685639

O'Brien, K. L., & Leichenko, R. M. (2000). Double exposure: Assessing the impacts of climate change within the context of economic globalization. *Global Environmental Change*, *10*(3), 221–232. https://doi.org/10.1016/S0959-3780(00)00021-2

O'Brien, K. L., Leichenko, R. M., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., … West, J. (2004). Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Global Environmental Change*, *14*, 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001

O'Brien, K. L., Quinlan, T., & Ziervogel, G. (2009). Vulnerability interventions in the context of multiple stressors: lessons from the Southern Africa Vulnerability Initiative (SAVI). *Environmental Science and Policy*, *12*(1), 23–32. https://doi.org/10.1016/j.envsci.2008.10.008

Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production: The case of small scale farmers in Kenya. *NJAS - Wageningen Journal of Life Sciences*, *77*, 71–78. https://doi.org/10.1016/j.njas.2016.03.005

Odgaard, M. V., Bøcher, P. K., Dalgaard, T., & Svenning, J. C. (2011). Climatic and non-climatic drivers of spatiotemporal maize-area dynamics across the northern limit for maize production-A case study from Denmark. *Agriculture, Ecosystems and Environment*, *142*(3–4), 291–302. https://doi.org/10.1016/j.agee.2011.05.026

OECD. (2008). *Handbook on Constructing Composite Indicators: Methodology and user guide*. Paris: Organization for Economic Co-operation and Development.

Ogwang, B. A., Chen, H., Li, X., & Gao, C. (2014). The Influence of Topography on East African October to December Climate: Sensitivity Experiments with RegCM4. *Advances in Meteorology*, *2014*, 1–14. https://doi.org/10.1155/2014/143917

Olayemi, O. A. (2012). Determinants of climate change and coping strategies among crop farmers in Ondo state , Nigeria. *Agricultural Research and Reviews*, *1*(4), 127–131. Retrieved from http://pakacademicsearch.com/pdf-files/agr/194/127-131 Vol 1 issue 4 May 2012.pdf

Omotosho, J. B., Balogun, A. A., & Ogunjobi, K. (2000). Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. *International Journal of Climatology*, *20*(8), 865–880. https://doi.org/10.1002/1097-0088(20000630)20:8<865::AID-JOC505>3.0.CO;2-R

Opiyo, F., Wasonga, O. V, & Nyangito, M. M. (2014). Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism: Research, Policy and Practice*, *4*(1), 10. https://doi.org/10.1186/s13570-014-0010-9

Oxford University Press. (2006). Oxford Dictionary of English. Oxford, UK: Oxford University Press.

Perez, C., Jones, E. M., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., & Barahona, C. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environmental Change*, *34*(SEPTEMBER), 95–107. https://doi.org/10.1016/j.gloenvcha.2015.06.003

Piya, L., Joshi, N. P., & Maharjan, K. L. (2015). Vulnerability of Chepang households to climate change and extremes in the Mid-Hills of Nepal. *Climatic Change*, *135*(3), 521–537. https://doi.org/10.1007/s10584-015-1572-2

Piya, L., & Lall, K. (2013). Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal. *Regional Environmental Change*, *13*, 437–447. https://doi.org/10.1007/s10113-012-0359-5

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., … Travasso, M. I. (2014). Food security and food production systems. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, … L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 485–533). Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability*, *9*(1), 5–24. https://doi.org/10.3763/ijas.2010.0583

Quinn, C. H., Ziervogel, G., Taylor, A., Takama, T., & Thomalla, F. (2011). Coping with multiple stresses in rural South Africa. *Ecology and Society*, *16*(3), 10. https://doi.org/10.5751/ES-04216-160302

Radhouane, L. (2013). Climate change impacts on North African countries and on some Tunisian economic sectors. *Journal of Agriculture and Environment for International Development*, *107*(1), 101–113. https://doi.org/http://dx.doi.org/10.12895/jaeid.20131.123

Ramirez-Villegas, J., & Thornton, P. K. (2015). *Climate change impacts on African crop production* (No. 119). Copenhagen, Denmark. Retrieved from https://ccafs.cgiar.org/publications/climate-change-impacts-african-crop-production#.WU0XvGjyjIV

Reid, H., Chambwera, M., & Murray, L. (2013). *Tried and tested: learning from farmers on adaptation to climate change. IIED Gatekeeper Series 153*. London. Retrieved from http://pubs.iied.org/14622IIED.html

Reid, P., & Vogel, C. (2006). Living and responding to multiple stressors in South Africa-Glimpses from KwaZulu-Natal. *Global Environmental Change*, *16*(2), 195–206. https://doi.org/10.1016/j.gloenvcha.2006.01.003

Salehi, S., Pazuki, Z., Mahmoudi, H., & Knierim, A. (2015). Gender, responsible citizenship and global climate change. *Women's Studies International Forum*, *50*, 30–36. https://doi.org/10.1016/j.wsif.2015.02.015

Saon, R. (2015). A framework for understanding adaptation by manufacturing industries. In D. Sumyananda (Ed.), *Handbook of research on climate change impact on health and environmental sustainability*. Hershey, USA: IGI Global.

Schirmer, J., Berry, H. L., & O'Brien, L. V. (2013). Healthier land, healthier farmers: Considering the potential of natural resource management as a place-focused farmer health intervention. *Health and Place*, *24*, 97–109. https://doi.org/10.1016/j.healthplace.2013.08.007

Scoones, I. (1998). *Sustainable rural livelihoods: a framework for analysis* (IDS Working Paper 72). *IDS working paper 72*. Brighton.

Shackleton, S., Ziervogel, G., Sallu, S., Gill, T., & Tschakert, P. (2015). Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. *Wiley Interdisciplinary Reviews: Climate Change*, *6*(3), 321–344. https://doi.org/10.1002/wcc.335

Shah, K. U., Dulal, H. B., Johnson, C., Baptiste, A., Bansha, H., Johnson, C., & Baptiste, A. (2013). Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum*, *47*(APRIL 2013), 125–137. https://doi.org/10.1016/j.geoforum.2013.04.004

Shi, X., Wang, Y., & Xu, X. (2008). Effect of mesoscale topography over the Tibetan Plateau on summer precipitation in China: A regional model study. *Geophysical Research Letters*, *35*(19), 1–5. https://doi.org/10.1029/2008GL034740

Shiferaw, B., & Holden, S. T. (1998). Resource degradation and adoption of land conservation technologies 1n the Ethiopian Highlands : A case study in Andit Tid , North Shewa. *Agricultural Economics*, *18*, 233–247. https://doi.org/https://ageconsearch.umn.edu/bitstream/174411/2/agec1998v018i003a003.pdf

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. G., … Stringer, L. C. (2013). Is rainfall really changing? Farmers ' perceptions, meteorological data, and policy implications. *Climate and Development*, *5*(2), 123–138. https://doi.org/10.1080/17565529.2012.751893

Simonet, G. (2010). The concept of adaptation: interdisciplinary scope and involvement in climate change. *Surveys and Perspectives Integrating Environment and Society [S.A.P.I.E.N.S]*, *3*(1), 1–9. Retrieved from http://sapiens.revues.org/index997.html

Sivakumar, M. V. K., Das, H. P., & Brunini, O. (2005). Impacts of Present and Future Climate Variability and Change on Agriculture and Forestry in the Arid and Semi-Arid Tropics. *Climate Change*, *70*, 31–72. https://doi.org/10.1007/s10584-005-5937-9

Smit, B., Burton, I., Klein, R. J. T., & Wandel, J. (2000). An Anatomy of Adaptation to Climate Change and Variability. *Climate Change*, *45*(1), 223–251. https://doi.org/10.1023/A:1005661622966

Smit, B., & Skinner, M. W. (2002). Adaptation Options in Agriculture To Climate Change: a Typology. *Mitigation and Adaptation Strategies for Global Change*, *7*(1), 85–114. https://doi.org/10.1023/A:1015862228270

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Smith, J. B., Schneider, S. H., Oppenheimer, M., Yohe, G. W., Hare, W., Mastrandrea, M. D., … van Ypersele, J.-P. (2009). Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "Reasons for Concern". *Proceedings of the National Academy of Sciences of the United States of America*, *106*(11), 4133–4137. https://doi.org/10.1073/pnas.0812355106

Soares, M. B., Gagnon, A. S., & Doherty, R. M. (2012). Conceptual elements of climate change vulnerability assessments : a review. *International Journal of Climate Change Strategies and Management*, *4*(1), 6–35. https://doi.org/10.1108/17568691211200191

Stanturf, J. A., Warren, M. L., Charnley, J. S., Polasky, S. C., Goodrick, S. L., Armah, F., & Nyako, Y. A. (2011). *Ghana Climate Change Vulnerability and Adaptation Assessment*. Washington, DC. Retrieved from http://www.encapafrica.org/documents/biofor/Climate Change Assessment_Ghana_FINAL.pdf

Stringer, L. C., Dyer, J. C., Reed, M. S., Dougill, A. J., Twyman, C., & Mkwambisi, D. (2009). Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy*, *12*(7), 748–765. https://doi.org/10.1016/j.envsci.2009.04.002

Swe, L. M. M., Shrestha, R. P., Ebbers, T., & Jourdain, D. (2015). Farmers' perception of and adaptation to climate change impacts in the Dry Zone of Myanmar. *Climate and Development*, *7*(5), 437–453. https://doi.org/10.1080/17565529.2014.989188

Teiksma Buseva. (2011). The vulnerability of Latvia's agriculture: Farm level response to climatic and non- climatic stimuli, 68.

Teshome, M. (2016). Rural households' agricultural land vulnerability to climate change in Dembia woreda, Northwest Ethiopia. *Environmental Systems Research*, *5*(14), 1–18. https://doi.org/10.1186/s40068-016-0064-3

Tessema, Y. A., Aweke, C. S., & Endris, G. S. (2013). Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics*, *1*(13), 1–17. https://doi.org/10.1186/2193-7532-1-13

Tesso, G., Emana, B., & Ketema, M. (2012). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. *Agricultural Sciences*, *3*(6), 871–888. https://doi.org/10.4236/as.2012.36106

Thorlakson, T., & Neufeldt, H. (2012). Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture & Food Security*, *1*(1), 15. https://doi.org/10.1186/2048-7010-1-15

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B, 365*, 2853–2867. https://doi.org/10.1098/rstb.2010.0134

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. *Global Change Biology*, *20*, 1–16. https://doi.org/10.1111/gcb.12581

Tibesigwa, B., Visser, M., Collinson, M., & Twine, W. (2016). Investigating the sensitivity of household food security to agriculture-related shocks and the implication of social and natural capital. *Sustainability Science*, *11*(2), 193–214. https://doi.org/10.1007/s11625-015-0332-6

Tompkins, E. L., & Eakin, H. (2012). Managing private and public adaptation to climate change. *Global Environmental Change*, *22*(1), 3–11. https://doi.org/10.1016/j.gloenvcha.2011.09.010

Tschakert, P. (2007). Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change*, *17*(3–4), 381–396. https://doi.org/10.1016/j.gloenvcha.2006.11.008

Tschakert, P., Sagoe, R., Ofori-Darko, G., & Codjoe, S. N. A. (2010). Floods in the Sahel: An analysis of anomalies, memory, and anticipatory learning. *Climatic Change*, *103*(3), 471–502. https://doi.org/10.1007/s10584-009-9776-y

Tschakert, P., van Oort, B., St. Clair, A. L., & LaMadrid, A. (2013). Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change. *Climate and Development*, *5*(4), 340–350. https://doi.org/10.1080/17565529.2013.828583

UNDRO. (1980). *Natural Disasters and Vulnerability Analysis*. Geneva: United Nations Disaster Relief Organization. Retrieved from http://archive.org/details/naturaldisasters00offi

UNESCO. (2012). *Managing Water under Uncertainty and Risk* (Vol. 1). Paris: United Nations Educational, Scientific and Cultural Organization.

UNFCCC. (2007). *Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries*. Bonn, Germany: United Nations Framework Convention on Climate Change.

United Nations. (1997). Glossary of Environment Statistics. In *Studies in Methods* (Series F,). New York: United Nations. Retrieved from http://unstats.un.org/unsd/publication/SeriesF/SeriesF_67E.pdf

van der Geest, K. A. M. (2011). *The Dagara farmer at home and away: migration, environment and development in Ghana*. *PhD Thesis*. University of Ansterdam. https://doi.org/10.1073/pnas.1000098107.

Vogel, C. (2005). “Seven fat years and seven lean years”? Climate change and agriculture in Africa. *IDS Bulletin*, *36*(2), 30–35. https://doi.org/10.1111/j.1759-5436.2005.tb00192.x

Wang, M., Li, Y., Ye, W., Bornman, J. F., & Yan, X. (2011). Effects of climate change on maize production, and potential adaptation measures: A case study in Jilin province, China. *Climate Research*, *46*(3), 223–242. https://doi.org/10.3354/cr00986

Weindl, I., Lotze-campen, H., Popp, A., Müller, C., Havlík, P., Herrero, M., … Rolinski, S. (2015). Livestock in a changing climate: production system transitions as an adaptation strategy for agriculture. *Environmental Research Letters*, *10*. https://doi.org/10.1088/1748-9326/10/9/094021

Westerhoff, L., & Smit, B. (2009). The rains are disappointing us: Dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana. *Mitigation and Adaptation Strategies for Global Change*, *14*(4), 317–337. https://doi.org/10.1007/s11027-008-9166-1

WHO. (1978). *Health and the family: studies on the demography of family life cycles and their health implications*. Geneva: World Health Organization.

Wilbanks, T. J., & Kates, R. W. (2010). Beyond Adapting to Climate Change: Embedding Adaptation in Responses to Multiple Threats and Stresses. *Annals of the Association of American Geographers*, *100*(4), 719–728. https://doi.org/10.1080/00045608.2010.500200

Wilk, J., Andersson, L., & Warburton, M. (2013). Adaptation to climate change and other stressors among commercial and small-scale South African farmers. *Regional Environmental Change*, *13*(2), 273–286. https://doi.org/10.1007/s10113-012-0323-4

Willroth, P., Massmann, F., Wehrhahn, R., & Diez, R. J. (2012). Socio-economic vulnerability of coastal communities in southern Thailand: The development of adaptation strategies. *Natural Hazards and Earth System Science*, *12*(8), 2647–2658. https://doi.org/10.5194/nhess-12-2647-2012

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. *Human Ecology* (2nd ed., Vol. 24). London: Routledge. https://doi.org/10.4324/9780203428764

Wolf, S., Hinkel, J., Hallier, M., Bisaro, A., Lincke, D., Ionescu, C., & Klein, R. J. T. (2013). Clarifying vulnerability definitions and assessments using formalisation. *International Journal of Climate Change Strategies and Management*, *5*(1), 54–70. https://doi.org/10.1108/17568691311299363

Wood, S. A., Jina, A. S., Jain, M., Kristjanson, P., & Defries, R. S. (2014). Smallholder farmer cropping decisions related to climate variability across multiple regions. *Global Environmental Change*, *25*, 163–172. https://doi.org/10.1016/j.gloenvcha.2013.12.011

Worldwatch Institute. (2009). *State of the World: Into a Warming World*. Washington, DC: Worldwatch Institute.

Wu, S.-Y., Yarnal, B., & Fisher, A. (2002). Vulnerability of coastal communities to sealevel rise: a case study of Cape May county, New Jersey, USA. *Climate Research*, *22*(3), 255–270. https://doi.org/10.3354/cr022255

Xie, S., Deser, C., Vecchi, G. A., Collins, M., Tom, L., Hall, A., … Cassou, C. (2014). Towards predictive understanding of regional climate change: Issues and opportunities for progress. *Nature Climate Change*, *5*(10), 1–29. https://doi.org/10.1038/nclimate2689

Yaro, J. A. (2013). The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change*, *13*(6), 1259–1272. https://doi.org/10.1007/s10113-013-0443-5

Yaro, J. A., Teye, J., & Bawakyillenuo, S. (2015). Local institutions and adaptive capacity to climate change/variability in the northern savannah of Ghana. *Climate and Development*, *7*(3), 235–245. https://doi.org/10.1080/17565529.2014.951018

APPENDICES

APPENDIX A

Vulnerability and Adaptation of farming households in semi-arid Ghana to climate change and other stressors

Individual Household Interview

Questionnaire #:		
Household ID:	Village:	Date:
Latitude:	Longitude:	Altitude:
Name of interviewer:	Interviewee's mobile number:	
Relationship to the household head:		

A. HOUSEHOLD COMPOSITION

If the male head is away from the home >6 months per year, then the wife (female) is the head of the household.

1. HH member (incl. those absent but contribute to household income	2. Currently present (P)/absent (A)	3. Gender [1] Male; [2] Female	4. Age (years)	5. Highest educational level		6. Disability (Y/N)	7. Valid NHIA card (Y/N)
				a)Education type	b) Total years in schooling		
HH head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							
.... of head							

Relationship code: Spouse=**1**, Son/Daughter=**2**, Grandchild=**3**, Father/Mother=**4**, Brother/sister=**5**, Nephew/niece=**6**,Uncle/Aunt=**7**, Son/Daughter-in-law=**8**, Father/Mother-In-Law=**9**, Brother/Sister-In-Law=**10**, Grandparent=**11,** foster child =**12**, others (**13**) specify:
Education code: No education = **1,** Primary = **2**, JSS/JHS/Middle = **3**, SSS/SHS/Secondary(O&A-level) = **4**, Voc/Tech/ Commercial = **5**, Post middle/secondary =**6**, tertiary (diploma/degree) = **7**

8. What is your marital status? [1] Married [2] Single [3] Widowed [4] Divorced [5] Cohabitation
9. Which ethnic group do you belong? ....

10. What is your religious affiliation? [1] Christianity [2] Islam [3] Others (specify) ……

11. How many of your household aged 6 and older can read and write a letter? ………
12. How many members of your household work on your farm? ………………

13. What is the main source of water for your household? (*observe and tick one*)

Improved (1)	Piped water		Public tap/ standpipe	Tube well/ borehole	Protected dug well	Protected spring	Rain water
	House (in)	House (out)					
Unimproved (0)	Unprotected spring		Unprotected well	River/ Stream	Dugout/ Pond/Lake/ Dam/Canal	Tanker supply/Vendor	

14. How far is this source of water from your house (*in metres*)?
…………………………………

15. What sanitation facility is used by this household? (*observe and tick one*)

Improved	Flush toilet	Piped sewer system	Septic tank	Flush/pour flush to pit latrine	KVIP	Pit latrine with slab	Composting toilet
Unimproved	Flush/pour flush to elsewhere	Pit latrine without slab	Bucket/pan	Public toilet	No facilities (bush/field)		

16. What is the distance to the toilet facility? [1] Within house [2] Within 100 m [3] More than 100m

17. What has been the health status of your household in the last 12 months?

HH member (incl. those absent but contribute to household income	Type of illness	No. of days the person was ill
HH head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		
………. of head		

B. FARM CHARACTERISTICS AND NATURAL ASSETS

18. How long have you been farming? (*in years*):………………………..

19. How did you acquire your farmland? [1] Inherited [2] rented/leased [3] purchased

20. What is the size of you farm holding in acres (*size under cultivation in the past 10 years*)? ………..

21. (*if the farmer cannot identify farm holding in acres, ask him about farm holdings in plots)*

22. What type of crops do you cultivate in the following season? (*Please list*)

Raining season	Dry season (dry season farming)

23. How many bags of the crops you have listed above did you harvest in the last five years?

Name of crop	Bags harvested				
	2015	2014	2013	2012	2011

24. Which crop do you grow for sale (cash) or consumption?

Name of crop	Cash	Consumption

25. Do you keep animals?(Y/N) If YES, how many animals do you keep? (*Please fill the box*)

Name of animals	Number of animals	*Present value of animal	Reasons for keeping

(**ask the farmer the minimum amount of money in Ghana cedi he will agree to sell the animal*)

26. Do you collect items from the wild? (YES/NO) If YES, How often is the collection of items done?

Name of things/food picked from the bush	Very often	Not often

27. Do you own fruit trees around your house? (YES/NO). If YES, list the types of fruit trees you own

Name of fruit	Reasons for keeping

28. Do you have access to extension service for your farming activities? (YES/NO) If YES, how many times in a year? ………………………………….

29. Do you receive weather forecast for your farming activity? (YES/NO) How do you receive weather forecast? (Please rank, 1 is most important)

Source of weather forecast	Rank

C. PHYSICAL ASSETS

30. Do you own any communication gadget (*TV, radio, phone, etc*)? (Y/N) If YES, how long have you been using the gadget?

Communication gadgets (TV, *radio, phone, etc*)	Number	How old is the gadget								

31. How does this communication gadget help you in your farming decision?
....
…………………………………………………………………………………
…………………………………………………………………………………

32. Do you own any means of transportation (*car, motor, and bicycle*)? (Y/N) If YES, how long have you been using the means of transportation?

Means of transportation	Number	How old is the means of transport								

33. Do you use tractor on your farm? (Y/N) If YES, do you own this tractor? (Y/N)

34. Do you irrigate your farm? (Y/N)

35. Do you use fertilizer? (Y/N)

36. Is your house connected to national electricity grid/solar? (Y/N)

D. FINANCIAL ASSETS

37. If you are married, does your spouse own her own farm? (Y/N)

38. Do you engage in non-farming activities? (Y/N) If YES, list the various non-farm activities?
…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

39. Does any of the members of your house involved in non-farming activities? (Y/N) If YES, how many members of your household are involved? …………………………

40. Does any of your household members migrate to somewhere during the dry season? (Y/N). If YES, how many members of your household migrate? ……………………

41. Do you have access to credit facility? (Y/N)

42. Is your household currently in debt? (Y/N)

43. Do you have enough of last year's harvested crops that can provide meal for your family till next harvest? (Y/N)

44. If NO, how are you meeting your household food requirement?
…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

45. What is the contribution of the following sources of income to annual household income?

Income source	Rank (*1 being the most important contributor to household income*)
Crop farming	
Animal rearing	
Bush products (fuel wood)	
Fruits	
Honey	
Handicraft	
Salaried job	
Remittances	
Daily wage labour	
Old age allowance (LEAP)	
Pension	
Petty trading	
Rent	
Development aid projects	
Others (specify)	

E. Social Assets

46. How many relatives do you have in other households in this village? …………

47. How many friends do you have in this village? ………………

48. Are you actively affiliated to political parties? (Y/N)

49. How many relatives are actively affiliated to political parties?? …………………..

50. How many friends are actively affiliated to political parties?? …………………..

51. Do you belong to any social group/organization in or outside this village? (Y/N) If YES, name the type or group and the assistance you receive.

Name of social group/organization	Type of assistance you receive

52. Do you receive assistance from government during bad times? Y/N

53. Do you receive assistance from NGOs during bad times? Y/N
Please rate the following questions on trust

	Trust question	**[1]** Strongly agree **[2]** Agree **[3]** Neither/no sure **[4]** Disagree **[5]** Strongly disagree
54.	I trust most people in this village.	
55.	Most people in this village will help me whenever I am in need	
56.	It is easy my household to influence the decision-making process in this village	

F. Perceptions worries affecting farming households

56. In the past 10 years, what are the greatest worries that affect your household and farming activities?

Worries	Code	Level of importance *(1 being most important)*	Severity *(Very low = 1, Low = 2, Medium = 3, High = 4, Very high =5)*
	W1		
	W2		
	W3		
	W4		
	W5		
	W6		
	W7		
	W8		
	W9		
	W10		

57. What has been the direction of worries you identified in the last 10 years? (*Please use challenge code*)

Year	Worries		
	Increased	Decreased	No change
2006			
2007			
2008			
2009			
2010			
2011			
2012			
2013			
2014			
2015			

58. Please indicate how the worries you have identified have affected your farm/household in the last 10 years *(indicate worries responsible and where possible include the quantity of loss*)

Worries	Farm	Animal rearing	Household activities

59. Do you consider your household to be most adversely affected by the worries you have listed than other households in this community (Y/N)
60. Who in this community do you think is mostly affected by the worries you have identified? …………………………………………..

61. What is/are the cause(s) of each worry you have identified?

Worries	Causes

62. Who should be responsible for solving each of the worries you have identified?

Worries	Responsibility (for examples: you?, God, the gods, government?, NGOs, church, chief)

63. Have you received any training to deal with the worries that affected your household/farming activities in the past 10 years? (Y/N)

Worries	Who organised the training?

64. Which of the worries do you think is likely to occur in the next 10 years in this village?
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……

G. ADAPTATION STRATEGIES EMPLOYED BY FARMERS

65. Have you taken measures to adapt to the worries you identified? (Y/N)

66. If NO, what is/are the reason(s) for you inaction or not doing anything about the worries you face?

Worries	Reasons for not taken any action

67. If YES (*to question 65*), what are some of the ways you have used to adapt to each of the worries you identified to affect your household/farming activities in the past 10 years?

Worries	Adaptation strategies adopted

68. Please, rank the adaptation options in terms of their importance in reducing the impacts associated with the worries. (*I being the most important*).

69. Please, rank the adaptation options in terms of their easiness to use to reduce the impacts associated with the worries. (*1 being the easiest to implement*).

70. If you were unable to take actions on some of the worries, please list the factors that prevented you from doing so?

Worries you could not take any action	Factors that prevented you from taken actions

APPENDIX B

Institute for Environment and Sanitation Studies (IESS)
University of Ghana, Legon

Vulnerability and Adaptation of farming households in semi-arid Ghana to climate change and other stressors

QUESTION GUIDE FOR FOCUS GROUP DISCUSSIONS

Type of group:	
Number of participants:	
Number of male:	
Number of female:	
Name of community:	
Meeting centre:	
Date:	
Start time:	Closing time:

1. List all livelihood activities in this village.
2. Which group of people in this village are involved in the livelihood activities you have listed?
3. What are the challenges that this village face in relation to the livelihood activities listed?
4. How have these challenges change over the last 30 years?
5. Please, rank the challenges in order of importance (*1 being the most important*).
6. What are the causes of each of the challenges you listed?
7. How have these challenges affected your faming activities and livelihoods?
8. Please, rank the group of people in this village in order of their vulnerability to the challenges listed (*1 being the most vulnerable*).
9. Which of the challenge(s) do you think is/are likely to occur in the next 10 to 30 years?
10. Who is responsible for solving each of the challenges that this village faces?
11. How do the people in this village tackle the challenges you listed?
12. Which things facilitated your efforts in tackling these challenges?
13. Which things constraint your efforts in tackling these challenges?